FINAL REPORT

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Procedures for Retrofitting Indoor Gas Service Regulators

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Legal Notice

Procedures for Retrofitting Indoor Gas Service Regulators

Project Objective

The project was funded by DOT PHMSA to provide natural gas Local Distribution Companies (LDCs) with best practices and guidelines for the inspection and retrofitting of inside gas service regulators and associated piping to maintain equivalent level of safety as outside regulators. This was be achieved by:

a) Providing a roadmap for a consistent decision-making tool when a gas service regulator needs to stay inside,
b) Identifying equipment and devices to manage vented natural gas and provide warning and emergency shutoff if gas accumulates indoors, and
c) Establishing best practices for the inspection, recording, and maintenance of gas regulators and utility indoor piping systems.

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Executive Summary

This project addresses NTSB and PHMSA recommendations to natural gas operators for reducing the consequences of failures of inside meters and regulators. It provides natural gas local distribution companies (LDCs) with best practices and consistent decision-making tools for inspection and retrofitting of gas service regulators which need to stay inside. There have been various improvements in regulators' designs over the past several years which incorporate features such as slam-shut, vent limiter, and excess flow valves to improve regulators safety as compared to earlier models. Some of DOT and ANSI standards do not currently account for such recent technical advances; however, some gas distribution operators have been successful in installing slam-shut style gas service regulators with over-pressure (OPSO) and under-pressure (UPSO) protections.

The research project recommends retrofitting indoor regulators with smart sensors which could connect to existing communication networks to notify the utility in the event of the detection of a gas leak, and if necessary, connects to valves to remotely shut off gas flow. In these safety systems, smart sensors to detect methane, flood, fire, and gas line pressure are deployed in residential and commercial buildings for these potential hazards. These smart sensors transfer normal or hazard warning data via a communication network to a host server. The data from these smart sensors can be continuously viewed through a software user-interface on the host server.

The benefits of these safety systems include lower emissions, prevention of customer property damage and personal injury in the event of a hazard, and a reduction of incidents caused by natural gas leaks. However, significant challenges currently prevent the adoption of this technology and its widespread use in gas distribution systems. The first challenge pertains to standardization of the various smart sensors, safety valves, and network communication protocols. After a fully functional smart shutoff safety system is commercialized, widespread rollouts and selection of the most important features will be required to meet the needs of customers, LDCs, and regulatory requirements.

Smart safety devices are categorized to include the following devices:

a) Smart Shutoff Valves which can be automatically closed by a sensor or remotely closed through a control center. These systems, such as the Lorax Smart Shutoff Valve, are paired with methane sensors to retrofit inside regulators. Other smart shut off devices such as devices from Itron, Sensus, and Honeywell are in the market but mostly have limited maximum allowable operating pressure (MAOP) shutoff capabilities, up to 10 psig, which limits their safety improvements in the event of a regulator failure upstream of the gas meter.
b) Low Emission Regulators which incorporate features such as slam-shuts for over and under pressure conditions, vent limiter devices, and excess flow shut off to improve

regulator safety as compared to earlier models. These new regulators include ones from Pietro Fiorentini and BelGas, which can incorporate over-pressure and under pressure shutoffs, and excess flow valve shutoff abilities to stop the flow in the event of large amounts of gas escaping into a structure.

The report presents the results of several pilot studies which involved products utilizing Residential Methane Detectors (RMDs) which send out an audio or digital signal to alert of hazardous conditions.

Studies on the inspection and rehabilitation of indoor piping systems has identified the factors which increase the corrosion potential of piping systems and associated risk of leakage in an inside meter room. These factors include piping age, installation procedures, piping support and placement, condition of pipe coating, and relative humidity. The piping point-of-entry (POE), in particular, demonstrated higher corrosion potential than other indoor piping. These studies have also shown that:

- Pipe age, percentage of humidity, and pipe type (i.e., bare vs. coated steel pipes) were significant parameters affecting pipe corrosion condition.
- Corrosion levels increased with the increase of humidity levels and pipe age. A liner surface model provided a simplified estimate of the expected level of corrosion based on these two parameters.
- Foundation type, presence of sleeves, and type of applied coatings were not significant terms to affect the piping corrosion conditions.

An indoor piping inspection procedure is presented, based on the evaluation of the corrosion potential and the review of the utilities' inspection codes for indoor gas service lines.

A risk assessment model for a DIMP program is developed for inside gas service regulators. The model is based on the DIMP considerations presented in Table 15 for determining the probability and impact of the indoor system characteristics.

A data capture procedure of the risk factors is compiled in the electronic form "Indoor Meter Sets/Regulators Inspection Form". The form was updated to gain needed information regarding inside service regulators conditions. A printout of the form is presented in Appendix B for use by gas utility employees when inspecting indoor gas utility-owned piping.

Recommended best practices are presented in Table 17 for implementation in utilities DIMP program as per the requirements in 192.1007. The table presents practices that have been compiled and discussed during gas operator interviews. The implementation of these practices would result in decreased emissions and prevention of customers property risks. Table 18 in the report further presents a comparison of the risks associated with outdoor and indoor regulators and meter sets to achieve an equivalent level of safety when gas service regulators need to stay inside.

Introduction

The design and operation of service regulators allow for gas emission through the regulators' vents to balance outlet pressures and accommodate sudden changes in the gas supply. Additionally, regulators' valves, orifices, and diaphragms are all subject to age-related deterioration and a malfunctioning of these components can lead to a gas volume release during a venting event.

When regulators need to be indoors, retrofitting is needed to provide an equivalent level of safety as that of outside installations. Best practice procedures for retrofitting, inspection, and record verification of indoor regulators and meter sets would help provide guidance to establish the safety levels and assessment under various installations.

General requirements for the placement of gas meters and regulators are provided in the Code of Federal Regulations 49 CFR Part 192 in § 192.353 - Customer meters and regulators, § 192.355 Customer meters and regulators - Protection from damage, and § 192.357 - Customer meters and regulators Installation. For the placement of service regulators, these requirements include:

- Service regulators must be located as near as practical to the point of service entrance.
- Where feasible, upstream regulators in a series must be located outside the building, unless it is located in a separate metering or regulating building.
- For service regulators installed indoors, vents and relief vents must terminate outdoors, and the outdoor terminal must be located in a place where gas from the vent can escape freely into the atmosphere.

There have been several incidents reported by PHSMA in their incident records [1] which were caused by regulator over-pressurization, improper installation, improper maintenance, and corrosion of vent lines of indoor regulators and meter sets. Table 1 presents a summary of various incidents related to the installation and operation of indoor regulators and gas meter sets from the PHMSA gas distribution incident records. The table shows various threats on the indoor sets which include the following:

- Regulator emission, threads, and connections leaks in confined space,
- Atmospheric corrosion,
- Improper installation,
- Operation: Maintenance and access,
- Outside force such as flood and damage to vents, and
- Tampering.

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[1] https://www.phmsa.dot.gov/data-and-statistics/pipeline/data-and-statistics-overview

Table 1. A summary of PHMSA Incident Records Related to Indoor Sets

YEAR	CAUSE	OPERATOR_NAME	CITY	STATE	NARRATIVE
1977	Construction	Southern Union Gas Co	El Paso	TX	NTSB Report PAB-78-01_07: The failure of an indoor mercury service regulator with an unconnected vent line that allowed natural gas into the meter room
1979	Other	Michigan Consolidated Gas Co	Detroit	MI	NTSB Report PAB-82-01_10: Human Failure to execute maintenance procedures when pressure sensing controls in regulators where isolated during replacement
1985	Other	Western Resources Inc.	Salina	KS	Vent To indoor Regulator Was Plugged With Insect Material.
1984	Corrosion	Citizens Gas & Coke Utility	Indianapolis	IN	The meter and regulator located inside the basement of the house had been damaged by fire.
1990	Other	Public Service Electric & Gas Co	East Windsor	NJ	Ignition occurred on the floor level above the basement utility rooms. the failure of floor drains resulted in a rising water level for several hours in the utility room containing the meters, pressure regulator, and meter set piping.
1996	Outside Force	Northern Indiana Public Service Co	Chesterton	IN	Operator struck a 1-inch regulator vent pipe extending about 8 inches out from the wood shed containing the gas meter and regulating equipment.
2005	Outside Force	Yankee Gas Services Co	Enfield	CT	The house piping, regulator, and two meters located in the basement were damaged when a vehicle hit the building.
2005	Incorrect Operation	Wisconsin Gas Co	Milwaukee	WI	While completing leak survey on the inside meter set, a leak was found at the end of a 2-inch tee located between the end of the gas service pipe entry point and the service regulator.
2006	Other	Washington Gas Light Co	Riverdale	MD	In a house fire, access to the meter, which was located in the basement, could not be gained which made the retrieval or examination of the meter build-up and regulator impossible at this time. the gas supply was shut off at the curb cock located at the sidewalk.
2008	Outside Force	Washington Gas Light Co	Fort Washingto	MD	House fire damaged the meter and regulator assembly located in the basement. The gas company shut off the outside curb valve for the service line.
2011	Outside Force	Northwest Natural Gas Co	Hillsboro	OR	Access to meter and regulator, which were in the garage, was denied until fire department extinguished flames and hotspots.
2015	Outside Force	Baltimore Gas & Electric Co	Columbia	MD	The resident backed out of garage and the car door struck and breached gas meter/regulator set inside the garage.
2016	Incorrect Operation	Keyspan Energy Delivery	Brooklyn	NY	Over pressurization of the gas service regulator due to improper installation of the vent lines. Parts of the vent lines were installed below grade and corroded over time.
2016	Construction	Washington Gas Light Co	Silver Spring	MD	NTSB Report PAR-19-01: failure of an indoor mercury service regulator with an unconnected vent line that allowed natural gas into the meter room
2017	Incorrect Operation	Centerpoint Energy Resources Corp	Minneapolis	MN	Workers were installing new piping to support the relocation of gas meters from the basement to the outside. while workers were removing the existing piping, a full-flow natural gas line at pressure was opened.
2018	Other	Public Service Electric & Gas Co	Lawrence Twp.	NJ	A plug on the service tee inside the basement had been mechanically removed and the open service tee was the source of the gas leak.
2018	Incorrect Operation	Entergy New Orleans Inc	New Orleans	LA	Contractor personnel used an unauthorized tool while performing a meter conversion at the residence.
2019	Outside Force	Rochester Gas & Electric	Rochester	NY	The indoor service regulator upstream of the company meter appeared to have been tampered with/disassembled that would have released natural gas into the building.

A recent apartment building explosion and fire in Silver Spring, Maryland in 2016 was reportedly caused by gas release in a failed indoor service regulator resulting from an unconnected or partially unconnected vent line in the meter room. Based on NTSB investigations, it recommended that interior service regulators be located outside in new installations and whenever the gas service line, meter, or regulator is replaced.

There are certain challenges of relocating indoor regulators where no outside space for a gas service regulator exists or when municipalities in certain business districts restrict outside piping. In these situations, when a regulator must be installed inside, equipment and devices may be used to manage vented natural gas and provide warning and emergency shutoff if gas accumulates indoors.

On September 2020, PHMSA issued an Advisory Bulletin titled Pipeline Safety: Inside Meters and Regulators [Docket No. PHMSA–2020–0115]. The Advisory Bulletin summary states the following:

"PHMSA is issuing this advisory bulletin to alert owners and operators of natural gas distribution pipelines to the consequences of failures of inside meters and regulators. PHMSA is also reminding operators of existing Federal regulations covering the installation and maintenance of inside meter and regulators, including the integrity management regulations for distribution systems to reduce the risks associated with failures of inside meter and regulator installations."

This project addresses the above NTSB and PHMSA Advisory Bulletin recommendations by providing natural gas LDCs with a consistent decision-making tool for inspection and retrofitting of gas service regulators which need to stay inside. The project also presents the best practices and guidelines for identifying equipment and devices to manage venting and emergency shutoff systems if gas accumulates indoors.

Chapter one of the report presents a review of federal installation requirements, current industry codes, and local LDCs piping installation practices. LDCs' work on indoor sets and piping systems focusses on the installation and renewal aspects. The majority of their work consists of emergency response to customer calls, gas turn-ons and shutoffs, meter repair and replacements, and the required maintenance and inspections. Although LDC's commonly install and thoroughly inspect inside piping, the types of records and available information on indoor installations vary.

Retrofitting indoor regulators with smart sensors could connect to existing communication networks to notify the gas utility in the event of the detection of a gas leak, and if necessary, remotely shut off the flow of gas. Chapter 2 of the report presents comprehensive safety shutoff systems which may include: (a) Smart sensors, such as methane, flood, fire, and pressure monitoring sensors, (b) Smart gas shutoff valves such as standalone valves and smart meters with integrated valves, and (c) Communication network and user interface software.

Chapter 3 presents the results of current testing programs and key elements of smart devices for retrofitting inside regulators such as the RMD and the smart shutoff valve. Chapter 4 evaluated the parameters affecting indoor piping system conditions and presents procedures of the inspection of corrosion potential in Indoor piping systems.

Risk Analysis for a Distribution Integrity Management Program (DIMP) is presented in Chapter 5. The analysis evaluated the risk factors associated with inside regulators. An electronic form "Indoor Meter Sets/Regulators Inspection Form" was updated as part of this project by adding more focus on inside service regulator installation as part of the indoor meter set. The vision is that gas utility employees would be required to complete the smart form when they enter a customer premise that contains gas utility owned piping. This data would then be stored electronically and available for analysis as part of a DIMP program.

The project conclusions and recommendations in Chapter 6 provide LDCs with best practices and consistent decision-making tools for inspecting and retrofitting gas service regulators which need to stay inside. A discussion of the risks associated with outdoor and indoor installations is presented in the chapter to provide a comparison of the required actions to obtain equivalent levels of safety.

Chapter 1 – Evaluation of Current Utilities Installation Practices and Procedures

1.1 Introduction

Local Distribution Companies (LDCs) have specific procedures that need to be followed by their field employees for the installation and maintenance of indoor natural gas piping. The LDCs procedures are based at a minimum on 49 CFR 192 requirements and other industry standards. This chapter provides a review of existing LDC procedures and practices including a review of some of the new technologies that are being utilized. The following activities and resources have contributed to the information contained in this chapter:

- Interviews with the Technical Advisory Panel (TAP) members and project sponsors,
- Review LDCs gas operating procedures,
- Interviews with gas service regulator manufacturer representatives,
- Review of technical bulletins and data sheets of various types of gas regulators,
- Review of the codes and standards governing service gas regulators.

Discussions with Subject Matter Experts (SMEs) and LDC operators show that, from a DIMP standpoint, inside regulators pose a high risk to gas leaks and that the safety risk may be lowered by utilizing newer low-emission inside regulators, using 2-stage regulators with slam-shut features, and RMDs located in the areas of company-owned inside piping.

This chapter provides a detailed summary of industry installation practices and further details on suggested procedures to lower gas leak risks.

1.2 Industry Codes and Standards for Gas Pressure Regulators

There are several industry codes and standards that provide guidance on the required performance requirements (e.g., inlet pressures, delivery pressures, and relief settings) for the installation and maintenance of gas pressure regulators. Typically, applicable DOT, state, and ANSI standards are adhered to and referenced by manufacturers and utility operators. A list of domestic and international standards includes the following:

a) Service Pressure Regulator (SPR) Standards:

- ANSI B109.4 Self-Operated Diaphragm-Type Natural Gas Service
- 49 CFR §192.197 Control of the Pressure of Gas Delivered from High-Pressure Distribution Systems
- CSA 6.18-02 Service Regulators for Natural Gas

- EN 14382 Safety Devices for Gas Pressure Regulation Stations and Installations.

b) Line Pressure Regulator (LPR) Standards:

- ANSI Z21.18/CSA 6.3 Gas Appliance Pressure Regulators
- ANZI Z21.80/ CSA 6.22 Line Pressure Regulators Up To 5 psig
- NFPA 54 National Fuel Gas Codes [2,3]
- CSA B 149.1 Natural Gas and Propane Installation Code.

There have been various improvements in regulator designs over the past several years which incorporate features such as slam-shut, vent limiter, and excess flow valves to improve regulators safety as compared to earlier models. Some of the current DOT and ANSI standards do not account for such recent technical advances and some gas distribution operators have been successful in installing slam-shut style gas service regulators with OPSO and UPSO shutoff protection. With these newer style regulators, LDCs have demonstrated a reduction in methane emissions and decreased operations and maintenance costs, thus improving system safety and performance.

Some LDCs have been successful in gaining waivers from their state public utility commission to use advanced outside service regulators that do not meet minimum clearances from sources of ignition, intake, and exhaust vents, and building openings. These advanced regulator designs also help control operations and maintenance costs associated with the placement of gas pressure regulators indoors and outdoors.

1.3 LDC's Indoor Piping Installation Practices

Many of the above industry codes specify the minimum spatial clearances between meter sets and windows, vents, utility boxes, and other sources of ignition. The National Fire Protection Association code NFPA-54-2006 requires that gas meters be located at least 3 ft from sources of ignition. Generally, utility guidelines provide larger clearances to air intake vents and electrical boxes. These guidelines differ in what is defined as the leak source. Some guidelines, for example, define the leak source as the regulator vent whereas others measure the clearance from the risers or the edges of the meter set.

Minimum horizontal clearances to the sides of windows and building vents in LDC installations range from 18 inches to 36 inches in utility manuals. Some LDC specifications do not

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[2] NFPA 54, ANSI Z223.1, National Fuel Gas Code, 2006.

[3] Combustible Gas Dispersion in Residential Occupancies and Detector Location Analysis, Fire Protection Research Foundation, August 2020.

recommend placing the meters directly under windows or building openings [4, 5, 6]. However, when specified, the vertical clearances to the bottom of windows vary from 6 ft to 10 ft. Figure 1 shows example of the spatial clearance requirements from utilities' specifications.

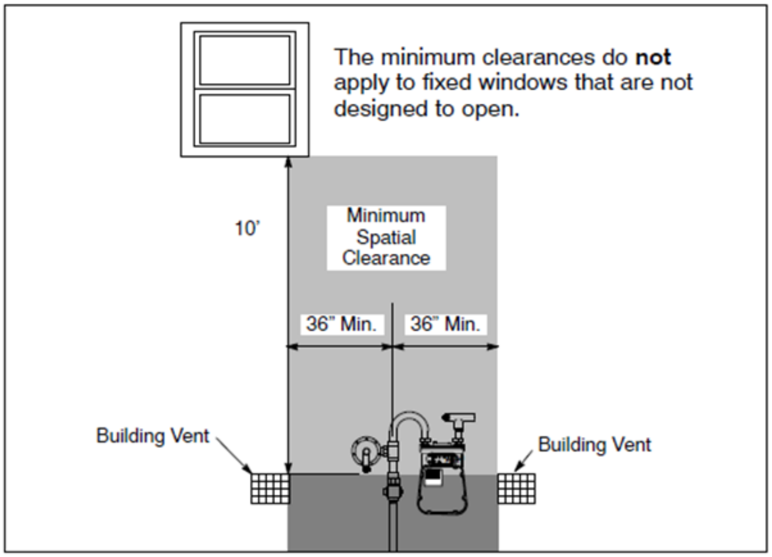

Figure 1. Example of regulator's spatial clearances to building openings [4]

Safety risks and maintenance costs increase significantly when gas service regulators and associated higher pressure piping are installed inside and therefore, much of the focus on LDC installations is on getting the meter and regulator installed outside. The reviewed LDC procedures adhered to the regulations but varied in the materials and equipment used, pipe entry into the structure requirements, piping support, regulator type and placement, regulator venting, and the verification records that should be reported during an inspection.

A best practice was identified to require field employees to obtain management (or Engineering Department) approval if a regulator and/or meter set needs to be installed inside a structure. In addition, in a situation where the entire meter set assembly cannot be located outside, the regulator should be installed outside and only the meter is to be installed inside. In most situations, if an outside above-grade riser can be installed, a regulator should be installed on the outside riser. Figure 2 shows a typical inside meter setup.

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[4] Electric & Gas Service Requirements, Pacific Gas Electric Company (PG&E) Greenbook, 2014.

[5] National Grid Blue Book, Revision 0, June 2010.

[6] Installation Requirements for Gas Meter Set Assemblies, Puget Sound Energy (PSE), 2009.

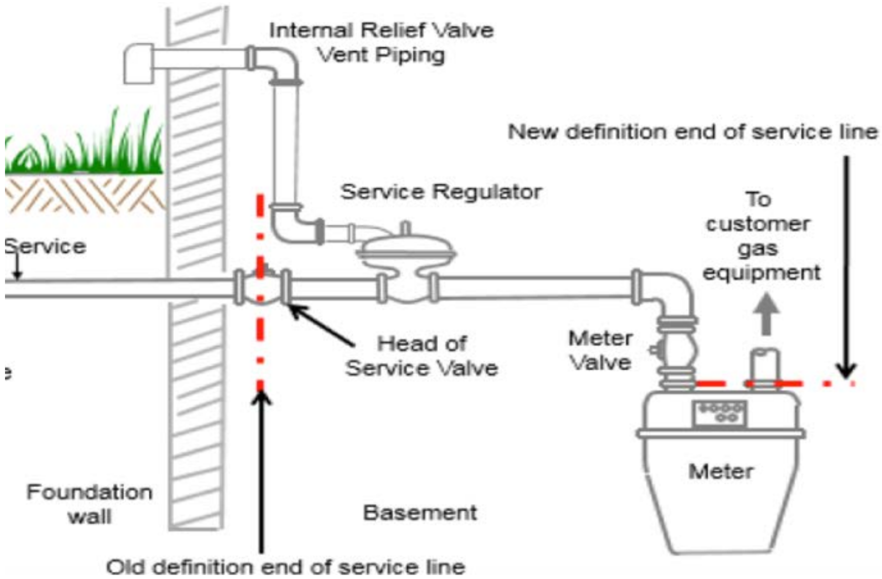

Figure 2. Layout of an indoor meter-regulator setup

When a service pipe enters a building completely below grade, field employees are instructed to rework the service pipe to create an "up/down" installation where the service pipe will come above grade outside the building wall to hang the regulator and meter; then once exiting the meter the service pipe will go back below grade prior to entering the building.

Prior to many LDC new installation or upgrade projects, mailings are distributed to customers that detail the need and safety aspects of installing or moving the meter and regulator to the outside of the building. Field crews performing service pipe installations or service pipe renewals would be trained to interact with customers for the need to install or move the meter and regulator outside of buildings. For many of the LDCs service pipe pressure upgrade projects from a low-pressure distribution system (0.25 psig) there will typically be a customer interface employee that sets up customer appointments to discuss the need to move the meter and the regulator to the outside of their building. When performing service pipe upgrades, some LDCs require a form to be signed by the customer that focuses on regulator and meter placement. When asking the customer to sign the form, usually the field employee or management employee describes the regulations, safety aspects and the necessity that the company owned equipment be installed outside of the structure. Many customers resist the moving and placing the meter and regulator to the outside of their building due to aesthetics alone. LDCs have often offered incentives to move the meter and regulator to the outside such as offering a bush or plant that would cover the outside meter set location. In addition, customers may have created cabinets and furnished obstructions that restrict access to company owned inside piping which increase customer resistance and require LDCs to hire carpenters to rework customer's cabinets and furnishing.

