Gas Leak Surveys

Technical Appendix to *Fixing Our Pipes: Coordinating Natural Gas Main Replacement between Local Governments & Gas Companies*

Introduction

The following Technical Appendix to the study, *Fixing Our Pipes: Coordinating Natural Gas Main Replacement between Local Governments & Gas Companies,* addresses in detail the methodology used to carry out the gas leaks surveys and the results of those surveys. The data presented in the appendix is representative of the objective results of the survey and the main report should be consulting for the full discussion and interpretation of the data.

Methods

Development

In late fall 2015, MAPC notified Eversource, Columbia Gas and National Grid of the project and indicated that the team would provide the gas companies with a chance to review and comment on the leak survey methodology. In late March 2016, the team circulated the proposed methodology for gas leak surveys to each of the gas companies and invited feedback. MAPC received feedback through email and in-person meetings, then circulated updated methodology to the gas companies in mid-April. The feedback primarily helped shape how each gas company wanted to be notified of leaks. As a result, the team determined that its gas leaks surveyor would call in Grade 1 leaks immediately to the gas company's emergency line; Grade 2 and Grade 3 leak would be reported when requested by the company after survey completion.

Selection of Municipalities

Similar to the municipal interviews for best practice development, the team endeavored to achieve municipal participation that reflected the mix of median-income levels, community types, and natural gas companies from within the MAPC region. 15 municipalities participated in the gas leak surveys (See Table 1).

Table 1. Municipal Participation in Gas Leak Surveys				
Municipality	Gas Company	Median Household Income (2010)	Median Household Income by Quartile in MAPC Region	Community Type*
ACTON	National Grid	$120,865	Q4	Maturing Suburbs
BEDFORD	National Grid	$114,676	Q3	Maturing Suburbs
BROOKLINE	National Grid	$93,640	Q2	Inner Core
CAMBRIDGE	Eversource	$75,909	Q2	Inner Core
CHELSEA	National Grid	$48,725	Q1	Inner Core
HOPKINTON	Eversource	$128,267	Q4	Developing Suburbs
LEXINGTON	National Grid	$137,456	Q4	Maturing Suburbs
MALDEN	National Grid	$55,523	Q1	Inner Core
MARLBOROUGH	Eversource	$71,424	Q1	Regional Urban Centers
MEDFIELD	Columbia Gas	$143,641	Q4	Maturing Suburbs
MILFORD	Eversource	$68,007	Q1	Regional Urban Centers
MILLIS	Columbia Gas	$96,773	Q3	Developing Suburbs
NEWTON	National Grid	$118,639	Q4	Inner Core
RANDOLPH	Columbia Gas	$63,259	Q1	Maturing Suburbs
SWAMPSCOTT	National Grid	$96,494	Q3	Maturing Suburbs

http://www.mapc.org/sites/default/files/Massachusetts_Community_Types_-_July_2008.pdf

Selection of Road Segments

The team surveyed 10 to 15 miles of road with gas infrastructure in each municipality. To identify candidate roads, the team used 1) Gas System Enhancement Plans submitted to the Department of Public Utilities (DPU) in fall of 2015 by the gas companies with data for 2016 and 2017-2020; 2) gas leak data from calendar year 2015 submitted to the DPU as part of each gas company's Annual Service Quality Report; 3) the presence of natural gas heating homes; and 4) the knowledge of Department of Public Works (DPW) staff. Road segments were selected in order to cover a mix of plastic pipe (i.e. new pipe) and non-plastic pipe, as well as roadways with various ages of pavement. The team primarily relied on DPW staff to provide a list of the street segments that had new plastic pipe replaced with in the past 3 years as well as those that had been re-paved within the past 3 years. Maps of road survey areas can be found in Exhibit 1.

Survey Data Collection

Contractor Robert Ackley of Gas Safety USA performed all gas leak surveys. Mr. Ackley was Operator Qualified by the Northeast Gas Association at the time of the surveys and has an extensive background surveying for gas leaks in Massachusetts (See Exhibit 2 for full details).

For each municipality:

1. MAPC notified both the municipality and the associated gas company of the intent to survey the selected road segments at least the day prior to start of surveying.
2. Prior to data collection contractor
    a. Ensured all equipment was calibrated to manufacturer's specifications; and

   b. Confirmed that wind and weather conditions allow for suitable data collection
3. Contractor drove each selected road segment between 5 and 10 mph while running a Picarro high-precision natural-gas analyzer (Picarro G2132i Cavity Ring-Down spectrometer), which logged the time of each measurement, levels of methane (parts per million) in the air, and the corresponding Geographic Positioning System (GPS) coordinates ("Picarro data").
   a. Contractor drove both sides of each road segment to capture Picarro data, unless the location of the natural gas main in the street is clearly identifiable and can be driven precisely
4. MAPC analyzed the Picarro data using ArcGIS to identify baseline methane levels in the air for that day and then identified the methane measurements that deviated from the baseline by more than 5%.
5. In each location that the Picarro data showed surface methane that exceeded baseline surface methane levels by more than 5%, contractor performed the following steps to determine whether the source of methane was sub-surface or not. MAPC believes the following procedure of 5.a. Through 5.d. conforms, to the degree possible, to the procedures identified by the natural gas distribution utilities for their mobile surveys of mains (See Exhibit 3 for details):
   a. Use a portable hydrogen flame ionization unit to determine the extent (i.e. boundaries) of fugitive methane emissions ("emissions") up to the boundaries of any private property. The distance from the unit to the ground will not exceed 3 inches. Once determined, the contractor found suitable location(s) within the emissions extent to take at least one sub-surface Combustion Gas Indicator (CGI) reading. This location may be:
      i. A sub-surface space that already exists, such as an opening in a manhole cover; or
      ii. A sub-surface space created by the use of 3/8 inch diameter bar, inserted into either an existing fissure or crack in the pavement or bare ground within the leak extent. This space will be located no closer than 20 inches perpendicular to the estimated source of the leak. The bar will be inserted no deeper than 6 inches below the surface of the pavement. This depth will be consistently achieved by affixing a measurement marker at 6 inches on the bar. The contractor will remove the bar and then insert the CGI into the space.
   b. The contractor avoided creating any new holes in the pavement. If, for some reason, a hole was created in the pavement, the contractor filled that hole.
   c. The contractor measured the level of methane detected with the CGI as percent of gas in air to verify the presence of a sub-surface leak.
   d. In the event that a fissure or crack does not exist to create space for the CGI and no manhole opening exists, the contractor assessed whether the leak extent encompassed any potential surface-level sources of methane, such as a meter leak. If none existed, it constituted a leak for the purposes of the MAPC survey.
6. For each leak, the contractor performed the following data collection:
   a. Estimated area of extent of the leak and record a sketch;
   b. Determine whether a leak exists or not

