

Consolidated Edison Company of New York, Inc.

July 19, 2018 Steam Incident
Fifth Avenue and 21st Street

Investigation Summary and Action Plan

January 22, 2020

Table of Contents

- I. EXECUTIVE SUMMARY 3
- II. OVERVIEW OF STEAM SYSTEM 5
- III. SUMMARY OF LPI CONCLUSIONS..... 6
- IV. ACTION PLAN 10
 - 1. Steam System Assessment..... 10
 - 2. Remote Monitoring System (RMS) and Equipment Enhancement 11
 - 3. Condensate Level Detection System..... 11
 - 4. Acoustic / Vibration Sensing System 12

I. EXECUTIVE SUMMARY

On July 19, 2018, at approximately 6:37 a.m., a steam main ruptured in the Flatiron district of Manhattan at Fifth Avenue and 21st Street.¹ Within minutes, Con Edison arrived at the scene, initiated its emergency plan, and worked with firefighters to evacuate and secure the area. No one was seriously injured.

Con Edison engaged Lucius Pitkin, Inc. (“LPI”) to investigate the rupture. LPI determined that the cause of the rupture was a water hammer that resulted from the failure of a third-party six-inch fire suppression line about 174 feet south of the rupture location. Water from the fire suppression line entered the steam main housing, came in contact with the steam main, and caused a large volume of condensate to form within the steam main. The condensate interacted with the steam that continued to flow through the steam main and induced an internal pressure pulse, or water hammer, causing the main to rupture. LPI also reviewed the system configuration and other factors to determine why the water hammer occurred when and where it did.

This report summarizes LPI’s conclusions and Con Edison’s action plan.² Although Con Edison cannot prevent third-party water lines from failing, the Company has developed the following initiatives to improve its ability to detect precursors to water hammer events, reduce the likelihood of a similar incident, and otherwise improve overall steam safety:

1. Steam System Assessment

- Con Edison will develop and implement a methodology for determining higher risk locations based on lessons learned from the July 19th incident and will establish an inspection program for those locations. The Company will develop a program to address findings and associated engineering recommendations.

¹ A steam main is a large pipe that carries steam from the power plant through the steam distribution system in the city. Smaller pipes, called services, branch off of mains and deliver steam to customers.

² Con Edison filed the LPI Report with the Records Access Officer because it contains non-public critical infrastructure information.

2. Remote Monitoring System (“RMS”) and Equipment Enhancement

- Con Edison will continue to implement its RMS initiative by evaluating and enhancing the current design of the remote telemetry unit (“RTU”) and associated devices. The Company is developing new prototypes that will seek to improve reliability. The Company will test viable prototypes in the laboratory and field. Upon completion of testing, the Company will update Department of Public Service (“DPS”) Staff on the feasibility of proceeding with this technology.
- Con Edison will evaluate current trap temperature and water level alarming strategies to determine what enhancements the Company can make. Upon completion of the review, the Company will update DPS Staff on the feasibility of proceeding with these enhancements.

3. Condensate Level Detection System

- Con Edison is conducting field testing of prototype condensate detection devices. The Company will review the devices’ performance, reliability, and practicality. Upon completion of field testing, the Company will update DPS Staff on the feasibility of proceeding with this technology.

4. Acoustic/Vibration Sensing System

- Con Edison will field test prototype acoustic/vibration sensing devices. The Company will review the devices’ performance, reliability, and practicality. Upon completion of the field testing period, the Company will update DPS Staff on the feasibility of proceeding with this technology.

II. OVERVIEW OF STEAM SYSTEM

Con Edison's steam system is the largest district steam system in the United States. A district steam system generates steam at central plants and distributes it through a network of underground pipes directly to buildings. Con Edison owns and operates five steam plants and 105 miles of underground steam mains and service pipes.³ The Company provides steam service in Manhattan from Battery Park at the south end to 96th Street on the West Side and 89th Street on the East Side.

Residential and commercial customers use steam for heat, domestic hot water, and air conditioning. Hospitals use it to sterilize equipment. Restaurants and cafeterias use it to cook and clean dishes. Museums use it to control humidity. Businesses use it for dry cleaning and laundry. Steam is a versatile commodity that powers New Yorkers' energy needs.

Con Edison's steam system offers many benefits. By using district steam, buildings free up space that would otherwise be occupied by oil or gas-fired boilers, and avoid tall stacks that would produce emissions and diminish Manhattan's skyline. Steam customers can also apply for points toward their Leadership in Energy and Environmental Design certification and increase their score in Energy Star's Portfolio Manager because the majority of the Company's steam is produced through cogeneration, the highly efficient concurrent production of steam and electricity. The steam system also reduces the need for investment in electric and natural gas infrastructure. For example, by choosing steam for air conditioning, steam customers reduce peak summer electric demand by about 266 megawatts. Moreover, New York City Local Law 97 recognizes the steam system's environmental benefits and has rated the steam system as the lowest carbon emitting energy

³ In addition, the Company has a long term steam supply contract with a vendor.

source currently available. Consistent with New York State and New York City's emission reduction goals, Con Edison will continue to evaluate new technologies to further reduce the steam system's environmental footprint. Finally, the Company participates in discussions and studies aimed at helping meet the State and City's emissions goals.