There are also safety factors and local codes which can impact the decision to install or move the LDC's owned piping to the outside of the structure. Many city high-rises and multiunit buildings have high pedestrian and vehicle traffic at the perimeter of the building that make the installation of outside gas utility owned piping safer to be installed inside the building. However, NTSB recommendations in P-19-002 prioritize moving meters and regulators to outside of multifamily structures over single-family dwellings. Additionally, historic districts in some areas will often not allow the LDC to install a meter and regulator set on the outside of a building.

1.4 Installation Requirements and Procedures for Inside Meters and Regulators

The minimum federal requirements for the installation and protection procedures of inside meters and regulators include:

§192.353 Customer meters and regulators: Location

(a) Each meter and service regulator, whether inside or outside a building, must be installed in a readily accessible location and be protected from corrosion and other damage, including, if installed outside a building, vehicular damage that may be anticipated. However, the upstream regulator in a series may be buried.

(b) Each service regulator installed within a building must be located as near as practical to the point of service line entrance.

(c) Each meter installed within a building must be located in a ventilated place and not less than 3 feet (914 millimeters) from any source of ignition or any source of heat which might damage the meter.

(d) Where feasible, the upstream regulator in a series must be located outside the building, unless it is located in a separate metering or regulating building.

§192.355 Customer meters and regulators: Protection from damage

(a) Protection from vacuum or back pressure. If the customer's equipment might create either a vacuum or a back pressure, a device must be installed to protect the system.

(b) Service regulator vents and relief vents. Service regulator vents and relief vents must terminate outdoors, and the outdoor terminal must—

1. Be rain and insect resistant.
2. Be located at a place where gas from the vent can escape freely into the atmosphere and away from any opening into the building; and
3. Be protected from damage caused by submergence in areas where flooding may occur.

(c) Pits and vaults. Each pit or vault that houses a customer meter or regulator at a place where vehicular traffic is anticipated, must be able to support that traffic.

§192.357 Customer meters and regulators: Installation

(a) Each meter and each regulator must be installed so as to minimize anticipated stresses upon the connecting piping and the meter.

(b) When close all-thread nipples are used, the wall thickness remaining after the threads are cut must meet the minimum wall thickness requirements of this part.

(c) Connections made of lead or other easily damaged material may not be used in the installation of meters or regulators.

(d) Each regulator that might release gas in its operation must be vented to the outside atmosphere.

§192.361 Service lines: Installation

(e) Installation of service lines into buildings. Each underground service line installed below grade through the outer foundation wall of a building must:

1. In the case of a metal service line, be protected against corrosion.
2. In the case of a plastic service line, be protected from shearing action and backfill settlement; and
3. Be sealed at the foundation wall to prevent leakage into the building.

(f) Installation of service lines under buildings. Where an underground service line is installed under a building:

1. It must be encased in a gas tight conduit.
2. The conduit and the service line must, if the service line supplies the building it underlies, extend into a normally usable and accessible part of the building; and
3. The space between the conduit and the service line must be sealed to prevent gas leakage into the building and, if the conduit is sealed at both ends, a vent line from the annular space must extend to a point where gas would not be a hazard, and extend above grade, terminating in a rain and insect resistant fitting.

§192.365 Service lines: Location of valves

(a) Relation to regulator or meter. Each service-line valve must be installed upstream of the regulator or, if there is no regulator, upstream of the meter.

(b) Outside valves. Each service line must have a shut-off valve in a readily accessible location that, if feasible, is outside of the building.

Besides the above required regulations and industry standards for clearances, some of the best practices documented in the associated LDC procedures for installation of company-owned piping include the following:

- Materials: All inside company owned piping including the regulator vent piping should be made from black iron pipe with malleable fittings.

- Communication: Sticker and/or tags on inside company owned piping notifying the customer of the requirement that this equipment must always be accessible for safety.
- Electrical Isolation: All company-owned piping would be electrically isolated immediately when entering a building with an approved fitting at the service entry point. All meters would have insulated fittings installed downstream of the meter. Inside regulator sets require an insulated vent line to the outside air with a bug ell.
- Location: Lists of set clearances for regulator and meter set locations. Information included that an inside regulator and meter should be located at the point of service entry and installed in a nonhazardous location where it cannot sustain physical damage. The location of the inside meter and/or regulator assembly should accommodate access for:
  - (a) Reading of the meter
  - (b) Inspecting the meter set assembly
  - (c) Testing of the service regulator
  - (d) Allowing the service regulator vent to a safe location outside
  - (e) Operation of the gas shutoff valve.

Some other best practices for inside location that have been identified are:

- The Engineering Department shall be contacted if a regulator and/or meter cannot be installed at the immediate location of an inside wall in a building.
- Regulators and/or meters located in parking garages require evaluation and may require the protection from vehicular damage.
- No installations of a regulator and/or meter are allowed in confined engine, boiler, heater, or electrical equipment rooms.
- No installations of a regulator and/or meter are allowed in living quarters, restrooms, bathrooms, or similar locations.
- No installations of a regulator and/or meter are allowed in cabinets or closets that are used by the customer.
- No installations of a regulator and/or meter underneath exposed water pipes.
- No installations of a regulator and/or meter in a stairway that is a sole emergency exit.
- No installations of a regulator and/or meter near elevator shafts.
- No installations of company owned piping through a floor or a crawl space.
- A meter supplying one tenant shall not be set in an apartment or a store in any location that is occupied by another tenant.
- A meter shall not be set inside a front building to supply a rear building.

1.5 Records for Installation of Inside Meters and Regulators

The installation of inside company-owned piping poses a higher risk and, accordingly, good records are important for incorporation in the DIMP program. Once installed, the following are best practices for recording service pipe data for inside regulators and meter sets:

1. Address or customer identification data
2. Installation Date
3. Company/Contractor employee that performed the installation
4. Size and length of inside service pipe
5. Service pipe (including vent pipe) material
6. Service pipe (including vent pipe) manufacturer of nipples, fittings, and couplings
7. Pressure Test Data
8. Regulator Data:
    a. Manufacture
    b. Model Number
    c. Orifice Size
    d. Delivery Pressure
    e. Set Pressure
    f. Lock-up Pressure
9. Meter Set:
    a. Meter Number
    b. Meter Reading.

1.6 Maintenance of Inside Meters and Regulators

LDCs procedures and training detail the requirements for performing inspection and maintenance activities on utility-owned inside piping. Many LDCs perform these inspections through work orders that send a field employee. In cases of customer un-availability, the field crew may not have access to the indoor piping. A common best practice is for utilities to schedule appointments with customers detailing the need to have access to company owned gas piping. Many of these appointments are initiated with customer mailings that outline the safety and compliance requirements for the inspection of the company-owned inside piping. Some LDCs inform customers that natural gas service will be interrupted if timely access to the inside piping is not granted as required by federal regulations.

The federal rules that are part of LDCs inspection procedures applicable to inside meters and regulators are:

§192.481 Atmospheric corrosion control: Monitoring

(a) Each operator must inspect each pipeline or portion of pipeline that is exposed to the atmosphere for evidence of atmospheric corrosion, as follows:

-Onshore Pipeline – At least once every 3 calendar years, but with intervals not exceeding 39 months.

(b) During inspections, the operator must give particular attention to pipe at soil-to-air interfaces, under thermal insulation, under disbonded coatings, at pipe supports, in splash zones, at deck penetrations, and in spans over water.

(c) If atmospheric corrosion is found during an inspection, the operator must provide protection against the corrosion as required by §192.479.

§192.723 Distribution systems: Leakage surveys

(a) Each operator of a distribution system shall conduct periodic leakage surveys in accordance with this section.

(b) The type and scope of the leakage control program must be determined by the nature of the operations and the local conditions, but it must meet the following minimum requirements:

1. A leakage survey with leak detector equipment must be conducted in business districts, including tests of the atmosphere in gas, electric, telephone, sewer, and water system manholes, at cracks in pavement and sidewalks, and at other locations providing an opportunity for finding gas leaks, at intervals not exceeding 15 months, but at least once each calendar year.
2. A leakage survey with leak detector equipment must be conducted outside business districts as frequently as necessary, but at least once every 5 calendar years at intervals not exceeding 63 months. However, for cathodically unprotected distribution lines subject to §192.465(e) on which electrical surveys for corrosion are impractical, a leakage survey must be conducted at least once every 3 calendar years at intervals not exceeding 39 months.

LDCs perform inspections on inside company-owned piping for atmospheric corrosion every 3 years and leak surveys every year to 5 years. The number of customer appointments to gain access can become excessive in business districts especially in larger cities.

Although LDCs work on downstream piping focus on the installation and renewal aspects of company-owned inside piping, the majority of their work consists of emergency response to customer calls, gas shut-offs, gas turn-ons, meter repair/replacements and the required maintenance and inspections. As a best practice, all field employees for an LDC may be trained and able to perform and record atmospheric corrosion and leak survey inspections on inside piping anytime that they are gained access into a customer' premise.

LDCs have paper inspection forms (check list) or electronic work orders for performing inspections on inside company-owned piping. Whenever an LDC employee gains access to inside company owned piping, the following are best practices for performing an inspection:

1. Verify that the company owned piping is easily accessible, no obstructions and that the shut off is accessible.
2. Verify that the inside piping assembly is straight, levelled, free from strain, adequately supported and that there are proper clearances.
3. Verify, if an inside regulator is present, that the vent line is continuous, supported, and vented properly. The inspection of the vent point termination needs to be verified on the outside of the structure and that there are no obstructions, meets proper clearances, and has a properly installed vent screen.
4. Verify, by visual inspection of the length of the assembly around fittings, that there is no atmospheric corrosion present. Special attention should be given to the service entry location and pipe support locations.
5. Verify that all construction is made of acceptable materials.
6. Verify that there are no foreign bonds on the company-owned piping including the vent pipe. Visually inspect the condition of any insulated fittings on company owned pipe.
7. Verify that the service pipe entry point condition is properly sealed and that there are no loads on the pipe.
8. Verify that there are no gas leaks along the length of company-owned pipe and around fittings by using a properly calibrated natural gas detection instrument. All inside gas leaks detected are treated as hazardous and are immediately repaired.

If the field employee cannot remediate any abnormal condition discovered during the inspection, maintenance should be scheduled for a later date. During inspection, if there are any abnormal conditions deemed hazardous then immediate corrective action should be performed by a qualified employee.

1.7 Records for the Inspection of Inside Meters and Regulators

Typical paper or electronic forms are used to capture the following data that could be used for DIMP analysis, especially in electronic reporting systems:

- Address or customer identification data and inspection date
- Company/Contractor Employee performing the inspection
- Is the company-owned piping, including the shutoff, easily accessible? (Yes, No - Remediation Performed, No - Remediation is Pending)

- Is the inside piping assembly straight, levelled, adequately supported, and that there are proper clearances? (Yes, No - Remediation Performed, No - Remediation is Pending)
- Is the inside regulator vent line continuous, supported, and vented properly to the outside? Does the vent adhere to proper clearances and has a properly installed vent screen? (Yes, No - Remediation Performed, No - Remediation is Pending)
- Is there atmospheric corrosion present on any company-owned piping including vent piping and supports? (Yes, No - Remediation Performed, No - Remediation is Pending)
- Is all construction made of acceptable materials? (Yes, No - Remediation Performed, No - Remediation is Pending)
- Are there any foreign bonds on the company-owned piping, including the vent piping? (Yes, No - Remediation Performed, No - Remediation is Pending)
- Is the service pipe entry point condition acceptable, properly sealed, and there are no loads on the pipe? (Yes - Remediation Performed, No- Remediation is Pending)
- Were any gas leaks found on company-owned piping? (Yes, No). If yes, identify the location, type, and cause of the leak.

1.8 LDC Interviews for Retrofitting Inside Regulators

Interviews were held with SMEs from multiple LDCs in New York and California that have a large number of inside regulators in their service territories. The following questions were discussed:

1. Do you have procedures that you can share for the installation and inspection of inside company-owned piping and inside regulators?
2. What records do you keep for inside piping installation and maintenance (including inside regulators and vent pipe)?
3. Do you have information on the number of inside regulators in your service territory?
4. Has your company used any types of newer regulators that contain a slam-shut and/or a vent limiter (such as the Pietro Fiorentini FE or Belgas P100SX)? Are there special considerations for an inside regulator as compared to an outside regulator?
5. What are your thoughts about what can be retrofitted with indoor regulators to improve safety to a level equal or better that an outside regulator?
6. Has your company developed any policies on the use of RMD?
7. Any developments on the use of smart technologies for the natural gas industry, such as remote shut-off valves, sensors that can communicate information back to the utility?

Question #1: Do you have procedures that you can share for the installation and inspection of inside company owned piping including the inside regulator (including vent pipe)?

All LDCs interviewed have detailed procedures used in the training and qualifying of their field employees for performing inside company-owned piping installations and inspections. These procedures adhere to existing codes, standards, and regulations. The majority of the LDCs have systems and processes in place for code compliance of inside piping to ensure that the piping was installed properly. Most utilities had an electronic system in place to ensure the timeliness of the required inspection orders on company-owned inside piping.

Question #2: What records do you keep for inside piping installation and maintenance (including inside regulators and vent pipe)?

All LDCs interviewed had records that detailed their distribution systems, installations, and inspections requirements. Company employees are commonly trained and qualified to install and perform a thorough inspection of inside piping. However, the types of records and available information on indoor installations varied and may need standardization. Suggested best practices and procedures are outlined later in this chapter.

Question #3: Do you have information on the number of inside regulators in your service territory?

All LDCs interviewed had information available whether a meter set or sets were located inside a structure; however, information on the location of the regulator varied and are not necessarily recorded. Discussions indicated an agreement that a higher risk is posted with inside regulators and that tracking the total number, regulator type, regulator age, and regulator and vent condition were mostly lacking and would be beneficial as part of the DIMP plan.

Question #4: Has your company used any types of newer regulators that contain a slam shut and/or a vent limiter? Such as the Pietro Fiorentini FE or Belgas P100SX? Are there any special considerations for an inside regulator as compared to an outside regulator?

All LDCs interviewed were familiar with the Pietro Fiorentini FE regulator and have used them or similar new regulator types to some extent. None of the LDCs interviewed had considered utilizing different regulator types for inside installations as compared to outside.

Question #5: What are your thoughts around what can be retrofitted with indoor regulators to improve safety to a level equal or better that an outside regulator?

Many LDCs expressed confidence in their inside regulators, safety of the venting, and ability of the regulators to work reliably. The discussions indicated that lifespans for regulators were unknown and that further analysis of this topic would be needed. Discussions indicated the need for a risk-based approach utilizing the data gathering information in Question #3.

All the LDCs that were interviewed agreed that retrofitting an inside regulator with an RMD would improve safety and reduce the leak risk of an inside regulator and overall risk associated with inside piping. Many of the retrofit discussions led to technologies that are currently being tested or piloting with smart valves that can stop the flow of gas if an RMD detects a hazard.

Question #6: Has your company developed any policies on the use of RMD?

All of the LDCs have indicated that they have members and/or following the updates for NFPA 715 but currently they have no documented policy that is in place for RMDs.   Most of the LDCs interviewed indicated that they are aware of NTSB recommendations on the RMD subject matter and have been following developments by the industry.   Several LDCs have performed research and have had success with connecting RMDs to their existing AMI communication networks. Consolidated Edison of New York (ConEdison) has made significant progress in the deployment and use of RMDs based on all of the LDCs that have been interviewed.

Question #7: A discussion on any developments on the use of smart technologies for the natural gas industry, such as remote shut-off valves, sensors that can communicate information back to the utility, e.g., thoughts for retrofitting?

ConEdison company has a system that is being tested which communicates RMD data for the purpose of dispatching a field employee to perform a corrective action. Overall, there were mixed discussions on smart technologies implementation in the interviews since there are many unknowns on how they can get implemented in their existing systems. An automatic shutoff valve that can be controlled by the LDC and an RMD should be considered. Currently, there is an ongoing project with the OTD and California Energy Commission to implement a pilot on a residential and a commercial building, utilizing a smart safety shutoff system that consists of:

1. The methane sensor (RMD),
2. Smart shutoff valve,
3. A communication network and
4. User interface/software.

1.9 Current Research Related to Meter and Regulator Procedures

The following research projects were funded and performed by the co-sponsor of this project: Operations Technology Development (OTD) for the placement, monitoring, and retrofitting of company-owned piping:

- Evaluation of Meter Set Placement and Clearances (OTD 5.15.h): This project provided LDCs with knowledge and support options regarding the placement of meters and regulators. The project performed leak analysis on pinhole size leaks on meters and regulators to calculate and confirm safe clearance distances for installations. Overall, the project provided LDCs with data to support meter set and regulator outdoor placement options and their ability to migrate to areas that may gain access into a building.
- Guidelines for Indoor Meters, Regulators, and Piping (OTD 5.17.a): This project provided utilities with a standardized process for assessing the risk associated with relocating an indoor meter set to outdoor or other suitable location. The project provided a smart form

for LDC placement data and calculated a risk score based on assessing the meter and regulator set's location. The inspector would receive real-time feedback on how to mitigate the current risk of indoor regulator and/or meter set.

- Non-Traditional Regulators Slam-Shut and Vent Limiters (OTD 5.17.e): This project examined the application, standards, and limitations of non-traditional service pressure regulators (SPR) and line pressure regulators (LPR). The project provided details of new style regulators that are retrofitted with slam-shuts, based on pressure conditions and vent limiters that only allow a minimum amount of gas to vent.
- Over-Pressure Protection Devices for Low-Pressure Gas Distribution Customers (OTD 5.19.q): This project investigated and tested the performance of multiple regulators and other overpressure protection devices on a low-pressure system operating at customer delivery pressures of 0.25 psig and less. The project investigated regulators that could potentially be installed inside a structure to provide overpressure protection.
- Smart Shutoff Technology for Commercial and Residential (California Energy Commission CEC, OTD 5.20.k) This current project is involved with the design and implementation of smart safety shutoff system that utilizes smart sensors (RMD, a smart shutoff valve, communication network, and user interface software). This project is investigating a system that will stop gas flow into a structure if an RMD senses hazardous conditions.

Chapter 2 – Monitoring and Retrofitting Indoor Regulators

2.1 Introduction

There are new products in the market that can potentially be used to retrofit new or existing inside regulators and stop the flow of gas in the event of regulator failure. Various projects on testing and evaluating these new technologies are presented in this chapter for their potential in stopping the flow of natural gas into a building in the event of a detection of a gas leak.

Buildings have several safety systems that protect life and property such as electrical circuit breakers, fire alarms (sprinkler systems) and CO alarms. However, there is no current smart safety system to monitor and turn off natural gas supply if a gas leak is detected, a natural disaster is taking place (e.g., earthquake, fire, and flood); or if any other problems are present in the natural gas supply system. Recent developments of RMD, improved battery technology, and improved low power consumption communication networks provide the opportunity to enhance natural gas safety within a building. A natural gas smart safety shutoff system can be designed with these new technologies to improve safety in both residential and commercial buildings.

There are several stand-alone safety devices such as natural gas monitors that are commercially available, but these devices do not possess connectivity to automate the safety response among emergency personnel, gas customers, and gas utility companies. However, there are new smart sensors and technologies to detect and respond to hazardous incidents such as natural gas leaks or fires at a building. By retrofitting an inside regulator with an integrated platform of smart hazardous detecting sensors, automated shutoff valves, two-way device communication, and a software user-interface, a comprehensive natural gas smart safety system can be created.

Several projects [7, 8] currently evaluate comprehensive smart safety shutoff sensors in residential and commercial buildings. These sensors are tested to communicate hazardous situations back to the gas utility operator to perform an appropriate first response. The benefits of these sensors include the following:

- With smart sensor deployment and automation, ratepayers will have the necessary interventions in place to avoid potentially hazardous events posed by gas leaks.
- Detection and intervention capabilities provided by natural gas smart safety technology can protect ratepayer life and property.

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[7] Smart Shutoff Technology for Residential and Commercial Buildings", OTD and California Energy Commission (CEC) Project 5.20.k, 2021.

[8] Development of an Integrated Safety System (IISS) for Commercial and Industrial Customers - Phase 3, OTD Project 1.12.a.3.

- This technology will limit pipeline downtime and recovery costs from hazardous incidents, providing ratepayers access to safe and reliable energy.
- By establishing the foundation for natural gas smart sensor shutoff requirements, technology developers will have the framework for continued innovations in this emerging market to improve customer satisfaction and lower costs.
- Gas concentration sensors installed in buildings can also help identify nuisance leaks for repair, thus reducing methane gas emissions.

2.2 Review of New Retrofitting Technologies

a) Comprehensive Smart Systems:

Retrofitting indoor regulators with smart sensors could connect to existing communication networks to notify the gas utility in the event of the detection of a gas leak, and if necessary, remotely shut off the flow of gas. A comprehensive safety shutoff system includes the following:

- Main components labeled as shown in Figure 3 (single customer) and Figure 4 (multiple customer building), [7]
- Smart Sensors, such as methane, flood, fire, and pressure,
- Smart Gas Shutoff Valve (standalone valve or a smart meter with integrated valve),
- Communication Network and user interface software.

