National Transportation Safety Board
Office of Railroad, Pipeline and Hazardous Materials Investigations
Washington, DC 20594

West Reading, Pennsylvania
March 24, 2023

PLD23LR002

INTEGRITY MANAGEMENT

Group Chair's Factual Report

Report Date: October 13, 2023

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A. ACCIDENT

Location:	West Reading, Pennsylvania
Date:	March 24, 2023
Time:	1655 EDT 2055 UTC
Operator:	UGI Corporation (UGI)
System Type:	Gas Distribution
Commodity:	Natural Gas

B. INTEGRITY MANAGEMENT GROUP

Group Chair	Dane Spillers National Transportation Safety Board Washington, DC
Group Member	Gerhardt Bauman Pipeline and Hazardous Material Safety Administration Oklahoma City, OK
Group Member	John Toumeh UGI Utilities, Inc Denver, PA

C. SUMMARY

For a summary of the accident, refer to the *Accident Summary* report within the docket.

D. FACTUAL INFORMATION

This report documents the facts, conditions, and circumstances relating to the accident which pertain to integrity management of the affected pipeline system.

1.0 Integrity Management Overview

Integrity management is a process that can be used to identify, assess, and manage pipeline risk. Risk can be defined as a measure of the probability and severity of adverse events. Risk is often estimated by answering the following questions:

- What can go wrong?
- How likely is this to happen?
- If it does happen, what are the consequences?

This risk is then managed by gathering additional information, taking action to reduce risk, continuing to evaluate risk as it changes, and improving the process over time. Integrity management programs can be iteratively improved over time as additional information is gathered, risk is better understood, and assessment techniques are further developed. In some cases, integrity management programs are required by regulation (See Section 7.0).

Figure 1. Integrity Management Flowchart

2.0 Integrity Assessments Completed Near the Accident Site

On February 16, 2021, UGI conducted an inside meter inspection of the gas meter in the basement of RM Palmer Building 2.[1] This was an inspection required by UGI's Gas Operations Manual (GOM) to evaluate the inside meter on a medium pressure system every 3 years.[2] The inspections required by the GOM are the primary assessments in the DIMP program. The inspection detected gas inside the basement of Building 2 and at the service curb valve outside the building.[3] UGI graded the leak as a "C" leak which required immediate attention or repair.[4] To repair the leak, a meter move out and service line renewal was initiated and completed on the same day.[5]

To retire the existing service and install the replacement service, UGI excavated Cherry St adjacent to Building 2. One member of the crew that retired and replaced the service line recalled vacuum excavation and hand shovels being used to excavate around the service and main[6]. An RM Palmer photograph from the day of the service line renewal shows a backhoe that was used during the work on February 16, 2021.

During post-accident interviews with the NTSB, UGI Mechanic II A recalled noticing an area of white powder on the edge of the excavation during the removal of the material over and around the existing service line. [7] The crew member told NTSB investigators that he asked to speak to someone at RM Palmer to help identify the substance. He recalled that an RM Palmer employee came out to the excavation and indicated a steam line was in the ground near or adjacent to the area of the white powder. The crew continued the excavation and completed the retirement of the original service line and installation of the new service. UGI Mechanic II A stated he did not see the steam line. The new service tee was installed opposite the reported steam line, to the east of the existing service tee. The service tee for the retired service remained in place approximately two feet from the reported steam line as calculated from survey data provided by UGI.

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[1] UGI Records of Inside Leak Surveys 17 S. 2nd Ave or 77 S. 2nd Ave 2018-2023
[2] UGI-Gas Operations Manual Required Leak Surveys
[3] The existing service line to Building 2 had been installed on April 29,1982 using ½" diameter Aldyl A polyethylene pipe with the gas meter and regulator located inside Building 2. The service line was connected to a 1 ¼" diameter Aldyl A main, also installed April 29, 1982.
[4] UGI-Gas Operations Manual-Classification of Natural Gas leaks
[5] A *service line renewal* is when a new service line is installed, including a new service tee attached to the existing main. When a service line is *renewed*, the old service tee for the retired service is typically left in-place with a capped section of the old service line.
[6] Interview of UGI Mechanic II A
[7] Interview of UGI Mechanic II A

Figure 2. Retired service tee and new service for RM Palmer Building 2

The meter moveout included the retirement of the original service line in the street outside the building. When the crew was interviewed by the NTSB after the accident, none of the crew members could remember exactly what happened during this work over two years earlier. Based on their account of what is generally done, the following summary was developed.

To retire the service line, the typical process was followed, where the crew would shut off the gas flow at the service tee by lowering the internal tap in the tee to stop the flow of gas into the service line. The crew would then cut off the service line and cap the remaining ½" diameter service line stub. The internal tap in the service tee would then be raised to reintroduce gas flow to the remaining stub of the service line and the work tested with soap to verify the repair was leak free. At the completion of the repair, the 1982 Aldyl A service tee and the short stub of the 1982 service line remained attached to the 1 ¼" gas main and exposed internally to full gas system pressure.

The original Aldyl A service tee was found to be cracked and leaking after the accident. Stray gas was analyzed post-accident by ECHELON Applied Geosciences

Consulting for the PA PUC in coordination with the NTSB and found to be from UGI's pipeline.[8] For additional details, see the *Pipeline Operations Group Chair's Factual Report* within the docket.

Figure 3. White powder visible in photograph during work performed on February 16, 2021 (Courtesy of R.M. Palmer)

[8] ECHELON Gas Geochemistry Study

3.0 Integrity Management Program

NTSB investigators met with UGI at their offices in Denver, Pennsylvania from July 25, 2023 to July 27, 2023 to review UGI's integrity management program. This section documents UGI's program as described and observed during this meeting and further explained through documentation provided by UGI.

3.1 Organizational Structure

At the time of the accident, the Distribution Integrity Management Program (DIMP) at UGI was centrally managed and administered. The VP Engineering and Operations Support was the DIMP sponsor and was responsible for providing a link between compliance and other corporate initiatives, ensuring budget and personnel were committed to manage and implement the program, and overseeing management of priorities and budgeting for integrity related improvements or replacements.[9]

The Director Pipeline Safety Management Systems was responsible for establishing risk factors and overseeing risk model parameters. The Manager DIMP/Leak Survey managed and approved the DIMP and was responsible for program implementation, budgeting, modifications, monitoring of DIMP metrics and composition of the DIMP team.

The DIMP Team met quarterly. It was staffed by, and worked under the guidance, of the Manager Distribution Integrity and Leak Survey. The team was comprised of Subject Matter Experts (SMEs) from throughout the company with expertise in threat areas, engineering, or operations. The team provided analysis and update considerations to the program. SMEs were tasked with reviewing all pertinent data related to the facilities and threats associated with the plan. They were expected to use this data along with their industry experience to provide the analysis necessary for maintaining and updating the SME High Level Risk Model and identifying any inspections, tests or accelerated actions needed to identify threats and consequences and lower risk.

