Analysis of Natural Gas Transmission Pipeline Releases and Mitigation Options for Pipeline MAOP Reconfirmation

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Acknowledgement

The objective of this report is to analyze the high-level impact of natural gas transmission pipeline MAOP reconfirmation as outlined in the Pipeline and Hazardous Materials Safety Administration (PHMSA) "Safety of Gas Transmission and Gathering Pipelines Noticed of Proposed Rulemaking" (NPRM), issued by PHMSA and published in the Federal Register on April 8, 2016. P-PIC's analysis provides an overview of the potential natural gas releases connected to aspects of the NPRM and reviews calculations and mitigation options outlined in the PHMSA Preliminary Regulatory Impact Analysis and the M.J. Bradley & Associates report "Pipeline Blowdown Emissions and Mitigation Options," prepared for the Environmental Defense Fund and the Pipeline Safety Trust in June 2016.

P-PIC developed high-level models to recalculate aspects of mileage and potential gas releases, derived from a subset of transmission operators representing a significant portion of interstate natural gas pipeline mileage in the U.S. and from a set of assumptions based on operator input and service provider feedback. No information should be attributed to a single operator or service provider, but instead should be attributed to the majority of interstate natural gas pipeline operations. Participation in this study does not imply agreement with the study's conclusions.

We thank all operators and service providers for providing data used in this analysis.

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1. Summary

The Pipeline and Hazardous Materials Safety Administration (PHMSA) published its "Safety of Gas Transmission and Gathering Pipelines Notice of Proposed Rulemaking" (NPRM)[1] and Preliminary Regulatory Impact Analysis (PRIA) in April 2016 to address congressional mandates from the 2011 Pipeline Safety, Regulatory Certainty, and Job Creation Act[2] and subsequent recommendations from National Transportation Board (NTSB) and U.S. Government Accounting Office (GAO). The PRIA justifies the NPRM by providing that its societal benefits outweigh the annual costs of the NPRM to industry, which the PRIA estimates at approximately $270-310.8 million in benefits compared to $47.4 million in costs annually.

PHMSA granted an initial 60-day public comment period on the NPRM, then extended for an additional 30 days, closing on July 7, 2016. Over 400 comments were submitted to the docket from a variety of trade organizations, operators, public citizens and non-governmental organizations.

In reviewing and developing comments on the NPRM, one of the major areas of concern for the natural gas transmission pipeline industry focused on the NPRM's proposed requirements for reconfirming maximum allowable operating pressure (MAOP) for certain pipeline segment in High Consequence Areas (HCAs), Moderate Consequence Areas (MCAs), and Class 3 and 4 locations. [3,4] The methods for reconfirming MAOP specified in the proposed rule include a hydrostatic pressure test ("hydrotest") or a series of In-Line Inspections (ILIs) as part of an Engineering Critical Assessment (ECA). Industry comments were generally supportive of PHMSA's goals in requiring MAOP reconfirmation. However, extensive requirements proposed for ECAs in the NPRM may discourage operators from employing the ECA approach, and industry comments have suggested that the MAOP reconfirmation requirements will substantially increase pressure testing for natural gas pipeline industry over the next 15 years.[5]

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[1] Pipeline Safety: Safety of Gas Transmission and Gathering Pipelines, 81 Fed. Reg. 20,722 (Apr. 8, 2016)

[2] Public Law 112-90

[3] Comments of the Interstate Natural Gas Association of America regarding "Pipeline Safety: Safety of Gas Transmission and Gathering Pipelines (Docket ID: PHMSA-2011-0023), http://www.ingaa.org/File.aspx?id=29912&v=ccaef774 (July 7, 2016).

[4] Comments of the American Gas Association on the Safety of Gas Transmission and Gathering Pipelines Proposed Rule, https://www.aga.org/sites/default/files/aga_comments_-_gas_transmission_gathering_lines_nprm_-_july_2016.pdf (July 2016).

[5] *Id.*

During the comment period for the NPRM, Environmental Defense Fund (EDF) and Pipeline Safety Trust (PST) submitted a M.J. Bradley & Associates ("M.J. Bradley") study evaluating the natural gas releases connected with the proposed rule and ways to mitigate those releases.[6] The M.J. Bradley report estimates the total volume of the gas releases that could result from hydrostatic pressure testing to reconfirm MAOP for certain sections of transmission pipeline.[7] Such releases, often referred to as "blowdowns," are used to remove natural gas from pipeline segments so that pressure testing can be completed safely.

In addition, the M.J. Bradley report describes a variety of mitigation methods to reduce gas releases: gas flaring, pressure reduction using in-line or portable compressors, gas injection to a near-by low-pressure line, and applying stopples to limit blowdown mileage. The report estimates costs and benefits for each mitigation method and calculates the reduction in release volumes associated with each method.

This report is intended to continue developing the gas release impacts on transmission pipelines associated with the NPRM, and recognizes the work M.J. Bradley and others have made in quantifying these releases. Adding more operator input and system data into the analysis and discussing innovative practices and technologies facilitates continued dialogue on this important topic, and provides the best outcome for minimizing gas releases while accomplishing the important pipeline safety goals of the NPRM.

P-PIC provides a review and analysis of key calculations and methodologies contained in the PHMSA PRIA and M.J. Bradley report. The review includes evaluating industry data compared to the theoretical models outlined in each report. As such, this report develops new models to quantify the total volume of gas releases associated with the new MAOP reconfirmation requirement and accounts for system variations, mileage impacts and operational constraints.

Select transmission operators provided data by analyzing parts of their system and providing input on the following factors related to MAOP reconfirmation:

- Estimated HCA and MCA mileage required to undergo MAOP reconfirmation per the NPRM
- Estimated total mileage that would undergo pressure testing due to valve-to-valve spacing

[6] "Analysis of Pipeline and Hazardous Materials Safety Administration Proposed New Safety Rules: Pipeline Blowdown Emissions and Mitigation Options," http://pstrust.org/wp-content/uploads/2015/10/PHMSA-Blowdown-Analysis-DRAFT-FINAL-30jun16.pdf (June 2016)

[7] A pipeline "blowdown" is an evacuation of natural gas from the pipeline segment that reduces pressure in that segment to atmospheric pressure. Pipelines must be gas-free and at atmospheric pressure to begin the hydrotesting process.