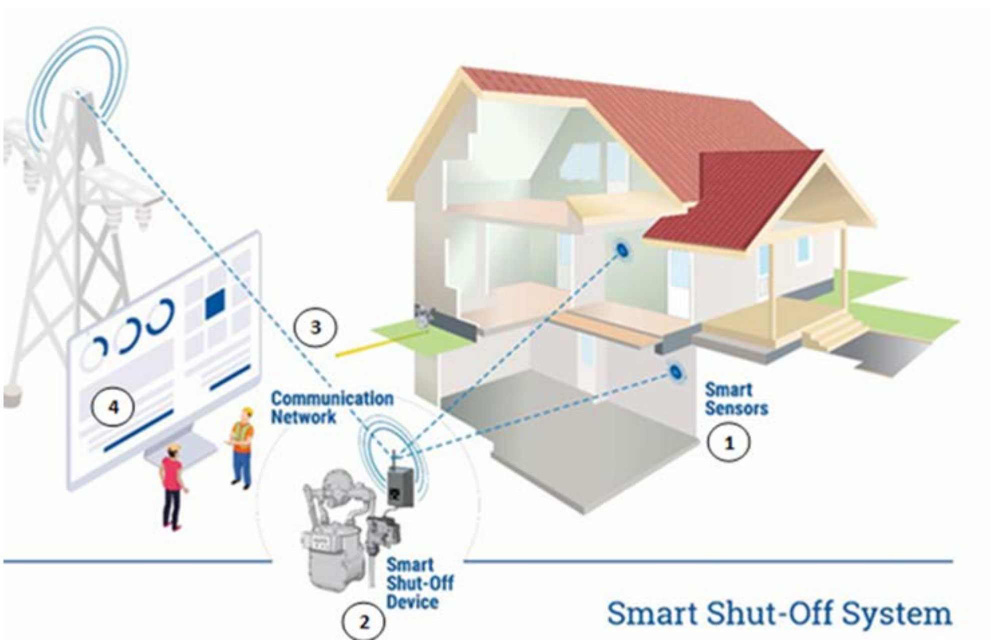

Figure 3. Single customer residential system [7]

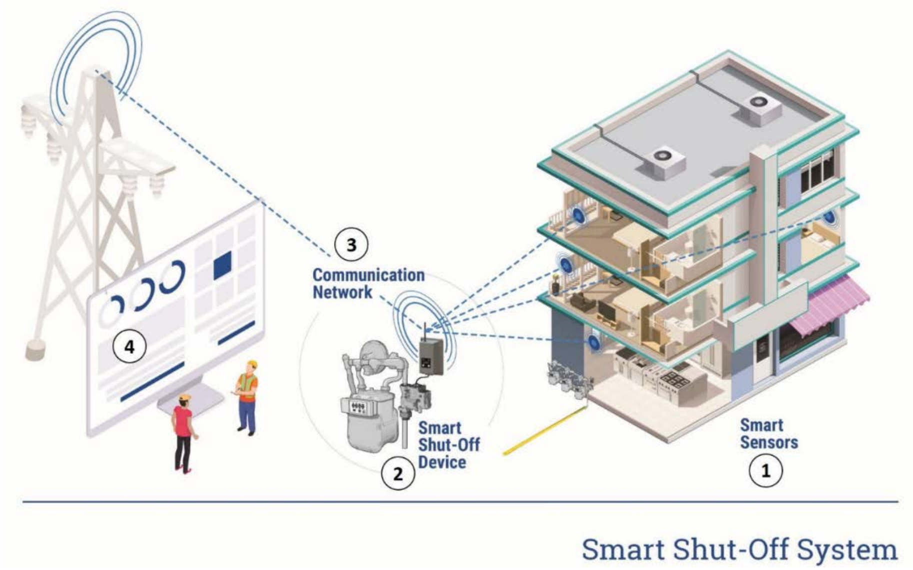

Figure 4. Multi-unit residential or multi-unit commercial system

In this safety system, smart sensors to detect methane, flood, fire, and gas line pressure are deployed in a residential and commercial buildings for these potential hazards. These smart sensors transfer normal or hazard warning data via a communication network to a host server. The data from these smart sensors can be continuously viewed through a software user-interface on the host server. The user interface provides insight to the hazard levels detected by the sensors and allows the user to intervene by remotely actuating the safety shutoff valve to stop the flow of natural gas into a structure before hazardous levels become too dangerous. In addition, the safety system does not require human inaction since the user interface software can be programmed to automatically close the shutoff valve based on the hazard levels received from the smart sensors.

The benefits of the safety system include decreased emissions, prevention of customer property damage and personal injury in the event of a hazard, and a decrease in incidents caused by natural gas leaks in distribution systems. However, significant challenges currently prevent the adoption of this technology and its widespread use in gas distribution systems. The first challenge is that various smart sensors, smart safety valves, and network communication technologies have not been assembled in such a way to provide a comprehensive smart safety shutoff solution. After a fully functional smart shutoff safety system is demonstrated, there will be challenges of widespread rollouts and decisions on the most important features that meet the needs of both the natural gas customer (ratepayer) and the local gas distribution company.

b) Smart Shutoff Valves:

Smart Shutoff valves can be automatically closed by a sensor or remotely closed through a control center. These systems, such as the Lorax Smart Shutoff Valve paired with a methane sensor to retrofit with inside regulators, come in two versions:

1. Service Line Valve (Figure 5): this 125 psig MAOP smart service valve is designed to be installed below grade on the service pipe as close as possible to the main. The valve automatically closes if the service line is punctured such as third-party damage and can also receive a cellular signal to close. This version of the valve could potentially be retrofitted with an inside regulator and methane sensor such that the valve could be quickly closed if methane is detected near the inside regulator.

Figure 5. Lorax Smart Shutoff service line valve

2. Meter Valve (Figure 6): This 175 psig MAOP smart service valve is designed to be installed above grade on the riser, either outside or inside a structure. This version of the valve could similarly be retrofitted with an inside regulator and methane sensor to shutoff if methane is detected near the inside regulator.

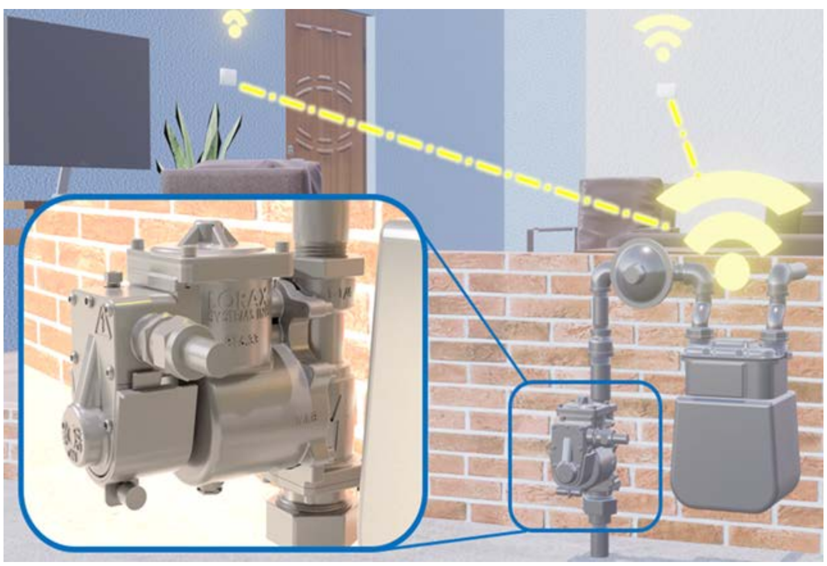

Figure 6. Lorax Smart Shutoff meter valve and inside sensors

There are other smart shutoff devices that are currently being researched to stop the flow of gas, such as devices from Itron (Figure 7 and Figure 8), Sensus (Figure 9) and Honeywell (Figure 10). However, the MAOP of these smart shutoff devices limit their ability for retrofitting inside regulators. Their highest MAOP of these shutoff devices is 7 psig and the highest MAOP for the smart meter with gas flow shutoff ability is 10 psig. Typically, natural gas meters are installed downstream of a regulator and therefore a smart shutoff feature in a meter would have limited safety improvements in the event of a regulator failure.

Figure 7. Itron 100T-GasGate remote disconnect (7 psig MAOP)

Figure 8. Itron Intelis Ultrasonic gas meter (250 class) (5 psig MAOP)

Figure 9. Sensus Ultrasonic gas meter (250 class) (10 psig MAOP)

Figure 10. Honeywell American AC 250NXS diaphragm meter (250 class) (5 psig MAOP)

c) Low Emission Regulators:

There have been various improvements in regulator designs over the past several years which incorporate features such as slam-shuts for over and under pressure conditions, vent limiter devices, and excess flow shutoffs to improve regulator safety as compared to earlier models. Some LDCs have been successful in installing slam-shut style gas service regulators and have demonstrated a reduction in methane emissions and decreased operations and maintenance costs, thus improving system safety and performance.

These new regulators include ones from Pietro Fiorentini (Figure 11) and BelGas (Figure 12) which can incorporate over pressure OPSO shutoff, under pressure UPSO shutoff, and may also incorporate excess flow valve shutoff abilities to stop the flow in the event of large amounts of gas escaping into a structure.

These regulators can incorporate a vent limiter that is compliant with ANSI Z21.80/ CSA 6.22 which keeps the vent flow to less than 2.5cfh in the event of diaphragm failure, and therefore, if installed properly, can prevent the natural gas that is escaping from reaching a hazardous limit if venting inside a structure. Several project are currently investigating these types of regulators inside, including compliant vent limiter type regulators.

Figure 11. Pietro Fiorentini FE200 regulator (125 psig MAOP)

Figure 12. Belgas P100SX slam shut regulator (125 psig MAOP)

Chapter 3 – Evaluation of Recent Smart Retrofitting Technologies

3.1 Introduction

Various technology improvements in regulator's design reduce hazardous gas from escaping the regulator and meter sets. Devices are being designed for smart shut-off technologies, to detect hazardous levels of methane, and to provide an alert system when these leaks are detected.

Recent NTSB's investigation to the 2016 incident in Silver Springs, Maryland, included recommendations to revise the International Fuel Gas Code (IFGC) and the National Fuel Gas Code (NFPA 54) and required methane detection systems for all types of residential occupancies with gas services. Currently, the IFGC and NFPA 54 codes are being updated to include the requirements for methane detectors, which involves working with stakeholders to retrofit inside regulators with methane detectors and work on incorporating these requirements in future codes.

As of the date of this report, the new standard NFPA 715 "Standard for the Installation of Fuel Gases Detection and Warning Equipment" has gone through a public input and comments period and it involves working with stakeholders on the recommendation for retrofitted regulators with methane detectors.

There are several pilots in the United States and other countries that involve products which utilize indoor methane sensors to send out an audio or digital signal to alert of hazardous conditions. For example, the New York State Public Service Commission has approved the installation of 376,000 natural gas detectors inside buildings throughout ConEdison natural gas territory [9]. One of these natural gas detectors (Figure 13) has an alarm threshold of 10% lower explosive limit (LEL) and provide an audible alarm.

Current pilot studies for testing natural gas smart safety shutoff systems consist of some or all the following four main components:

1. The methane sensor,
2. Smart shutoff valve,
3. A communication network, and
4. User interface/software.

These systems consist of either an automatic stand-alone smart shutoff valve or a shutoff valve that is incorporated into a smart gas meter.

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[9] Artificial Intelligence for Natural Gas Utilities: A Primer, National Association of Regulatory Utility Commissioners (NARUC), October 2020.

Figure 13. ConEdison new Cosmos ML-310 natural gas detector

The basic operation of the safety system is that if the detected methane is approaching the explosive limit, the sensor will send a communication signal to the smart valve or smart valve operator and a signal will be sent to close the smart valve to stop the flow of gas into a structure. These systems also incorporate other safety sensors such as fire, flood, earthquake and overpressure protection and they incorporate multiple types of communication networks such as AMI, Wi-Fi, and cellular communication. Future developments of the safety system will electronically alert the customer, the LDC, and possibly emergency management services through a communication network and user interface.

3.2 Retrofitting Inside Regulators with Smart Devices

As indicated in the previous section, there are several pilot studies which involve products that utilize RMDs to send out an audio or digital signal to alert of hazardous conditions. There are several versions of these safety systems operating on wired-powered, battery-powered, and with combinations of both. For practicality and possible unavailability of electrical lines around a natural gas meter set system, the preference is for battery-powered smart devices.

The key elements of smart devices for retrofitting inside regulators are the RMD and the smart shutoff valve. In these systems, safety issues need be addressed and corrected as illustrated in Table 2. Smart meters with integrated shutoff valves stop the flow of gas downstream of the service regulator and would not be effective if a gas leak is in the regulator or any of the piping upstream of the smart meter. In addition, buildings that have caught on fire have gas meters that may also catch fire (melted) and it is important to stop the flow of gas as close to the source as possible.

Table 2. Smart Safety System Mitigation

Inside Abnormal Condition	Corrective Action Steps to Ensure Safety
Any leak cause: - Corrosion - Natural Forces - Excavation Damage - Other Outside Force Damage - Material, Welds or Joints - Equipment - Incorrect Operations - Other Any natural gas leak that allows 10% LEL to migrate to the RMD: - Leaks on any inside piping such as at the service pipe entry, regulator, vent pipe, joints, and meters, e.g. - Leaks that may have migrated from an outside source.	- When the RMD senses a minimum of 10% LEL an audible alert will occur telling the building occupants to evacuate and contact emergency services. - A digital signal hazard alert is sent through a communication network to notify the gas utility of the location and gas reading levels. - A digital signal hazard alert is sent through a communication network to the gas utility customer on file in a form of a text, email, or smart phone application. - The gas utility operator decides whether to close the gas service valve remotely or leave the valve open based on the hazard data obtained. The gas service valve may potentially automatically close shut based on preprogrammed hazard thresholds. - The gas utility dispatches an employee to investigate the hazard and perform corrective actions.

The ideal smart shutoff valve will be rated for the higher pressure and installed upstream of the inside regulator, either outside of the building or at the first fitting on the service pipe once entering a building structure.

3.3 Evaluation of Residential Methane Detectors (RMD)

To prevent undetected leaks in residential homes, an alert system, such as a RMD, benefits both the customer and the utility. Although methane detection technology has advanced in recent years and viable systems are commercially available, their reliability and accuracy need to be evaluated to ensure their effectiveness. Lessons learned during similar technology deployment, such as carbon monoxide (CO) detector deployment in the 1980's, have proven that availability of technology alone does not get the desired level of implementation and there is a need for a comprehensive program that includes technology development, stakeholder engagement, and market research to drive the use of methane detectors to maximize public safety benefits and ensure widespread public and regulatory acceptance.

a) Early Methane Sensor Development:

In the mid-1990s, Gas Research Institute (GRI) sponsored research to develop a low-cost detector for Carbon Monoxide (CO) and methane. [10, 11] Testing was conducted using a commercially available Metal Oxide Semiconductor (MOS) sensor, with the intent to optimize the sensor for methane and CO detection. A MOS device works on the principle that as a combustible gas is adsorbed onto an active semi-conductor layer, the electrical resistance of the sensor changes. The change in resistivity is calibrated as gas concentration varies.

This work also included checking the responses of the sensor to ammonia, ethanol, acetone, and other gas components. The GRI report stated that the device "exhibited no false positives when exposed to interference gases only, and no false negatives when exposed to mixtures of the gases". The detector was found to be adequate for methane detection and demonstrated immunity to both false positives and false negatives when detecting methane. Other sensors in use for industrial applications include thermal conductivity and infrared detectors.

Similar systems can be used for residential combustible gas monitoring, but they are cost prohibitive. Less expensive and simpler detectors for monitoring combustible gases frequently use catalytic sensors. These types of monitors are typically constructed using a catalyst material mounted on an alumina substrate. The catalyst induces a combustion reaction in the presence of hydrocarbon gases. The rise in heat is measured as resistance and is directly related to the concentration of combustible gas.

There is limited data about the relative responses to other combustible gases of catalytic sensor combustible gas sensors calibrated to methane. Representative data of these sensors when calibrated to methane vary from brand to brand and over the life of the sensor.

b) Early CO Sensor Evaluation:

During the period from 1994 to 1998, GRI has conducted Carbon Monoxide Response Survey Analyses project. [12, 13] The data was received as field reports completed by utility personnel when they conducted CO investigations for residential customers following an alarm activation. A total of 35,632 records were reviewed which examined the conditions surrounding the

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[10] GRI-95/0136, "A Wall-Mount Multi-Hazard Alarm for Methane and CO Phase 1", Mosaic industries, Inc., February 1996.

[11] GRI-96/0046, "A Wall-Mount Multi-Hazard Alarm for Methane and CO Phase 2", Mosaic industries, Inc., February 1996.

[12] GRI-96/0409, "Carbon Monoxide Response Survey Analyses: Utility Data – Final Report", Resource Strategies, Inc., February 1997.

[13] GRI-98/0139, "Carbon Monoxide Response Survey Analyses: Supplemental Report 1994-98", Resource Strategies, Inc. April 1999.

activations of alarms, including the time of the activation and the subsequent call to the utility, outdoor conditions (CO levels and temperature), indoor conditions (CO levels and symptoms of illness in the residents), and alarm type.

In 1998, a total of 9,946 surveys were sent to consumers in six different cities around North America. [14] Of the six cities surveyed, only two of the cities had ordinances in place for the use of carbon monoxide detectors in residences. Only 17.4% of the residences that were surveyed had carbon monoxide alarms amongst the six cities.

Of those alarms, 42.7% had been installed within the year that the report concluded. In the two cities which had an ordinance in place for residential carbon monoxide detectors, less than 50% of the surveyed residences had CO detectors.

The CO alarm activation rate for the six different cities was 19.2%. Of the 19.2%, 61.7% of the residences did not call anyone during alarm activation, 10.1% called the utility company, 14.4% called the fire department, 2.1% called the contractor, 5.3% called a family member or friend, and 6.4% called "other". Though this information is related to carbon monoxide alarm activation rates, it provides an insight as to how the consumer behaves. Reaching out to the consumers to gain a better understanding as to how they respond to a natural gas leak either when they smell the odor or have an alarm activation provides valuable information for the residential methane detector program and in supporting the development of appropriate codes and standards as well as targeted public awareness and education programs.

In addition, a workshop was performed in the above GRI project with various stakeholders including American Gas Association (AGA), Environmental Protection Agency (EPA), and the National Association of State Fire Marshals to develop a national strategy to address CO issues. Their strategy included technical guidance for emergency response, field and lab testing, consumer and professional education, standards and evaluation, and data gathering.

c) Early Combustible Gas Sensor Evaluation:

In 1986, GRI issued a final report on the Evaluation of Low-Cost Gas Sensor Technology. [15] At the time of the report, Japan was the only country that established a mass market for domestic and commercial gas leak alarms, incomplete combustion monitors, and automatic gas shutoff systems. Phase 1 of the report focused on the use of such systems by the Japanese gas utilities.

In the late 1970's and early 1980's, regulations were developed in Japan to mandate the use of gas leak detectors in residences for town gas. A majority of town gas supplied in Japan was derived from LNG and contained 88% methane, 6% ethane, 4% propane, and 2% butane. While

[14] GRI-00/0144, "Residential Carbon Monoxide Alarm Population: Six Cities Study", Resources Strategies, Inc., October 2000.

[15] GRI-86/0173, "Evaluation of Low-Cost Sensor Technology, Phase 1", Mosaic Systems, Inc., July 1986.

Approximately 20% of the residences were receiving gas which contained 40-50% hydrogen, 22-28% methane, 10-14% carbon dioxide, 10% nitrogen, and 5% carbon monoxide.

The Japanese regulations were driven primarily by accidents and the public concern for safety. Japan is especially prone to gas leaks for several reasons including earthquakes that are prominent throughout the country, resident's access to gas outlets in the home in order to connect and disconnect popular unvented gas appliances, and the high population density which increases the number of multi-family dwellings.

Japanese utilities such as Osaka Gas and Tokyo Gas aggressively marketed the idea of safety for appliances used by the gas consumers. The utilities sell consumers wall-mounted gas leak and CO alarms, gas appliances that incorporate automatic shutoff in case of oxygen depletion or CO generation, and smart gas meters that shut off flow when leaks are detected. The alarms are typically leased by the gas utility, and LPG alarms are replaced approximately every 4 years, while town gas alarms were replaced every 3 years. As of 1986 a total of 25 million LPG and town gas alarms were installed in residences throughout Japan. This study identified that education, appropriate standards, effective residential methane sensors, and the utilities commitment, consumer adoption of residential methane detectors is possible.

d) Detectors Accreditation Procedures:

A Nationally Recognized Testing Laboratory (NRTL) is an independent laboratory recognized by a governmental agency to test products to the specifications of applicable product safety standards. NRTL provides independent testing and certification of any electrically operated product. Once testing has been performed to a specific standard, a manufacturer is allowed to place a registered mark on literature, packaging, and the actual product, which indicates a product has met specific testing requirements. There is no absolute requirement that testing and certification of products for sale in the United States must be performed, although this is commonly done by many manufacturers. The regulations are different internationally where such testing is mandatory.

In the U.S., the most common NRTL is Underwriters Laboratories (UL) and Intertek Electrical Testing Labs (ETL), with accreditation by the Occupational Safety and Health Administration (OSHA). Other countries have specific requirements for products sold within their borders, such as the Consumer Product Safety Mark (Japan), Bureau of Indian Standards, and Standards Australia.

e) Residential Combustible Gas Detectors:

Current residential combustible gas detectors are small AC powered or battery-powered plug-in devices intended to detect natural gas (methane) and LP-Gas (propane), which may be present in a residential building, or in certain cases, in recreational vehicles. These devices are currently intended to sound an alarm at or above 25% LEL of natural gas and LP-Gas. When used in a residence, they are commonly referred to as RMDs.

Catalytic bead detectors [16] were the first type of detectors in the market. They function by oxidizing (burning) the combustible gas at the hot surface of a sensing bead with a catalyst coating and comparing the resistance to a non-sensing bead using a Wheatstone Bridge type circuit. The difference is directly proportional to concentration. They are relatively low-cost and have an approximate life span of five years because the oxidation process consumes the sensor material, and it eventually depletes and becomes unresponsive. Catalytic bead sensors respond to all combustible gases, but they respond at different rates can be calibrated for gases in specific applications. The bead surface can be contaminated by certain gases and reduce sensitivity and lifetime.

Semiconductor based combustible gas detectors [17] were introduced in the late sixties as an alternative to the catalytic bead. They are usually constructed from transition metal oxides and are often known as metal oxide semiconductors (MOS). Advantages include low cost, easy fabrication, simplicity of use, and ability to detect different gases. With these sensors, gas is adsorbed onto the sensor surface, changing the resistance of the metal oxide. Concentration of the combustible gas is proportional to the resistance. When the gas disappears, the sensor returns to its original condition. No sensor material is consumed in the process, and as a result, they can have a longer life expectancy. Like the catalytic bead sensor, they are susceptible to contamination. Limitations include high cross sensitivity and poor selectivity to some gases. Sometimes the interferences from other gases are minimized by using appropriate filtering materials that absorb all other gases except the gas to be detected. They are commonly used sensing materials for the residential methane detector market. A typical lifetime is five years.

Nondispersive Infrared (NDIR) sensors [18] work on the principle that gases containing two or more dissimilar atoms absorb infrared radiation that can be easily detected. Each gas has a unique fingerprint spectrum and specific bands of the spectrum are targeted for analysis. Dual infrared radiation detectors measure the methane band with a reference detector measuring a non-methane band. As the gas concentration increases, the absorption band difference increases. Infrared sensors are highly selective and offer a wide range of sensitivities, from parts per million levels to 100 percent concentrations. The selection of the band for monitoring is important to eliminate interferences from other gases. A typical lifetime is ten years.

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[16] Swapan Basu, Plant Hazard Analysis and Safety Instrumentation Systems, October 2017.

[17] Ranjeet Mandal, "Application of Gas Monitoring Sensors in Underground Coal Mines and Hazardous Areas" in International Journal of Computer Technology and Electronics Engineering, vol 3, June 2013.

[18] NDIR Sensor Image from OptoSence, LLC (http://www.gascliptech.com/documents/GCT-IR-Technology-White-Paper-v2.02-WEB.pdf).

One of the keys to achieving full customer adoption of RMD is having a product that is reliable and accurate. A concern associated with these detectors is their false positive rate and sensitivity to chemicals other than natural gas or LP-Gas. A false positive is defined as a test result that mistakenly gives a positive reading. False or nuisance alarms can cause unnecessary panic and generate an inappropriate response. Over time, repeated false or nuisance alarms may cause consumers to ignore all alarms because of a suspicion that they are not real.

An early project in 2010 was performed to determine whether commercially available residential methane gas detectors were susceptible to giving false-positive responses to an assortment of typical household chemicals. [19] The research showed that few commercially available devices had good performance while many of the off-brand units gave significantly more false positive responses in comparison to the name-brand units.

In 2014, an expanded work of the original study was performed on a larger set of commercially available RMDs. [20] The results confirmed that known name-brand RMDs had the best overall performance. These results allowed utility companies to add to their environmental and safety awareness interaction with the public by offering information regarding the safety and reliability of in-home combustible gas detectors. Additionally, new RMDs and sensors were identified and tested in 2020. Advancements in the field of RMDs is continual due to increasing awareness by the industry of the benefits of these safety devices.