Several other staff members were responsible for execution of various requirements of the DIMP plan using procedures found in the Gas Operations Manual. The work these individuals performed included inspections, tests and accelerated actions identified by the DIMP team to obtain information on assets threats, consequences, and ultimately lower risk.

[9] UGI-Management Responsibilities for Distribution Integrity Management Program

Figure 4. UGI Integrity Management Organizational Chart[10]

3.2 Risk Identification

Risk assessments were based on the current understanding of the system, its operating environment, and potential threats. This section documents the risk identification process used by the operator in its most recent assessment.

3.2.1 System Knowledge

The UGI DIMP program used information from data maintained and collected by the company in various reports, inspections, tests, and records to inform SMEs to gain knowledge of the system. The information is divided into two general categories:

[10] UGI-Distribution Integrity Management Staff Organization Chart

- the physical assets of the distribution system, including records of construction and modifications to the system, and
- the operating and maintenance history of the assets.

Table 1 below provides a listing of the assets covered by the UGI DIMP.

Table 1. Summary of UGI and All US Gas Distribution Operators' Natural Gas Assets [11](2022)

	UGI		All Operators	
Description	**Main** (miles)	**Services** (#)	**Main** (miles)	**Services** (#)
Steel	4,227	47,641	511,849	14,330,342
Ductile Iron	0	0	444	180
Copper	0	4,785	5	579,216
Cast/Wrought Iron	119	0	17,004	5,773
PVC	29	166	9,923	55,972
PE	7,961	562,413	809,739	53,839,094
ABS	0	0	2,133	1,254
Other Plastic	0	0	427	474,817
Other	1	2,064	941	2,122,885
Reconditioned Cast Iron	0	0	38	0
Grand Total	**12,337** (~0.9% of US Mains)	**617,069** (~0.9% of US Services)	**1,352,503**	**71,409,533**

UGI's system of record for its natural gas mains and leak survey results was Smallworld GIS. UGI's system of record for service lines was an in-house application called, "Gas Service Web Application." The Gas Service Web Application housed tabular data on UGI's service lines and available digitized sketches.[12]

Data in both Smallworld GIS and the Gas Service Web Application were controlled by groups within UGI responsible for maintaining the information, approving needed changes, and updating the systems. Changes may have been needed due to physical changes to UGI's natural gas assets, such as updated facilities, or inaccuracies that were discovered. For example, at the time of the accident, UGI provided records of the 1982 installation indicating that the main was

[11] From PHMSA source data web site: https://www.phmsa.dot.gov/data-and-statistics/pipeline/source-data

[12] UGI-System of Records for distribution gas mains and services.

Aldyl AAAA.[13] However, it was exposed after the accident and determined to be Aldyl A.

MapFrame was a tool used by field employees with many attributes available in real-time for each asset, including field sketches if they were scanned into the system. Data displayed in MapFrame came from the systems of record (e.g., Smallworld GIS or Gas Service Web Application) for visualization. In MapFrame, field employees could enter leaks, sketches, repair information, and pipe condition reports. When pipe condition reports were submitted, the system prepopulated some information for mains (not services) and the field employee could override fields that were prepopulated as needed. When a service line was updated, as was done during the meter relocation and service line renewal in 2021, UGI's field staff submitted the field changes through MapFrame.

The system of record for leaks was UGI's Smallworld GIS. UGI employees utilized "Leak App" to view information from Smallworld on leaks that were found, sketches of those leaks, and leak repair information.

Other UGI tools for viewing information included a Valve app (Valve maintenance and inspections), Regulator Station app, Odor Monitoring and Report app, and Substructure Damage Report app (records first/second/third-party damage to UGI assets). Damages to private assets were not recorded in any UGI database, but would require a notification to One-Call, an Alleged Violation Report (AVR) filed, and UGI's claims team would log the damage.

Nearby private, subsurface facilities were not currently captured anywhere in UGI's data systems or on any forms. As such, UGI had not trained and did not expect its crew to submit a form or provide notification of the steam line that was discovered near its assets on February 16, 2021. The crew could have alerted their management or engineering, at their discretion.

UGI estimated the extent of Aldyl A in its system by including all pipe identified in Smallworld GIS and Gas Service Web Application to be manufactured by Du Pont installed from 1965-1991, manufactured by Uponor and installed between the years 1991-2001, or identified with Aldyl A as its material type.[14] Based on these criteria, UGI provided the information in Table 2 below UGI noted that there may be hundreds of additional Aldyl A main miles and tens of thousands of additional Aldyl A services in its system (shown as potential mileage and potential services in Table 2).

[13] UGI Cherry Street assets information
[14] UGI-Extent of Aldyl A piping in UGI distribution system

Table 2 Estimated Aldyl A in UGI system[15]

	Main (mi)	"Active" Services (#)	"Retired" Services (#)
Reported Aldyl A (1965-2001)	32	1211	48
Potential Aldyl A (including reported, 1965-1986 installation date)	636	86,891	6,482

UGI used a repair kit for Aldyl A tapping tees.[16] UGI North had installed repair kits anytime they encountered Aldyl A service tees with black caps while working on replacement projects. UGI estimated the usage of Aldyl A repair kits, as shown in Table 3. UGI did not mandate the use of the Aldyl A tapping tee repair kits.

Table 3. UGI estimate of Aldyl A tapping tee repairs

Aldyl A Tapping Tee Repair Fittings Issued by Year (Last 3 years)	
Year	Number of Fittings
2020	701
2021	1,035
2022	1,186
2023	271[17]
Grand Total	**3,193**

[15] UGI-Aldyl A piping by asset counts in UGI distribution system
[16] UGI-Aldyl-A TT Refurbish Tool Operation Manual, UGI-Supplemental Information on Installation of Aldyl A tapping tee repair fittings, UGI-History of Aldyl A tapping tee repair fitting installation
[17] from January 1-April 25, 2023