i. If a sub-surface CGI reading verified the presence of natural gas below ground, then it constituted a **sub-surface** leak.
ii. If a CGI reading could not verify the presence of natural gas below ground and the contractor could identify a source of gas leakage attributable to the distribution system (e.g. meter leak), it constituted a **surface level leak.**
iii. If a CGI reading could not verify the presence of natural gas below ground and the contractor could **not** identify any other source of gas leakage attributable to the distribution system (e.g. meter leak), then it did **NOT** constitute a leak.

c. Classify the leak as Grade 1, 2, or 3, according to each natural gas distribution utility's written procedures, attached and incorporated herein as **Exhibit 3**. If the extent of the leak trespasses onto private property, a sub-surface CGI reading cannot be taken, or the leak for other reasons cannot be assigned a Grade, the contractor will record it as Unable to Classify;
d. Count the number of trees within the extent of the fugitive methane emissions. A tree was deemed to be within the leak extent if the drip line, the area defined by the outermost circumference of a **tree canopy** where water drips from and onto the ground, intersected with the leak extent;
e. Record all of the aforementioned data from 4.a through 4.c in an electronic spreadsheet, along with the nearest street address or, if appropriate, street intersection; and
f. Immediately notify the appropriate gas distribution utility of any instance in which a Grade 1 leak is identified;

Roads Surveyed

The project surveyed 173 linear miles of road across the 15 municipalities and achieved a median distance of just over 10.5 miles per municipality (See **Table 2**).

Table 2. Miles Surveyed per Municipality

Municipality	Miles Surveyed		
	Total	New Pipe	New Pavement
National Grid			
ACTON	15.07	1.25	0.23
BEDFORD	13.9	2.32	2.88
BROOKLINE	10.51	1.58	1.7
CHELSEA	13.44	1.33	0.54
LEXINGTON	10.31	1.34	3
MALDEN	12.48	0.46	0.36
NEWTON	10.51	0.89	1.59
SWAMPSCOTT	9.02	0.78	0.83
Eversource			
CAMBRIDGE	10.84	5.5	3.25

HOPKINTON	14.95	3.96	6.9
MARLBOROUGH	14.85	0.97	1.27
MILFORD	10.18	0.4	0.65
Columbia Gas			
MEDFIELD	9.89	2.1	1.03
MILLIS	7.71	3.14	1.35
RANDOLPH	8.88	1.4	0.74
Grand Total	172.56	27.42	26.32

The proportion of distance surveyed in each gas company's territory corresponds roughly to the proportion of municipalities in the study (see Table 3). National Grid municipalities comprise 53% of the study and 55% of the mileage. Mileage from Columbia Gas is slightly under represented, comprising 20% of the municipalities but only 15% of the mileage. Conversely, mileage from Eversource is slightly over-represented, with 27% of the municipalities and 29% of the mileage.

Table 3. Mileage Surveyed per Gas Company			
Gas Provider	Median Miles Per Municipality	Miles Surveyed	Municipalities
Columbia Gas	8.88	26.49	3
Eversource	12.85	50.82	4
National Grid	11.5	95.25	8
Grand Total		172.56	15

Mileage surveyed on new pipe and new pavement relatively over-represents Eversource with 40% of the new pipe and 44% of the new pavement but just 27% of the municipalities (see Table 4).

Table 4. Miles of New Pipe and Pavement Gas Company		
Gas Provider	Miles of New Pipe	Miles of New Pavement
Columbia Gas	6.64	3.11
Eversource	10.84	12.07
National Grid	9.94	11.13
Grand Total	27.42	26.32

Timing

Gas leak surveys began in late April 2016, after the ground had sufficiently thawed, in order to allow methane to escape to the surface where it can be detected. Surveys continued through mid-June.

Findings

Quantity, Detection and Grade of Leaks

The surveys identified 513 gas leaks. Less than 1% of the leaks (5) occurred above ground, near a home or business' external gas meter. The remaining 508 leaks were determined to be subsurface. The vast majority of the leaks were classified as Grade 3 (76%) with 18% Grade 2 and only 5% Grade 1 (see Table 5).