- Average pressure and diameter data
- System characteristics and percentage of time mitigation options are not feasible due to system constraints

Based on the analysis, P-PIC projects that the gas release estimates contained in PHMSA's PRIA and the M.J. Bradley report underestimate the total volume of gas that would be released for transmission operators to comply with the MAOP reconfirmation requirement. The key conclusions of P-PIC's study include:

- **Substantially larger gas release** — Operators will use pressure tests as the primary method for reconfirming MAOP under PHMSA's NPRM, and valve-to-valve spacing greatly impacts total pressure test mileage. Therefore, P-PIC estimates that the total volume of gas releases for MAOP reconfirmation, before mitigation, would be approximately 25 times that reported in the PRIA and the M.J. Bradley report.

- **Mitigation options do have limits** — There are five mitigation options outlined in the M.J. Bradley report that operators may employ when practicable and cost-effective. However, not all blowdowns can be mitigated, and mitigation options may not recover all of the gas within a pipeline.

1.1 PHMSA Blowdown Calculations

PHMSA conducted a cost and benefit analysis of the NPRM, which outlined the amount of mileage impacted by the proposed requirement to reconfirm MAOP. The Preliminary Regulatory Impact Analysis (PRIA) contends that a total of 11,757 miles of pipeline would need MAOP reconfirmation and, of that, 3,148 miles would require a pressure test or ILI upgrade that would include a blowdown.[8]

PHMSA estimates that 3,148 miles of blowdowns would release 62,216 MCF of methane into the atmosphere each year, which corresponds to 65,012 MCF per year of natural gas releases, as methane is not the only component of natural gas.[9] This number was calculated by using a weighted average diameter of pipeline and assumes a 400 pounds per square inch (psi) average operating pressure for interstate and intrastate pipelines and a weighted average diameter of 22.0 inches for interstate pipelines and 15.2 inches for intrastate pipelines. PHMSA multiplied the volume of natural gas releases per year (65,012 MCF) by 15 years to generate the total volume of methane releases over 15 years; this appears to be an error.

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[8] PHMSA pressure test (PT) and ILI Upgrade mileage for interstate and intrastate are found in Table 3-50 and 3-54 (page. 64 and 65 of the PRIA).

[9] See Table 3-55: Total Emissions Per Year found on page 65 in the PRIA.

PHMSA should have used its estimate for the volume of methane releases per year (62,216 MCF) for this calculation.

These calculations assume that reconfirming MAOP for one mile of pipe will only require one mile of pipe to be blown down; these calculations do not account for the valve-to-valve mileage that must be isolated to accommodate a hydrotest or ILI modifications. PHMSA also subtracts baseline integrity assessment mileage from the estimated total mileage required to reconfirm MAOP to estimate the net blowdown mileage associated with the NPRM.

1.2 M.J. Bradley Report Calculations

The M.J. Bradley report outlines a slightly different mileage estimate. The report uses the PHMSA total mileage for pressure test without subtracting out the baseline integrity assessment mileage. As such, the total mileage used in the M.J. Bradley analysis is 3,509 total miles for interstate and intrastate that would include a pressure test or ILI upgrade.

The M.J. Bradley report recognizes the highly varied system and operational parameters, such as diameter and operating pressure, which significantly impact the overall volume of gas releases. M.J. Bradley reviewed PHMSA's methodology and agrees with their overall approach; however, M.J. Bradley caveats that there are many uncertainties that PHMSA's PRIA does not take into account, including average pressure and average length of blowdown segments.

To estimate the total volume of gas releases associated with the MAOP reconfirmation requirements, M.J. Bradley utilizes PHMSA annual report data to determine the average pipe diameters for interstate and intrastate pipelines. Table 2 in the M.J. Bradley report illustrates the diameters used in their calculation and the weighted average of those diameters. Similar to the PHMSA PRIA, the M.J. Bradley calculations use an average diameter of 22 inches for interstate systems and 15.2 inches for intrastate systems, and a 400-psi initial pipeline pressure value. The M.J. Bradley report recognizes that this pressure estimate may be unsupported due to a lack of available data on average interstate and intrastate system pressures. However, the report does provide a range as low as 200 psi up to 1500 psi.

The M.J. Bradley report estimates that reconfirming MAOP will result in 20,291 metric tons (1,060,657 Mcf) of methane over a 15-year period.

Additionally, the M.J. Bradley analysis identifies five mitigation methods to reduce gas releases associated with blowdowns for MAOP reconfirmation, and suggests that employing one or more of these methods may reduce methane releases by

50%-90%. The most cost effective method identified in the report is using in-line compression or transferring to a low-pressure system.

1.3 P-PIC Analysis and Modeling Methodology

PHMSA's PRIA underestimates the amount of mileage impacted by the NPRM when implementing the requirements within the MAOP reconfirmation topic area. The PRIA assumes operators would overwhelmingly use ILIs to reconfirm MAOP. The NPRM would allow MAOP reconfirmation using "Method 3," where operators could utilize ECA, incorporating data from ILI runs, in lieu of pressure testing. However, industry commenters have generally suggested that the ECA approach proposed in the NPRM is overly complicated, burdensome, and impracticable.[10,11] Therefore, the amount of pipe that would experience blowdowns for pressure testing would far exceed PHMSA's calculations. Additionally, PHMSA subtracts mileage for other baseline integrity assessment programs from its estimates for MAOP reconfirmation blowdown mileage. Industry commenters have suggested that hydrotests for MAOP reconfirmation would be accomplished on a different timeline and process than baseline integrity management assessments.[12] MAOP reconfirmation is a one-time activity with the goal of confirming pipeline material strength, whereas integrity management is a continuous process designed to evaluate and mitigate the range of ongoing threats to a specific pipeline. The majority of baseline integrity management assessments utilize ILI, not hydrotesting, so MAOP reconfirmation would likely be an entirely separate program.