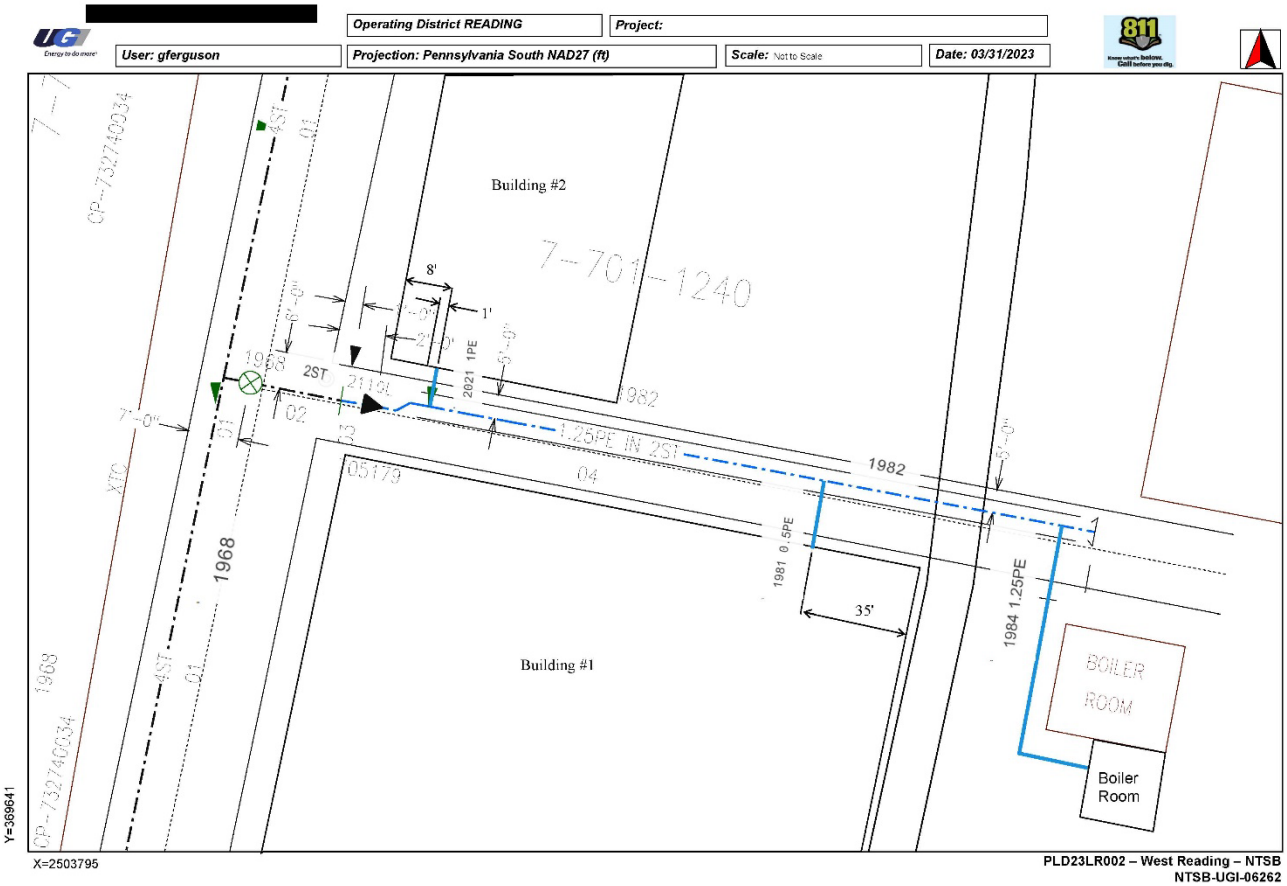

Figure 5. UGI map of failure area[18]

3.2.2 Threat Identification

UGI used PHMSA's eight cause categories in their risk models. The UGI DIMP descriptions of the risk categories were:

1. Corrosion – resulting from a hole in the pipe or other component that was caused by galvanic, bacterial, chemical, stray current, or other corrosive action.
2. Natural Forces – resulting from earth movements, earthquakes, landslides, subsidence, lightning, heavy rains/floods, washouts, flotation, mudslide, scouring, temperature, frost heave, frozen components, high winds, or similar natural causes.

[18] UGI-Cherry Street Detail Sketch

3. Excavation Damage – resulting from damage caused by earth moving or other equipment, tools, or vehicles. Include leaks from damage by operator's personnel or contractor or people not associated with the operator.
4. Other Outside Force Damage – caused by fire or explosion and deliberate or willful acts, such as vandalism and due to vehicle damage.
5. Pipe, Weld, or Joint Failure – resulting from failure of original sound material from force applied during construction that caused a dent, gouge, excessive stress, or other defect that eventually resulted in a leak. This includes those due to faulty wrinkle bends, faulty field welds, and damage sustained in transportation to the construction or fabrication site, resulting from a defect in the pipe material, component, or the longitudinal weld or seam due to faulty manufacturing procedures.
6. Equipment Failure – resulting from malfunction of control/relief equipment including valves, regulators, or other instrumentation; stripped threads or broken pipe couplings on nipples, valves, or mechanical couplings; or seal failures on gaskets, O-rings, seal/pump packing, or similar leaks.
7. Incorrect Operation – resulting from inadequate procedures or safety practices, or failure to follow correct procedures, or other operator error.
8. Other – resulting from any other cause, such as exceeding the service life, not attributable to the above causes.[19]

UGI studied records of leaks and failures associated with the Aldyl A tees with the Delrin insert. The study concluded they had a history of leakage from the black service tee caps, however, the leaks were found through normal operations, leak surveys or odor complaints and without serious consequences.

3.3 Risk Assessment

At the time of the accident, UGI used three risk models to identify and evaluate risk in the distribution system.[20] The Optimain model was used exclusively to prioritize replacement of gas mains. The remaining two models, the Data Driven Risk Model (DDRM) and the Subject Matter Expert (SME) Model were used for risk evaluation and to analyze risk on both mains and service lines.

[19] UGI-Distribution Integrity Program Threat Identification
[20] UGI-Evolution of UGI Distribution Integrity Risk Models

3.3.1 Data-Driven Risk Model (DDRM)

The DDRM was a quantitative model that estimated the probability and consequence of failure for facility groups referred to as Asset-Threat Groups (ATGs). The ATGs were based on five elements: DOT Facility (main or service), pressure (high, medium, low), material (cast iron, copper, other, PE, PVC, Red Thread/fiberglass, steel, unknown, or wrought iron), component, and DOT cause. The service tee involved in this accident would have been identified by one of the groups shown in Table 4.

Table 4. Asset-Threat Groups (ATGs) of Retired Service Tee Involved in Accident According to UGI's DDRM

	Group 1	**Group 2**
DOT Facility	Service	Main
Pressure	Medium	Medium
Material	PE	PE
Component	Service	Main

3.3.1.1 Likelihood Determination (DDRM)

For each Asset-Threat Group, the DDRM estimated the probability of failure based on statistical models of leaks and incidents which were combined using Boolean Algebra, assuming leaks and incidents were independent.

Using a rolling three-year average of repaired leaks, the probability of a leak for each ATG was calculated. Similarly, using the thirty-year rolling average of incidents by the DOT cause, a probability of an incident was calculated for each ATG. The two values were then combined to calculate an overall probability of failure for each ATG.

The probability of failure (likelihood) presented by Aldyl A service tees, as estimated by the DDRM by DOT Failure Cause, is shown in Table 5 and Table 6 below.