During this work [21], several standards and regulations related to the performance requirements of methane detectors were identified and are shown in Table 3. Various odorization standards for distribution pipelines are shown in Table 4 and they describe the performance standards and percentage of LEL activation points. Of note is the varying % LEL numbers for each standard and that none of these standards were specifically developed to address methane releases and associated gas migration patterns within typical residential structures. While it is important to understand these standards as a "reference point", simply applying existing standards to residential methane detectors would be inappropriate, thus there is need for reevaluation of an enhanced, "Fit-for-Purpose" standard for residential methane detection applications.

[19] Residential Methane Gas Detector Testing Program – Phase 1, OTD Project 1.9.h, GTI project 20939, 2010.

[20] Residential Methane Gas Detector Testing Program – Phase 2, OTD Project 1.14.g GTI project 21650, 2015.

[21] Residential Methane Gas Detector Testing Program – Phase 3", OTD Project 1.14.g.2GTI project 21696, 2021.

Table 3. Performance Standards for Methane Detectors

Performance Standards for Methane Detectors				
Standard	Section	Organization	Details/ Title	% LEL Alarm Activation Point
UL-1484	43.1.1	ANSI/ Underwriters Laboratories	Standard for Safety: Residential Gas Detectors	<25%
BS EN 50194-1:2009	4.3.3	British Standards Institute	Electrical apparatus for the detection of combustible gases in domestic premises - Part 1 : Test methods and performance requirements	3-20%
49 CFR 192	.736	DOT	Transportation of Natural and Other Gas by Pipeline: Minimum Federal Safety Standards: Compressor Stations: Gas Detection	<25%
2012 NFPA 30A	7.4.7	NFPA	The gas detection system shall be designed to activate when the level of flammable gas exceeds 25 percent of the lower flammable limit (LFL).	25%

Table 4. Distribution Pipeline Odorization Standards

Distribution Pipeline Odorization Standards				
Standard	Section	Governing Body	Details	% LEL
49 CFR 192	.625	DOT	• Title 49: Transportation PART 192—TRANSPORTATION OF NATURAL AND OTHER GAS BY PIPELINE: MINIMUM FEDERAL SAFETY STANDARDS Subpart L—Operations • 192.625 Odorization of Gas • a) A combustible gas in a distribution line must contain a natural odorant or be odorized so that at a concentration in air of one-fifth of the lower explosive limit, the gas is readily detectable by a person with a normal sense of smell.	20%
49 CFR 192	COMAR 20.55.09.06A	Maryland State	• Code of Maryland Regulations (COMAR)) Title 20 Public Service Commission, Subtitle 55 Service Supplied by Gas Companies, Chapter 9 Safety • Requires that odorants level throughout the entire company distribution system shall be sufficient so that gas is detectable at 1/10th of the LEL	10%
49 CFR 192	101.06(20)	Massachusetts State	• 220 Department of Public Utilities, Code of Massachusetts Regulations, Title 101 General R • Gas must be odorized so that it can smelled at .15% gas-in-air	3%
49 CFR 192	255.625b	New York State	• 16 (NYCRR) New York Compilation of Rules and Regulations, Title 16 Public Service Commission, Volume B Chapter 3 Gas Utilities, Sub Chapter C Safety, Part 255 Transmission and Distribution of Gas • All gas transported in distribution mains, and service laterals is to be adequately odorized so that it is readily detectable at all gas concentrations of one tenth of the lower explosive limit and above.	10%

The results of the above testing programs indicated that an appropriate alarm level for residential methane detectors should be lowered from 25% LEL methane to 10% LEL. This new alarm level will better align with actual day-to-day response thresholds common in the gas distribution industry today (typically less than 0.5% gas-in-air thresholds) and will address utility First Responder concerns regarding build-up and dispersal of natural gas in a home.

In 2019, NTSB released their findings and recommendations on the Silver Springs, MD incident that occurred in 2016. [22] NTSB recommended that GTI work with the International Code Council (ICC) and NFPA to develop a standard for methane detection systems for homes. GTI joined the NFPA Research Foundation technical committee overseeing the project "Combustible Gas Detection in Buildings and Detector Location". This effort is on-going and as of this report date, the new standard NFPA 715 "Standard for the Installation of Fuel Gases Detection and Warning Equipment" has gone through a public comment period. The current version of the standard incorporates the 10% LEL alarm recommendation, ethanol, and acetone interference test suggestions, mounting distances from the ceiling, and increased safety messaging.

3.4 Summary of RMD Testing Results

The three testing project phases referenced in the previous section included testing 21 brands of RMD devices. Specific manufacturers were kept anonymous and assigned a randomized letter. At least three devices from each manufacturer were tested. These devices were first tested with methane gas, followed by propane then household products and chemicals. The order in which the exposures occurred were random. Duration for exposure was 15 minutes unless the alarms sounded earlier. Ethanol, acetone, and paint thinner were tested at a calculated 25% and 12% LEL in air. Others used a typical amount that would be spilled in a home.

Given the volumes of an assumed-typical 9-ft by 12-ft by 7.5-ft room in a home and the test chamber (Figure 14), estimation of the exposure volume was based on the ratio of the room dimensions and the volume of the test chamber to simulate "typical exposure" levels in a home.

Figure 14. Test chamber used in evaluating the RMD devices

[22] NTSB Accident Report PAR-19/01, PB2019-100722, April 2019.

In the cases of non-hydrocarbon chemicals and/or slow to evaporate chemicals, the conclusions and quantities mentioned below are based on the amount of each test chemical which evaporated into the vapor space of the test chamber. In the case of these chemicals, it is not known which portions of the mixture(s) may have selectively evaporated and which may have remained in the dish. The interpretation of data in those cases is still considered to be valid.

a) Response to Methane and Propane

Testing criteria changed when the Phase 3 project evaluated methane concentrations at 25% LEL, 12% LEL, and 6% LEL. In Phase 3 [18], the standard alarm level included 10% LEL. The responses to methane and propane are shown in Table 5. A green box indicates a positive response to the flammable gas. A red box indicates no response. In evaluating response to methane, a lack of propane is not necessarily a negative.

Of note are three models that exhibited no response to methane (D, G, and O). Two of these (D and O) responded to propane instead of methane implying that the models were mislabeled as natural gas detectors, or had the wrong sensor used. One brand (G) had no response to flammable gas at all, and it was not listed to any of the RMD standards. None of these were commonly marketed name brand detectors. Figure 15 is a bar chart summarizing the percentages of model responses to various methane and propane levels.

Table 5. Summary of RMD Responses to Methane and Propane

ID	Listed?	Methane				Propane			
	(UL, EN, JIA)	25% LEL	12% LEL	10% LEL	6% LEL	25% LEL	12% LEL	10% LEL	6% LEL
A	y	y	n	n	n	y	n	NT	n
B	y	y	y	n	n	y	y	NT	n
C	y	y	y	NT	n	y	y	NT	y
D	y	y	y	NT	n	y	y	NT	y
D	y	n	n	NT	n	y	y	NT	n
E	y	y	y	NT	y	y	y	NT	n
F	n	y	n	NT	n	y	y	NT	n
G	n	n	n	NT	n	n	n	NT	n
H	n	y	y	NT	n	y	n	NT	n
I	y	y	y	y	n	y	n	NT	n
J	y	y	y	y	y	n	n	n	n

K	y	y	n	NT	n	n	n	NT	n
L	n	y	y	NT	n	y	y	NT	n
M	y	y	n	NT	n	n	n	NT	n
N	y	y	y	y	y	n	n	NT	n
O	y	n	n	NT	n	y	y	NT	y
P	y	y	NT	y	NT	n	NT	n	NT
Q	n	y	NT	y	NT	n	NT	n	NT
R	n	NT	NT	y	NT	n	NT	n	NT
S	n	y	NT	y	NT	y	NT	y	NT
T	y	y	NT	n	NT	n	NT	n	NT

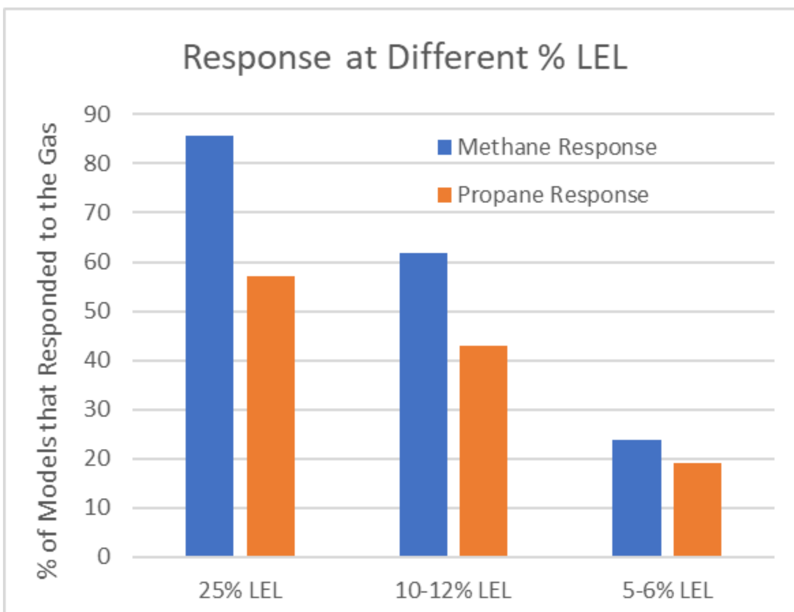

Figure 15. Methane and propane responses at different % LEL

b) Response to Household Chemicals

A list of products and chemicals tested in the above listed project is shown in Table 6 and the household chemical testing is summarized in Table 7 and Table 8.

Table 6. List of Household Products and Chemicals

Test Material	Typical Use or Application
Methane	Natural gas
Propane	LP gas
Ethanol	Alcohol
Acetone	Fingernail polish remover
Paint Thinner	Oil based paint and cleaners
Laundry Detergent	Clothes washing machines
Stain Remover	Clothes washing machines
Cyanoacrylate Adhesive	Household gluing tasks
Bathroom Cleaner	Toilet and shower cleaning
Home Dry-Cleaning Kit	Clothes dryer machines
Fabric Freshener	Household cleaning tasks
Aerosol Hairspray	Personal grooming
Furniture Polish	Household cleaning tasks
Bleach	Clothes washing machines
Household Ammonia	Household cleaning tasks
Duster Spray	Computer cleaning spray
Disinfectant Spray	Household cleaning tasks
Oven Cleaner	Household cleaning tasks
Rust Stain Remover	Household cleaning tasks

Table 7. Summary of RMD Responses to Household Chemicals, Part 1

ID	Ethanol	Acetone	Paint Thinner	Duster Spray	Home dry-cleaning kit	Oven Cleaner	Cyano-acrylate Adhesive	Fabric Re-fresher	Hair-spray
A	n	n	n	n	n	n	n	n	n
B	n	n	n	n	n	n	n	n	n
C	y	y	y	n	n	n	n	n	y
D	y	y	n	n	n	n	n	n	y
D	y	n	n	y	n	n	n	n	n
E	y	y	n	n	n	n	n	n	y

F	y	n	n	y	n	n	n	n	n
G	y	n	n	n	n	n	n	n	n
H	y	y	n	n	n	n	n	n	n
I	n	n	n	n	n	n	n	n	n
J	n	n	n	n	n	n	n	n	n
K	n	n	n	n	n	n	n	n	n
L	y	y	n	y	n	n	n	n	y
M	n	n	n	n	n	n	n	n	n
N	n	n	n	n	n	n	n	n	n
O	y	y	n	y	n	n	n	n	n
P	n	n	n	n	n	n	n	n	n
Q	n	n	n	n	n	n	n	n	n
R	n	n	n	n	n	n	n	n	n
S	y	y	y	n	n	n	n	n	n
T	n	n	n	n	n	n	n	n	n

Table 8. Summary of RMD Responses to Household Chemicals, Part 2

ID	Furniture Polish	Bleach	Ammonia	Liquid Laundry Soap	Spray Dis-infectant	Bath-room Cleaner	Fabric Stain Remover	Rust Stain Remover
A	n	n	n	n	n	n	n	n
B	n	n	n	n	n	n	n	n
C	n	n	n	n	y	n	NT	NT
D	n	n	n	n	n	n	NT	NT
D	n	n	n	n	n	n	n	n
E	n	n	n	n	y	n	NT	NT
F	n	n	n	n	n	n	n	n
G	n	n	n	n	n	n	n	n

H	n	n	n	n	n	n	n	n
I	n	n	n	n	n	n	n	n
J	n	n	n	n	n	n	n	n
K	n	n	n	n	n	n	n	n
L	n	n	n	n	y	n	n	n
M	n	n	n	n	n	n	n	n
N	n	n	n	n	n	n	n	n
O	n	n	n	n	n	n	n	n
P	n	n	n	n	n	n	n	n
Q	n	n	n	n	n	n	n	n
R	n	n	n	n	n	n	n	n
S	n	n	n	n	n	n	n	n
T	n	n	n	n	n	n	n	n

In the above tables, a green box indicates no positive response to the household chemical. A red box indicates a false positive response. Ethanol and acetone are the household chemicals most likely to elicit a false positive signal. This is followed by duster spray, hairspray, and disinfectant (both containing ethanol), and paint thinner. The remaining chemicals had no response on the detectors. The bar chart in Figure 16 summarizes the percentages of model responses to the various chemicals.

A few tested detectors also contained a carbon monoxide sensor. When exposure to ethanol occurred, a cross-sensitivity to the CO sensor occurred. The CO sensors usually required several hours to return to a non-alarming state.

In order to detect when a gas leak is present, the first step industry takes is to odorize the gas in certain classes of natural gas transmission pipelines and in all distribution lines. The 49 CFR 192.625 states that gas must be odorized such that a person with an average sense of smell can recognize the odor of gas at one-fifth of the lower explosive limit in air. For methane, this concentration is commonly 1%. Some states odorize at even lower odor thresholds (for example New York and Maryland at one-tenth of the lower explosion limit in air). As current codes and regulations stand today, consumers could smell gas in their residence prior to their residential methane detector activating an alarm.

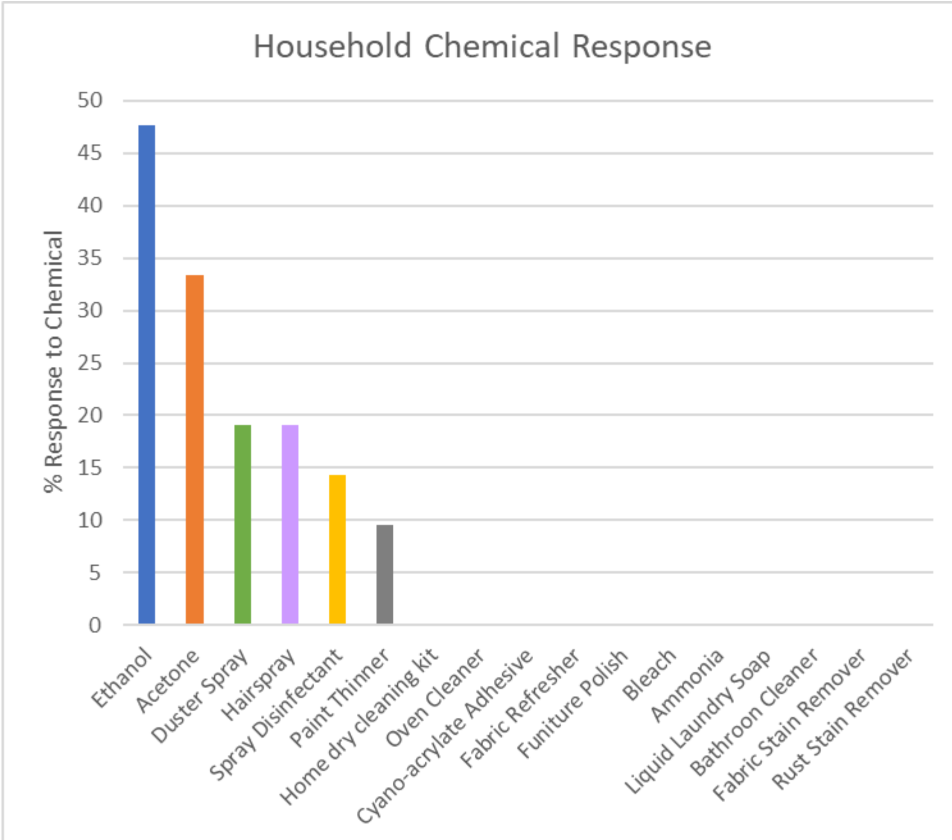

Figure 16. Household chemical responses

Current testing at GTI has found that each of these sensor types can be applied for detection levels of 10% LEL. Infrared based sensors do appear to extend sensitivity even lower, to near 5% LEL in some cases. The initial cost may be higher but over the lifetime of a sensor, the NDIR based sensors are favored due to lower power consumption and longer lifetimes.

In addition, some of the gas detectors identified have communications modules built into the detector. Having the ability to transmit a signal back to a utility in the instance of a detectable gas leak or battery/sensor failure is an important safety/ alert improvement. A customer would only hear a gas alarm in the instance of a gas leak with all other monitoring would be silent. Ideally such devices would be battery powered with a low power RF radio signal to allow for a minimal 5-year lifetime. A longer lifetime is preferred. Devices that alarm at 10% LEL methane in air and are currently available with specific communication capabilities include those listed in Table 9 [23].

[23] Smart Shutoff Technology for Residential and Commercial Buildings, OTD and California Energy Commission (CEC) Project 5.20.k, GTI project 22801, current.

Table 9. Methane Detectors with Communication Capabilities

Manufacturer	Model	Listed Certification	Power	Sensor	Life (yrs)	Communication Network
Centmark	GAMMA 652/4-O/M	EN 50194	Wired	C / M	NA	Wired Relay
CNIguard	GasMarshal	Pending	Li battery	NDIR	10	LoRaWAN/ Itron
eLichens	Avolta	Pending	Li battery	NDIR	10	LoRaWAN
FireAngel	NG-9B	EN 50194	Li battery	C / M	5	Wired Relay
Gas Sense	H-220-CH4	EN 50194	Wired	C / M	NA	Wired Relay
Heath / BAH Holdings, LLC	experimental	experimental	experimental	NDIR	NA	None
Honeywell	HF500NG	EN 50194	Wired	C / M	5	Wired Relay
International Gas Detectors	TOC-10	EN 50194	Wired	NA	NA	Wired Relay
Jablotron	GS-133 GS-130	EN 50194	Wired	C / M	NA	Wired Relay
New Cosmos	ML-310	UL 1484	Li battery	C / M	5	Itron
New Cosmos	DeNova Detect 806	UL 1484	Li battery	C / M	6	LoRaWAN/ Itron
Ornicom	S2014ME S2013ME	EN 50194	Wired	NA	NA	Wired Relay
Primatec	Prevent d Prevent m	EN 50194	Wired	C / M	5	Wired Relay
Seitron	Segugio	EN 50194	Wired	C / M	5	Wired Relay
Sensitron	LA-ME220SC LAME220-P	EN 50194	Wired	C / M	NA	Wired Relay

Note: C / M = Catalytic or MOS sensor

3.5 Evaluation of Smart Shutoff Valves

Previous tests in an early project on Lorax Smart Shutoff Valve [24] (Figure 17) showed that it can be automatically closed by a smart sensor (such as an RMD) or remotely closed through a control center. The Lorax Smart Shutoff Valve is rated at MAOP of 175 psig and would typically be installed on a riser location upstream of the regulator and the meter. There are two versions of the Lorax Smart Shutoff Valve where the first version could be installed above grade on the

[24] Development of an Integrated Safety System (IISS) for Commercial and Industrial Customers - Phase 3, OTD Project 5.12.a.3, current.

riser and the second version is installed on the service pipe below grade as close to the main as possible with a feature that stops the flow of gas if the service pipe is damaged during excavation. Figure 18 shows inside/outside installation locations with respect to a building wall.

Figure 17. Lorax Meter Valve [25]

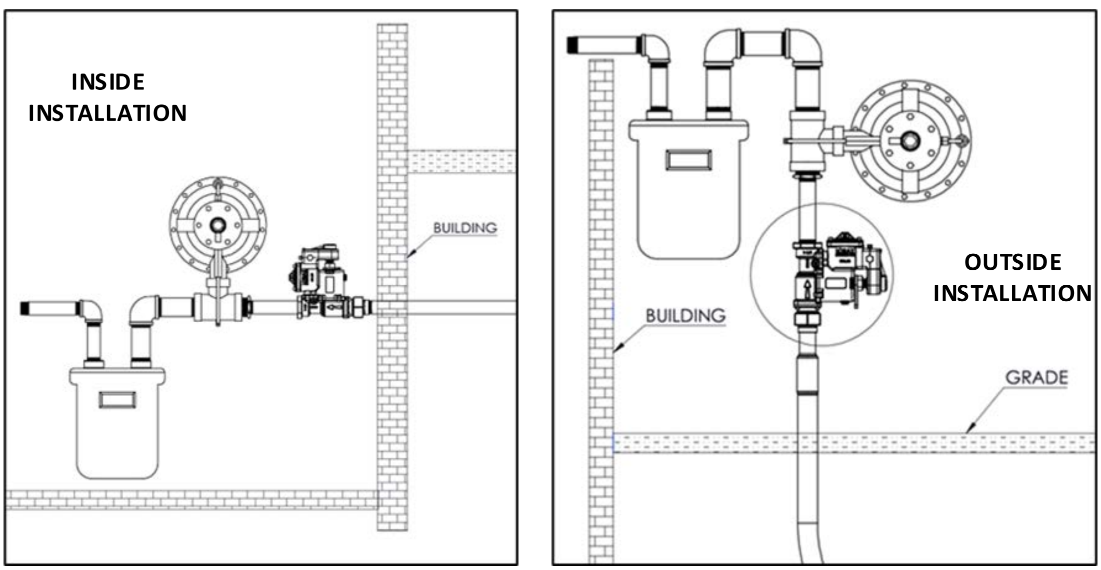

Figure 18. Lorax meter valve inside (right) and outside (left) installations

There are other smart sensors on the market. However, there are few stand-alone natural gas smart safety shutoff valves that can be installed on service pipes. Up to the time of this report, the Lorax Systems Meter Valve is the only one in the market that can be installed on the high-pressure side of the service regulator (upstream side). This will allow shutoff protection not only

[25] Lorax Systems Inc. Meter Valve Brochure, 2020.

for piping downstream of the meter, including customer piping and appliances, but also piping upstream of the gas meter including the service regulator.

As outlined earlier in section 2.2 of the project, the MAOP of the other smart devices do not make them ideal for retrofitting inside regulators. They typically have MAOPs of 5 psig and would have to be installed downstream of the regulator for building delivery pressures beyond their MAOP.

3.6 Network Communication for RMDs and Smart Shutoff Valves

An international search was performed in a related project [26] to review natural gas safety systems in other countries. Many European and Asian gas utilities have developed or are in the process of developing natural gas safety systems from RMDs and smart shutoff valve devices. Some of these safety systems are managed by third-party providers. One of the key technologies used for some of these safety systems was the use of Low Power Wide Area Networks (LPWAN).

