National Transportation Safety Board
Washington, DC 20594

Safety Recommendation Report

Natural Gas Distribution System Project Development and Review (Urgent)

Ongoing Investigation

On September 13, 2018, about 4:00 p.m. eastern daylight time, a series of explosions and fires occurred after high-pressure natural gas was released into a low-pressure gas distribution system in the northeast region of the Merrimack Valley, Massachusetts. The distribution system was owned and operated by Columbia Gas of Massachusetts (Columbia Gas), a subsidiary of NiSource, Inc. The system overpressure damaged 131 structures, including at least 5 homes that were destroyed in the city of Lawrence and the towns of Andover and North Andover. Most of the damage was a result of structure fires ignited by gas-fueled appliances. Several structures were destroyed by natural gas explosions. One person was killed and at least 21 individuals, including 2 firefighters, were transported to the hospital. Seven other firefighters received minor injuries.

The cast-iron, low-pressure natural gas distribution system was installed in the early 1900s and had been partially improved with both steel and plastic pipe upgrades since the 1950s. The low-pressure distribution system in the affected area relied on 14 regulator stations to control natural gas at the required pressure into structures serviced by the system. Each of the regulator stations reduced the natural gas pressure from about 75-pounds per square inch, gauge (psig) to about 12 inches of water column (about 0.5 psig) for delivery to customers.[1]

Prior to the accident, Columbia Gas had an overarching plan consisting of multiple projects to replace 7,595 feet of low-pressure, existing cast-iron and plastic natural gas main with 4,845 feet of low-pressure and high-pressure plastic gas main on South Union Street and neighboring streets.

On September 13, prior to the overpressure event, a Columbia Gas-contracted work crew, which included a Columbia Gas inspector, executed one of the Columbia Gas-designed and -approved pipe-replacement projects at the intersection of South Union Street and Salem Street in South Lawrence. The project was to install a plastic distribution main and abandon in place a cast-iron distribution main. The distribution main that was abandoned still had the regulator-sensing lines that were used to detect pressure in the distribution system and provide input to the regulators to control the system pressure. Once the contractor crews disconnected the distribution main that was being abandoned, the section containing the regulator-sensing lines began losing pressure.

[1] *Inches of water column* is a unit of pressure measurement that is typically used for low-pressure gas systems, such as a low-pressure natural gas distribution system.

As the pressure in the abandoned distribution main dropped about 0.25 inches of water column (about 0.01 psig), the regulators responded by opening further, increasing pressure in the distribution system. The regulators opened completely when they no longer sensed system pressure, allowing the full flow of high-pressure gas to release into the distribution system supplying the neighborhood. As a result, natural gas was delivered to customers at a pressure well above the maximum-allowable operating pressure which led to the ignition of fires and explosions in homes.

Minutes before the fires and explosions occurred, the Columbia Gas monitoring center in Columbus, Ohio, received two high-pressure alarms for the South Lawrence gas pressure system: one at 4:04 p.m. and the other at 4:05 p.m. The monitoring center had no control capability to close or open valves; its only capability was to monitor pressures on the distribution system and advise field technicians accordingly. Following company protocol, at 4:06 p.m., the Columbia Gas controller reported the high-pressure event to the Meters and Regulations group in Lawrence. A local resident made the first 9-1-1 call to Lawrence Emergency Services at 4:11 p.m.

In response, three technicians were dispatched to perform field checks on 14 regulators. Columbia Gas shut down the regulator at issue by about 4:30 p.m. The critical valves of the natural gas distribution system were closed by 7:24 p.m. Beginning about midnight, crews consisting of two Columbia Gas technicians escorted by two emergency response personnel began shutting off the meters at each house to isolate the homes from the natural gas distribution system. All meters were shut off by the following morning.

Engineering Work Package Approval Process

Omissions in the engineering work package and construction documentation for the project near South Union Street and Salem Street were discovered during the National Transportation Safety Board (NTSB) investigators' review. Although Columbia Gas used its project workflow process to develop, review, and approve the engineering plans, the work package did not include consideration of the existence of regulator-sensing lines within the scope of work—in particular, the regulator-sensing lines connected to the distribution lines that were slated to be abandoned. This omission was not identified by the Columbia Gas constructability review.

Constructability reviews are a recognized and generally accepted good engineering practice for the execution of professional design services and are intended to provide an independent and structured review of construction plans and specifications to ensure there are no conflicts, errors, or omissions.[2] The review should be performed by qualified professionals to identify deficiencies and incorporate improvements into the construction documents. Many jursidictions also require that plans be approved (sealed) by a professional engineer licensed to perform engineering in the jurisdiction.[3]

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[2] J.G. Kirby, R.P. Cannalte, D.K. Hicks, and E.J. Japel, *Constructability and Design Reviews: Analysis and Recommendations for Improvement*, US Army Corps of Engineers Constructional Engineering Research Library Technical Report P-89/15 (Washington, DC: US Army Corps of Engineers, 1989).