3.3.1.2 Consequence Analysis (DDRM)

For each facility group, the DDRM estimated the consequence of failure based on a calculation that included the number of hazardous leaks, the number of leaks, the number of incidents (by primary and secondary cause), and an importance weighting factor. The importance weight was a manual adjustment factor used to better align risk ranking results with UGI incident history.

UGI used the Importance Weight (IW) value to allow SME adjustment based on engineering and operational judgement. The following IW values were used:[21]

- Primary Incident Cause Rate IW: 5.0[22]
- Secondary Incident Cause Rate IW: 1.0
- Specific Hazardous Leak Rate IW: 1.0
- Total Hazardous Leak Rate IW: 1.0

No Importance Weight values were used to adjust risk for any Aldyl A piping or fittings.

The Consequence of Failure computed by the DDRM is shown in Table 5 and Table 6 below.

3.3.1.3 Risk Estimation (DDRM)

The DDRM estimated risk for Aldyl A services by DOT Failure Cause, is shown in Table 5 and Table 6.

Table 5. Risk of Medium Pressure Aldyl A Service (Classification 1) by DOT Cause based on 2021 data

Cause	Probability of Failure Indicator	Consequence of Failure Indicator	Risk Indicator
Corrosion Failure	0.0001	0.6325	0.0001
Equipment Failure	0.0001	1.778	0.0001
Excavation Damage	0.0002	6.0626	0.0013
Incorrect Operation	0	2.8741	0
Natural Force Damage	0.0002	3.375	0.0005
Other Cause	0.0002	1.740	0.0004
Other Outside Force Damage	0	3.6354	0.0001
Pipe, Weld, or Joint Failure	0.0002	1.6269	0.0004
TOTAL			**0.003**

[21] UGI-Importance Weighting in Consequence of Failure calculation

[22] The Primary Incident Cause Rate IW was adjusted from 1.0 to 5.0 in 2020 by the DIMP team to better align risk ranking results with company incident history.

Table 6. Risk of Medium Pressure Aldyl A Main (Classification 2) by DOT Cause based on 2021 data

Cause	Probability of Failure Indicator	Consequence of Failure Indicator	Risk Indicator
Corrosion Failure	.0013	.6659	0.0009
Equipment Failure	.0022	1.7611	0.0039
Excavation Damage	.0056	5.3668	0.0298
Incorrect Operation	.0001	2.8225	0.0002
Natural Force Damage	.0024	3.3652	0.0080
Other Cause	.0101	1.6882	0.0170
Other Outside Force Damage	.0008	3.3182	0.0026
Pipe, Weld, or Joint Failure	.0057	1.4595	0.0083
TOTAL			**0.07**

For comparison, the DDRM model results determine the overall high risk asset type for UGI was: Main / Low / Cast Iron / Main / Equipment Failure / POF = 0.6765 / COF = 1.7611 / Risk Score per Unit = 1.1913 / Population = 109 miles

The second highest risk asset type (per unit) is: Main / Medium / Red Thread / Main / Other Outside Force Damage / POF = 0.2212 / COF = 3.3182 / Risk Score per Unit = 0.7340 / Population = 1 mile

Table 7. Risk of Low Pressure Cast Iron Main by DOT Cause based on 2021 data

Cause	Probability of Failure	Consequence of Failure	Risk Indicator
Corrosion Failure	0.1790	0.6659	0.1192
Equipment Failure	0.6765	1.7611	1.1913
Excavation Damage	0.0622	5.3668	0.3340
Incorrect Operation	0.00002	2.8225	0.0001
Natural Force Damage	0.1619	3.3652	0.5448
Other Cause	0.2475	1.6882	0.4179
Other Outside Force Damage	0.0046	3.3182	0.0153
Pipe, Weld, or Joint Failure	0.0382	1.4595	0.0558
TOTAL			**2.7**

3.3.2 SME Risk Model

UGI used the SME Risk Model to validate the findings of the DDRM and, when applicable, to evaluate risk at a more granular level than was possible in the DDRM.

In the SME Risk Model, a total risk score was derived from SMEs assessment of each intersection of "Asset Group" (facility) and "Threat". The SMEs, through the

model, also considered and assigned values to consequence factors for each asset group.[23]

UGI had three separate SME models, each tailored to their assets in the South, North, and Central regions of their service area.[24] The March 24, 2023, failure occurred in the South Region.

UGI prepared data summaries for their SMEs prior to refreshing SME model factors, an exercise that was done periodically, every 1-3 years. The data summaries were based on UGI's experience.

Per the UGI plan, the SME model discretized UGI's assets based on asset groups that UGI expected would have similar modes of failure, probabilities of failure, and consequences of failure. The service tee involved in this accident would have been included in the following asset group:

- Environment: Buried
- Asset Group: Plastic Mains
- Asset Sub-Group: Aldyl-A Mains or Aldyl-A Services (with or without EFV)

In the SME model, UGI broke out Aldyl-A Mains and Services as separate asset sub-groups (since 2015).

3.3.2.1 Likelihood Determination (SME Risk Model)

For failure probability factors, SMEs determined whether each threat subcategory contributed to failure and the extent to which it had been observed by UGI. The failure probability factors ranged from 0 to 6, where 0 indicated that the SMEs determined the factor had no material impact on probability of failure and 6 meant that the SMEs determined the factor could cause failure on the asset group, and the factor had caused many failures.

The failure probability score, as computed by the SME Model, is included in Table 8 below.

3.3.2.2 Consequence Analysis (SME Risk Model)

In the SME model, for consequence factors, SMEs determined whether each factor increased the magnitude of consequences, given a failure occurred. Consequence factor ratings ranged from 0 to 1.

Results shown for Aldyl A assets including those involved in this accident compared to assets that resulted in higher risk scores, for UGI SOUTH.

[23] UGI-Management Responsibilities for Distribution Integrity Management Program
[24] UGI-Natural Gas Service Territory Map

3.3.2.2 Risk Estimation (SME Risk Model)

The SME model used the incident factor to give additional weight to the risk scores for facilities that have experienced PHMSA reportable incidents on UGI's assets, regardless of the cause of those incidents. A score of 0 indicated the asset type had not experienced an incident while a score of 1 indicated one or more incidents have been attributed to the asset type.

A consequence factor was also used in the SME Mode. The factor is established by the SME group and used to amplify the magnitude of the consequence for identified asset types. A consequence factor was not used for Aldyl A fittings.

In the SME Model, the Total Risk Score for each asset group per the formula: Total Risk Value = (Failure probability score + Incident probability score) × (1 + (Consequence of failure score))[25]

The SME Model computed Risk is shown in Table 8.