III. SUMMARY OF LPI CONCLUSIONS

At approximately 6:37 a.m. on July 19, 2018, a 20-inch carbon steel steam main buried approximately 8.5 feet below the road ruptured just south of the intersection of Fifth Avenue and 21st Street. Within minutes, Con Edison arrived at the scene, initiated its emergency plan, and worked with firefighters to evacuate and secure the area. No one was seriously injured.

Con Edison engaged Lucius Pitkin, Inc. ("LPI") to investigate the rupture. LPI determined that the cause of the rupture was a water hammer that resulted from the failure of a third-party six-inch fire suppression line about 174 feet south of the rupture location. Water from the fire suppression line entered the steam main housing, came in contact with the steam main, and caused a large volume of condensate to form within the pipe.⁴ The condensate interacted with the steam that continued to flow through the steam main and induced a water hammer of between 800 to 950 psi. The steam system typically operates at approximately 150 psi and has a maximum system design pressure of 200 psi. The water hammer, which was at least four times the system's maximum design pressure, caused the main to rupture.

Condensation is a naturally occurring process in steam systems, and during normal operation does not cause water hammers. Typically, a steam pipe has relatively small

⁴ Condensate is the water that forms within a steam pipe when the steam cools. This process is known as condensation.

amounts of condensate that are removed by drainage devices called steam traps. If, however, an excessive amount of condensate accumulates in a pipe, it can interact with the steam that continues to travel through the pipe. If the volume and temperature of this condensate reaches unstable conditions, a water hammer is possible.

Condensate can accumulate in a steam pipe if the traps malfunction or if an external source rapidly cools the pipe and converts steam into condensate. The investigation confirmed that the traps near the rupture site were removing condensate from the system.

The steam main that ruptured runs beneath Fifth Avenue. Sometime before 4:17 a.m., a six-inch fire suppression line failed near the curb line in front of 135 Fifth Avenue, unleashing a flood of cold water underground. The fire suppression line, which was about 174 feet south of the rupture, separated by as much as 3/4 inch at a mechanical coupling device used to connect water pipe sections. As LPI explained, the mechanical coupling uses a series of wedges around the pipe circumference that are torqued into the inserted pipe to secure the pipe. These wedges use a special torque limiting head, such that when the required torque is reached, the head snaps off. At the separated mechanical joint, the torque limiting heads remained in-place, indicating that the required torque was not reached during assembly and the water pipe was not secured as intended. In addition, the water pipe did not have any physical indentations on its surface (scoring) indicating that the mechanical joint was installed properly. There were also ground voids and sink holes near the failed fire line, indicating a significant water release.

The cold water from the failed fire suppression line penetrated the housing that protects the steam main under Fifth Avenue between 20th and 21st Streets. Steam main housing is not designed to be waterproof. Housing drainage paths are not sized to handle a large ingress of water from a failed water main or fire suppression line. LPI estimated that

water flowed from the failed fire suppression line at a rate between 1,250 and 2,500 gallons per minute.

Just south of the failed fire suppression line, the steam main housing was built through a retired manhole, which had a solid wall at its south end. This wall, about nine feet south of the failed fire suppression line, slowed housing drainage.

The amount of water needed to fill the housing half-way up from the south wall of the retired manhole to beyond the pipe rupture location (more than 183 feet) was less than 5,000 gallons. If only a fraction of the escaping water penetrated the housing, it could fill this area within minutes.

As cold water accumulated in the housing between 20th and 21st Streets, it came in contact with the steam main. The water cooled the main, causing rapid condensation inside the pipe, and boiling of the water external to the pipe, which caused vapor to form outside of the pipe. Security camera video from 139 Fifth Avenue showed a vapor plume escaping through a service valve manhole to the street beginning at 4:17 a.m. – an indication that external water was in contact with the steam pipe. The vapor plume was visible until 5:30 a.m. and ceased by 5:44 a.m.

The steam main on Fifth Avenue between 20th and 21st Streets has a downward slope towards 20th Street. Using pressure telemetry information from meter records around the incident site, LPI determined that prior to the incident the steam flow was from south to north for this section of Fifth Avenue. The velocity of the steam flow was sufficient to hold the accumulating condensate in-place, allowing it to build-up along this section.

LPI determined that after 5:44 a.m. the pipe was most likely at least half filled with condensate. The condensate rapidly cooled and stratified, producing a hot layer on top and cooler layers toward the bottom. Condensate that is cooled to a lower temperature than the

saturation point for the steam in the pipe is called “subcooled” and increases the risk for water hammer.

As steam flow increased to meet customer demand, the relationship between the steam and the condensate changed from stratified layers (steam flowing over water) to “slug flow” (condensate moving through the pipe in waves). This was an unstable condition because it disturbed the hot upper condensate layer and exposed the steam to subcooled condensate below. As the waves bridged to the top of the pipe, steam bubbles became trapped. Condensation of the trapped steam bubbles on the subcooled condensate occurred rapidly, and formed a low pressure void that caused the adjacent condensate waves to collide, resulting in a water hammer that caused the pipe to rupture.