Table 5. Leak Classifications

Leak Grade	Count
1	28
2	94
3	391
Grand Total	513

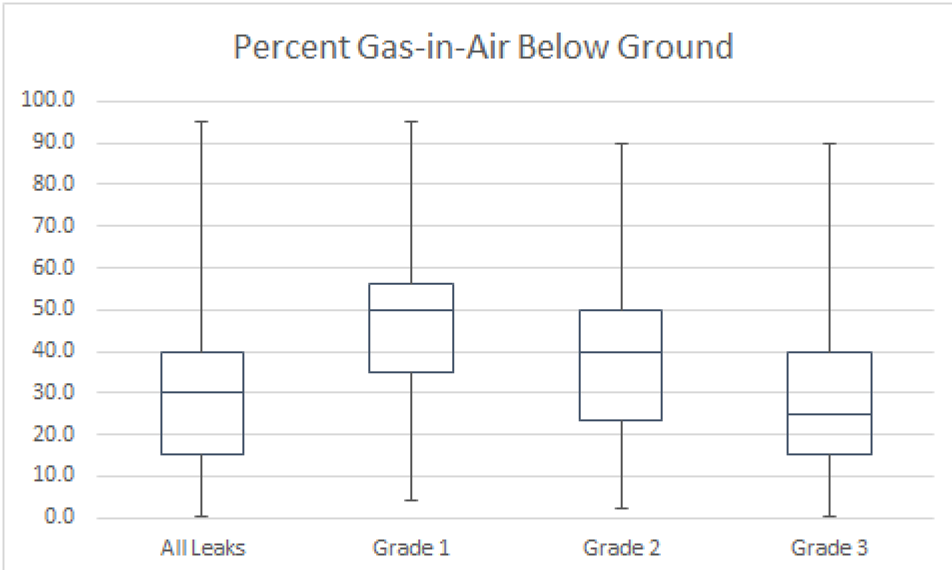
Of the subsurface leaks, 95% (482) were identified based on a combustible gas indicator (CGI) reading, which measures the percent of gas-in-air below ground (taken after creating a ¼ inch diameter hole in which to insert the CGI). The remaining 5% (26 leaks) were identified using a flame ionization unit to measure the parts per million (ppm) of gas in the air above ground. In these cases, the contractor assessed the scene to determine if there was any potential surface source of methane. If none could be located, the reading was determined to be caused by a subsurface leak. In the majority of cases, the FIU reading was taken at a storm drain. 42% of theses leaks were found in Newton and 29% in Brookline (See Table 6.)

Table 6. Sub-Surface Leaks by Detection Method

Municipality	Flame Ionization Unit (FIU)	Combustible Gas Indicator (CGI)	Total
ACTON	0	58	58
BEDFORD	1	29	30
BROOKLINE	5	63	68
CAMBRIDGE	2	17	19
CHELSEA	0	37	37
HOPKINTON	1	22	23
LEXINGTON	2	20	22
MALDEN	0	56	56
MARLBOROUGH	2	27	29
MEDFIELD	1	14	15
MILFORD	0	0	0
MILLIS	0	25	25
NEWTON	11	58	69
RANDOLPH	0	29	29
SWAMPSCOTT	1	27	28
Grand Total	26	482	508

Of those 482 leaks with a CGI reading, the median reading was 30% gas-in-air below ground. When broken out by Grade, the median percentage of gas-in-air below ground increased with the severity of the Grade, with the median for Grade 1 (50%) twice as high as Grade 3 (25%) (See Figure 1).

Figure 1. Percent Gas-in-Air Below Ground



The cause of Grade 1 leaks were split roughly evenly, with 54% occurring due to gas build up in an enclosed space such as a sewer or utility manhole, and 46% occurring due to elevated percentages within five feet or less from a building's outer wall. In both cases, gas has the potential to accumulate which could pose an explosion risk. The ability to accumulate in an enclosed space or against a foundation is the likely reason for the higher percent gas-in-air below ground readings from the CGI with the Grade 1 leaks.

The distribution between Grades on new, plastic pipe and on old or unknown pipe was largely similar (see Table 7).

Table 7. Leak Grade by Pipe Type

Pipe Type	Grade			Total
	1	2	3	
Non-Plastic Pipe (n=470)	5%	19%	76%	100%
Plastic Pipe (n=9)	0%	22%	78%	100%
Multiple or Intersection (n=29)	10%	17%	72%	100%

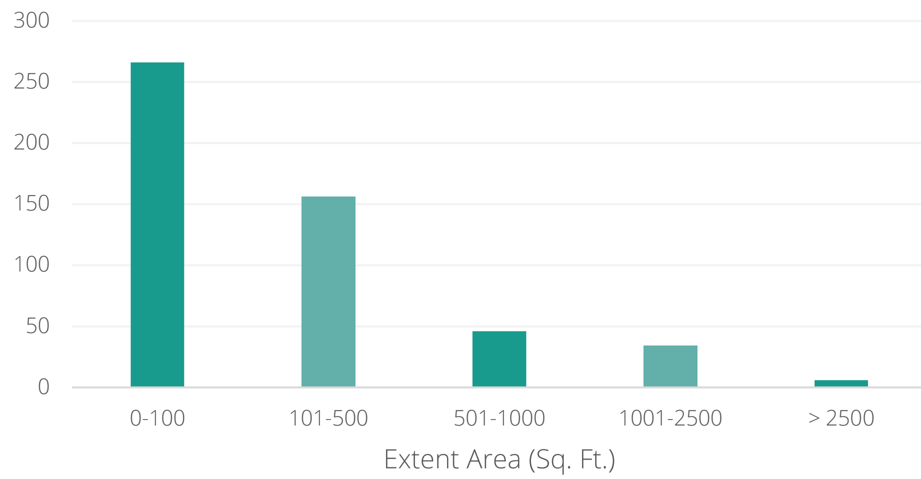
Two scenarios prevented attributing some leaks to either type of pipe. 21 leaks occurred at the intersection of plastic and non-plastic pipe. Another 8 leaks occurred on street segments with both plastic and non-plastic pipe running parallel.