Table 8. SME Model Consequence Factors

	Plastic Mains/ Aldyl A Mains	Plastic Services/ Aldyl A Services, no EFV	Plastic Services/ Aldyl-A Services, w/ EFV
Corrosion/Acidic Soil			
Rock Impingement			
Internal Corrosion Failure			
Natural Forces/Frost	1	2	2
Subsidence	0	1	1
Near recent excavation			
Earthquake	1	1	1
Flooding	0	0	0
Damage by Rock Impingement	0	0	0
Other Natural Forces			
Excavation Damage	4	5	5
OOF/Vehicular			
Malicious Actions	1	1	1
Water Main Break	4	4	4
Electrical Faults/Arcs	2	1	1
Material, Weld,/Steel			
Cast Iron			
Plastic	2	1	1
Wrought Iron			
Copper			
Weld			
Mechanical Fitting	2	2	2
Cast Iron Bell Joint			

[25] UGI-Annual Risk Review Process

Fusion Type Joints	4	2	2
Other Equipment Failure			
Incorrect Operation	4	5	5
Failure Probability Score	**25**	**25**	**25**
Low/Standard Pressure	1	1	0
Medium Pressure	1	1	0
High Pressure	0	1	0
Migration through Utility Conduits or Porous Backfill	1	1	1
Wall to Wall Paving	1	1	1
Within 50' of Public Building or Populated Place	1	1	0
Common Trench or Minimal Utility Clearance	1	1	1
Depth of Cover > 4'	1	1	1
Meter/Inside Meter Set	1	1	0
Outside Meter Set	0	0	0
Business/Commercial District	1	1	1
Difficulty of Detection	0	0	0
Incident Factor	1	0	0
Consequence of Failure Score	**1.75**	**0.83**	**0.42**
Total Risk Score	**43.8**	**20.8**	**10.4**

3.4 Risk Management

Pipeline risks were managed through completing targeted assessments, reducing risks through repairs, replacements, or other risk reduction actions, continual evaluation, and improvement.

3.4.1 Integrity Assessments

The UGI assets in the vicinity of the March 24, 2023, failure did not have any required assessments beyond the inspections and patrols required by the Gas Operations Manual which included distribution leak surveys required every 5 years and inside meter inspections required every 3 years. [26] UGI did not designate the area of RM Palmers facilities at the intersection of Cherry Street and 2nd Ave in West Reading as a business district.[27]

[26] UGI-Gas Operations Manual-Required Leak Surveys
[27] UGI-Business District Leak Survey 2018-2018 near RM Palmer Buildings

3.4.2 Risk Reduction

UGI developed Additional/Accelerated Actions (A/A Actions) to address threats that were perceived to be prevalent in UGI's distribution system and to address risk and enhance safety. UGI defined Additional or Accelerated Actions (A/A Actions) as "activities that are performed in addition to the requirements of the Federal Regulations."[28]

UGI did not identify any mandatory Addition/Accelerated actions for any of Aldyl A assets relevant to the March 24, 2023, failure.[29] The Cherry Street main was not scheduled for replacement as UGI had not identified any issues that would warrant its replacement.[30]

According to UGI's Subject Matter Expert risk evaluation, Aldyl A services are generally assessed at a level of risk comparable to other categories of polyethylene (PE) services. The SME evaluation of risk of Aldyl A or other vintage PE services did not suggest the need for additional A/As beyond those already underway. The following were identified as A/A Actions and were underway prior to the March 24, 2023 failure: 1) damage prevention activities to mitigate the risk of third party damage, including a cross bore investigation program, 2) submission of Pipe Condition Reports and Material Failure Reports for leaks on PE as well as analysis and submission of data to the AGA Plastic Failure Database to assess the risk of material failure, and, 3) leak survey at increased frequency to mitigate the risk of material or joint failure.[31]

3.4.3 Continual Evaluation and Improvement

The integrity management risk models were reviewed for improvement opportunities. The DIMP Team met quarterly to review metrics and complete more comprehensive annual and 5-year reviews. The primary function of the DIMP team was to provide analysis of results and update recommendation to the program manager.

UGI had about 65 key performance indicators (some duplicative) it trended to measure the effectiveness of its DIMP program. UGI's DIMP team reviewed its progress with in-house SMEs on a quarterly or annual basis. Some metrics were shared on a monthly, quarterly, or annual basis with others within UGI, including management.

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[28] UGI-Staff Distribution Integrity Program responsibilities
[29] UGI-Aldyl A Additional Accelerated Actions
[30] (a)UGI-2nd Ave and Cherry St Replacement Schedule response, (b) UGI-Gas Asset Replacement Program information
[31] UGI-Explanation of Additional Accelerated Actions evaluation for Aldyl A piping

Risk models were reviewed periodically, per plan every 1-3 years.

Since Spring of 2013, a SME review of current risks and potential new threats was completed quarterly, with an Annual Review of the factors included in the SME Risk Model. DIMP staff provided SMEs inputs such as performance metrics and reviews of external notices (such as PHMSA advisories, PUC advisories, and etc.) for the SMEs to review.[32] The Quarterly and Annual SME Review processes are illustrated in the process flow diagrams below:[33]