As such, INGAA commissioned a separate survey of its member operators to estimate the amount of mileage that would be impacted by the MAOP reconfirmation requirements outlined in the NPRM. Operators were asked to conduct a system analysis to determine the amount of mileage that would require MAOP reconfirmation and the method they would use to perform the work. Operators provided mileage estimates for both pipeline sections requiring MAOP reconfirmation, and also valve-to-valve spacing that would impact total blowdown mileage.

Over 100,000 miles of interstate and intrastate miles were assessed from a number of diverse systems. Systems were unique in terms of geographic locations, sizes and pressures, and represent roughly 44 percent of all interstate

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[10] Comments of the Interstate Natural Gas Association of America regarding "Pipeline Safety: Safety of Gas Transmission and Gathering Pipelines (Docket ID: PHMSA-2011-0023), http://www.ingaa.org/File.aspx?id=29912&v=ccaef774 (July 7, 2016).
[11] Comments of the American Gas Association on the Safety of Gas Transmission and Gathering Pipelines Proposed Rule, https://www.aga.org/sites/default/files/aga_comments_-_gas_transmission_gathering_lines_nprm_-_july_2016.pdf (July 2016).
[12] *Id.*

and intrastate mileage.[13] Respondents voluntarily participated in the analysis by pulling data from at least one of their pipeline systems and estimating the amount of mileage that would be impacted by MAOP reconfirmation requirements in the NPRM. Operators were then prompted to estimate the percent of the blowdown mileage where a mitigation technique could be applied and the relative cost of the mitigation. Data was collected and modeled to reflect ranges from operator input, and finally extrapolated for the entire industry.

P-PIC's analysis aims to estimate the total volume of gas releases associated with the MAOP reconfirmation requirements in the NPRM as currently proposed. To create the model, the following steps were used to estimate the blowdown mileage and associated gas releases:

1. Estimate the mileage of pipe segments required to reconfirm MAOP, including considerations for valve spacing
2. Estimate the total volume gas releases from blowdowns, using operator pressure and diameter data
3. Estimate the mileage for which each mitigation option could be used

1.4 Recalculating Blowdown Mileage Estimate

Mileage is an important component in calculating the total volume of gas releases associated with the requirement to reconfirm MAOP. As show in Table 1, Table 2 and Table 3, there are different numbers reported in the PRIA, in the M.J. Bradley report, and by industry. This section discusses the various mileage estimates and P-PIC's approach to accounting for the section of pipe that must be isolated during pressure testing.

PHMSA Blowdown Mileage Estimates

PHMSA calculates mileage using the *2014 PHMSA Annual Report data* and in addition, uses certain assumptions, such as the estimated percent of MCA mileage assumed to be piggable, to determine the total MAOP reconfirmation mileage. P-PIC assumes PHMSA's mileage calculations are an accurate representation of industry transmission mileage. **Table 1** reflects mileage outlined in the PRIA in Topic Area 1.

[13] Total Interstate mileage is based on 2014 PHMSA data as reported in the PRIA in Table 3-1: *Onshore Gas Transmission Mileage by Percent SMYS*, found on page 33. Total mileage is reported as 278,003 total interstate and intrastate miles.

Table 1: PHMSA MAOP Reconfirmation Mileage Reported in RIA

Location	Untested HCA> 30% SMYS Mileage[1]	Inadequate Records Mileage[2]	Untested HCA Operating at 20-30% SYMS[3]	Untested Class 3, Class 4 HCA[3]	MCA Mileage Class 1 and Class 2[3]
Interstate					
Class 1	59	79	3	0	630
Class 2	19	97	2	0	538
Class 3	357	1,109	41	888	0
Class 4	0	1	0	0	0
Intrastate					
Class 1	10	32	1	0	78
Class 2	13	34	4	0	147
Class 3	451	2,886	213	724	0
Class 4	3	126	3	1	0
Subtotal	912	4,364	267	1,613	1,393

Source: PHMSA 2014 Annual Report data. Reportable in-service incident since last subpart J pressure test data was not included in the RIA.

PHMSA separately calculated the miles that would require a blowdown due to pressure tests and ILI upgrade. The result of the estimation is contained in Table 3-50 in the PRIA and equates to 3,146 miles of blowdown. Note that PHMSA estimates that all MCA mileage would require an ILI as opposed to pressure test. In addition, PHMSA's calculation subtracts mileage from compliance with MAOP reconfirmation requirements from HCA pressure test miles.

Table 2: PHMSA Pressure Test and ILI Upgrade Mileage Reported in RIA

Location	Untested HCA> 30% SMYS Mileage[1]	Inadequate Records Mileage[2]	Untested HCA Operating at 20-30% SYMS[3]	Untested Class 3, Class 4 HCA[3]	MCA Mileage Class 1 and Class 2[3]
Interstate					
Pressure Test	2	36	59	36	0
ILI Upgrade	23	267	0	259	0
Intrastate					
Pressure Test	47	566	191	109	0
ILI Upgrade	118	1,174	0	259	0
Subtotal	190	2,043	250	663	0

Source: PHMSA data contained on page 64 and page 65 of the RIA.

M.J. Bradley Blowdown Mileage Estimate

M. J Bradley cites PHMSA's PRIA as the basis for their estimated 3,509 total miles of blowdown. The total mileage does not back out the current compliance requirements to complete integrity management assessments in HCA segments under Subpart O of the Pipeline Safety Regulations. As such, the M.J. Bradley estimate is slightly higher than PHMSA's total pressure test and ILI upgrade mileage.

Table 3: M.J. Bradley Mileage Used In Report

Location	Total Mileage
Interstate	776
Intrastate	2,733
Subtotal	3,509

Source: M.J. Bradley Report page 12.