[3] (a) According to the National Society of Professional Engineers (NSPE), in order to use the PE seal, an engineer must earn a 4-year degree in engineering from an accredited engineering program, pass the Fundamentals of

According to the Columbia Gas project workflow process, a company field engineer is responsible for the development of design and engineering modifications to the pipeline system.[4] The plans are packaged as a project package that is circulated to other departments for the constructability review.[5] Columbia Gas requires the Engineering department and the Construction department to approve all projects, but the Land Services department and the Meter and Regulation department review the packages on an "as needed basis," depending on the project.

While the engineering design package for the South Union Street project underwent a constructability review, NTSB investigators found that the constructability review did not identify the impact on pressure regulation and control. The Columbia Gas field engineer who developed the engineering plans told NTSB investigators that he developed them without reviewing engineering drawings that documented the regulator-sensing lines.

The field engineer said that the Meter and Regulation department within Columbia Gas had the maps containing control line information and he was unaware if his department had access to such records. Furthermore, the field engineer had limited knowledge about the importance of the regulator-sensing lines or the consequences of losing the capability to sense the main pressure via the regulator-sensing lines. The constructability review records for the overarching South Union Street and Salem project indicate that the plans were seen and approved by the Engineering department and the Construction department. The Meters and Regulation department and the Land Services department were not required to review the project because the field engineer did not believe at the time that the proposed scope of work was applicable to or affected these departments.[6] The NTSB believes a comprehensive constructability review, which would require all departments to review each project, along with the seal of approval from a professional engineer (PE), would likely have identified the omission of the regulator-sensing lines, thereby preventing the error that led to the accident. By sealing the project plans, the PE takes responsibility for the accuracy and completeness of the engineering package. Neither the Commonwealth of Massachusetts nor Columbia Gas policy require a registered PE to develop or review public utility engineering plans.[7]

According to the National Society of Professional Engineers (NSPE), in most states PE's are not required to review and approve project plans, such as those used in this accident, because they have industrial, public utility, or other exemptions. The NSPE has advocated for the phasing out of existing industrial exemptions in state licensing laws. According to the NSPE:

Engineering exam, complete 4 years of progressive engineering experience under the guidance of a registered PE, and pass the Principles and Practice of Engineering exam. (b) The qualifications required for licensure as a PE in the United States are set by each jurisdiction through the state's engineering statute, and rules established by the state board of licensure of professional engineers implementing those statutory requirements. The law and the rules differ in each state.

[4] The field engineer was not a registered professional engineer.

[5] Columbia Gas often refers to the project package as a "pouch."

[6] The Columbia Gas Capital Design Job and Constructability Review Checklists allow the Engineering department to determine what departments outside of the Engineering and Construction departments review the project.

[7] Massachusetts Public Health Regulations, Title XVI, Chapter 112, Section 81R.

> [m]any engineers in industry have responsibility for activities that directly affect the public health, safety, and welfare. But exemptions place these individuals and organizations performing engineering services outside of the licensing system. Exempt individuals and organizations are not subject to the same legal and ethical requirements as those who are licensed.[8]

The NTSB believes that it is critical that an engineer with the appropriate qualifications and experience review engineering plans for a gas company, if not develop them. The Commonwealth of Massachusetts exemption for the requirement of PE licensure to perform "industrial" and public utility work foreclose an opportunity to detect this design oversight. The seal of a PE should be required on all public utility engineering plans to reduce the likelihood of accidents such as this occurring.[9]

The PE licensure is a regulatory instrument for advancing the public good, protecting employers and the public, and ensuring that the engineering work was performed consistent with a standard of care and in accordance with a strict code of ethics. A PE seal on a plan would illustrate that the plan had been approved by an accredited professional with the requisite skills, knowledge, and experience to provide a comprehensive review. Therefore, the NTSB recommends that the commonwealth of Massachusetts eliminate the professional engineer licensure exemption for public utility work and require a professional engineer's seal on public utility engineering plans. Additionally, the NTSB recommends that NiSource revise the engineering plan and constructability review process across all its subsidiaries to ensure that all applicable departments review construction documents for accuracy, completeness, and correctness, and that the documents or plans be sealed by a PE prior to commencing work.

Pipeline System Records

NTSB investigators also learned that the engineering plans used during the construction work did not document the location of regulator-sensing lines. A review of the engineering work package indicated that the location of the nearest regulator was identified on the plans and maps but did not indicate the location of the regulator-sensing lines.

Documentation and record-keeping are critical parts of a pipeline safety management system (PSMS) program. In fact, American Petroleum Institute Recommended Practice 1173, *Pipeline Safety Management Systems*, states in Section 14.1:[10]

> The pipeline operator shall maintain a procedure for the identification, distribution, and control of documents required by its PSMS. The procedure shall specify responsibilities for document approval and re-approval and shall identify the

[8] NSPE, *Industrial Exemption*, https://www.nspe.org/sites/default/files/IndustrialExemptionFINAL2017.pdf, accessed October 23, 2018.

[9] The seal of a PE signifies that the document has been developed or reviewed by an individual who has met the necessary prerequisites of engineering education, experience, and examination.

[10] American Petroleum Institute, *Pipeline Safety Management System Requirements*, API Recommended Practice 1173, First edition, July 2015 (Washington, DC: American Petroleum Institute, 2015).