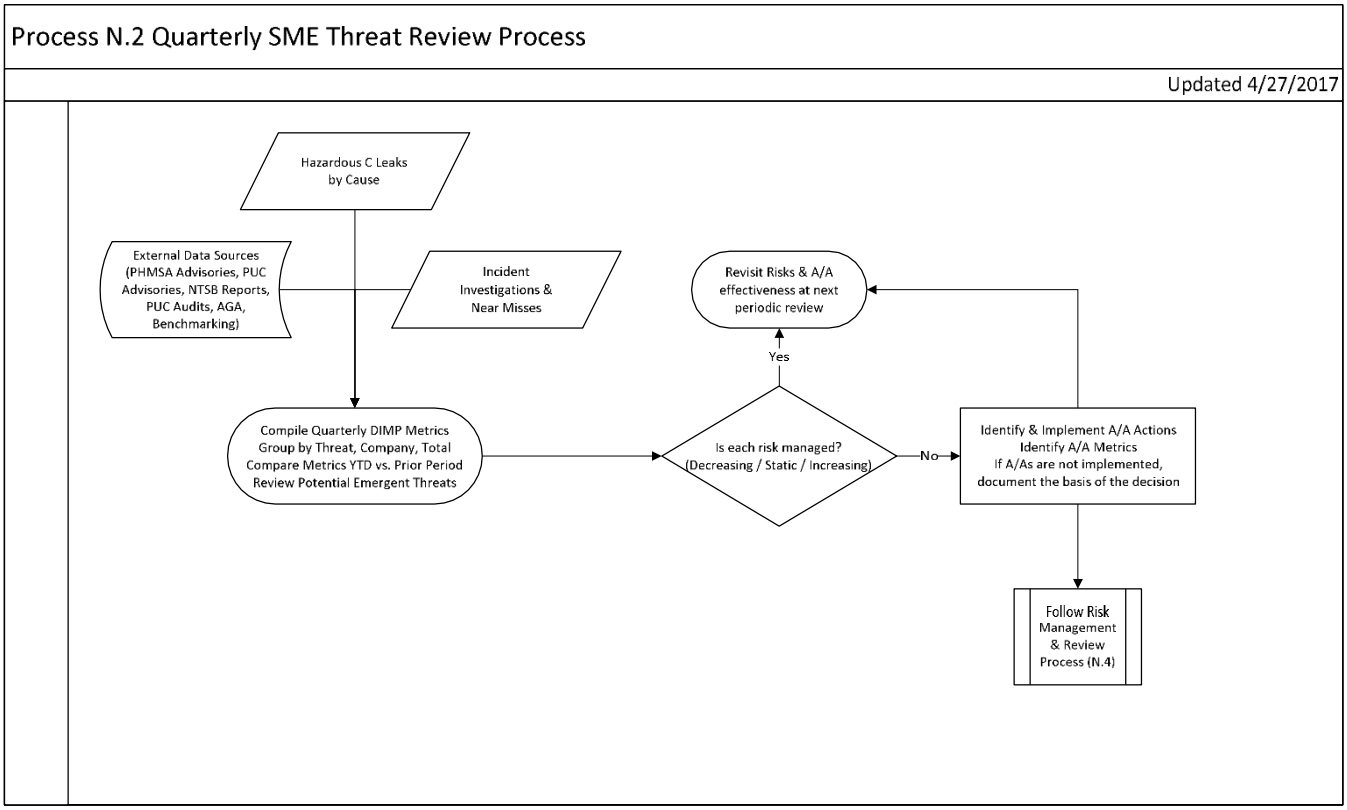

Figure 6. Quarterly SME Threat Review Process[34]

[32] UGI-External sources of information for the Distribution Integrity Program
[33] UGI- SME Integrity Threat Review Process
[34] UGI-Quarterly Subject Matter Expert Review Process

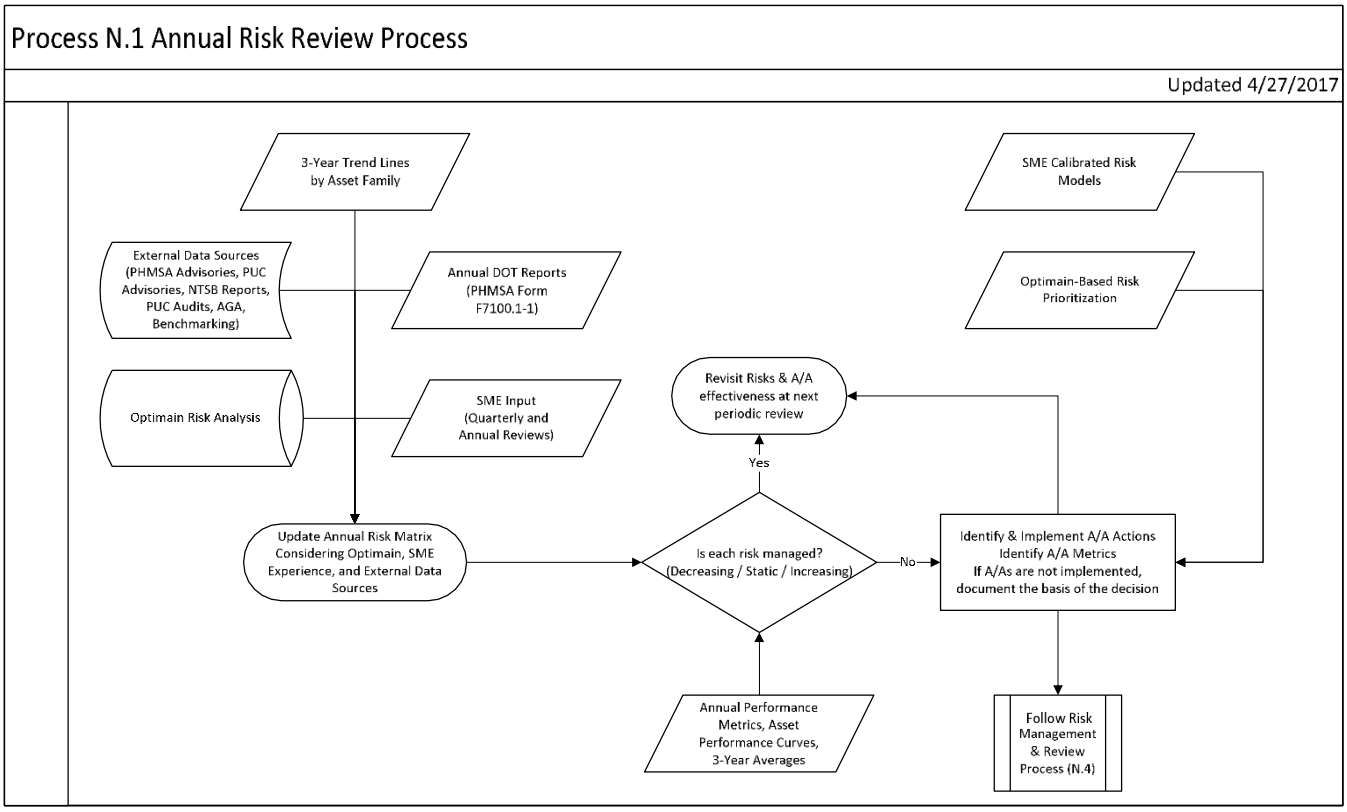

Figure 7. SME Annual Risk Review Process[35]

4.0 Post-Accident Engineering Studies

NTSB has conducted material testing of failed gas service assets from the March 24, 2023, failure. The following components were examined:

1. Aldyl A service tee from the retired service to 17S. 2nd Ave installed in 1982 that failed.
2. service tee providing gas service at the time of the failure to 17 S. 2nd Ave installed in 2021.
3. Aldyl A service tee installed in 1982 for the service to 77 S. 2nd Ave (the exemplar for the 1982 service from 17 S. 2nd Ave.)
4. 1-marker ball from 17S. 2nd Ave.
5. 1-exemplar marker ball.
6. 3-1/2" steam line found leaking.

For a summary of the testing, refer to the *Materials Laboratory Factual* report within the docket.

[35] UGI-Annual Risk Review Process

5.0 Procedures

UGI first implemented the UGI Distribution Integrity Management Program on August 2, 2011, and issued a total of 9 versions of the plan in the subsequent years.[36] The program utilized a relative risk model for gas mains to aid in replacement decision and both a quantitative and subject matter expert model to identify asset risks. UGI used several systems and applications to capture or maintain facility information. When errors in UGI's systems of record were discovered by field staff, UGI expects its staff to submit a Revised Facility Request form. UGI's process for completing this form is not included in the GOM.