Extent of Leaks

The surveys estimated how much area of soil each of the 508 subsurface leaks covered, and in total, the surveys found 196,987 square feet of leak extent. This area corresponds to roughly 3.4 football fields of soil with measureable concentrations of gas-in-air below ground.

The median leak extent was 100 square feet or less, with the largest leak estimated at 5,000 square feet (See Figure 2).

Figure 2. Leak Distribution by Extent Area



Leaks over 1,000 sq. ft. are more than ten times larger than the median leak extent, and the study refers to these leaks are "over-sized". Over-sized leaks constitute 7.9% of the leaks in the survey, yet they represent 46.8% of the total leak extent area (See Table 8).

Table 8. Oversized Leaks

Leak Size	Quantity	Extent Area (sq ft)
Oversized (>1,000 sq ft)	40	92,100
All	508	196,987

Of these over-sized leaks, roughly two-thirds (62.5%) are classified as Grade 3 and those leaks comprise over two-thirds (68.8%) of the extent area (See Table 9).

Table 9. Over-sized Leaks By Grade

Grade	Quantity	Extent of Oversize Leaks (sq ft)
1	5	10,000
2	10	18,700
3	25	63,400
Total	40	92,100

Of the over-sized leaks, as the severity of the Grade increases, the relative frequency of oversized leaks increases, too. It is almost three times more likely that a Grade 1 will be oversized than a Grade 3 (see Table 10).

Table 10. Frequency of Over-sized Leaks in Each Grade	
Grade	Percent of Grade that is Oversized (>1000 sq ft)
1	17.90%
2	10.60%
3	6.50%
Total Oversized	7.90%

Figures 3 and 4 show how the distribution of leak extents varies with Grade. Figure 3 includes *all* 508 leak extents, showing the minimum, first quartile, median, third quartile and maximum values. Figure 4 zooms in to provide a more detailed view of data without the outliers.

When analyzed according to Grade, each Grade shows a similar distribution pattern, with median extents under 500 square feet and all Grades having leaks exceeding the "over-sized" threshold of 1,000 square feet. However, the Grades do differ in important ways. As the severity of the Grade increases:

- The maximum leak extent decreases;
- The leak extents deviate more from the median;
- The median leak extent increases, more than tripling from Grade 3 (100 sq ft) to Grade 1 (325 sq ft)

Figure 3. Distribution of All Leak Extents by Grade

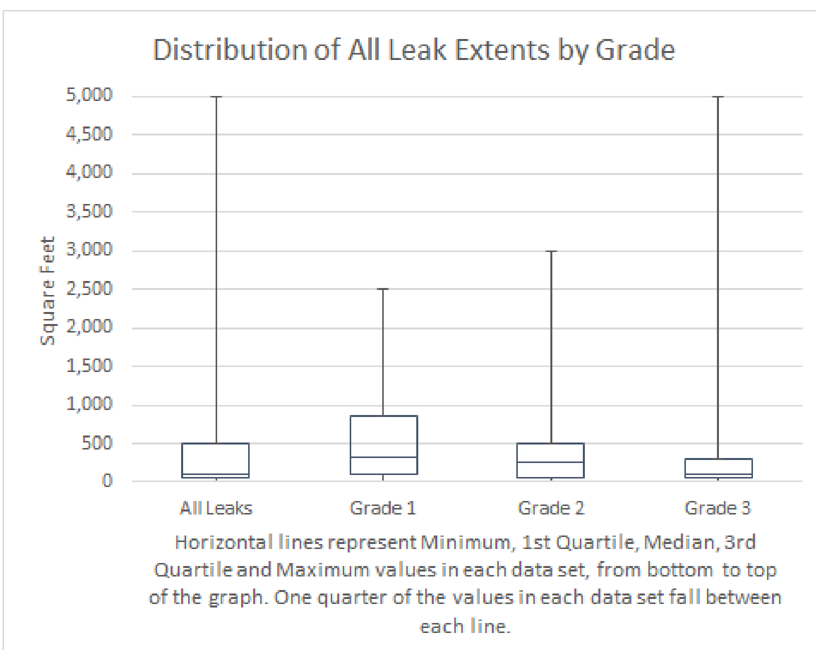
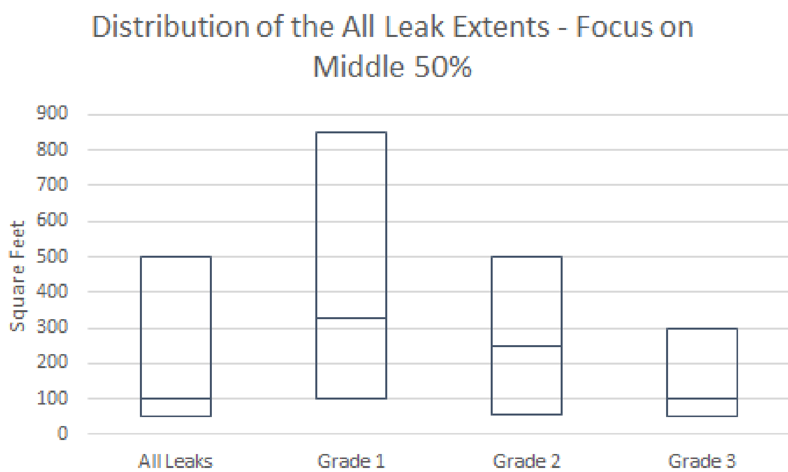


Figure 4. Distribution of All Leak Extents by Grade without Outliers



Horizontal lines represent 1st Quartile, Median, and 3rd values in each data set, from bottom top of the graph. One quarter of the values in each data set fall between each line. The lower quarter and top quarter of the data set are not shown.