P-PIC Blowdown Mileage Estimate

P-PIC's blowdown calculations use the total mileage reflected in Table 1, with the addition of reportable in-service incident mileage since last pressure test, which adds an additional 468 miles of blowdown. This additional mileage was not included in the PRIA, but would be required to undergo MAOP reconfirmation, per the NPRM.

Table 4: P-PIC Mileage To Reconfirm MAOP Without Valve-to-Valve Spacing

Location	Untested HCA> 30% SMYS Mileage[1]	Inadequate Records Mileage[2]	Untested HCA Operating at 20-30% SYMS[3]	Untested Class 3, Class 4 HCA[3]	MCA Mileage Class 1 and Class 2[3]	Reportable In-Service Incident since last Pressure Test
Interstate						
Class 1	59	79	3	0	630	354
Class 2	19	97	2	0	538	
Class 3	357	1,109	41	888	0	
Class 4	0	1	0	0	0	
Intrastate						
Class 1	10	32	1	0	78	114
Class 2	13	34	4	0	147	
Class 3	451	2,886	213	724	0	
Class 4	3	126	3	1	0	
Subtotal	912	4,364	267	1,613	1,393	468

Source: PHMSA 2014 Annual Report data. Reportable in-service incident since last subpart J pressure test data was not included in the RIA. Mileage based on industry data.

P-PIC assumes that all mileage requiring MAOP reconfirmation will be pressure tested as opposed to any other type of assessment approach, based on industry comments regarding the impracticable nature of the ECA approach as proposed in the NPRM. [14,15] Even if the proposed ECA approach can be used to reconfirm

[14] Comments of the Interstate Natural Gas Association of America regarding "Pipeline Safety: Safety of Gas Transmission and Gathering Pipelines (Docket ID: PHMSA-2011-0023), http://www.ingaa.org/File.aspx?id=29912&v=ccaef774 (July 7, 2016).

[15] Comments of the American Gas Association on the Safety of Gas Transmission and Gathering Pipelines Proposed Rule, https://www.aga.org/sites/default/files/aga_comments_-_gas_transmission_gathering_lines_nprm_-_july_2016.pdf (July 2016).

MAOP in select cases, P-PIC's gas release estimates serve as a bookend for the potential impacts of the proposed MAOP reconfirmation requirements. Thus, summing the subtotals in Table 4, the total blowdown mileage due to MAOP reconfirmation used in P-PIC's analysis is 9,017 miles of pipeline. This is substantially larger than the 3,148 miles outlined in PHMSA's PRIA or the 3,509 miles outlined in the M.J. Bradley study, and reflects operator feedback that pressure testing for MAOP reconfirmation will generally occur separately from integrity management program assessments, as discussed above.

It is also critical to consider the impact of valve-to-valve spacing on the total mileage that would be blown down for MAOP reconfirmation. Using only the total mileage for calculating the volume of gas releases underestimates the total impact. Typically, when conducting a hydrotest, operators will need to blowdown the complete segment between two valves, even if only a short section within the segment requires MAOP reconfirmation. Analysis of participating operator data demonstrates that for every mile of pipeline requiring MAOP reconfirmation, 4 to 6 miles of pipeline will need to be blown down to accommodate a hydrotest, even though MAOP reconfirmation is not required on this extra mileage[16].

Table 5 recalculates total blowdown mileage based on these changes and gives a more realistic view of the amount of pipeline mileage that will be impacted by the MAOP reconfirmation requirements in the NPRM. P-PIC estimates an average of five pipeline miles must be blown down for every 1 mile of pipeline requiring MAOP reconfirmation, based on the 4-6 mile range indicated by operator data.

Table 5: P-PIC Total Blowdown With Valve-to-Valve Spacing

Mileage	Industry PT Mileage Estimate without Valve to Valve	Industry PT Mileage with Valve to Valve spacing every 4 miles	Industry PT Mileage with Valve to Valve spacing every 6 miles	Average PT Mileage with Valve-To Valve Spacing
Interstate	4,177	16,708	25,062	20,885
Intrastate	4,840	19,360	29,040	24,200
Totals	9,017	**36,068**	**54,102**	**45,085**

Source: Industry system data

1.5 Estimate of Total Gas Release Without Mitigation

The total volume of gas releases is dependent on several factors, including pipeline diameter, pressure, temperature, and other factors. Gas releases are associated with normal maintenance operations, including blowdowns related to pressure tests and upgrading pipeline facilities, in addition to other gas-operated pneumatic

16 Based on operator system data analysis.

devices that sometimes release gas. However, the gas release estimates in P-PIC's analysis only apply to blowdowns associated with the specific requirements for MAOP reconfirmation outlined in the NPRM.

As it relates to MAOP reconfirmation, the mileage reported in Table 5 would result in a substantial volume of gas releases. The majority of natural gas is composed of methane (95.7 percent), while carbon accounts for 1.3 percent and the remainder is other types of fluid equals 3.0 percent[17].

Gas releases are calculated on a per mile basis and take into consideration pipeline diameter as proposed by M.J. Bradley and averages of operating pressure data provided by participating operators. For simplicity purposes, this analysis does not take into account the average blowdown length, which the M.J. Bradley report estimates at 15 miles, on average, and operators estimate between 10-22 miles.

Pipeline Diameter Estimate

M.J. Bradley aggregated pipeline operator data annually submitted to PHMSA to calculate the weighted average pipeline diameter for interstate and intrastate pipelines. The data was organized into three categories: less than 12 inch, 12-34 inches and greater than 34 inches. The following table is a re-creation of Table 2 in the M.J. Bradley report. The percentage of pipeline mileage is based on the 2014 annual report presented in PHMSA's PRIA. Total average mileage from Table 2 above is multiplied by the percentage of weighted diameters to estimate blowdown mileage for each diameter range.