When errors in UGI's systems of record were discovered by field staff, UGI expected its staff to submit a Revised Facility Request form. There was no formal training on this process. Nearby private, subsurface facilities were not captured anywhere in UGI's data systems or on any forms. These foreign subsurface facilities can become threats to distribution assets. UGI's instructions for completing the Revised Facility Request form was documented in *Revisions and Corrections of Facility Records Document.pdf*; is also not included in the GOM.[37]

UGI defined business district in GOM 60.20.15 which states the business district is normally associated with the assembly of people in shops, offices and similar buildings in close proximity and where pavement extends from the main to the building wall.

6.0 Industry Guidance and Consensus Standards

There were several industry guidance documents and consensus standards available to help pipeline operators implement their pipeline safety integrity management programs.

UGI program documents listed the following documents as references used to develop or maintain the program.

- ANSI/GPTC Z380.1, *Guide for Gas Transmission, Distribution, and Gathering Piping Systems,* Appendix G-192-8 Distribution Integrity Management Program (DIMP) (current edition)
- Integrity Management for Gas Distribution, Report of the Phase 1 Investigations, December 2005
- AGF Study "Safety Performance and Integrity of the Natural Gas Distribution Infrastructure." January 2005

[36] UGI Integrity Management Program effective date
[37] UGI-Revised Facility Record Instructions

ANSI/GPTC Z380.1, *Guide for Gas Transmission, Distribution, and Gathering Piping Systems,* 2018 edition included guidance on the location of steam lines to natural gas pipelines. Similar guidance was included in previous versions dating back at least to 2012.

- Subpart B, 192.63, which states, "The manufacturer marks the pipe and fittings with the maximum temperature at which the pipe and fittings have been qualified for use."
- Subpart C, 192.121, which states, "Hydrostatic Design Basis (HDB) values are awarded by the Hydrostatic Stress Board (HSB) of the Plastics Pipeline Institute (PPI)… ASTM D2513 requires elevated temperature HDB listings for plastic piping materials used at temperatures above 73°F."
- Subpart G, 192.325 which states, "The operator should consider the degree of the hazard presented by the heat source when determining the clearance, insulation, or protective material. For installations near… steam lines, the operator should also consider… a minimum radial separation of 12 inches is recommended by the Common Ground Alliance's 'Best Practices' Guide, Practice Statement 2-12…"
- Subpart H, 192.361 which states," Each gas service line should be installed with sufficient clearance from, or insulated from, any known heat source (e.g.,… steam line), which could impair the serviceability of the gas service line… If 12-inch separation cannot be feasibly attained at the time of installations, the Practice Statement recommends taking mitigating measures, including the use of insulators, casing shields, or spacers."
- Subpart O, 192.917 which states, "Construction threats are related to the methods used in the construction and installation of a pipeline and include… exposure to elevated temperature (e.g., … steam lines)."

The following list of consensus standards, advisory bulletins listed in Section 7.1, or industry advisory also may include information or guidance.

- American Society of Mechanical Engineers (ASME) B31.8S, *Managing System Integrity of Gas Pipelines*. ferrous materials that transport gas.
- INGAA, *Integrity Characteristics of Vintage Pipelines*, 2005
- INGAA, *The Role of Pipeline Age in Pipeline Safety*, November 8, 2012
- PHMSA, *Pipeline Risk Modeling Overview of Methods and Tools for Improved Implementation*, February 1, 2020

- White Paper- "Correlating Aldyl 'A' and Century PE Pipe Rate Process Method Projections with Actual Field Performance," E.F. Palermo, Ph.D., Plastics Pipes XII Conference, April 2004, available at https://www.aga.org/wp-content/uploads/2022/12/gptctechpaper.pdf
- White Paper "Effect of Elevated Ground Temperature (from Electric Cables) on the Pressure Rating of PE Pipe in Gas Piping Applications," E.F. Palermo, Ph.D., AGA Operations Conference, April 2007, available at https://www.aga.org/wp-content/uploads/2022/12/Effect-of-Ground-Temperature.pdf

7.0 Safety Oversight

7.1 Federal Pipeline Safety Requirements

Federal pipeline safety regulations are found in 49 *CFR* Parts 190-199. Integrity management requirements are included in 49 CFR Part 192, Transportation of Natural and Other Gas by Pipeline: Minimum Federal Safety Standards, Subpart P, Gas Distribution Pipeline Integrity Management.

PHMSA has issued the following Advisory Bulletins related to premature cracking of older plastic pipe:

- ADB-07-01, *Updated Notification of the Susceptibility to Premature Brittle-Like Cracking of Older Plastic Pipe*[38]: This advisory bulletin called operators' attention to cracking issues on pipe and components manufactured by Century Utility Products, Inc.; low ductile inner wall "Aldyl A" piping manufactured by Dupont before 1973; polyethylene gas pipe made from PE 3306 resin; Delrin insert tap tees; and caps made of Celcon (polyactal) on Plexco service tees.
- ADB-02-07, *Notification of the Susceptibility to Premature Brittle-Like Cracking of Older Plastic Pipe*[39]

7.2 State Pipeline Safety Requirements

The Pennsylvania Public Utilities Commission (PA PUC) regulates the enforces 49 CFR Part 192 regulation for all gas distribution operators in the state. The PA PUC

[38] Federal Register :: Pipeline Safety: Updated Notification of the Susceptibility to Premature Brittle-Like Cracking of Older Plastic Pipe
[39] Federal Register :: Notification of the Susceptibility To Premature Brittle-Like Cracking of Older Plastic Pipe

does not impose any addition distribution integrity regulations beyond 49 CFR Part 192 Subpart P.

The PA PUC has inspected UGI for safety compliance with PHMSA's Minimum Federal Safety Standards. However, the PA PUC refused to produce relevant, unredacted inspection reports for the UGI Distribution Integrity Management Program (DIMP) for the five years prior to the accident on the grounds that they are protected from disclosure by the PA Confidential Security Information (CSI) Act.[40] Consequently, the NTSB has issued a subpoena to the PA PUC to obtain these reports needed to support this investigation. Accordingly, the factual information relevant to these regulatory interactions and this investigation will be included in an addendum to this factual report at a later date.

8.0 Historical Records

UGI completed inside leak surveys per the following table for 17 S. 2nd Ave and 77 S. 2nd Avenue since 2018.