Between municipalities, Acton had the most over-sized leaks (40% of over-sized leaks) followed by Marlborough (18% of over-sized leaks).

Table 11. Over-Sized Leaks

Municipality	Over-Sized Leaks (<1,000 sq ft)	Other Leaks	Total
ACTON	16	42	58
BEDFORD	1	29	30
BROOKLINE	5	63	68
CAMBRIDGE	1	18	19
CHELSEA		37	37
HOPKINTON	4	19	23
LEXINGTON		22	22
MALDEN	1	55	56
MARLBOROUGH	7	22	29
MEDFIELD		15	15
MILFORD		25	25
MILLIS		0	
NEWTON	3	66	69
RANDOLPH	1	28	29
SWAMPSCOTT	1	27	28
Grand Total	40	468	508

Trees within Leak Extents

A tree located within the extent of a subsurface leak is referred to in the study as an exposed tree. The project found that 130 trees were exposed across 102 separate leak extents, representing 20% of all leak extents. (See **Table 12).** Over the 181.8 miles surveyed, this returned 0.72 exposed trees per mile.

Table 12. Trees in Leak Extents	
	Leak Extents
With a Tree	102
No Tree	406
Total	508

Of those leak extents with a tree, the vast majority (81.3%, n=102) had only one tree. The maximum number of trees in a leak extent was 6 (See **Table 13**).

Table 13. Distribution of Trees in Leak Extents	
Number of Trees in a Leak Extent	Number of Leaks
1	83
2	14
3	3
4	1
5	0
6	1
Grand Total	102

The majority of exposed trees occurred in Grade 3 leaks (See **Table 14**).

Table 14. Exposed Trees by Grade	
Grade	Number of Exposed Trees
1	2
2	42
3	86
Grand Total	130

Pavement Type: Leaks per Mile

The study defined new pavement as any pavement laid in the past 3 years (2015, 2014, and 2013). The following data only includes leaks that were subsurface (i.e. not meter leaks). As shown in **Table 15**, sections of old pavement had more than twice the number of leaks per mile compared to old pipe.

Table 15. Leaks per Mile on Old and New Pavement			
Pavement Age	Miles	Leaks	Leaks per Mile
Old Pavement	146.24	460	3.15
New Pavement	26.32	36	1.37
Grand Total	172.56	496	2.87

12 leaks could not be attributed to either type of pavement because they occurred at the intersection of old and new pavement.

On new pavement, nearly half (7) of the municipalities had less than 1 leak per mile, and only a third (5) had more than 2 leaks per mile (See Table 16).

Table 16. Leaks on New Pavement per Municipality			
Municipality	Miles of New Pavement	Leaks on New Pavement	Leaks Per Mile
ACTON	0.23	2	8.78
BEDFORD	2.88	7	2.43
BROOKLINE	1.7	4	2.36
CAMBRIDGE	3.25	0	0
CHELSEA	0.54	0	0
HOPKINTON	6.9	2	0.29
LEXINGTON	3	3	1
MALDEN	0.36	0	0
MARLBOROUGH	1.27	2	1.57
MEDFIELD	1.03	0	0
MILFORD	0.65	3	4.61
MILLIS	1.35	0	0
NEWTON	1.59	12	7.53
RANDOLPH	0.74	0	0
SWAMPSCOTT	0.83	1	1.21

In contrast, on old pavement, only 1 municipality had less than 1 leak per mile, and three quarters, (75%, n=12) had more than 2 leaks per mile (See Table 17).

Table 17. Leaks on Old Pavement per Municipality			
Municipality	Miles of Old Pavement	Leaks on Old Pavement	Leaks Per Mile
ACTON	14.85	56	3.77
BEDFORD	11.03	23	2.09
BROOKLINE	8.81	64	7.26
CAMBRIDGE	7.59	19	2.5
CHELSEA	12.9	37	2.87

HOPKINTON	8.04	19	2.36
LEXINGTON	7.31	17	2.33
MALDEN	12.12	55	4.54
MARLBOROUGH	13.58	25	1.84
MEDFIELD	8.86	15	1.69
MILFORD	9.53	22	2.31
MILLIS	6.37	0	0
NEWTON	8.91	52	5.83
RANDOLPH	8.14	29	3.56
SWAMPSCOTT	8.19	27	3.3
Grand Total	146.24	460	3.15

When analyzed according to gas company, Columbia Gas had by the lowest rate of leaks on old pavement, at less than 1 leak per mile. Columbia Gas also had the lowest rate of leaks on new pavement, with zero, showing a 100% reduction. Despite different starting points of leaks per mile on old pavement, all three gas companies reduced leaks per mile by a similar amount when compared to new pavement (See Table 18).

Table 18. Leaks per Mile by Gas Company

Gas Company	Leaks per Mile			% of Leaks at Intersection of Old & New Pavement
	New Pavement	Old Pavement	Difference	
Columbia Gas	0	1.88	1.88	N/A
Eversource	0.58	2.19	1.61	4%
National Grid	2.6	3.94	1.33	2%
Total	1.37	3.15	1.78	0

Pipe Type: Leaks per Mile

Leaks per mile on new, plastic pipe were 90% lower than leaks per mile on old, non-plastic pipe (See Table 19).