Table 6: PHMSA Weighted Average Pipe Diameter (inches)

Size Bin	WTD Avg. Diameter[1]	% Of Pipeline Mileage[2]	Blowdown Mileage[3]
Interstate			
<12 inches	8.0	27%	5,639
12-34 inches	24.3	57%	11,904
>34 inches	37.8	16%	3,342
Totals	**22.0**	**-**	**20,885**
Intrastate			
<12 inches	8.2	56%	13,552
12-34 inches	21.7	37%	8,954
>34 inches	38.7	7%	1,694
Totals	**15.0**	**-**	**24,200**

1. For analysis purposes, this report uses the PHMSA and M.J. Bradley average diameters from Table 2: *Weighted Average Pipe Diameter (inches), Transmission Pipelines* (page 10 of the report).
2. Based on 2014 Annual Report data for Gas Transmission outlined in the PRIA Tal

[17] See table 3-46 in the RIA. Source is cited based on Enbridge and Spectra estimates and reflects the percent volume of the composition of natural gas.

3-47: *Proportion of Gas Transmission Mileage by Diameter* (page 63 of the PRIA).
3. Blowdown mileage is calculated by using average mileage estimates from Table 1 of this report multiplied by the percentage of pipeline diameter.

Pipeline Pressure Estimate

One of the key assumptions in the PHMSA PRIA is that the average operating pressure of pipeline systems is approximately 400 psi. This is an inaccurate and unsubstantiated assumption that impacts the gas release calculation significantly, especially as it relates to interstate pipelines. The M.J. Bradley reports addresses this aspect (starting on page 10), but M.J. Bradley does not determine a more appropriate average pressure, due to a lack of independent data.

Operators were asked to analyze their system and report on the pressures. Similar to the method for estimating diameter, pressures have been grouped into three categories to arrive at an average pressure.

Table 7: P-PIC Estimated Weighted Average Pipeline Pressure (psi)

Size Bin	WTD Avg. Pressure (PSI)	% Of Pipeline Mileage[2]	Weighted Average (PSI)
Interstate			
<500	409	1%	4.09
500-1,000	680	85%	578
>1,000	1,234	14%	172.76
Totals	-	-	**754.85**
Intrastate			
<500	200	36%	71
500-1,000	750	61%	456
>1,000	1020	3%	31
Totals	-	-	**558**

Source: Operator system data provided to INGAA

1.6 Estimated Total Gas and Methane Release Calculations

To calculate the total volume of gas releases during blowdowns, the PHMSA PRIA used the following equation (page 37 of the PRIA):

$$\text{Gas Released } (Vb) = (28.798 \times (Tb/Pb)) \times (Pavg/(Zavg \times Tavg)) \times D^2)/100$$

Vb = Volume of gas released per mile (Mcf)
Tb = Temperature at standard conditions (70° F)
Pb = Pressure at standard conditions (14.7 psi)
Pavg = Pressure at blowdown conditions
Zavg = Compressibility factor at packed conditions (0.88)
Tavg = Temperature at packed conditions (70° F)

D = Inside diameter of pipeline in inches

The M.J. Bradley report addresses inaccuracy in the gas compressibility factor reported in the PHMSA PRIA, which uses a value of 0.88, which does not correctly correspond to a 400 psi pressure. M.J. Bradley uses a value of 0.926, which more correctly reflects the pressure of 400 psig. However, a 400 psig again does not accurately reflect the average pressure supported throughout pipeline systems. In addition, M.J. Bradley correctly uses an absolute scale for the temperature values in the equation (Kelvin), which was undefined in the PHMSA PRIA.

P-PIC conferred with a number of sources and determined that the gas compressibility factor should be calculated using the Peng and Robinson equation of state, which is consistent with the compressibility factor in the M.J. Bradley report.[18] P-PIC used the PHMSA equation with a corrected compressibility factor, temperature scale and diameter. P-PIC used degrees Rankine instead of Kelvin for temperature, an absolute pressure instead of gauge pressure, and a compressibility factor from the same source as M.J. Bradley. P-PIC opted to align with the M.J. Bradley calculation for consistency when comparing total gas release estimates.

Gas Released (Vb) = (28.798 x (Tb/Pb)) x (Pavg/(Zavg x Tavg)) x D^2)/100

Vb = Volume of gas released per mile (Mcf)
Tb = Temperature at standard conditions (520° R)
Pb = Pressure at standard conditions (14.7 psi)
Pavg = Pressure at blowdown conditions
Zavg = Compressibility factor at packed conditions (0.88)
Tavg = Temperature at packed conditions (530° R)
D = Inside diameter of pipeline in inches

Table 8 below summarizes P-PIC's blowdown gas release calculations, based on the mileage, diameter, and pressure estimates discussed above for pipelines that would be required to undergo MAOP reconfirmation per the NPRM. Blowdown mitigation options are addressed later in this report, so Table 8 assumes no blowdown mitigations are employed.

[18] Blue Source Canada, Blowdown Protocol for Pipeline Systems, Appendix A GAS DEVIATION FACTOR QUANTIFICATION, April 2011. http://pacificcarbontrust.com/assets/Uploads/Protocols/Blowdown-ProtocolApr-14.pdf .

Table 8: P-PIC Estimated Total Gas Release

Size Bin	12"	14-34"	36"+
Interstate			
Weighted [1]	27%	57%	16%
Mileage	5639	11,904	3,342
Gas Release per Mile[2]	207	886	2,035
Total Gas Release (MCF, 15 Yr[3])	1,169,107	10,541,595	6,801,799
Methane Release (MCF, 15 Yr[4])	1,118,836	10,088,306	6,801,799
Methane Release (MCF per Year)	74,589	672,554	453,453
Intrastate			
Weighted [1]	57%	37%	7%
Mileage	13,794	8,954	1,694
Gas Release per Mile[2] (MCF)	154	659	1,514
Total Gas Release(MCF, 15 Yr[3])	2,127,743	5,899,117	2,565,403
Total Methane (MCF, 15 Yr[4])	2,036,250	5,645,455	2,455,091
Methane Release per Year (MCF)	135,750	376,364	163,673

1. Based on percentages contained in the PHMSA PRIA
2. Based on pressure from Table 6 and diameters contained in the PRIA and rounded pressure of 750 psi, using equation contained in the PHMSA PRIA with modifications of temperature and z factor. Example equation for 12" interstate: = $28.798*(520/14.7)*(750/(0.88*530))*(11.25)^2/1000$
3. Gas released per mile multiplied by mileage
4. Gas released multiplied by mileage by .957

1.7 Comparison of Methane Release Calculations

Table 9 below compares the P-PIC, M.J. Bradley, and PHMSA methane release impacts of the MAOP reconfirmation requirements in the NPRM.