LPWAN communication networks are easy to deploy, reliable, ideal for battery operated sensors, easy to use to complement other communication networks, and have a lower cost to install and a low cost to maintain as compared to other communication networks. These advantages provide a highly reliable system which complement existing utility communication systems. The LPWAN communication network is designed for smart sensors with batteries and many of the sensor manufacturers have been designing their devices to work on this communication network.

The LPWAN communication network will allow the RMDs to reliability maintain ongoing communication with the gas utility, the gas customer and other smart devices while maintaining a long battery life. This new technology is secure from hacking and can complement existing AMR, AMI and Telco communication networks that are being used by gas utility operators in the United States.

3.7 Two-stage Regulator Systems

There have been various improvements in regulator designs over the past several years which incorporate features such as slam shuts for over and under pressure conditions, vent limiter devices, and excess flow shut offs to improve regulator safety as compared to earlier models. Many of these regulators have a small footprint and are easier to install outside because of their low clearance requirements. These regulators can incorporate a vent limiter that is compliant with ANSI Z21.80/ CSA 6.22 which keeps the vent flow to less than 2.5cfh in the event of

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[26] Smart Shutoff Technology for Residential and Commercial Buildings, OTD and California Energy Commission (CEC) Project 5.20.k, GTI project 22801, current.

diaphragm failure, and therefore if installed properly can prevent the natural gas that is escaping from becoming hazardous inside a structure. The following are advantages and disadvantages of using a two-stage slam shut style regulator.

Advantages:

1) Provides overpressure protection redundancy through the shut off valves and redundant diaphragm.
2) Regulator models with vent limiters can be used for certain indoor and outdoor conditions that allow usage of vent limiters.
3) Options available in terms of mounting style and additional protection such as excess flow valve.
4) Two stage balanced regulation provides stable delivery pressure which ensures that billing accuracy is maintained.
5) Some have strainers to trap contaminants in the gas stream which enhances the reliability of the regulator.

Disadvantages:

1) Larger pressure loss across the regulator,
2) More expensive than single stage regulator.

Some LDCs have been installing slam-shut style gas service regulators and have demonstrated a reduction in methane emissions and decreased operations and maintenance costs, thus improving system safety and performance. Testing of some of these newer regulators [27] included Pietro Fiorentini and BelGas. These models incorporate OPSO and UPSO shutoffs and may also incorporate excess flow valve shut off abilities that could be effective to stop the flow in the event of large amounts of gas escaping into a structure.

a) Pietro Fiorentini FE200 Regulator (Figure 19):

Table 10 outlines the specifications for the Pietro Fiorentini FE series regulator which is two-stage balance valve spring-controlled regulator and is used in residential and commercial installation for natural gas delivery services. The FE series regulator is equipped with a slam-shut valve for overpressure protection and an excess flow valve. The regulator consists of a double diaphragm assembly which acts as a redundant back up. The diaphragm incorporates a vent limiter which limits the vented gas flow in case of a diaphragm failure, however regulations may require the gas be vented outside.

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[27] Overpressure Protection Options for Low-Pressure, OTD Project 5.19.g, GTI project 22620, 2020.

Figure 19. Pietro Fiorentini FE200 regulator

Table 10. Pietro Fiorentini FE200 Specifications

Parameters	
Maximum (operating) Inlet pressure	125 psig
Maximum (emergency) inlet pressure	150 psig
Outlet pressure range	6 iwc – 7.1 psig
Over pressure set point (for regulation set point of 8 iwc	19 iwc
Flow capacity at 12 iwc inlet and 7 iwc outlet	240 SCFH
Operating Temperature	-20^{0}F to 160^{0}F

b) Belgas P100SX Slam Shut Regulator (Figure 20):

Table 11 outlines the specifications of the Belgas P100SX which is a slam-shut pressure regulator for natural gas usage. It is a double stage regulator with over pressure, under pressure, excess flow protection. The overpressure protection is activated when the downstream pressure exceeds the set point.

Figure 20. Belgas P100SX slam shut regulator

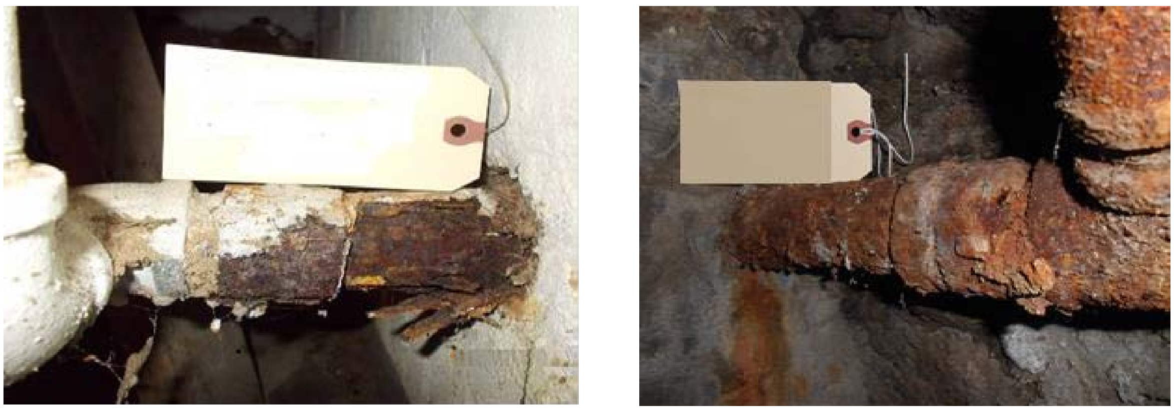
Table 11. Belgas P100SX Specifications

Parameters	
Maximum (operating) Inlet pressure	125 psig
Outlet pressure range (Spring range)	6 iwc – 5 psig
Flow capacity at 14 iwc	385 SCFH (0.5 in. orifice)
OPSO setting	16 iwc ±10%
UPSO setting (optional)	3 iwc ±25%
Operating Temperature	-20^{0}F to 150^{0}F

Chapter 4 - Inspection and Rehabilitation of Indoor Piping Systems

4.1 Review of Previous Field Monitoring Studies

Several factors increase the piping systems corrosion potential and associated risk of leakage in an inside meter room. These factors include piping age, installation procedures, piping support and placement, condition of pipe coating, and relative humidity. The piping point-of-entry (POE), in particular, may show higher corrosion potential than other indoor piping as shown in Figure 21. This chapter reviews utilities inspection data of inside piping systems for atmospheric corrosion and leakage in order to provide informed decisions about installation requirements and frequency of inspection for a robust risk-based inspection and rehabilitation program.



(a) Flaking of pipe surface indicating metal wall loss

(b) General rust build-up with pitting near fitting

Figure 21. Corrosion at Point of Entry in meter rooms

4.2 Parameters Affecting Indoor Piping Condition

The American Gas Association (AGA) has performed a field study in cooperation with PHMSA, National Association of Pipeline Safety Representatives (NAPSR), and gas utility operators [28] to evaluate indoor atmospheric inspection and leakage survey procedures. A standardized form (shown in Appendix A) was developed for use by the participating utilities in collecting data about 63,210 installations in 2008. The study provided the following conclusions from the collected data:

[28] Atmospheric Corrosion Inspection and Leak Survey Study, Avent Design Corp., for American Gas Association, Project# 7176, 2009.

- Atmospheric corrosion rate and number of leaks in inside meter sets were lower than those in outside sets.
- Indoor risk factors such as contact with wall and soils increase the risk of corrosion.
- There is no definitive connection between atmospheric corrosion and indoor gas leaks. Most of indoor leaks resulted from loose and poorly connected threads, couplings, and mechanical connections rather than due to atmospheric corrosion.

Additionally, historical records of inside meter-sets from LDCs in the northeast in 2007 were presented in an earlier study [29] for information related to corrosion and leakage. These records focused on high-pressure unprotected steel installations since leaks in this category have a greater potential to create risk hazards. The data set of 126 inspection records covered a wide range of leak and corrosion observations. Pressure tests were also performed to a maximum of 90 psig on the through-wall service lines. The parameters related to leak and corrosion potential in this study (installation year, inside room humidity, temperature, piping material, foundation type, and pipe coating) are shown Figure 22 to Figure 27.

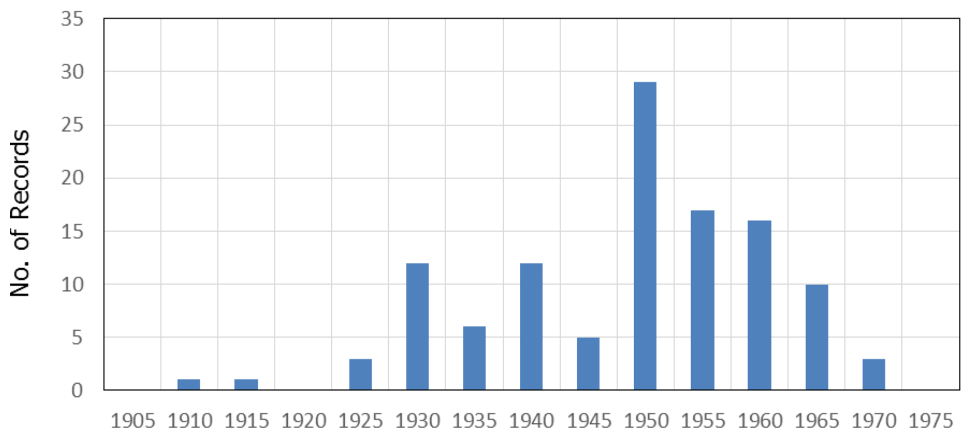


Figure 22. Inside meter 'Installation Year' in the data set

[29] Risk-Based Atmospheric Corrosion/ Leak Survey Considerations, Gas Technology Institute, White Paper 21678, 2014.

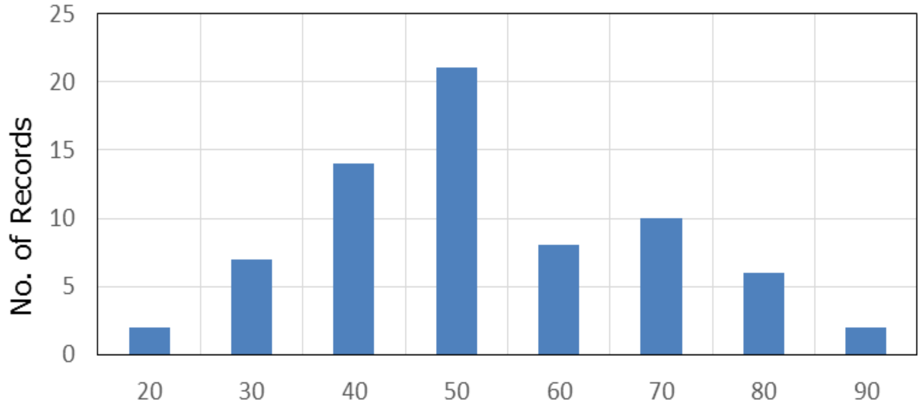


Figure 23. Distribution of Humidity (%) in the data set

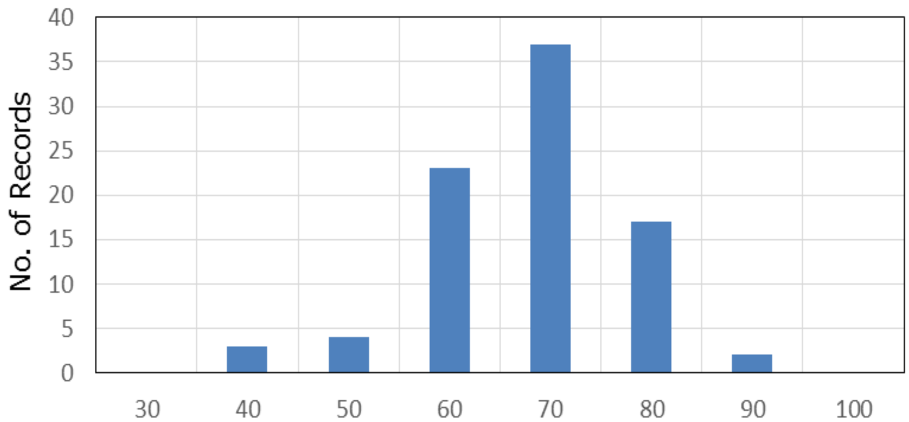


Figure 24. Distribution of Atmospheric Temperature (^{0}F) in the data set

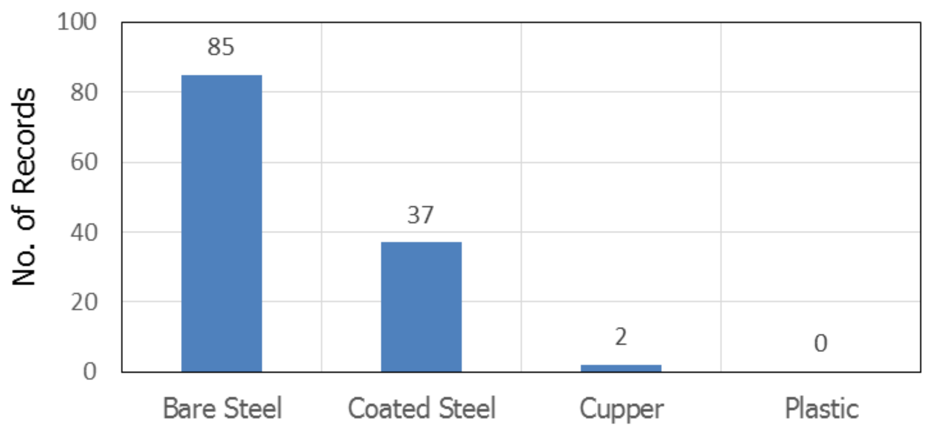


Figure 25. Distribution of the Pipe Material in the data set

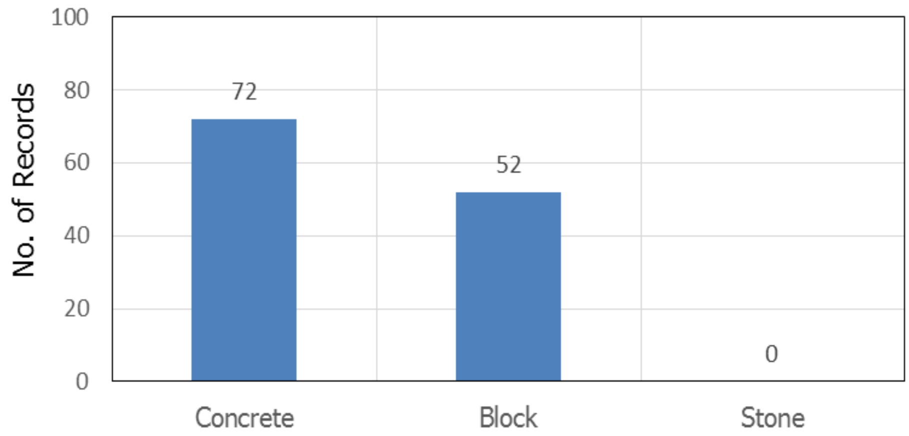


Figure 26. Foundation types in the inside meter-sets data

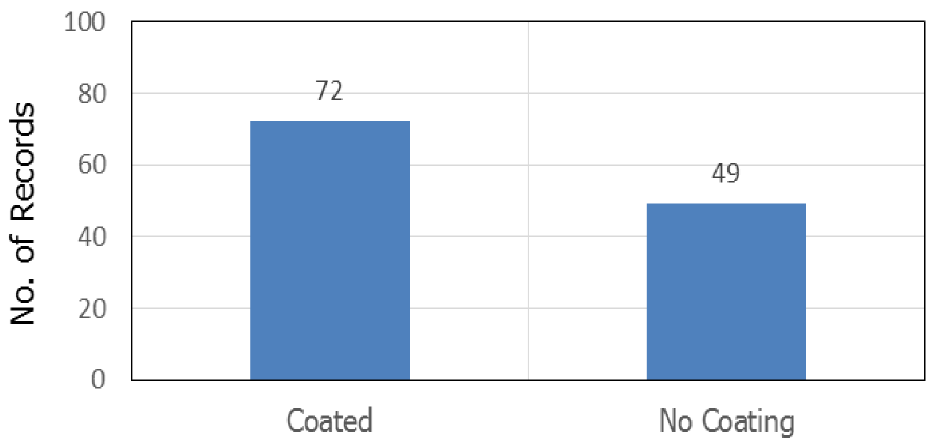


Figure 27. Piping coating types in the inside meter-sets data

The analysis evaluated the effect of the above parameters on the following observed responses:

- Leak record (Leak vs. No-Leak),
- Pipe condition at wall (POE),
- Meter piping condition, and
- Results of pressure tests (Pass vs. Fail).

The pipe and meter piping conditions were categorized from 1 to 4 with respect to their corrosion level as follows:

1. Satisfactory - no corrosion,
2. Mild oxidation, slight surface rust,
3. Slight corrosion, and
4. Sever corrosion – metal loss.

Figure 28 shows the conditions of the pipes at POE and meter piping in these installations. The results show that more than 90 percent of the records had mild surface rust or no-indication of corrosion. About 8% had slight corrosion and 1% had sever corrosion.

Leaks were reported in 29 out of the 126 installations and 7 installations failed the pressure tests at the POE, with the rest of the installations passing the pressure tests.

The data sets were analyzed in the above study using Analysis of Variance (ANOVA) of the Design-Expert® Software program to investigate the significance of these parameters on the piping corrosion conditions. Table 12 shows the ANOVA results. In the table, a p-value below 0.05 indicates that the model terms are significant. The results of the data analysis show the model terms which were significant, indicating a strong relationship between corrosion and these parameters.

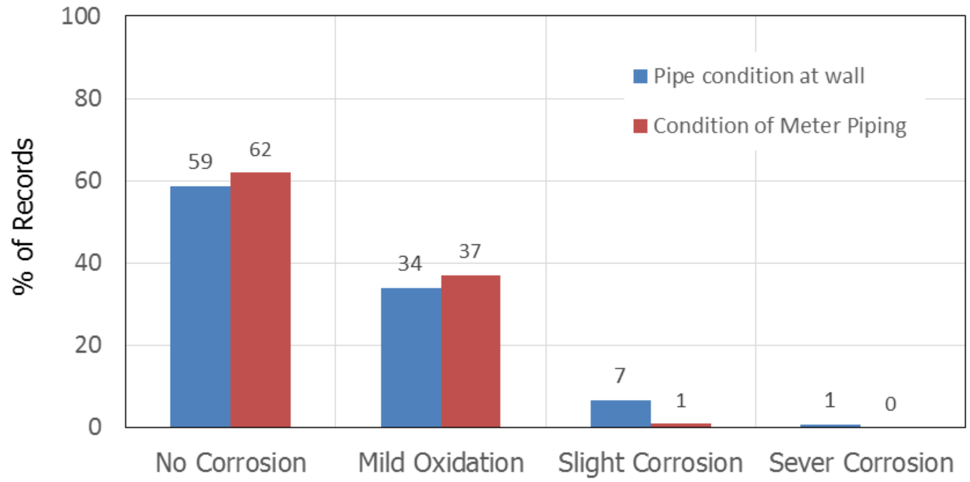


Figure 28. Meter and piping conditions in the inside meter-sets

Table 12. ANOVA for Response Parameters on Pipe Corrosion

Analysis of variance table [Partial sum of squares - Type III]						
Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	9.30	6	1.55	4.70	0.0006	significant
A-Year Built	*2.93*	*1*	*2.93*	*8.89*	*0.0041*	
B-Humidity	*2.58*	*1*	*2.58*	*7.81*	*0.0070*	
C-Steel Pipe Materi	*1.49*	*1*	*1.49*	*4.53*	*0.0375*	
D-Foundation	*0.62*	*1*	*0.62*	*1.88*	*0.1751*	
E-Coating	*1.13*	*1*	*1.13*	*3.43*	*0.0691*	
F-Sleeved	*0.45*	*1*	*0.45*	*1.35*	*0.2492*	

The results in the above table show that:

- Pipe age, percentage of humidity, and pipe type (i.e., bare vs. coated steel pipes) were significant parameters affecting pipe corrosion condition; with p-values below 0.05.
- Corrosion levels increased with the increase of humidity levels and pipe age. A liner surface model provided a simplified estimate of the expected level of corrosion based on these two parameters.
- Foundation type, presence of sleeves, or applied coatings were not significant terms to affect the piping corrosion conditions.

The above referenced study [29] also included further analysis of data collected in 2014 from LDC's in the northeast. The study included random survey using the data collection sheet shown in Table 13 during 1,050 routine utilities inspection and repair visits in their service areas. The survey addressed both indoor atmospheric corrosion and leakage.

Table 13. Corrosion and Leakage Survey Form in the 2014 Study

Inside Meter Sets
Atmospheric Corrosion & Leak Survey

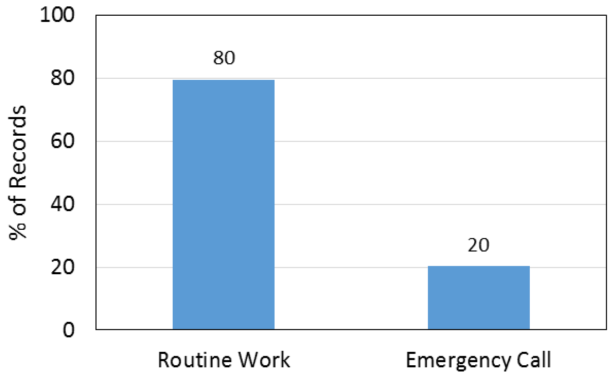
Item #	Code	Check Item
		Reason For Visit
1		1=(Routine Work) 2=(Emergency Leak/Odor Call)
		Building Info
2		1= (1-2 Family) 2=(Multifamily residence) 3 =(Commercial)
3		1= (Meter at POE) 2=(Meter Room) 3=(Meters in Multiple Remote Locations)
4		1= (All Piping Visible POE to Meter) 2= (Some Piping POE to Meter Concealed in Floors, Walls, Chases, etc.)
5		1= (Access Easy Without Local Contact) 2=(Access Requires Local Contact)
		Corrosion
6		1= (None or Light Oxidation) 2= (Mild - Can be Cleaned and Used) 3= (Needs Repair/Replace.)
7		1= (No Work Needed) 2= (Repaired/Replaced On Site) 3=(To Be Repaired/Replaced by Co.) 4=(Tagged/Referred to Owner For Repair/Replacement)
		Leakage POE to Meter Outlet)
8		1= (None) 2=(Minor Soap Bubbles) 3=(Lifting Soap Bubbles) 4=(Blowing)
9		1= (No Work Needed) 2= (Repaired/Repl. On Site) 3=(To Be Repaired/Repl. by Co) 4= (Tagged/Referred to Owner For Repair/Repl.)
10		1= (No Leaks) 2= (Leak @ Threads) 3= (Leak @ Pipe Barrel) 4= (Leak @ Valve Body/Regulator/Meter/Insulator)

Other Leakage - If Noted - Location, Readings, Disposition (Write in)

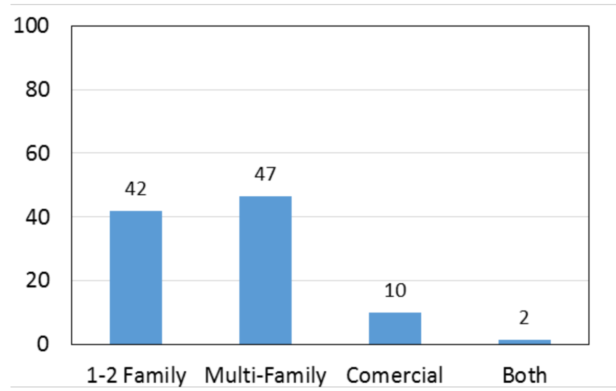
____

The survey addressed several factors which were not present in the corrosion inspection records in the earlier study. Notably, the study included the type of the building (commercial vs. residential), visibility of the piping system, and accessibility to the meter sets. The results of the survey are shown in Figure 29 (a) to (f). The results show that about 60% of the indoor corrosion inspections required prior local contact for the crew to perform inspection, and that most of the inside piping systems (78%) were low pressure systems.