Table 19. Leaks per Mile on Old and New Pipe

Pipe Type	Miles	Leaks	Leaks per Mile
Non-Plastic	144.24	470	3.26
Plastic	27.42	9	0.33
Grand Total	171.66	479	2.79

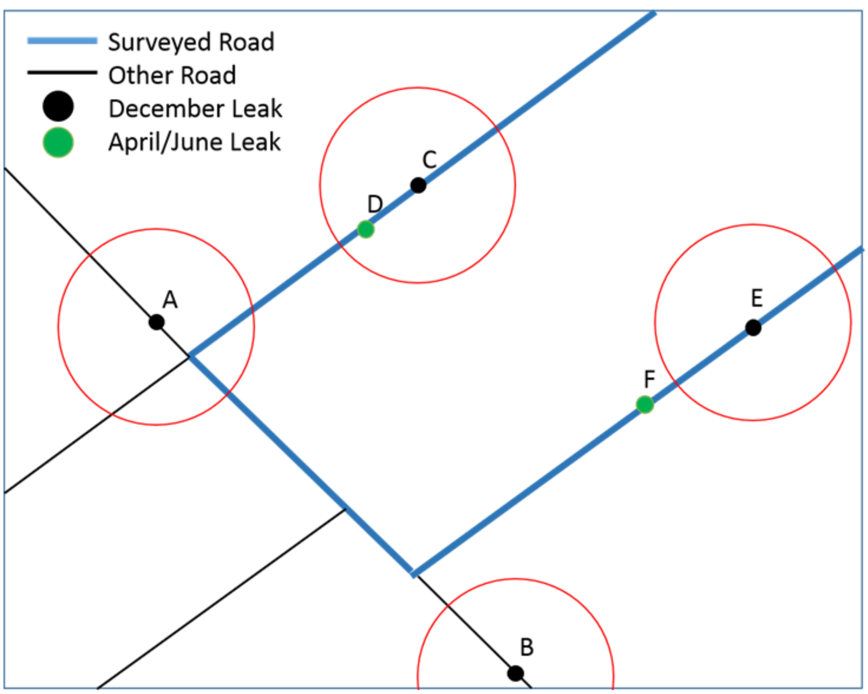
Two scenarios prevented attributing some leaks to either type of pipe. 21 leaks occurred at the intersection of plastic and non-plastic pipe. Another 8 leaks occurred on street segments with both plastic and non-plastic pipe running parallel (0.89 miles total).

COMPARISON OF GAS COMPANY LEAKS TO STUDY LEAKS

The study afforded the opportunity to assess the change in gas leaks over time. The most recent gas company data was reported as of December 31, 2015, in each gas company's Annual Service Quality Report for 2015, submitted to Department of Public Utilities (DPU) on March 1, 2016. The study's surveys occurred between April 15 and June 15, 2016. In that intervening time, from January to June the winter freeze thaw cycle as well as general pipe and joint degradation is expected to lead to new many new leaks. At the same time, the gas company is expected to be repairing leaks.

To assess the change in leaks over time, the study first determined which of the December gas company leaks to include in the study area. First, the study mapped all of the December leaks for each surveyed municipality, using the address and/or cross street provided in the gas company data using Geographic Information Systems (GIS). Any leak listed that was located on a segment of surveyed road was included. Additionally, the team included any leak that was within a 100 ft. radius of the end of our surveyed roads and on a road that intersected with the surveyed road. The radius allowed for leaks recorded on a road that intersects with the surveyed road to be included, in case the gas company chose to record the address of the leak using either of the streets or both (See Figure 5). This resulted in 291 leaks from the December data set being included in the survey area. The team included all 513 leaks from the April/June data and mapped it in GIS as well.

Figure 5. Mapping December and April/June Data Sets



Example showing leaks existing as of December 31, 2015 in gas company data and leaks existing as of April-June from the study. Red circles show the 100 ft buffer. Point A is included in the survey area because it is located on a street that intersects with a surveyed road and is within 100 feet of that road. Point B is not because it is too far away. A 100 ft buffer was also put around each leak to identify nearby leaks that were possible matches between the December and April-June data sets. Point C and D match, but Point E and F are too far apart to match.

Next, the study determined which leaks existed in both the December and April/June data sets, and therefore could be assumed to be the same, pre-existing leak. Based on comparing the mapped locations and the leak reports for the April/June leaks, it became apparent that the mapped location of an address does not always match with the center of the leak extent. For example, the mapped address may place the leak in the middle of a property's frontage, but the leak may be to one side of the property. Additionally, for a leak that spreads to both sides of a street, the address might vary between the gas company data and the study data, because one could record the address from the even- or odd-side of the street. Finally, the extent of the same leak can change over time due to conditions including saturation of soil, wind and other factors. To account for the possible discrepancies between how the leaks are mapped and between how study and the gas company may have recorded the location of the same leak, as well as potential migration of the leak extent over time, the study chose to put a 100 ft buffer around each gas company leak for comparison purposes.

If a buffered December leak overlapped or encompassed an April/June leak, then the study determined that those leaks matched. The team visually inspected each match on a map, to check whether there existed a conflict. Conflicts were considered leaks that were located on different streets that did not intersect (e.g. parallel streets); matches with conflicts were removed. On a small percentage of the matches (3.6%) occurred on intersecting streets.

The study found that of the 291 December leaks, 139 matched to one or more April/June leaks (total of 155 April/June leaks). This left 152 leaks from December that were not in the April/June study; these leaks may have been fixed by the gas companies since December. Of the 513 April/June leaks, after subtracting the 155 matched leaks, it leaves 358 leaks that were not in the December data; these leaks may have been created since December.

Since December 31, 2015 with a potential reduction of 152 leaks and a potential increase in 358 new leaks, the data suggest a net increase of 206 leaks by June 15, 2016 over the 291 existing in December, or a 70.8% increase (See Table 20).