Per the PHMSA PRIA, the MAOP reconfirmation requirements would result in 975,180 MCF of methane releases, due to pressure tests and ILI upgrade. As reviewed above, P-PIC's methane estimates are larger due to operator data evidencing that higher average system operating pressure and larger amounts of blowdown mileage should be reflected in the calculation. Similarly, M.J. Bradley was unable to re-calculate mileage and, therefore, the volume of methane releases estimated in the M.J. Bradley report are lower than P-PIC's estimates.

Table 9: Estimated Methane Release Comparison Over 15 Years

Mileage	Total Methane (MCF)	Total Methane (Tonnes)
P-PIC	28,145,736	538,445
PHMSA	975,180[1]	18,656
M.J. Bradley	1,060,657[2]	20,291

1. Methane Emissions contained in PRIA, Table 3-54 *Total GHG Emissions due to Blowdowns* (page 65).
2. Based on 20,291 Metric Tons of Methane reported in the M.J.

Bradley Report (page 13). Metric tons converted to MCF.

P-PIC estimates that 28 billion cubic feet of methane may be released as a result of the MAOP reconfirmation requirements in the NPRM, which is 25 times more than the M.J. Bradley and PHMSA estimate. This assumes no blowdown mitigations techniques are employed.

2.0 Interstate Mitigation Option Analysis

The M.J. Bradley report describes a variety of mitigation methods to reduce gas releases: gas flaring, pressure reduction using in-line or portable compressors, gas injection to a near-by low-pressure line, and applying stopples. Details about each method are highlighted starting in section 2.1 of this report.

Surveying *interstate* transmission pipeline operators, the majority of planned maintenance blowdowns, including hydrotests for MAOP reconfirmation, can and often do utilize one of the five mitigation option outlined in the M.J. Bradley report, if operationally and economically feasible. Mitigation options are not only beneficial from an environmental perspective, but as the M.J. Bradley report highlights, there is an economic incentive for operators to mitigate when appropriate. However, there are important considerations that must be taken into account with respect to mitigation. System type is an important factor, and there are inherent differences between interstate and intrastate pipelines, which impact the feasibility of certain mitigation options.

The scenarios below reflect a future estimate for the usage of mitigation options for the blowdowns associated with the MAOP reconfirmation requirements in the NPRM. This analysis is applicable only to blowdowns associated with scheduled hydrotest work for MAOP reconfirmation. When maintenance work cannot be planned far in advance (e.g. immediate repair conditions), equipment availability, customer reliability impacts, and other limitations may significantly restrict the mitigation methods that could practicably be employed. The analysis is derived from a subset of operators assessing the possibility of using specific mitigation techniques based on a number of system factors. However, it is important to keep in mind that the variety of systems and system characteristics make it difficult to apply accurate usage estimates for mitigation alternatives that represent the entire industry.

Table 10 outlines the amount of interstate mileage assumed to be looped versus a single barrel system; these system differences impact the likelihood that certain blowdown mitigation options can be practicably employed. A looped system is when two or more pipelines are laid in parallel to increase capacity along a right-of-way, both ends connect to the original pipeline. In these systems, low-pressure diversion is much more common as a mitigation option because there are multiple lines available in the right-of-way. At the same time, in-line compression may provide limited benefit as a mitigation option for looped systems, because the other lines in the right-of-way are relying on the compression to maintain a consistent line pressure. A single barrel system is a single pipeline between the origin and destination. These are typically larger in diameter, long-haul, trunkline systems that tend to have fewer receipt and delivery points. These systems have fewer low-pressure diversion options, but utilizing in-line compression to reduce pipeline pressure prior to blowdown may be more feasible provided the interruption of service can be accommodated.

P-PIC segmented the amount of looped and single barrel system mileage based on industry data. From there, certain assumptions were used to reflect the amount of time mitigation options could be utilized. As shown in **Table 10** below, these utilization estimates for each mitigation option and non-mitigation are multiplied by mileage per system type to generate a mileage estimate for which each of the mitigation options can be utilized.

Table 10: P-PIC Estimated Mileage for Mitigation Options (Interstate)

Mileage	Avg. Estimated Looped System Mitigation Option Utilization	Avg. Estimated Single Barrel System Mitigation Option Utilization	Estimated Looped System Mitigation Option Utilization, by Mile	Estimated Single Barrel System Mitigation Option Utilization, by Mile	Total Mitigation Option Utilization, by Mile
% of Mileage	70%	30%	14,620	6,266	**20,885**
12" Weighted	15%	30%	3,133	1,880	
14-34"	70%	60%	14,620	12,531	
36"+	15%	10%	3133	2,089	
Flaring	2.50%	2.50%	365	157	522
In-Line Compression and Mobile Compression	60%	70%	8772	4386	13,158
Low Pressure Diversion	15%	5%	2193	313	2,506
Stopples	2.50%	2.50%	365	157	522
No Mitigation Option Available	20%	20%	2924	1253	4,177
TOTAL	**100%**	**100%**	**14,620**	**6,266**	**20,885**

1. Based on 2.5%
Source: Operator system data., which represents over 100,000 miles of interstate mileage.

As explained in the M.J. Bradley report, each mitigation option has limits to the gas pressure reduction achievable prior to blowdown. In some cases, operator data suggests more reduction than reported by M.J. Bradley. In other cases, there may be less. **Table 11** outlines the pressure reductions by mitigation option based on industry feedback.