> controls needed to assure that the documents required by the PSMS, including revisions, translations, and updates:
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> a) are reviewed and approved for adequacy prior to issue and use;
> b) identify changes and revision status;
> c) remain legible and readily identifiable; and
> d) are readily available and accessible to workers performing an activity.
>
> Obsolete documents shall be removed from all points of issue or use, or shall otherwise be identified to assure against unintended use if they are retained for any purpose.

Had accurate alignment sheets with comprehensive system information been available and used during the construction project, engineers and work crews would have been able to identify the regulator-sensing lines and ensure their relocation prior to abandoning the pipeline main.[11] Therefore, the NTSB recommends that NiSource review and ensure that all records and documentation of its natural gas systems are traceable, reliable, and complete.

Management of Change

Columbia Gas's implementation of management of change (MOC) is limited to the management of its Distribution Integrity Management Plan (DIMP), a program required by Pipeline and Hazardous Materials Safety Administration (PHMSA) regulations to enhance safety by identifying and mitigating risks that could cause serious consequences to the integrity of the pipeline system." Columbia Gas does not practice MOC for managing maintenance and construction changes to pipeline operations. Engineering department personnel rely upon checklists within its workflow documentation to manage change within the work packages generated through the department.

NTSB interviews of Columbia Gas managers and staff revealed that the company did not conduct separate risk assessments for each construction project. Performing risk assessments and developing risk mitigation plans or procedures are critical components of in a PSMS program. API RP 1173 states in Section 8.4.1:[12]

> The pipeline operator shall maintain a procedure for management of change (MOC). For each MOC, the pipeline operator shall identify the potential

[11] The alignment sheet is a document that represents the "as built" location of the pipeline and includes the description of the pipe laid. The pipeline is typically represented as a single line or centerline and typically drawn to scale. The description will include the outside diameter of the pipe, grade, weight-per-foot, and wall thickness, as well as the type of connection used to join the individual lengths or joints of pipe. The sheet may indicate whether the land is forest or in cultivation. Stations along the pipeline indicate distance from the starting point to that "station" and are reference points, as there also will be various crossings designating oil and gas pipelines of varying sizes, water lines, sewer lines, and underground cables, etc. Other topographical features might be listed as well such as the type of soil, hilly, rolling hills, and wetlands, etc.

[12] American Petroleum Institute, *Pipeline Safety Management System Requirements*, API Recommended Practice 1173, First edition, June 2014 (Washington, DC: American Petroleum Institute, 2014).

risks associated with the change and any required approvals prior to the introduction of such changes.

MOC procedures require an analysis of implications, among several other elements. Additionally, a risk identification and assessment are necessary to establish the appropriate prevention and mitigation measures to reduce the likelihood of consequences should an incident occur. Columbia Gas failed to perform such an analysis and failed to establish appropriate controls to mitigate the risks of the work that was being performed.

NTSB investigators also learned that, until about 4 years ago, Columbia Gas required that a technician monitor any gas main revision work which required depressurizing the main. The technician—typically from the Meter and Regulation department—would use a gauge to monitor the pressure readings on the impacted main and would communicate directly with the crew making the change. If a pressure anomaly occurred, the technician could quickly act to prevent an overpressurization action. Columbia Gas offered no explanation as to why this procedure was phased out. Although the Columbia Gas monitoring center in Columbus, Ohio, received high-pressure alarms and reported the event to the Meters and Regulations department 2 minutes after receiving the first alarm, there were no technicians prestaged or positioned to immediately close valves when the overpressurization occurred.

Had Columbia Gas adequately performed MOC and placed personnel at critical points along the system, Columbia Gas could have immediately addressed the issue and mitigated the consequences of the event.

Therefore, the NTSB recommends that NiSource apply management of change processes to all changes to adequately identify system threats that could result in a common mode failure. Additionally, the NTSB recommends that NiSource develop and implement control procedures during modifications to gas mains to mitigate the risks identified during MOC operations. Gas main pressures should be continually monitored during these modifications and assets should be placed at critical locations to immediately shut down the system if abnormal operations are detected.

Recommendations

As a result of this report, the National Transportation Safety Board makes the following safety recommendations:

To the Commonwealth of Massachusetts:

Eliminate the professional engineer licensure exemption for public utility work and require a professional engineer's seal on public utility engineering drawings. (P-18-005)

To NiSource, Inc.:

Revise the engineering plan and constructability review process across all of your subsidiaries to ensure that all applicable departments review construction documents for accuracy, completeness, and correctness, and that the documents or plans be sealed by a professional engineer prior to commencing work. (P-18-006) (Urgent)

Review and ensure that all records and documentation of your natural gas systems are traceable, reliable, and complete. (P-18-007) (Urgent)

Apply management of change process to all changes to adequately identify system threats that could result in a common mode failure. (P-18-008) (Urgent)

Develop and implement control procedures during modifications to gas mains to mitigate the risks identified during management of change operations. Gas main pressures should be continually monitored during these modifications and assets should be placed at critical locations to immediately shut down the system if abnormal operations are detected. (P-18-009) (Urgent)

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