Table 20. Leak Discovery and Repair Data for January to June 2016

	Leaks Existing as of December 31, 2015	Leaks Discovered Between Jan 1 and June 15, 2015		Discovered Before Jan 1, 2015 and Repaired Between Jan 1 and June 15, 2015
		Not Repaired by End of Period	*Repaired by End of Period*	
Survey	291	358	Unknown	155

To put the data into perspective, the team assessed the growth of leaks against the published gas company data for all of 2015. The gross rate includes the total number of leaks that were created, whether they were repaired or still existing at the end of the period. The net rate subtracts the repaired leaks from the total. The team found that over the January 1 to June 15 period used by the study, in 2015, the gross growth rate was 65% and net only 18%. Over the course of the calendar year 2015, gross leaks increased 123%, but net leaks only 21% (Tables 21 and 22).

Table 21. Leak Discovery and Repair Data for January to June 2015				
Gas Company	Leaks Existing as of December 31, 2014	Leaks Discovered Between Jan 1 and June 15, 2015		Discovered Before Jan 1, 2015 and Repaired Between Jan 1 and June 15, 2015
		Not Repaired by End of Period	*Repaired by End of Period*	
Columbia Gas	2,088	632	1,619	331
Eversource	2,657	288	868	22
National Grid	8,349	2,031	3,059	198
Grand Total	13,094	2,951	5,546	551

Table 22. Leak Discovery and Repair Data for Calendar Year 2015				
Gas Company	Leaks Existing as of December 31, 2014	Leaks Discovered Between Jan 1 and Dec 31, 2015		Discovered Before Jan 1, 2015 and Repaired Between Jan 1 and Dec 31, 2015
		Not Repaired by End of Year	*Repaired by End of Year*	
Columbia Gas	2,088	1,089	3,355	598
Eversource	2,657	989	2,001	28
National Grid	8,349	1,894	6,769	623
Grand Total	13,094	3,972	12,125	1,249

The growth rate of 70.8% calculated by the study should represent the net rate, because it captured the leaks that were still existing at the time. In comparison to the 18% and 20% net growth rates over the same period in the previous year and the entire previous calendar year, respectively, based on gas company data, 70.8% is significantly higher.

The reason for the higher than expected growth rate in net leaks is unclear. It is possible that the gas company data for the time period, which will be provided to DPU in early 2017, will show a similar number of leaks as found by the survey. Without that data, the study can only use previous data as a reference point. Unlike most other previous studies, this study included an on-the-ground investigation process, like the gas companies, to determine if elevated methane readings in the air actually constituted a sub-surface or above ground leak. As a result, it may be instructive to compare leak detection methodologies between the study and gas companies, which could be divided into two categories:

1) Identifying areas of elevated methane in the air
2) Investigating those areas to determine if a potential leak exists

MAPC and HEET acknowledge that the process to identify areas of elevated methane in the air did differ from that used by gas companies, but MAPC and HEET understand that the process to investigate those areas to determine if a leak exists followed almost exactly the same process as the gas companies.

To identify areas of elevate methane in the air, both the gas companies and the study use mobile survey vans equipped with air monitoring equipment that can detect levels of methane in the air. Gas companies use a Flame Ionization Unit (FIU), which measures methane in parts per million. The FIU has a dial to show the current reading, but it does not record any data and must be monitored during the drive. In contrast, the study used a Picarro analyzer to monitor methane levels in the air. The Picarro can detect parts per billion, however for leak detection, parts per million is sufficient. The main difference of the Picarro compared to an FIU is that the Picarro takes continuous samples of the air and digitally logs each measurement, along with a timestamp and GPS point, in addition to other metrics. This log enabled the study to process data and quantitatively identify areas of deviation from baseline levels, to which the contractor returned to perform the leak investigation.

When the contractor returned to investigate the leaks, the contractor took sub-surface readings of the percent of gas-in-air below ground to determine if sub-surface methane exists and the physical extent of the leaks. The gas company certainly performs additional work once it decides to repair a gas leak, such as drilling deeper test holes, aerating and purging the pipes and ultimately excavating the pipe. However, at the time of leak detection, its procedures describe the same type of process as used by the survey, which relies on sub-surface CGI readings. If the CGI did not return any sub-surface gas-in-air reading, the contractor may have also found a surface-level leak, such as a meter leak.

Exhibit 1: Maps of Surveyed Roads

Maps of the surveyed roads in each municipality can be downloaded at the following link: https://mapc-org.sharefile.com/d-sb0c9529a35f4fb4a

Exhibit 2: Resume of Mr. Ackley

Robert C. Ackley
Gas Safety Inc.
16 Brook Lane
Southborough, MA, 01772
bobackley@gassafetyusa.com
508-344-9321

Curriculum Vitae

April 7, 2016

Education

Graduate Degree: Graduate College for Financial Planning Denver, Colorado, 1992

Undergraduate Degree: Quinnsigamond College, Worcester, MA, 1977-80

Certification

"Operator Qualified" certified by Northeast Gas Association through March 2019 for the following:

- Conduct natural gas pipeline surveys
- Investigation of natural gas odor complaints
- Leak classification
- Patrolling natural gas transmission lines
- Abnormal Operating Conditions

Employment

Sole Stockholder, Gas Safety Inc. (Gassafetyusa.com), 2006-Present

- Gas Safety Inc. detects fugitive methane emissions from natural gas extraction to end use.
- Selected examples of gas leak surveys include:
    - City of Fitchburg through Technical Assistance Grant for Pipeline and Hazardous Materials Safety Administration;
    - Damascus Citizens for Sustainability, Narrowsburg, New York; and
    - Town of Hingham
- Current collaborations continue with research teams from Boston University and Stanford University working on quantifying emissions from various sources. See Publications for detail.