The section of pipe that ruptured had been in service since 1932. Based on metallurgical testing, LPI determined that it had met the strength requirements of the American Society of Mechanical Engineers Code B31.1 for service in the steam system. The ruptured pipe did exhibit local inside diameter wall thinning, which is a sign of flow accelerated corrosion (“FAC”). However, nearby sections of pipe wall were consistent with required specification thickness, indicating that FAC was not related to the pipe’s age, i.e., age had not degraded the pipe.

IV. ACTION PLAN

While the July 19, 2018 rupture was caused by circumstances beyond Con Edison's control, the Company has identified four initiatives to improve its ability to detect precursors to water hammer events, reduce the likelihood of a similar incident, and otherwise improve overall steam safety:

1. Steam System Assessment

Con Edison will develop and implement a methodology for determining higher risk locations based on lessons learned from the July 19th incident and will establish an inspection program for those locations. The Company will develop a program to address findings and associated engineering recommendations.

- *Goal* - Identify highest risk areas that require action and/or further inspection.
- *Brief Description* - Review design documentation, sensor data, field conditions, along with use of various analytical models to develop a system assessment plan.
- *Methodology* - Divide the entire system into various drainage districts. Using predictive analytics coupled with data from various sources, implement a risk rating system that would calculate a score for each individual district and develop an inspection plan for the higher risk locations. Examples of the types of characteristics that the analytical assessment may consider are as follows: piping geometry, steam flow direction and steam velocity, pipe leak history, insulation and housing type, customer impact, location, etc.
- *Schedule* - This effort is currently underway. Con Edison will finalize and implement the engineering analysis and risk rating system by the end of the second quarter of 2020. Con Edison will also commence inspections of select locations identified by the engineering team in the second quarter of 2020.
- *Deliverables* - Update DPS Staff on the risk rating system by the end of the first quarter of 2020; update DPS Staff on final engineering assessment and preliminary inspection results by the end of the second quarter of 2020; update DPS Staff annually on the inspection program and as needed.

2. Remote Monitoring System (RMS) and Equipment Enhancement

Con Edison will continue to implement its RMS initiative by evaluating and enhancing the current design of the remote telemetry unit (“RTU”) and associated devices. The Company is developing new prototypes that will seek to improve reliability. The Company will test viable prototypes in the laboratory and field. Upon completion of testing, the Company will update DPS Staff on the feasibility of proceeding with this technology.

In addition, Con Edison will evaluate current trap temperature and water level alarming strategies to determine what enhancements the Company can make. Upon completion of the review, the Company will update DPS Staff on the feasibility of proceeding with these enhancements.

- *Goals* - (1) Develop an RTU enclosure and associated connections that can provide reliable data to our central monitoring system; (2) review current alarm set points and evaluate improved alarming strategies.
- *Brief Description* - Develop new RTU/float prototypes that will address the most common modes of failure in the existing design.
- *Methodology* - Conduct laboratory and field testing of various prototypes. Perform detailed data reviews of historical data as it relates to current alarm set points.
- *Schedule* - Ongoing; Con Edison will update DPS Staff as appropriate.
- *Deliverables* - Update DPS Staff on testing results, feasibility of prototype technologies, and alarming strategy review.

3. Condensate Level Detection System

Con Edison is conducting field testing of prototype condensate detection devices. The Company will review the devices’ performance, reliability, and practicality. Upon completion of field testing, the Company will update DPS Staff on the feasibility of

proceeding with this technology.

- *Goal* - Determine if this technology can: (1) successfully identify condensate levels within the steam mains; and (2) survive in the manhole environment.
- *Brief Description* - Complete production of prototypes and perform field testing of condensate detection devices.
- *Methodology* - Conduct various field tests. Determine if the sensors can replicate the associated laboratory tests and identify condensate accumulation within the steam main.
- *Schedule* - Ongoing; Con Edison will update DPS Staff as appropriate.
- *Deliverables* - Update DPS Staff on the findings of the field testing and associated collected data.

4. Acoustic / Vibration Sensing System

Con Edison will field test prototype acoustic/vibration sensing devices. The Company will review the devices' performance, reliability, and practicality. Upon completion of the field testing period, the Company will update DPS Staff on the feasibility of proceeding with this technology.

- *Goal* - Determine if this technology can: (1) successfully identify abnormal acoustic and/or vibration signatures within the steam mains; and (2) survive in the manhole environment.
- *Brief Description* - Conduct a feasibility analysis to determine if an acoustic/vibration sensing system can be used to identify specific water hammer conditions
- *Methodology* - Conduct tests to determine the feasibility of using this technology. Determine if the sensors have the capability to identify condensate accumulation, abnormal flow conditions, and rapid changes in velocity.
- *Schedule* - Ongoing; Con Edison will update DPS Staff as appropriate.
- *Deliverables* - Update DPS Staff on the findings of the field testing and associated collected data.