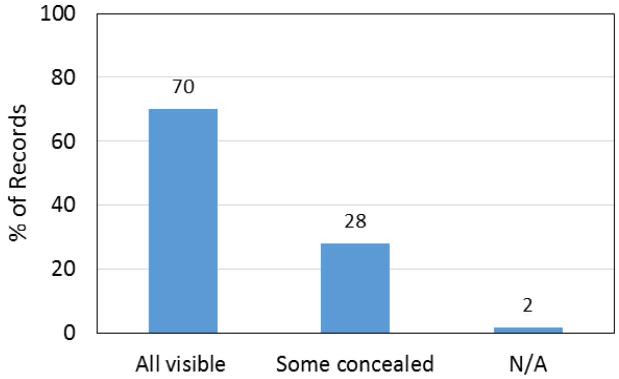
The results in Figure 30 show that most of the inspections (98%) had no-corrosion to mild surface condition which can be cleaned with brush. About 1% of the inspections had corrosions which required repair or replacement. This percentage is similar to the earlier studies.



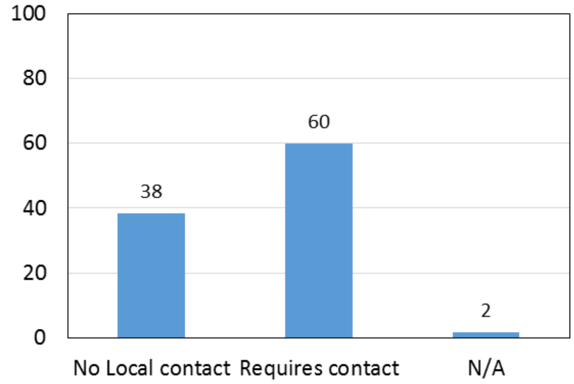
(a) Inspection Reason



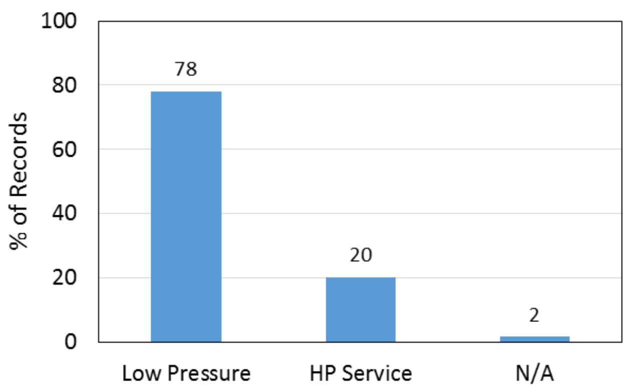
(b) Building Type



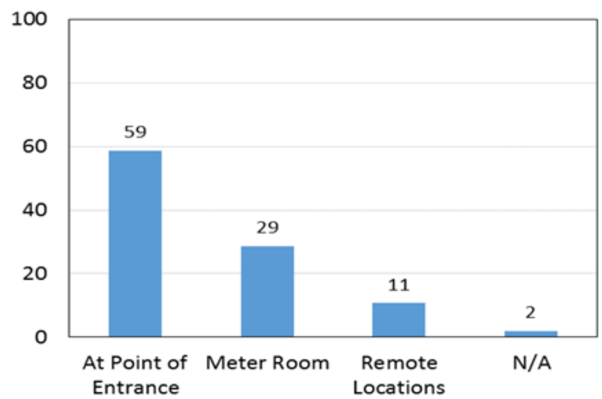
(c) Piping Visibility



(d) Service Access



(e) Pipe Pressure



(f) Meter Location

Figure 29. Results of the indoor inspection LDC Survey, 2014

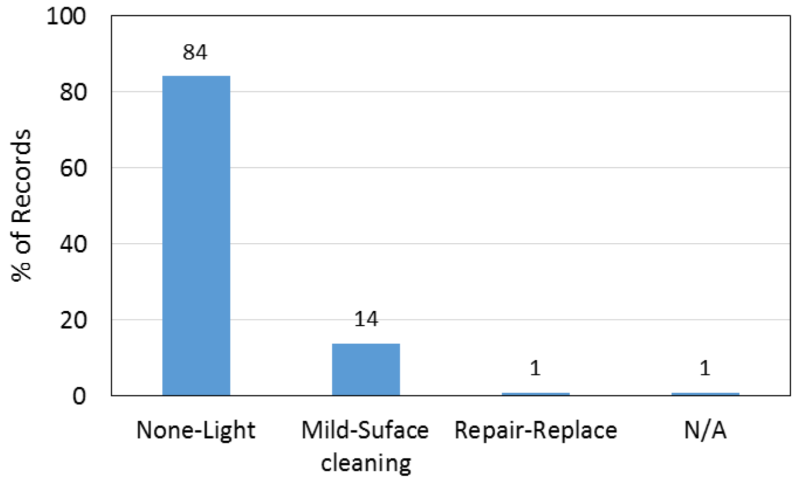


Figure 30. Corrosion records in the utilities' inspection forms

The characteristics of the indoor installations with significant corrosion (i.e., the 1% records in Figure 30) were further investigated. Figure 31 (a) and (b) show the percentages of building types and meter locations where corrosions were recorded, respectively. Most of the corrosions (70%) were found in multi-family buildings. Corrosions were higher (60%) in meters at POE locations than inside meter rooms. Figure 32 shows that most of the corrosion was in low pressure lines and in buildings which required prior local contact to perform inspection.

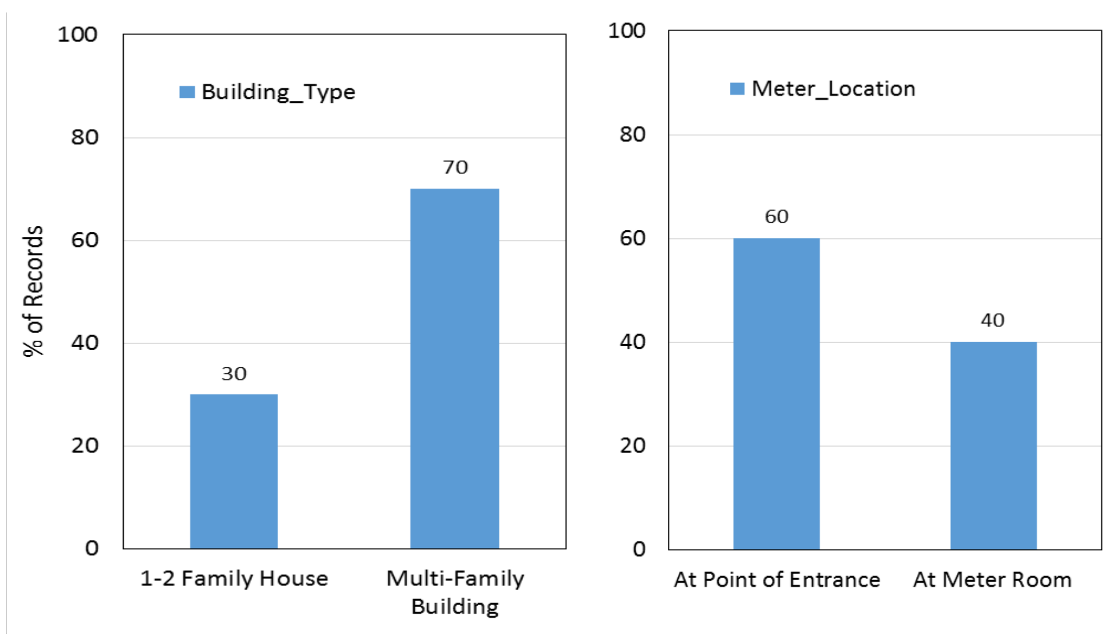


Figure 31. Corrosion in various building types and meter locations

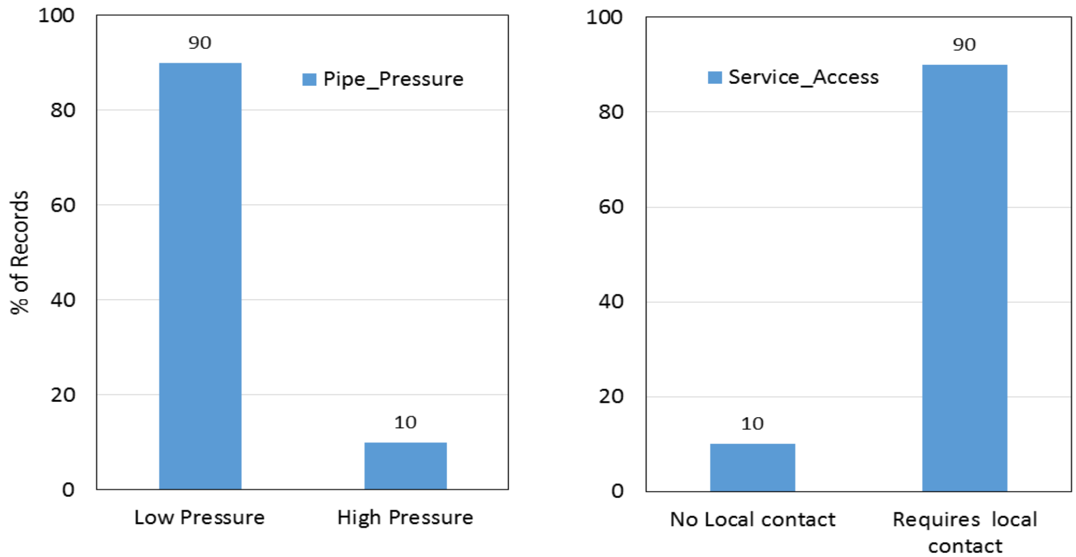


Figure 32. Pipe pressure and accessibility in records with corrosion

The sample size of the survey data was sufficiently large (1,050 records) to integrate the results in an estimation of the likelihood of corrosion due to the occurrences of certain independent parameters. The process utilized the conditional probability approach to link the likelihoods of certain events to the occurrence of other ones. For instance, the analysis may provide the probabilities of corrosion in commercial versus residential buildings or at high- and low-pressure service lines.

The following example illustrates the application of the conditional probability for the estimation of leaks in low pressure systems $P\ (LP, Corr)$:

$$P\ (LP, Corr) = P(Corr)x\ P(LP|Corr)$$

Where, $P(Corr)$ = Un-conditional probability that corrosion existed in the system. It is obtained from Figure 30 and equals 2& (0.02),

$P(LP|Corr)$ = Conditional probability of having a low-pressure system with corrosion. It is obtained from the distribution of the pipe pressure in the records with corrosion in Figure 32 and equals 0.90.

Substituting in the above equation results in a probability of corrosion $P\ (LP, Corr)$ = 0.02 x 0.90 = 0.018

This value is the likelihood of having a corrosion indication in a low-pressure system, based on the data from the surveyed population. A graphical representation of the probabilities of corrosion for the high- and low-pressure systems is illustrated in a 'decision tree' approach in Figure 33.

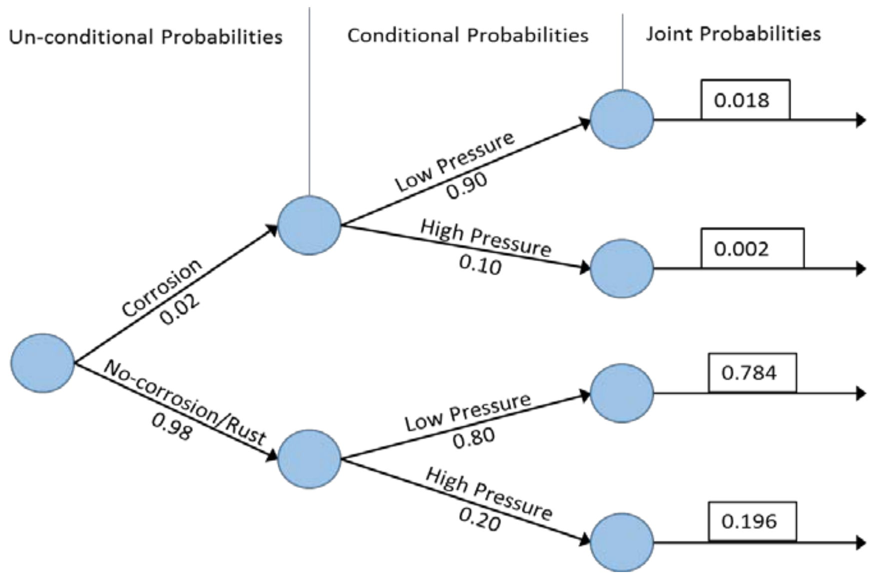


Figure 33. Decision tree representation of corrosion based on system pressure

4.3 Corrosion Potential in Indoor Piping Sysgtems

The following summarizes the findings from the above studies:

- Most of inside-meter inspection records show either mild surface rust or no indications of corrosion. About 1% of the records had corrosion indications which prompted immediate or scheduled repairs.
- Pipe age, percentage of humidity, and pipe material type (i.e., bare vs. coated steel pipes) were significant parameters affecting inside pipe corrosion condition.
- Foundation type, presence of sleeves, and applied repair coatings were not significant terms to affect the pipe or meter piping corrosions.
- The parameters affecting corrosion were not significant parameters for leakage, indicating that these two responses are independent. Most of the leakage records occurred at connections and threaded joints where corrosion was not present.
- Investigation of corrosion is routinely performed during utilities work inside buildings. More than 80% of the utilities work records in the northeast included reporting corrosion condition, regardless to the type of job performed on site. The other 20% included jobs performed in other parts of the house or at locations with no access to the pipe.
- The number of locations with pitting corrosions were very small. An average of 1% of the atmospheric corrosion inspections in the above studies had pitting corrosion which required repair or referring for further actions.
- About 90% of the corrosion indications were in low-pressure systems, and about 60% were at the point-of-entrance locations.

- About 70% of the significant corrosions (i.e., requiring repair) were in multi-family buildings.
- The leakage records and the last study showed that about 5% of the records had minor to medium indications from the soap bubble tests. About 0.1% of these records had a higher leak indication.
- Leaks were mostly identified from emergency calls (72%); this is in contrast to the corrosion indications which were mostly identified from routine inspection work (80%).
- Leak records did not correlate to corrosion indications. Most of the leaks were at the pipe barrels. About 16% of the leaks were at the threaded joints and a small percentage (2%) was at the meter and regulator piping system.

4.4 Utilities Indoor Piping Inspection Procedures

Inspection requirements for service line valves, regulator vents, vent line protection (VLP) devices, and service regulators are referenced in the following codes of federal regulations: [30]

- 192.481 for atmospheric corrosion control monitoring: the frequency of inspection for service lines is at least every 5 calendar years. If atmospheric corrosion is found on a service line during the most recent inspection, then the next inspection of that pipeline or portion of pipeline must be within 3 calendar years,
- 192.723 for leakage surveys: A leakage survey with leak detector equipment must be conducted at least once every 3 calendar years for cathodically unprotected systems where electrical surveys for corrosion are impractical. In business districts, a leakage survey must be conducted at least once each calendar year.

A review of the utilities' inspection codes shows the following procedures for the inspection of indoor gas service lines:

a) scope of Inspection:

- Most of LDC procedures follow the PHMSA scope of gas meter inspection. In New York, the Public service Commission requirements [31] for the inspection of indoor gas service lines where gas meters are located indoors are from the point of entry (POE) to the gas meters outlets or at the connection to a customer's piping, whichever is further downstream (jurisdictional piping).

b) Method of Inspection:

[30] Code of Federal Regulations, Title 49, Part 192, "Transportation of Natural and Other Gas by Pipeline: Minimum Federal Safety Standards", 192.481 and 723.

[31] Rules and Regulations of the State of New York, Public Service Commission, 16 NYCRR Part 255 "Transmission and Distribution of Gas", 255.481 and 723.

- Exposed service regulators are inspected visually for atmospheric corrosion. A leakage survey using an approved combustible gas indicator of service regulators, points of entry, line valves, and risers.

c) Inspection Frequency:

- Regulators are inspected when they are newly installed and at meter replacement and when gas services are reactivated after scheduled work or service interruption.
- For regulators supplying multi-meter headers, the regulator shall be inspected at the time of the first meter installation
- Regulators on multi-meter headers shall be inspected at intervals not to exceed twenty years.
- A visual inspection of the regulator, associated equipment, vent assembly and associated piping shall be conducted for any substandard conditions.

d) Atmospheric Corrosion Inspection:

- Corrosion severity is categorized at the following 4 levels based on severity:
  1. Non or vert minimal corrosion severity
  2. Low corrosion severity
  3. Medium corrosion severity
  4. High corrosion severity.
- Level 3 (medium Corrosion severity) requires scheduling of timely repair. Level 4 "High Corrosion Severity" requires replacement. Other utilities identify three corrosion levels as follows:
  a) Heavy – is deeply pitted pipe with wall loss that requires immediate repair or within 6 months.
  b) Moderate - have some light pipe pitting (less than 70% wall loss) and flaking of the existing coating that requires repair prior to the next inspection cycle.
  c) None or Mild – includes surface rust conditions including oxidation.

e) Vent Pipes:

- When a regulator and/or relief device is located inside a building, each regulator and/or relief device shall have a separate relief vent line vented to the outdoors so in the event gas is discharged.
- Regulator vents be installed outdoor at a height 12 to 18 inches above grade. The vent line shall be as short as possible and continuous from the regulator vent port to the outside terminus. Some utilities require metallic piping for vents with increased diameter in excess of 10 ft length.

- The outside vent shall be located a minimum of 18 inches horizontally from any opening into the building (e.g., windows, doors, etc.) and at a minimum of 3 feet from any sources of ignition.
- Some utilities require vents to be located three 3 feet radially from, and not below any first floor opening into a building. Vents also shall be located not less than 10 feet radially from, and not below, any forced air inlet into a building.
- Vent regulators are inspected for appropriate diameter and length, proper connection to the regulator, test for the presence of gas using leak detection device, and proper location of vent terminus.
- Regulator relief vent terminus shall face down. The vent caps should be screened.
- The regulator/relief vent terminus shall be protected from damage caused by submergence in areas where flooding or ice accumulation may occur.

4.5 Gas Leak Measurements in Indoor Regulators

Measurements of gas concentrations in confined spaces around 'limited-release' 2-stage Fiorentini regulators and typical 'full-release' IRV American regulators were performed to evaluate gas emission in these regulator types. [32] The results of tests are summarized as follows:

- Both types of regulators allow for gas emissions through their vents to balance outlet pressure and accommodate sudden changes in the gas supply. However, this type of release was relatively small and momentarily for short durations during changes of their outlet flow rates.
- Gas leaks image from the regulator vent of the American regulator is shown in Figure 34. The image was taken of a regulator with a 1/8-inch hole in the diaphragm to investigate diaphragm-damaged regulators.
- In regulators with leaking diaphragms, gas emissions were continuous and significantly higher than those in regulators with no defects. This is observed in both the camera images and sensors measurements of gas concentrations.
- Figure 35 shows the test set up for gas concentration measurements around the regulators. The vented volumes from the 2-stage Fiorentini regulators were smaller than those from standard regulators. The maximum vented volume measurements in the lab for both types of regulators are shown in the last column of Table 14.

[32] Meter Set Placement and Clearances, Phase 2 - Regulators Emissions, Operations Technology Development, OTD Project 5.15.h, 2020.

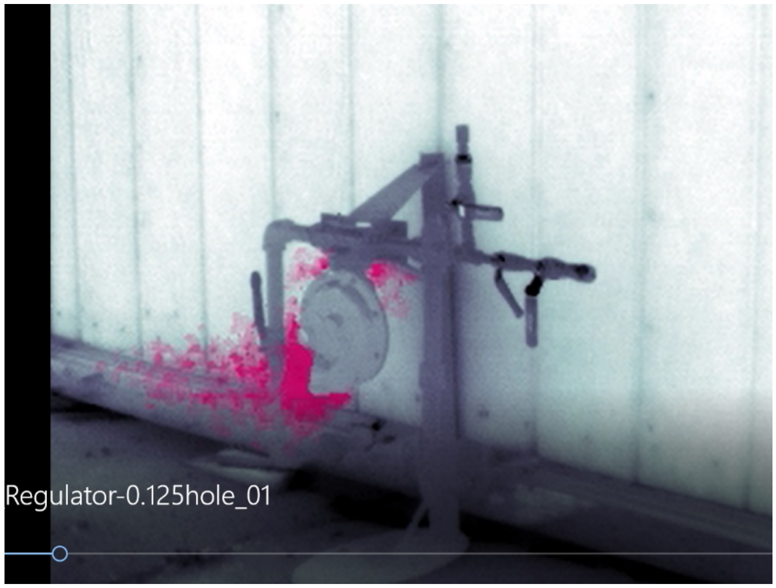


Figure 34. Gas Leak Image of the American Regulator, with hole and closed outlet

Figure 35. Sensors' setup and data collection system

- Gas concentrations around the regulators varied with the changes of the outlet pressure and gas flow. The maximum readings of the gas concentrations around leaking and non-leaking regulators are shown in Table 14. These maximum measurements were recorded in gas sensors at 4-8 inches from the regulators' vents.

- The results show that maximum gas concentrations in the 2-stage Fiorentini regulators were significantly lower than those in standard regulators. Figure 36 shows the maximum sensors readings around both types of regulators with leaking diaphragms.