Vice President of Operations and Training, Omark Consultants, 2001-2006

- A natural gas leak consulting company. In charge of operator qualification for over 40 employees, contract bidding and general corporate operations.

Previous experience, 1978-200, providing training and compliance safety services to natural gas operators to identify and classify natural gas leakage, transmission line patrolling, and atmospheric corrosion inspections and training.

PUBLICATIONS

1. Crosson E, Phillips N, Hutyra L, Turnbull J, Sweeney C, Ackley R, Tan S (2011) Identification of Methane Emissions in an Urban Setting. NOAA Research Abstract, ESRL Global Monitoring Ann. Conf., May 17-18. www.esrl.noaa.gov/gmd/annualconference/abs.php?refnum=99-110418-A

2. Phillips NG, R Ackley, ER Crosson, A Down, LR Hutyra, M Brondfield, JD Karr, K Zhao, RB Jackson. 2013. Mapping urban pipeline leaks: methane leaks across Boston. *Environmental Pollution* 173:1-4, doi:10.1016/j.envpol.2012.11.003.

3. Jackson, RB, A Down, NG Phillips, RC Ackley, CW Cook, DL Plata, K Zhao. 2014. Natural gas pipeline leaks across Washington, D.C. *Environmental Science & Technology,* 48: 2051-2058, doi:10.1021/es404474x.

4. Natural Gas Pipeline Replacement Programs Reduce Methane Leaks and Improve Consumer Safety *ENVIRONMENTAL SCIENCE & TECHNOLOGY LETTERS* Gallagher, M. E., Down, A., Ackley, R. C., Zhao, K., Phillips, N., Jackson, R. B. 2015; 2 (10): 286-291

5. Fugitive methane emissions from leak-prone natural gas distribution infrastructure in urban environments. Margaret F. Hendrick, Robert Ackley, Bahare Sanaie-Movahed, Xiaojing Tang, Nathan G. Phillips. doi:10.1016/j.envpol.2016.01.094

Invited Speaker, “Natural Gas: Energy, Economics, Environment”, Boston University, Sept. 27, 2011.

Invited Speaker, Ecological Society of America Oral Session: Natural Gas: Energy, Environment, Economics. Approved for August, 2012, Portland, Oregon.

E. Collaborators, co-Editors, and Other Affiliations

(i) Collaborators (last 48 months):

- Nathan Phillips, Boston University
- Eric Crosson, Picarro, Inc., Santa Clara, CA
- Robert Jackson, Duke University
- Shanna Cleveland, Conservation Law Foundation

Adjunct Faculty Boston University Earth & Environment 2013 spring semester, natural gas working group.

Invited Speaker HEET Home Energy Efficiency Team Cambridge, Massachusetts September 30, 2014 Methane Program.

Exhibit 3: Gas Companies Methodologies

National Grid

To develop MAPC's leak survey methodology, MAPC consulted National Grid's procedure for mobile surveys on mains, found in the "Attachment DPU 1-1-D – LSUR-5010: Mobile Surveys" from the "First Set of Information Requests" submitted in response to D.P.U. 15-GLR-01 on May 18, 2015 by Camal O. Robinson. The attachment was submitted in response to DPU's information request DPU-1-1 "Please explain in detail how the Company detects natural gas leaks on its gas distribution system."

Classification will be done according to the criteria from "Attachment DPU 1-1-B – LEAK-5030: Leak Receipt and Classification" from the "First Set of Information Requests" submitted in response to D.P.U. 15-GLR-01 on May 18, 2015 by Camal O. Robinson. This attachment was submitted in response to DPU's information request DPU-1-2 "Please explain in detail how the company categorizes natural gas leaks as a Grade 1, Grade 2 or Grade 3 leak." Note that the chart on page 5 of 5 is difficult to read and the same chart is produced on page 32 of 32 in "Appendix A of Attachment DPU 1-1-A – LEAK-5010" and reproduced below.

Eversource

To develop MAPC's leak survey methodology, MAPC consulted pages 7-10 out of 10 of "Attachment DPU 1-2" from the "First Set of Information Requests" submitted in response to D.P.U. 15-GLR-01 on May 18, 2015 by John K. Habib.

Classification will be done according to the criteria from pages 3-4 out of 10 of "Attachment DPU 1-2" from the "First Set of Information Requests" submitted in response to D.P.U. 15-GLR-01 on May 18, 2015 by John K. Habib. The attachment was submitted in response to DPU's information request DPU-1-2 "Please explain in detail how the company categorizes natural gas leaks as a Grade 1, Grade 2 or Grade 3 leak."

Columbia Gas

To develop MAPC's leak survey methodology, MAPC consulted Columbia Gas' procedure for mobile surveys on mains, found in the "Attachment DP-CMA-1-1(f) Leakage Survey and Test Methods" from the "First Set of Information Requests" submitted in response to D.P.U. 15-GLR-01 on May 18, 2015 by Danielle C. Winter. The attachment was submitted in response to DPU's information request DPU-1-1 "Please explain in detail how the Company detects natural gas leaks on its gas distribution system."

Classification will be done according to the criteria from pages 1-6 out of 10 of "Attachment DPU –CMA-1-1(n)" from the "First Set of Information Requests" submitted in response to D.P.U. 15-GLR-01 on May 18, 2015 by Danielle C. Winter. The attachment was submitted in response to DPU's information request DPU-1-2 "Please explain in detail how the company categorizes natural gas leaks as a Grade 1, Grade 2 or Grade 3 leak."