In **Table 11**, an initial pressure of 750 psi (rounded, per Table 4) was multiplied by the blowdown reduction percentage to arrive at a final pressure. Gas release calculations take into account the 22.0-inch diameter for interstate pipelines used by PHMSA and M.J. Bradley, as well as the compressibility and temperature factors discussed above.

Table 11: P-PIC Estimated Gas Released with Mitigation (Interstate)

Mileage	Blowdown Reduction	Miles of Interstate Pipeline	Initial Pressure (psi)	Final Blowdown Pressure (psi)	Gas Released Per Mile (Mcf)[1]	Total Gas Released over 15 Years (Mcf)	Total Methane Released over 15 Years (Mcf)
Flaring[2]	95%	522	750	37.5	138	20,487	19,606
In-Line Compression with Mobile Compression	80-90%	13,220	750	112.5	418	1,556,622	1,489,688
Low Pressure Diversion	25%	2,444	750	562.5	2,176	1,544,984	1,478,688
Stopples	75%	522	750	187.5	700	103,580	99,126
No Mitigation Option Available	0%	4,177	750	750	3,128	3,702,500	3,543,293
TOTAL	-	**20,885**	-	-		**6,928,173**	**6,630,261**

1. Based on 22.0 ID and Z factor based on final kPA
2. Flaring emits CO2 from combustion, but has not been accounted for in P-PIC's estimate
Source: Operator system data

Table 12: P-PIC Estimated Total Volume of Methane Releases from Reconfirming MAOP

Total Volume of Methane Releases without Mitigation (MCF)[1]	Total Volume of Methane Releases with Mitigation (MCF)
18,008,940	**6,630,261**

1. Total Interstate methane releases over 15 years from Table 8 (1,118,326 + 10,088,306 + 6,801,799 = 18,008,940)
2. From Table 11.

The following sections review the various mitigation options and operator feedback on each option in further detail.

2.1 Flaring

Flaring is the process of recovering natural gas that would typically be blown down to the atmosphere and instead is combusted in a flare. According to service providers, using flares may result in a pressure reduction down to 0 psi, resulting in a 95% to 100% pressure reduction. However, CO_2 is the predominant combustion-related emission. According to M.J. Bradley, the CO_2 produced during this process equates to 2.75 metric tons of carbon per one metric ton of methane.

According to operators, flaring to mitigate pipeline blowdown volumes is utilized rarely – only for 1-5% of blowdowns. State air quality regulations and permit requirements limit the use of flaring. The time duration required to reduce line pressure through flaring is also a concern; depending on the on the size of the flare, this can range from 8 to 18 hours. Larger flares burn gas faster and minimize the time duration for a blowdown operation; however, these flares require more manpower, setup and additional equipment, which raise the overall cost of the blowdown. Safety is a critical concern, and flare size and utilization to mitigate blowdowns are limited by the heat affected zone. The public may also consider flaring to be a visual nuisance.

2.1.1 Environmental Permits

While a portable flare will reduce the volume of natural gas releases to the atmosphere, it will result in releasing additional compounds, like CO, NOx, and $CO_{2,}$ that would not have been released from a non-flared gas release. State air quality regulations require operators to submit a notification, obtain an air permit or air authorization for using a portable flare along the pipeline. Air quality permitting timeframes may limit the feasibility of using a flare, and in some locations (e.g., nonattainment areas) flaring for blowdown mitigation may not be allowed at all.

2.1.2 Heat Affected Zone

Temporary or permanent flares are required to be installed in locations away from gas sources, flammable materials, overhead lines, homes, and any other places that pose problems. The area outside of these locations is known as the heat affected zone, an area where the thermal radiation emitted from the flares would be detrimental. The levels of thermal radiation that could be emitted from a flare is dependent on a number of factors including gas composition, air dispersion, wind, flare design (type, burner design, flame temperature and height). In some cases, depending on the height of the flare, guy wires are required to support the flare. These factors may limit the size or utilization of flaring as a mitigation option for pipeline blowdowns.

2.1.3 Public Concerns

Flaring may attract public concern, based on the combustion and burning of natural gas, from homeowners and landowners that live in close proximity to flaring. Members of the public may consider flaring to create a visual disturbance.

2.2 Pressure Reduction with In-Line Compressors

In some cases, existing in-line compression can be used to reduce the operating pressure prior to blowdown, which would ultimately reduce the volume of gas released during the blowdown. This "drawdown" method can be a practical option for operators due to the ability to utilize existing infrastructure and incurring minimal costs for labor and engineering analysis.

That being said, operators need to assess the feasibility of the pressure reduction and impact on customer deliveries. Operators must evaluate the original engineering design to determine compressor discharge temperature limits and minimum delivery pressure requirements prior to drawdown. Stationary compression equipment is designed to operate within a specific pressure and flow range, which varies by equipment type. Many factors are considered when selecting compression, such as controls, number of compressors, bore size, staging, impeller diameter and mass. Operating outside of the specified range of this equipment can risk mechanical failure or compliance exceedances.

As drawdowns occur and compression ratios increase, compressor discharge temperatures increase, and operating a compressor/pipeline above temperature design limits can cause damage to the pipeline system. An engineering analysis is needed to evaluate the effect of temperature changes on the outside coating and cathodic protection on the pipeline.

In addition, as the pressure ratio increases across the compressor, so does the risk of damaging compressor components, such as the compressor valves, compressor rods, and bearing. There is risk of a failure of an in-line reciprocating compressor unit if suction drops too low resulting in the unit unloading and incomplete combustion. The same applies for centrifugal units. This limits the pressure reduction achievable prior to blowdown, as units will automatically shut down when the head pressure drops below the suction pressure minimum set point.