Table 14. Results of the Gas Concentration Measurements

Type of Regulator	Outlet Pressure	Condition	Maximum Reading	Reading Location	Vented Volume** (in^3)
American	7 iwc*	No Defect	7% LEL	6-in above vent	0.1
		With Hole	9% Gas	6-in above vent	-
Fiorentini	7 iwc	No Defect	3.2% LEL	6-in from vent	0.04
		With Hole	30% LEL	6-in from vent	0.06
Fiorentini	2 psig	No Defect	40% LEL	6-in above vent	-
		With Hole	6% Gas	4-in above vent	0.07

** Inches of water column*
*** Instantaneous flow volume when outlet valve is shut*

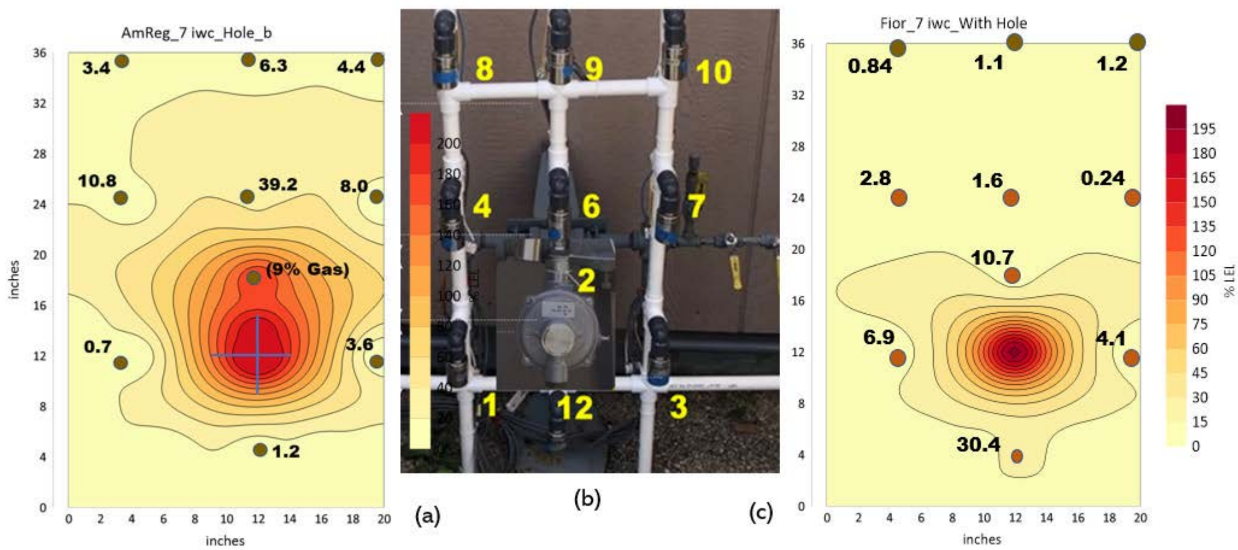


Figure 36. Maximum LEL readings around leaking 7-iwc regulators - (a) Standard American, (b) Fiorentini Regulator

Chapter 5 - Best Practice Guidelines and Recommendations

5.1 Risk Analysis for a Distribution Integrity Management Program

Utilities integrity management programs focus on evaluating risks that are important to their gas systems and on the collection of accurate data for a proper risk assessment. It is recommended for gas operators to learn from industry incidents by reviewing reports pertaining to natural gas incidents and incorporating lessons learned into their DIMP. Industry incidents involving indoor service regulators provide insights into the risks associated with their installations and characteristics.

It is a best practice for a gas operator to obtain system information, verify existing data, and update records with current conditions whenever the operator enters a building that contains utility-owned inside piping The data should be utilized in a risk assessment model to determine priority for corrective action that includes relocating of the regulator to the outside of the building and/or performing a risk reduction measure. The recommended practice is to account for inside gas service regulators in DIMP for the development of a risk assessment model. The following data in Table 15 outlines risk factor considerations that can assist with determining the impact and the probability within existing gas utility DIMP risk assessment models which typically utilize a definition of Risk = Probability of Occurrence x Impact.

Table 15. Associated Risk Factor Considerations for Inside Service Regulators

Risk Factor	Probability and Considerations for the DIMP Risk Model
Inside Regulator	The impact weighted value for risk assessment should be larger for inside service regulators as compared to an outside service regulator installation. The number of inside service regulator installations within the distribution system should be a factor considered in determining the probability.
Inside Regulator Type/Age	The impact and probability weighted values should be larger for older style regulators and specific regulator models identified in DIMP. The impact and probability would be lower for newer styles and two-stage gas service regulators.
Pressure of inside piping upstream of regulator.	The higher the pressure of the piping inside a building the greater the impact: - Pressure less the 5 psig - Pressure between 5 and 20 psig - Pressure greater than 20 psig

Property Type	The impact varies and should be weighted differently based on property type: - Single Family Home - Multi-unit Housing - Commercial Building - Building of Public Assembly. The number of inside service regulators for each property type should be a factor used in determining the probability. The higher number of meters and regulators at each property increases the probability for each property type.
Accessibility of Indoor Regulator	The probability varies and should be weighted differently based on the following factors related to the difficulty to gain access: - Does the gas utility have a key or public access? - Does an occupant need to provide access? - Did the customer build an inside structure around gas utility owned inside piping? The number of various types of accessibility to gas utility-owned inside piping should be factored into determining the probability.
Volume of Enclosed Room	The size and venting of the enclosed room that contains gas utility owned piping has a decreasing impact with size and venting: - 25 cubic feet - 25-50 cubic feet - Greater than 50 cubic feet. The size of the room that contains inside gas utility-owned piping should be factored into determining the probability.
Length of Gas Utility Owned Inside Piping	Inside piping upstream of the service regulator has a higher impact as compared to inside piping downstream of the service regulator. The probability increases with longer inside company-owned piping. The total distance of inside gas utility owned piping: - Less than 10 feet - 10 to 20 feet - Greater than 20 feet. The length ranges for inside company owned piping should be a factor in determining probability.
Combustible materials	The impact would increase if combustible materials were discovered in the vicinity of the inside gas utility owned piping. The responses in an audit form should be used for risk analysis probability. Also, the data can be used as customer marketing and information as a part of risk reduction efforts.

Shut off location	The probability considerations vary based on the ability to shut off gas service to the building. - Can the building be shut off from the outside? - Does an employee need to enter the building to shut off the gas? The number of the shut off locations should be used for probability analysis purposes.
Ignition Sources	The probability would increase if ignition sources are located near an inside service regulator. The responses should be used for analysis considerations for probability.
Vent Piping Length	The probability increases if the length of the vent pipe increases. - Less than 5 feet - 5 to 20 feet - 20 to 35 feet - 35 to 50 feet - Greater than 50 feet. The vent piping length should be used for analysis considerations for probability.
Number of fittings	As the number of pipe fittings in inside gas utility-owned piping increases, so does the probability. The range of the number of fittings in inside piping: - 1 to 3 - 4 to 5 - Greater than 5 fittings.

There are multiple risk models, including software packages, which are used in by the gas distribution industry for calculating risk and total DIMP risk ranking. When this data is available, it can be entered into the risk model to assist in risk ranking and risk reduction efforts pertaining to inside service regulators.

5.2 Data Capture for DIMP

One way for LDCs to collect the required data for DIMP is by providing company employees with a form to record inside piping characteristics and maintenance records. An electronic form was created with several LDCs [33] to collect inspection and collect gas system data. The form was based on the Esri's Survey123 platform which serves as a repository of standardized, gas-related field data.

[33] Regulatory Compliant Smart Forms, OTD Project 5.20.k, GTI project 22744, 2021.

The Esri forms are customizable, so they can be specified to meet gas utilities specific needs and satisfy their regulatory requirements. The Survey123 application is available for download on smartphones, tablets, and desktops (iOS, Windows, or Android). There are multiple uses for Survey123 forms and data captured is immediately available to the ArcGIS Platform, so users can generate maps, reports, and dashboards to both visualize and analyze the data obtained in the field for DIMP purposes. A gas utility can customize the forms and assign different weighting values to the input parameters to obtain a risk assessment estimate.

Another electronic form provided gas utilities with a standardized process for assessing the risks associated with indoor meter set installations [34]. The survey-based form calculates a risk score based on assessing the meter set's characteristics. The inspector would receive real-time feedback on mitigating the current risk of the indoor meter set or evaluating the possibility of relocating the meter set to the outside of the building.

The form was evaluated by an LDC to test its functionality in a real-world setting. This consisted of using the inspectors' mobile devices, receiving instruction on using the form, and using it during actual indoor meter set inspections. The pilot study evaluated the form over the course of two days, visiting over 25 residences and completing surveys for 14 indoor meter sets. Overall, the smart form was received positively by the participating utility, and the participants were interested in implementing the form into their existing GIS asset management structure.

The electronic form "Indoor Meter Sets/Regulators Inspection Form" was updated as part of this project by including the characteristics of inside service regulators. Questions were added to the smart form to gain information on inside service regulators conditions and risk factors that are outlined in Table 15. Gas utility employees would be required to complete the smart form any time they enter a customer premise that contains gas utility-owned piping. This data would then be stored electronically and available for analysis as part of a DIMP.

A web-based version of the "Indoor Meter Sets/Regulators Inspection Form" can be accessed from the following link: https://arcg.is/1jPrCj2. A printout of the electronic form is in Appendix B. Each question and associated response on the smart form can be assigned a weighed value depending on its risk scale.

The weighted numbers assigned to each question need to be determined by the SMEs in the gas utility (typically the DIMP group) and entered into the platform for analysis and reporting purposes. The DIMP analysis can be performed on results of multiple smart forms (such as the entire distribution system) and can assist in identifying inside regulator installations that have the highest risk score. An example of the composite risk score for an inside service regulator installation is shown in Table 16.

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[34] Guidelines for Assessing Indoor Meter Set Relocation Risk, OTD Project 5.17.a, GTI project 22146, 2020.

Table 16. Inside Service Regulator Composite Risk Score

Composite Risk Score	Meter Set Risk Rating
6 - 10	Very Low
11 - 20	Low
21 - 30	Moderate
31 - 40	High
41 -50	Very High
>50	Extremely High

Note: risk ranges are determined by the gas utility's DIMP and will vary based on the selected weighing of questions and responses.

5.3 Recommended Best Practice Guidelines and DIMP Program

As required in Title 49 CFR Subpart P Gas Distribution Pipeline Integrity Management (IM), gas operators are required to have a written integrity management plan which contains procedures for developing and implementing the seven main elements listed in 192.1007. The following table shows recommended practices that have been compiled and discussed during distribution operator interviews.

Table 17. Recommended Best Practices

Requirement	Best Practice Recommendation
(a) Knowledge. An operator must demonstrate an understanding of its gas distribution system developed from reasonably available information. (1) Identify the characteristics of the pipeline's design and operations and the environmental factors that are necessary to assess the applicable threats and risks to its gas distribution pipeline. (2) Consider the information gained from past design, operations, and maintenance. (3) Identify additional information needed and provide a plan for gaining that information over time through normal activities conducted on the pipeline (for example, design, construction, operations, or maintenance activities).	Do you have inside service regulators? Gas distribution operators interviewed for the project had records indicating the location of the meter set. However, these records are not always clear whether the service regulator is inside or outside. - As part of identifying the characteristics of the system, it is a good practice to capture and verify existing data identifying inside service regulators. - The number and location of inside service regulators should be quantified and entered into the DIMP risk model. - The inside service regulator knowledge should be captured or verified during inspections for: - Leak survey, - Atmospheric corrosion monitoring, - Patrolling activities,

(4) Develop and implement a process by which the IM program will be reviewed periodically and refined and improved as needed. (5) Provide for the capture and retention of data on any new pipeline installed. The data must include, at a minimum, the location where the new pipeline is installed and the material of which it is constructed.	- Customer visits or service Calls. These activities provide an opportunity to increase knowledge, obtain risk assessment data and perform a periodic review of conditions based on the inspection interval. Operating procedures need to be updated directing how the inside service regulator data are captured, verified, and reviewed to incorporate into DIMP.
(b) Identify threats. The operator must consider the following categories of threats to each gas distribution pipeline: Corrosion (including atmospheric corrosion), natural forces, excavation damage, other outside force damage, material or welds, equipment failure, incorrect operations, and other issues that could threaten the integrity of its pipeline. An operator must consider reasonably available information to identify existing and potential threats. Sources of data may include incident and leak history, corrosion control records (including atmospheric corrosion records), continuing surveillance records, patrolling records, maintenance history, and excavation damage experience.	Threats on piping upstream of the inside service regulator are greater than the threats on piping downstream of the inside service regulator. It is a good practice to identify threats separately on the inside piping that is upstream of the service regulator. The higher-pressure piping inside a building will amplify the hazard when exposed to threats. Operating procedures should detail how to identify the threats separately in upstream higher-pressure piping and the lower pressure downstream piping.
(c) Evaluate and rank risk. An operator must evaluate the risks associated with its distribution pipeline. In this evaluation, the operator must determine the relative importance of each threat and estimate and rank the risks posed to its pipeline. This evaluation must consider each applicable current and potential threat, the likelihood of failure associated with each threat, and the potential consequences of such a failure. An operator may subdivide its pipeline into regions with similar characteristics (e.g., contiguous areas within a distribution pipeline consisting of mains, services, and other appurtenances; areas with common materials or environmental factors), and for which similar actions likely would be effective in reducing risk.	The risk of an inside service regulator is greater in comparison to an outside service regulator. The threats of corrosion, natural forces, excavation damage, other outside force damage, material or welds, equipment failure, and incorrect operations, have a greater consequence for the higher pressure inside piping upstream of the inside service regulator. It is a good practice to weigh the consequences of threats in a risk model greater for inside service regulator piping because the higher upstream pressure has the ability to rapidly fill a building as compared to the customer delivery pressure that is downstream of the regulator.

(d) **Identify and implement measures to address risks**. Determine and implement measures designed to reduce the risks from failure of its gas distribution pipeline. These measures must include an effective leak management program (unless all leaks are repaired when found).	**What measures are being implemented for inside meter risk reduction?** Gas distribution operators have a priority to work with the customer to install service regulators outside and to move inside regulators to the outside. Good practices for inside service regulator risk reduction include: - Capturing data for inside service regulator analysis, - Increased inspections, - Tracking regulator aging and periods of a replacement program, - Utilization of low-emission service regulators. Regardless to the location of the service regulator, installation of a residential methane detector is a good practice for a gas leak risk reduction in utility-owned inside piping. Advances in smart technology allow for a communication network that can provide methane leak alert back to the gas utility. The gas utility should immediately send an employee to investigate. This technology can also be incorporated with a smart gas shutoff valve that would automatically stop the flow of gas if a natural gas hazard were detected [35].

[35] Smart Shutoff Technology for Residential and Commercial Buildings, California Energy Commission (CEC) Project 5.20.k, GTI project 22801.

(e) **Measure performance, monitor results, and evaluate effectiveness**. (1) Develop and monitor performance measures from an established baseline to evaluate the effectiveness of its IM program. An operator must consider the results of its performance monitoring in periodically re-evaluating the threats and risks. These performance measures must include the following: (i) Number of hazardous leaks either eliminated or repaired as required by § 192.703(c) of this subchapter (or total number of leaks if all leaks are repaired when found), categorized by cause: (ii) Number of excavations damages. (iii) Number of excavation tickets (receipt of information by the underground facility operator from the notification center). (iv) Total number of leaks either eliminated or repaired, categorized by cause. (v) Number of hazardous leaks either eliminated or repaired as required by § 192.703(c) (or total number of leaks if all leaks are repaired when found), categorized by material. (vi) Any additional measures the operator determines are needed to evaluate the effectiveness of the operator's IM program in controlling each identified threat.	The following data records should be included for measuring performance, monitoring results, and evaluating effectiveness: - Number of inside service regulators by type/model of regulator, - Age of each inside service regulator, - Number of inside service regulators moved to the outside of building, - Number of abnormal operating conditions (AOC) discovered in inside service regulators and associated vent piping. What type of AOCs discovered and how many of each? - Number of AOCs discovered on upstream of the service regulator. What type of AOCs discovered and how many of each? - Residential Methane Detectors (RMD) Performance Metrics: - Number of RMDs installed at utility-owned inside piping and how many had inside service regulators. - Number of RMD alerts in buildings with gas utility-owned inside piping. What were the causes of the alerts? Examples include: - Type of damage (Inside/outside) - Meter leak (piping and connections) - Vent piping leak and its cause? - Inside service regulator failure - Unauthorized piping operation - Device tampering - Gas utility-owned valve leak - Outside leak that migrated to the inside - Customer piping and Equipment - Sewer Gas - Number of smart and shutoff valve closes and the causes - Other and unknown causes.

(f) Periodic Evaluation and Improvement. An operator must re-evaluate threats and risks on its entire pipeline and consider the relevance of threats in one location to other areas. Each operator must determine the appropriate period for conducting complete program evaluations based on the complexity of its system and changes in factors affecting the risk of failure. An operator must conduct a complete program re-evaluation at least every five years. The operator must consider the results of the performance monitoring in these evaluations.	Inside Service Regulator Evaluation Based on the project interviews, inside service regulators "alone" were not considered in DIMP since associated data were missing. A recommended good practice is to begin tracking data for inside service regulators to use and implement with DIMP.
(g) Report results. Report, on an annual basis, the four measures listed in paragraphs (e)(1)(i) through (e)(1)(iv) of this section, as part of the annual report required by § 191.11. An operator also must report the four measures to the state pipeline safety authority if a state exercises jurisdiction over the operator's pipeline.	Inside Service Regulator Reporting The reporting of inside service regulators metrics and risk reduction efforts are not currently a requirement; however, it is recommended as a good practice.

Chapter 6 – Summary and Conclusions

The project addresses NTSB and PHMSA recommendations to natural gas operators of reducing the consequences of failures of inside meters and regulators. It provides natural gas local distribution companies with best practices and consistent decision-making tools for inspecting and retrofitting gas service regulators which need to stay inside. There have been various improvements in regulator designs over the past several years which incorporate features such as slam-shut, vent limiter, and excess flow to improve regulators safety as compared to earlier models. Some of the current DOT and ANSI standards do not account for such recent technical advances and some gas distribution operators have been successful in installing slam-shut style gas service regulators with over-pressure (OPSO) and under-pressure (UPSO) protections.

Chapter one of the report presented a review of federal installation requirements, current industry codes, and LDCs piping installation practices. Although LDCs work on indoor sets and piping systems focus on the installation and renewal aspects, the majority of their current work consists of emergency response to customer calls, gas shut-offs, gas turn-ons, meter repair and replacements, and the required maintenance and inspections. LDCs commonly install and thoroughly inspect inside piping. However, the types of records and available information on indoor installations varied.

The research project recommends the use of retrofitting indoor regulators with smart sensors which could connect to existing communication networks to notify the utility in the event of detection of a gas leak, and if necessary, connects to valves to remotely shut off the flow of gas. In this safety systems, smart sensors to detect methane, flood, fire, and gas line pressure are deployed in a residential and commercial buildings for these potential hazards.

Chapter 2 of the report presented comprehensive safety shutoff systems which include: (a) Smart Sensors for monitoring methane, flood, fire, and pressure, (b) Smart Gas Shutoff Valves such as a standalone valve or a smart meter with integrated valve, and (c) Communication Network and user interface software.

The benefits of these safety systems include lower emissions, prevention of customer property damage and personal injury in the event of a hazard, and a reduction of incidents caused by natural gas leaks. However, significant challenges currently prevent the adoption of this technology and its widespread use in gas distribution systems. The first challenge pertains to standardization of the various smart sensors, safety valves, and network communication protocols. After a fully functional smart shutoff safety system is commercialized, widespread rollouts and selection of the most important features will be required to meet the needs of customers, LDCs, and regulatory requirements.

Smart safety sensors were categorized to include the following devices:

a) Smart Shutoff valves which can be automatically closed by a sensor or remotely closed through a control center. These systems, such as the Lorax Smart Shutoff Valve, are paired with a methane sensor to retrofit inside regulators. Other smart shutoff devices such as devices from Itron, Sensus, and Honeywell are in the market but mostly have limited maximum allowable operating pressure (MAOP) shutoff capabilities, up to 10 psig, which limits their safety improvements in the event of a regulator failure upstream of the gas meter.

b) Low Emission Regulators which incorporate features such as slam-shuts for over and under pressure conditions, vent limiter devices, and excess flow shutoffs to improve regulator safety as compared to earlier models. These new regulators include ones from Pietro Fiorentini and BelGas, which can incorporate over-pressure and under pressure shutoffs, and excess flow valve shutoff abilities to stop the flow in the event of large amounts of gas escaping into a structure.

Chapter 3 presented the results of several pilot studies for evaluating RMD devices and smart shut off valves which send out an audio or digital signal to alert of hazardous conditions. Smart meters with integrated shutoff valves stop the flow of gas downstream of the service regulator but would not be effective if a gas leak is in the regulator or any of the piping upstream of the smart meter.

Studies on the inspection and rehabilitation of indoor piping systems has identified the factors which increase corrosion potential of piping systems and associated risk of leakage in an inside meter room. These factors include piping age, installation procedures, piping support and placement, condition of pipe coating, and relative humidity. Chapter 4 presented an evaluation of these parameters and procedures for the inspection of corrosion potential in indoor piping systems. The piping point-of-entry (POE), in particular, demonstrated higher corrosion potential than other indoor piping. These studies have also shown that:

- Pipe age, percentage of humidity, and pipe type (i.e., bare vs. coated steel pipes) were significant parameters affecting pipe corrosion condition; with p-values below 0.05.
- Corrosion levels increased with the increase of humidity levels and pipe age. A liner surface model provided a simplified estimate of the expected level of corrosion based on these two parameters.
- Foundation type, presence of sleeves, or applied coatings were not significant terms to affect the piping corrosion conditions.

An indoor piping inspection procedure is presented in the chapter, based on the review of the utilities' inspection codes for indoor gas service lines.

A risk analysis for a distribution integrity management program is presented in Chapter 5. The recommended practice is to account for inside gas service regulators in DIMP for the development of the DIMP risk assessment model. Considerations for determining the probability and impact of the indoor systems is presented in Table 15.

A data capture procedure of the indoor sets risk factors is compiled in the electronic form "Indoor Meter Sets/Regulators Inspection Form". The form was updated as part of this project to gain needed information regarding inside service regulators conditions. The form is presented in Appendix B for use by gas utility employees when inspecting indoor gas utility-owned piping. The data would then be stored electronically for analysis as part of a DIMP program.

Recommended best practice guidelines are presented in Table 17 for implementation in utilities DIMP program as per the requirements in 192.1007. The table presents recommended practices that have been compiled and discussed during distribution operator interviews.

The implementation of the best practices discussed in Table 17 results in decreased emissions and prevention of customers property risks associated with indoor installations. Table 18 further presents a comparison of the risks associated with outdoor and indoor regulators and meter sets in order to achieve an equivalent level of safety when gas service regulators need to stay inside.

Table 18. Risk Assessment and Mitigation in Outdoor and Indoor Installations

Threat	Outdoor Installation	Indoor Installation
Gas leak and emissions from regulators and piping system	Lower risk when gas emissions escape to the atmosphere. Mitigation: - install low emission regulators and excess flow valves.	Higher risk due to high consequences of indoor gas accumulation. Mitigation: - Implement decision-making tools for moving indoor installations to outdoors. - Install smart shutoff valves, OPSI protection, and RMD with remote monitoring and shutoff. - Install communication network. - Install low emission regulators. - More periodic Inspections and immediate repair of indoor connections and vent pipes.

Atmospheric corrosion	Mitigation: Scheduled inspection of outdoor meter sets.	Higher risk when access is restricted for periodic inspections. Mitigation: - Increase public awareness and scheduled inspections. - Control humidity and improve coating at piping POE.
Improper installation,	Mitigation: Maintain safe clearances from buildings inlets.	Higher risk of poor installation of the longer piping systems. Mitigation: Implement best practices in Table 15.
Operation: Maintenance and access	Lower risk due to unrestricted access the meter set.	- Higher maintenance risk due to restricted access to meter rooms and private homes. - Higher probability and consequences of gas accumulation in multi-regulator rooms in high-rise buildings. Mitigation: Implement best practices of Table 17.
Outside force	Higher risk to vehicles hits, wind, and other outside force.	Risk to flooding and vents blockage and damage. Mitigation: Implement best practices of Table 17.
Tampering	Higher risk of tampering.	Lower risk in controlled public access meter rooms.