Table 9. 5 year inside leak survey results[41]

Corresponding Service Address	Service Order	Order Type	Description	Completion Date	Resolution Code	Premise Supplement	Meter inside leak survey	Meter corrosion level
17 S 2nd Ave	100271459	ZCOM	Inside Slip 3 Yr	6/6/2018	99-Resolvd to Satisf of UGI/Cust	*2	Completed - No Leak Found	Yes - Mild
77 S 2nd Ave	100272606	ZCOM	Inside Slip 3 Yr	6/6/2018	99-Resolvd to Satisf of UGI/Cust	*3	Completed - No Leak Found	Yes - Mild
17 S 2nd Ave	101099547	ZCHG	Replace Meter	6/11/2020	99-Resolvd to Satisf of UGI/Cust	*2	Completed - No Leak Found	Yes - Mild
77 S 2nd Ave	101316718	ZCOM	Inside Slip 3 Yr	2/16/2021	99-Resolvd to Satisf of UGI/Cust	*3	Completed - Leak Found	Yes - Mild
17 S 2nd Ave	200077987	ZEMG	Device	2/16/2021	52 -Gas Leak Pos-Referred to CnM	*2	Completed - Leak Found	Yes - Mild

8.1 Leak and Failure History

UGI used incident data maintained by PHMSA as the system of record for incident information. Prior to March 24, 2023, UGI had no incidents they attributed to

[40] PA PUC Party Removal Letter- 18Sept2023.pdf (ntsb.gov)
[41] UGI-Inside Leak surveys for 17 S. 2nd Ave or 77 S. 2nd Ave 2018-2023

Aldyl A services or mains.[42] According to the PHMSA data, nine significant incidents[43] have involved UGI assets since 2010. These incidents were attributed to the following causes:

- (2) excavation damage
    - October 31, 2011 – Millersville, PA, 0 fatalities/injuries – An 8-inch diameter plastic, polyethylene main (installed 1998) was damaged by third-party horizontal directional drilling. excavation damage (PHMSA Report 20110387)
    - August 9, 2018, Jersey Shore, PA – 0 fatal, 0 injured – steel main (installed 1961) – excavation damage (PHMSA Report 20180083)
- (2) material failure
    - July 2, 2017, Millersville, PA – 1 fatal, 3 injured – plastic service (installed 1998) – material failure of pipe or weld [NTSB Report] (PHMSA Report 20170064)
    - December 25, 2020, Swiftwater, PA – 1 fatal, 2 injured – plastic main (installed 2019) – material failure of pipe or weld. 12-inch diameter high density PE separated at the butt fusion interface. PHMSA Report (20210013)
- (2) natural force damage
    - February 9, 2011 – Allentown, PA, 5 fatal, 3 injured – A circumferential crack (with separation) in a 12-inch diameter cast iron main (installed 1928) fueled an explosion destroyed two row homes and a subsequent fire destroyed six others. Frost, frozen ground, and vehicular loads were reported as contributors to failure of the partially graphitized main. (PHMSA Report 20110046)
    - August 18, 2021, Knoxville, PA – 0 fatalities/injuries – steel regulator station (installed 1976) – natural force damage. Flood. (PHMSA Report 20210079)
- (1) incorrect operation
    - December 22, 2017, Wilkes-Barre, PA – 0 fatal, 1 injured – steel 10" bottom out fitting (installed 2015) – incorrect operation (PHMSA Report 20180011)
- (1) other outside force damage

[42] UGI-Aldyl A Reportable Incidents

[43] PHMSA defines *significant incidents* as: incidents including any of the following conditions, but gas distribution incidents caused by a nearby fire or explosion that impacted the pipeline system are excluded: 1) Fatality or injury requiring in-patient hospitalization. and 2) $50,000 or more in total costs, measured in 1984 dollars.

- December 4, 2014, Dunmore, PA – 1 fatal, 0 injured – A 2-inch diameter high-density plastic main (installed 2014) was damaged by water jetting from a corroded cast iron water main which was operating at 100 psig. (PHMSA Report 20150001)

- (1) other incident cause
  - March 24, 2023, West Reading, PA – 7 fatal, 3 injured – (PHMSA Report 20230022) *this accident.

8.2 Odor Complaint History

In the 5 years prior to the accident, three odor complaints were received by UGI in the vicinity of the accident. None were related to this accident.[44]

9.0 Post-accident Actions

9.1 PA PUC

Following the explosion, the PA PUC Bureau of Investigation and Enforcement (I&E) Safety staff queried UGI Utilities about leaks and work in the West Reading area, which led to an elevated I&E Safety presence throughout West Reading in the months following the explosion.

Additionally, on April 10, 2023, the PA PUC provided a letter to UGI stating the following:

> "As the investigation in West Reading PA continues, UGI Utilities, Inc, ("UGI") is reminded that the safe operations of its natural gas facilities in the Commonwealth of Pennsylvania are its responsibility. State and federal regulations require UGI to provide safe and reliable service that meet or exceed public utility and applicable safety regulations.
> In light of the time lag in discovery of any potential facility failures due to site access restrictions, I&E Safety advises UGI to review standards, procedures, plans and training pertaining to work associated with Aldyl A piping and potentially other plastics classified as first-generation plastics.
>
> I&E further recommends that planned work involving directly attaching, fusing or coupling to Aldyl A piping be halted until the standards, procedures, plans and training are reviewed and deemed appropriate

[44] UGI 5 Year Leak History and Odor Complaints 2nd Ave

by UGI. I&E also advises that UGI begin gathering any and all data available when first generation plastic is exposed or retired.

I&E also reminds UGI to review their Public Awareness program and requirements specifically regarding instructions for gas odors and leaks. I&E advises UGI to review the program messages and languages commonly understood by a significant number and concentration of the non-English speaking population in the operator's area."

I&E Safety Division Manager told the NTSB they are exploring UGI's historical classification, data collection, integrity history and inclusion of all applicable plastics for integrity purposes. He also reported that any enforcement actions will be considered at the conclusion of the investigation.

9.2 UGI

UGI indicated that they've taken or plan to take the following post-accident safety actions: [45]

- Create an electronic data repository and training program for subject matter experts that utilizes, and documents external knowledge sources related to distribution system risks and threats.
- Implement a probabilistic risk modeling tool that normalizes risk outputs across a granular set of asset types (transmission pipe, distribution pipe, services, regulator stations, etc.).[46]
- Review Aldyl-A assets and define an asset population comprised of plastic pipe and fittings historically installed at UGI and its predecessor companies.
- Create visual tip cards for field personnel identifying the various plastic piping and fittings installed at UGI to increase awareness of different materials and manufacturers of
- Apply additional preventative measures on this asset population including the following:
    - Opportunistic remediation of Aldyl-A Tapping Tees w/Delrin inserts whenever one is fully excavated.
    - Opportunistic data collection of plastic pipe and fittings to increase UGI's knowledge base.
    - Enhanced Material Failure metrics to trend failures against install date.
    - Continuous analysis of incoming data on UGI's plastic pipe composition.

[45] UGI-Post Accident Safety Improvements
[46] UGI-Migration to a Probabilistic Risk Model

- Additional preventative and mitigative actions as identified by UGI.

Submitted by:

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