Reciprocating compression engines offer benefits for drawdowns because they provide the most flexibility for reducing pipeline pressure. Reciprocating compressors are more effective and flexible, within design limits, in drawing down a pipeline segment. Reciprocating compressors used in mainline transmission service are designed for high throughput low differential applications. Reciprocating engines with pollution controls are better suited for drawdowns since they can control A/F ratio, speed, load, temperature and exhaust. That said, compressor rod load limits restrict the pressure reduction that can be achieved utilizing in-line compression, and air quality permits may not allow these controls to be changed. As the differential between suction and discharge pressures increases, the compressor rod load limit will eventually be reached, generally resulting in a shutdown of the compressor.

Turbine-and electric-driven centrifugal compressors may have limited effectiveness in drawing down lines, because centrifugal compressors have a more narrow operating range than reciprocating compressors. As the suction pressure drops during a pull down, the flow across the compressor also decreases. When this occurs on centrifugal compressors with automatic recycle capability, the recycle valve opens rendering the drawdown ineffective. For centrifugal compressors that do not have recycle capability, the reduced flow pushes the compressor toward its surge line, and the unit controls take the unit off-line to protect itself.

The distance from the blowdown sites to the compressor station is an important factor. In certain situations, the hydrotest segment could be 50 to 60 miles upstream of the compressor station, and this may limit the pressure reduction that can be achieved prior to blowdown at the hydrotest segment

Based on these considerations, pressure reduction using stationary compression prior to blowdown is not practical for every blowdown scenario. According to interstate pipeline operators, they are likely to use this reduction option 60-70 percent of the time, whereas intrastate systems are less likely to use this type of technology. This disparity is due to the nature of intrastate pipelines, where outages often have a more direct impact on gas customers. This creates an urgency for intrastate operators to return the pipeline to service quickly, so it may not be feasible to wait for in-line compression to reduce pressure prior to starting a hydrotest.

Operators agree with the M.J. Bradley report that the estimated pressure reduction that can be achieved using in-line compression is approximately 50 percent. Combining in-line compression with mobile compression, operators will see a greater gas release reduction of approximately 80-90 percent.

2.3 Pressure Reduction with Mobile Compressors

Mobile compression can be used to gradually reduce pipeline pressure prior to blowdown, and ultimately reduce the volume of gas released during the blowdown. The majority of operators use third-party service providers for supplying mobile compression rentals, and mobilization of this equipment can take two weeks to schedule, at a minimum. Mobile compressors are capable of drawing the affected pipeline down from MAOP to approximately 50 psig. However, because these units are small, the drawdown duration of a pipeline segment with a single mobile compressor can take several days. Utilizing several mobile pull down units in parallel, at a higher cost, can reduce the drawdown duration.

Siting, staging and permitting mobile compression units can present significant challenges, especially in more populated areas. Noise, physical footprint, engine emissions, and other factors may limit the feasibility of utilizing mobile compression.

The percent of time mobile compressors are used by operators is very dependent on the system. In addition, the cost of either renting or purchasing mobile compression can be very expensive. These smaller mobile compressors are sized and staged for draw down applications. The number of mobile compressor units will impact the schedule and overall cost of the pulldown operation.

For purposes of this report, operators suggested that utilizing in-line compression with mobile compression represents the most effective and most often employed strategy for reducing the volume of gas releases due to MAOP reconfirmation blowdowns

2.4 Low Pressure Diversion

Low pressure diversion involves transferring gas from the pipeline segment that will be blown down into another nearby line, which must be at a lower pressure in order to move the gas. As discussed previously, due to limitations in nearby transmission pipelines, transferring gas to other systems is often unavailable. According to most operators, diversion is available for only 15% of blowdowns on interstate systems. Low pressure diversion is a more feasible option for intrastate systems, due to the increased prevalence of nearby lower-pressure lines on intrastate systems. When diversion is available, interstate operators typically see a gas pressure reduction of 25%.

2.5 Stopples

When only a short section of pipe needs to undergo MAOP reconfirmation, short sections between valves can be isolated using temporary isolation stopples. This results in a reduction of the length of pipe requiring a blowdown and, as a result, a reduction in the volume of gas released. Using stopples with a temporary bypass can provide operators with the ability to perform a variety of pipeline maintenance activities, including pressure testing, without interruption of gas deliverability to downstream customers on single line systems.

There are a variety of concerns with this method, including personnel safety with installing this equipment on an operating pipeline, especially at higher pressures. There are also the integrity risks that stopples present to a pipeline. A portion of the stopple apparatus remains attached to a pipeline after the work has been completed. These stopple attachments are known to accumulate liquids over time and not feasible to inspect. Typically, operators remove these stopples when practical, such as during downtime for the downstream customer or LDC.

Using stopples can be very costly. Depending on the system diameter and stopple size, stopples can range between $100,000 to $1,000,000. Industry reports that they are likely to use stopples only one to five percent of the time, with an estimated pressure reduction of 75 percent[19].

3. Results of Analysis

This study considered two aspects associated with reconfirming MAOP using pressure tests, per the requirements of PHMSA's "Safety of Gas Transmission and Gathering Pipelines Notice of Proposed Rulemaking (NPRM)." The first part of the study focused on truing up the volume of gas that could be released during pressure testing for MAOP reconfirmation. The second part of the study was dedicated to evaluating the methods and likelihoods by which certain blowdown mitigation options may be utilized. Although the mitigation methods and utilization breakdowns will shift depending on unique pipeline system characteristics, the overall outcomes and feasibility of the various methods throughout the industry were discussed.

In reaction to the M.J. Bradley report, P-PIC determines the following:

- The amount of mileage that would be impacted by valve-to-valve blowdowns for MAOP reconfirmation results in a significant increase in mileage over M.J. Bradley and PHMSA's estimates. Underreporting this mileage underreports the total gas release and methane release estimates.
- The amount of mileage that may be mitigated using the methods outlined in the M.J Bradley report may be overreported. Operators may be able to use a mitigation option for the majority of projects, but that will need to be determined on a case-by-case basis.

[19] Based on operator system data and reducing the entire valve to valve section.