List of Acronyms

ANSI	American National Standards Institute
ANOVA	Analysis of Variance
CEC	California Energy Commission
CFR	Code of Federal Regulations
CSA	Canadian Standards Association
DIMP	Distribution Integrity Management Program
DOT	Department of Transportation
iwc	Inches-water-column
GRI	Gas Research Institute
GTI	Gas Technology Institute
IFGC	International Fuel Gas Code
LDC	Local Distribution Company
LEL	Lower Explosive Limit
LPR	Line Pressure Regulator
LPWAN	Low Power Wide Area Network
MAOP	Maximum Allowable Operating Pressure
MOS	Metal Oxide Semiconductor sensor
MSA	Meter Set Assembly
NAPSR	National Association of Pipeline Safety Representatives
NDIR	Nondispersive Infrared sensor
NFPA	National Fire Protection Association
NTSB	National Transportation Safety Board
OTD	Operations Technology Development, NFP
OPSO	Over Pressure Shutoff
PHMSA	Pipeline and Hazardous Materials Safety Administration
psig	Pound-per-square inch
POE	Point-of-Entry
RMD	Residential Methane Detectors
SCFH	Standard Cubic Feet per Hour
SMEs	Subject Matter Experts
SPR	Service Pressure Regulator
TAP	Technical Advisory Panel
UPSO	Under Pressure Shutoff

Appendix A - AGA Study, Data Collection Form

Service Sampling Program – Atmospheric Corrosion, Leakage and Safety
Data Collection Sheet (Final Version)

!!!!! PLEASE USE THE DEFINITIONS ON THE SECOND SHEET FOR EXACT DESCRIPTIONS OF THE BELOW TERMS !!!!!

Address ______________________ **City** ____________________ **State** ______

Date (mm/dd/yyyy) ______________ **Year of Installation (if known)** (yyyy) __________

Reason for Visit (check one)
□ Meter Change □ Turn On or Turn Off □ Periodic Survey (leak survey or corrosion inspection) □ Service Call
□ Other, please specify: ______________________________

Meter Location □ Inside □ Outside

Regulator Location (check all that apply) □ None (no regulator) □ Inside □ Outside □ Unknown □ Special (downstream of meter)

Service Piping Material (check one) □ Bare Steel □ Coated Steel □ Plastic □ Insert (copper or plastic) □ Unknown

For inside sets - Is service piping from wall to meter concealed? (check one) □ No □ Yes

Corrosion (check one) □ No corrosion and no oxidation □ Minor surface oxidation/rust only
□ Pitting and/or flaking (minor) □ Pitting and/or flaking (severe)

Environment (check one) **for inside sets** □ Normal □ Damp/Wet □ Corrosive
for outside sets □ Normal □ Corrosive

Are there any temporary repairs present on the service piping? (check one) □ No □ Yes

Regulator Vent Visual Inspection (check one) □ Not Applicable (no regulator) □ OK □ Needs Terminus
□ Needs Pipe Work □ Needs Relocation

Meter Protection (check one) □ Not needed □ Installed & OK □ Installed but work needed □ Missing

Improper Electrical Contact (check one) □ None □ Yes, needs correction

Improper Contact with Concrete or Masonry (check all that apply)
□ None □ Valve □ Meter □ Regulator □ Insulator □ Piping

Improper Soil Contact – Outside Sets (check all that apply)
□ None □ Valve □ Meter □ Regulator □ Insulator

Other Site Conditions (check all that apply)
□ OK (normal) □ Tampering □ Coating Damage □ Needs Coating
□ External Loads □ Settlement □ Contact with Foreign Objects

Is there a gas leak present (check one) □ No □ Yes (If yes, please complete the remaining questions below)

Gas odor present (check one) □ No □ Yes

Leakage Reading ________ % LEL / % GAS / ppm (circle one)

Instrument Type (check one) □ Motorized CGI □ Manual Bulb CGI □ Wand (e.g. GasTrac) □ Lapel Badge Detector

Leak Location (check one)

If Inside Regulator □ Below Ground Outside □ Inside at Gas Service Entry □ Between Building Wall or Floor and Regulator
□ Between Building Wall or Floor and Regulator □ Between Regulator and Meter
□ After Meter □ Unknown

If Outside Regulator □ Below Ground Outside □ Between Ground and Regulator □ Between Regulator and an Outside Meter
□ Between Regulator and an Outside Meter □ Between an Outside Meter and Building Entry
□ At Building Entry □ Between Building Wall or Floor and an Inside Meter
□ After an Inside Meter □ Unknown

If No Regulator □ Below Ground Outside □ From Outside Riser Through Outside Meter
□ From Outside Meter Outlet to Building □ Inside at Gas Service Entry
□ Between Building Wall or Floor and Inside Meter □ Inside Building Piping Downstream of Meter
□ Unknown

Leaking Item(s) (check all that apply)
□ None □ Fitting Threads □ Coupling □ Insulator □ Pipe
□ Meter □ Regulator □ Wall (pipe penetration) □ Migration from Outside

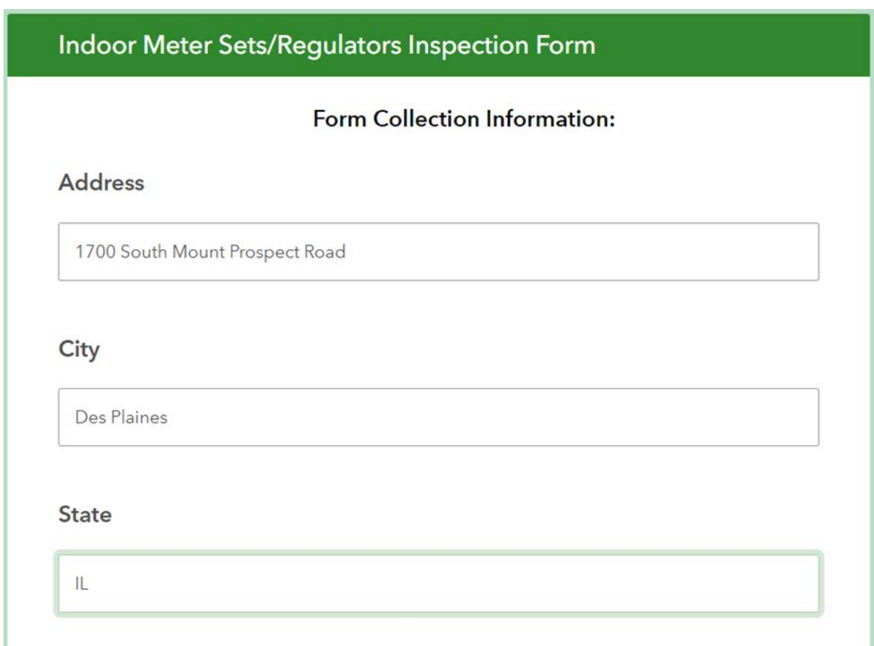
Appendix B - Indoor Meter Sets/Regulators Inspection Form

The electronic inspection form compiles the inspection data of inside gas service regulators and meter sets for implementation in a DIMP risk assessment model. It is based on the associated risk factors listed in Table 15, which include:

- Regulator type and age
- Property type, number of meter/regulator units, and enclosure size
- Pressure of the inside piping system
- Accessibility to indoor sets
- Indoor piping and venting pipe characteristics
- Corrosion and leak survey inspection data.

Gas utility employees would complete the form during inspection and maintenance of indoor gas utility-owned piping. The form consists of several sections as follows:

1. Location information as to where the inspection is being performed:



Indoor Meter Sets/Regulators Inspection Form

Form Collection Information:

Address

1700 South Mount Prospect Road

City

Des Plaines

State

IL

2. Information as to what is included in the indoor gas utility-owned piping:

Indoor Unit

◉ Meter Set (meter & regulator)

○ Meter Only

[The form can be customized for the gas utility to record dates for other inside piping activities which may include recent meter and regulator changes].

Installation Year

*If available

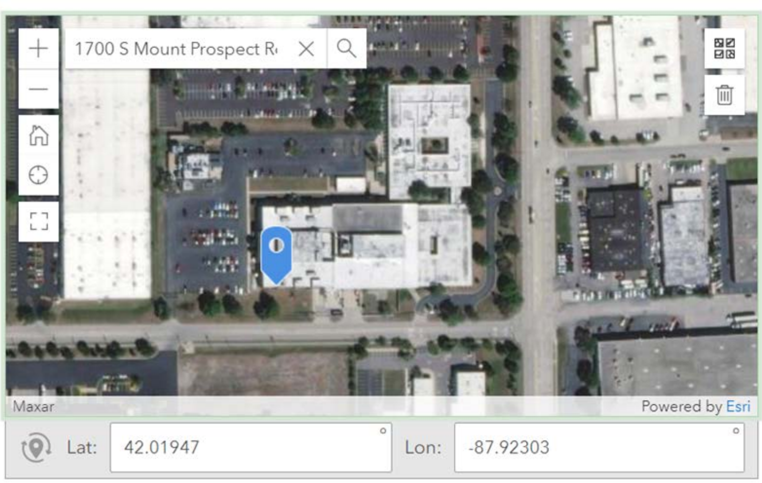
1995

Inspection Date

11/12/2021

3. Identify the address on the map in the smart form for GIS records:

[Moving the “blue arrow” on the map identifies where the meter is on the building].



4. Reason for the visit:

1. Reason for Visit:

Select reason for visit:

- Routine Leak/Corrosion Inspection
- Service Call/Meter Change
- **Emergency Leak/Odor Call**
- Other

5. Property type and number of units:

2. Property Type:

Select property type:

- Single Family Home
- **Multi-Unit/Commercial**
- Building of Public Assembly

Select number of meter/regulator units in Indoor location:

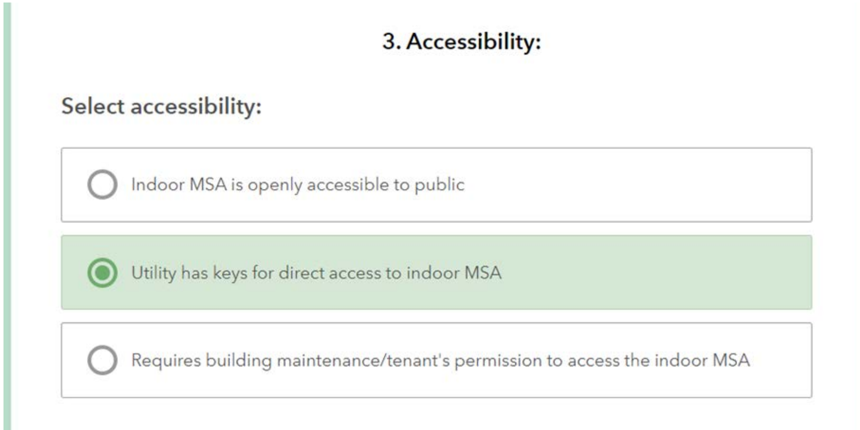
- **2 to 3**
- 4 to 10
- > 10

[Picture of the gas utility-owned inside piping].

Attach picture(s) of meter room

Select image file

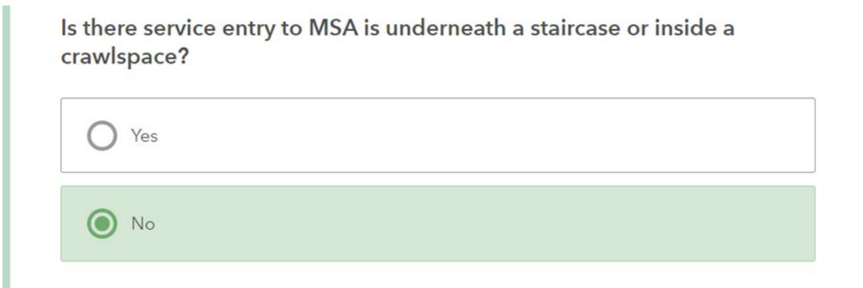
6. Accessibility to gas utility-owned inside piping:



3. Accessibility:

Select accessibility:

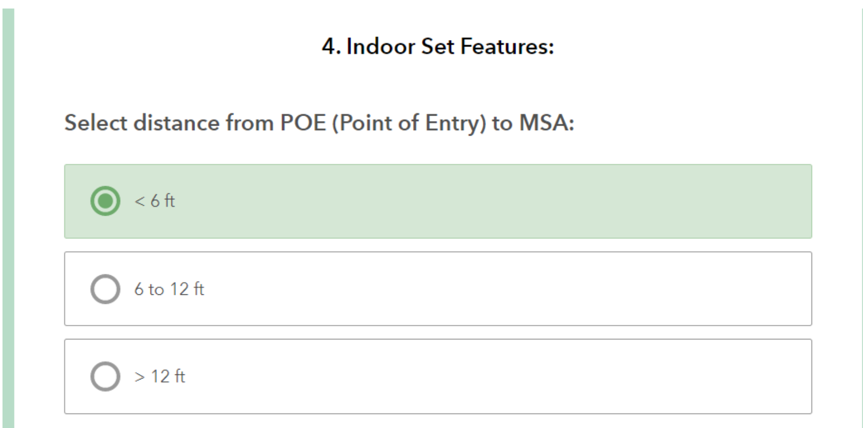
- ○ Indoor MSA is openly accessible to public
- ◉ Utility has keys for direct access to indoor MSA
- ○ Requires building maintenance/tenant's permission to access the indoor MSA



Is there service entry to MSA is underneath a staircase or inside a crawlspace?

- ○ Yes
- ◉ No

7. Distance of the Point of Entry (POE) to the MSA:



4. Indoor Set Features:

Select distance from POE (Point of Entry) to MSA:

- ◉ < 6 ft
- ○ 6 to 12 ft
- ○ > 12 ft

8. Indoor set features:

Is regulator in the Indoor MSA?

- ◉ Yes
- ○ No

Select regulator Type (if Indoor):

- ◉ Standard
- ○ Two-stage, low emission

Select service line pressure at POE:

- ○ 0.25 to 3 psig
- ○ 3 to 15 psig
- ◉ > 15 psig

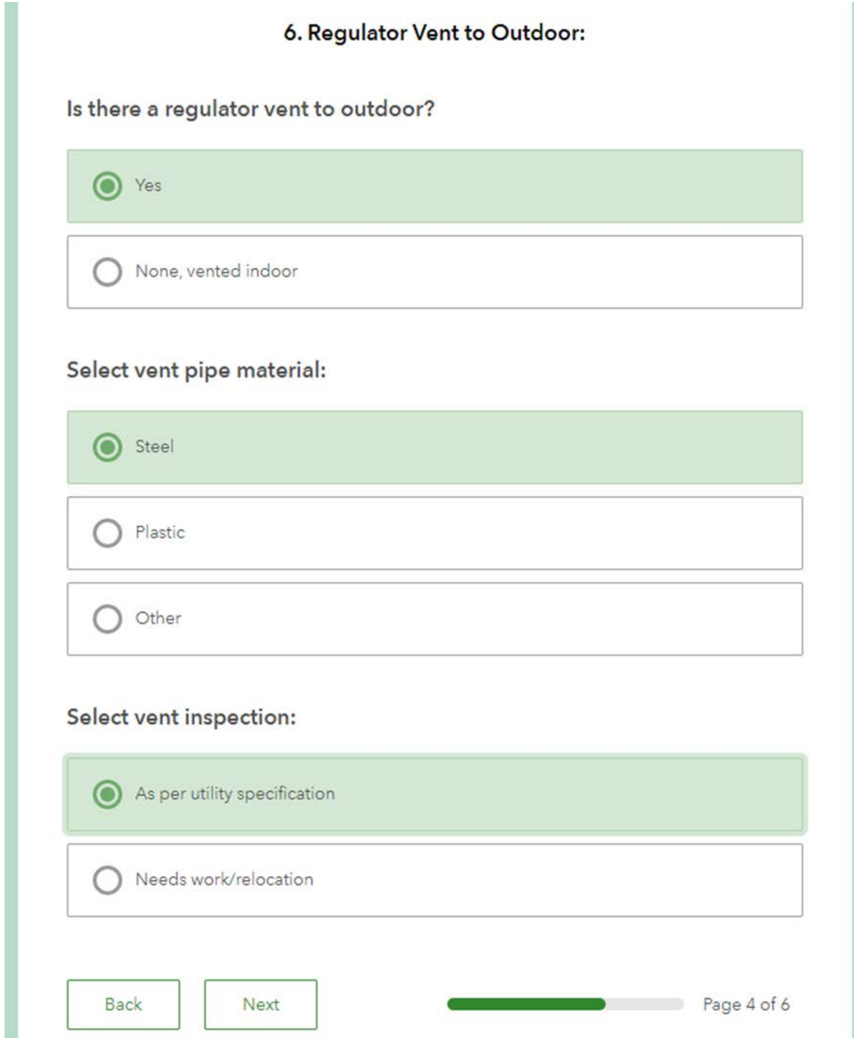
Is the Gas Utility piping system visible and accessible?

- ◉ Yes
- ○ No

Select piping material:

- ◉ Coated Steel
- ○ Unprotected Steel
- ○ Plastic
- ○ Other

9. Inside service regulator vent pipe:


6. Regulator Vent to Outdoor:

Is there a regulator vent to outdoor?

- (●) Yes
- ( ) None, vented indoor

Select vent pipe material:

- (●) Steel
- ( ) Plastic
- ( ) Other

Select vent inspection:

- (●) As per utility specification
- ( ) Needs work/relocation

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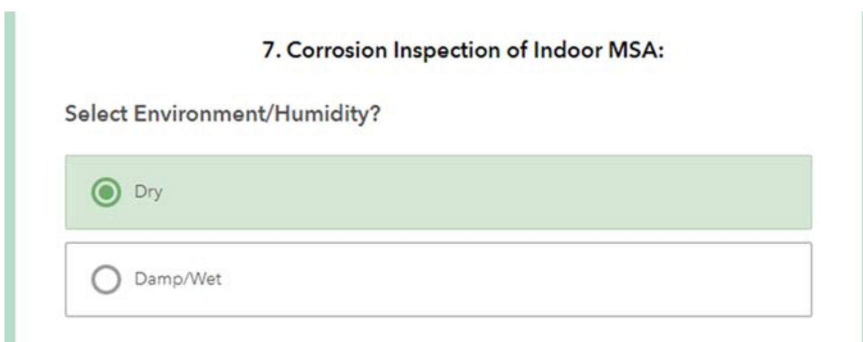
10. Inspection for atmospheric corrosion:


7. Corrosion Inspection of Indoor MSA:

Select Environment/Humidity?

- (●) Dry
- ( ) Damp/Wet

Is a temporary repair present?

- ( ) Yes
- (•) No

Select MSA condition:

- ( ) No corrosion or oxidation
- (•) Minor surface oxidation/rust
- ( ) Pitting and/or minor flaking
- ( ) Sever pitting and/or flaking

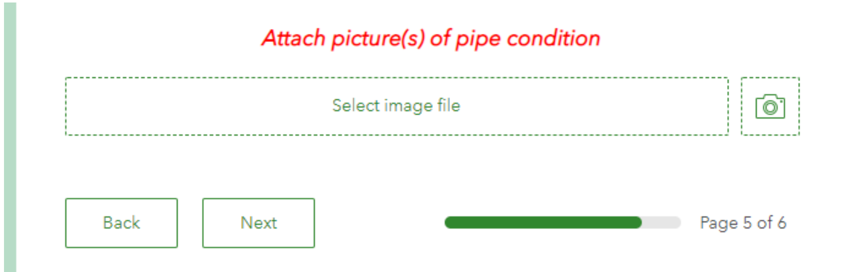
Select corrosion location:

- [x] At Point of Entry (POE)
- [ ] At contact with soil
- [ ] Coating damage
- [x] At Uncoated surface

Select corroded Item:

- [ ] At fitting
- [x] Piping/coupling
- [x] Meter
- [ ] Regulator
- [ ] Unknown/Other

[Picture of the inside piping condition].


Attach picture(s) of pipe condition

Select image file

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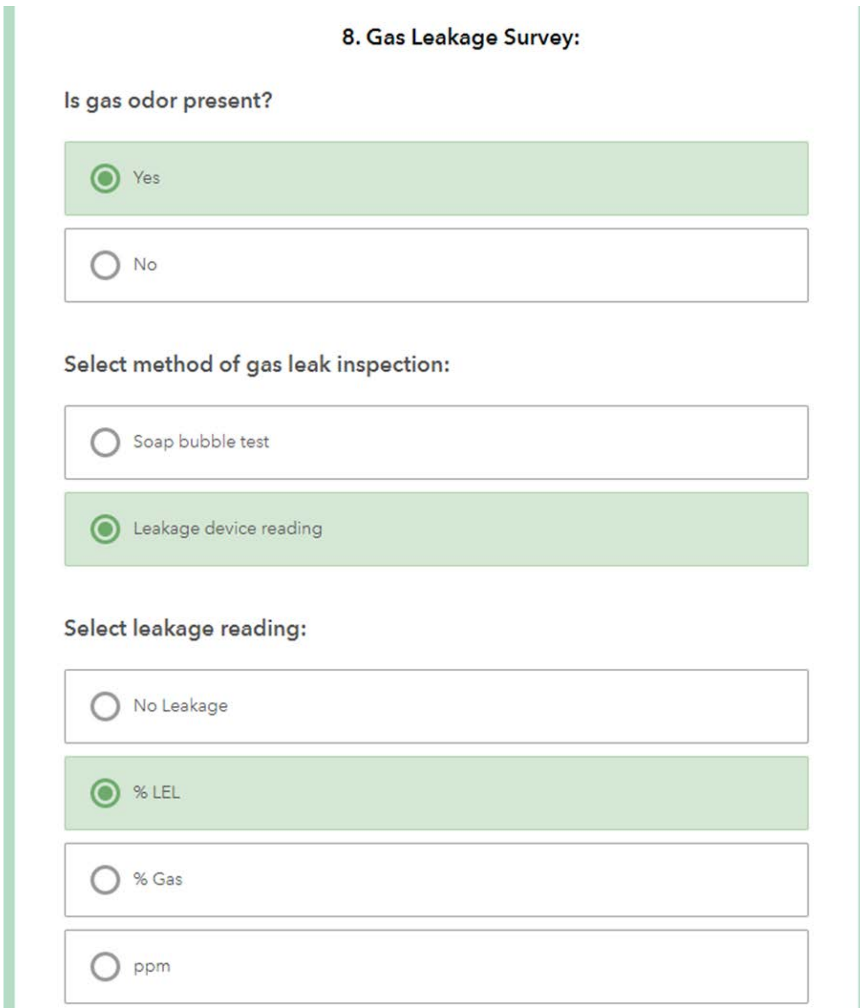
11. Leak survey data:


8. Gas Leakage Survey:

Is gas odor present?

- (•) Yes
- ( ) No

Select method of gas leak inspection:

- ( ) Soap bubble test
- (•) Leakage device reading

Select leakage reading:

- ( ) No Leakage
- (•) % LEL
- ( ) % Gas
- ( ) ppm

Enter leakage reading value:

20% LEL

Select leaking location:

- (●) At Point of Entry (POE)
- ( ) Between regulator and meter
- ( ) After an Inside meter
- ( ) Unknown/Other

Select leaking Item:

- ( ) Fitting threads
- ( ) Pipe/coupling
- ( ) Meter
- (●) Regulator
- ( ) Unknown/Other

[END OF DOCUMENT]