Case 18-S-0448: In the Matter of the Investigation of a Rupture at Fifth Avenue and 21st Street on July 19, 2018 in the Service Territory of Consolidated Edison Company of New York, Inc.

NEW YORK STATE DEPARTMENT OF PUBLIC SERVICE

CASE 18-S-0448

TECHNICAL REPORT

Executive Summary

On July 19th, 2018, at approximately 6:37 AM, a 20-inch diameter steam pipeline owned and operated by the Consolidated Edison Company of New York, Inc. (Con Edison, CECONY or the Company) ruptured in the Flatiron District of Manhattan near the intersection of 21st Street and Fifth Avenue. Con Edison notified Staff of the rupture 30 minutes after Con Edison arrived at the site. The escaping steam broke through the pavement, resulting in a crater that was approximately 34 feet (North to South) by 15 feet (East to West). There were no fatalities as a result of the rupture; five people who suffered minor injuries were treated and released at the scene. The rupture impacted water, natural gas, and electric distribution facilities in the area.

At 9:34 AM, Con Edison steam crews, responding to the incident finished closing a total of 11 steam main valves to isolate the ruptured section. Because the steam main was insulated with asbestos, the rupture caused a release of asbestos-contaminated debris into the air and onto surrounding buildings. First responders restricted public access to the incident site. Con Edison began sampling for asbestos contamination began soon after the rupture at 9:00 AM, debris

testing for one of the samples found greater than 1.5% asbestos. Therefore, the site was treated as an asbestos clean-up site.

Con Edison alerted the public through social media and other methods about the possible asbestos exposure in the vicinity of the rupture. Con Edison also recommended that anyone possibly exposed to the debris take precautions, such as bagging clothing and taking a shower; the Company established locations where they would collect potentially contaminated personal items and articles of clothing. Among the 2000 air samples Con Edison collected, 82 had detectable amounts of asbestos; no personnel, including DPS investigators, were allowed into the ruptured steam main trench without respirators and protective clothing. Soon after the rupture, all traffic lanes along Fifth Avenue in the area, along with surrounding streets, were closed. Four days after the incident, on July 23rd, the street was partially opened to traffic.

Upon notification of the steam main rupture, DPS Staff immediately responded to the location. On July 19th, Governor Cuomo directed the Department of Public Service (DPS) to conduct an investigation into the cause of the explosion and to determine whether any utility activities contributed to it. DPS Staff (Staff) investigated the incident to identify causal factors, and to make recommendations to prevent reoccurrence.

To ensure proper handling of the specimens collected and analyzed to determine the cause of the rupture, Con Edison retained a separate evidentiary company, CFI Evidence Services LLC (CFI), who specializes in documentation and preservation of physical evidence from property and casualty loss locations.

Staff and other interested parties[1] monitored the exposing, removal, packaging, and transport of facilities critical to the investigation.

Staff, pursuant to a Memorandum of Understanding with Con Edison, contracted with Affiliated MRD LLC to perform metallurgical testing and analysis on the ruptured pipe section. DPS Staff also retained a water hammer consultant, Kirsner Consulting Engineering (Kirsner), to produce an independent report on the causal factors of the incident in relation to Con Edison's steam system. Separately, Con Edison retained Lucius Pitkin, Inc. (LPI) to produce its own report for the Company based on LPI's engineering analysis and evaluation of the event. LPI's report, a summary of which was filed with the PSC Secretary on January 22, 2020, has been made available for Staff's review.[2]

As detailed further in this report, based on the work of its contactor and Staff's own observations, Staff determined that the cause of the steam pipeline rupture was an overpressure event: specifically, a condensation-induced water hammer (CIWH).

CIWH occurs when a steam bubble is trapped in a layer of subcooled condensate. The condensate cools the steam bubble, which is otherwise operating at a very high temperature, to the point where it immediately collapses, resulting in a significant

[1] Interested parties to this investigation include representatives from the City of New York, representatives of building 135 Fifth Avenue, representatives from New York City Water Works plumbing company, representatives for Travelers insurance company, and representatives for Chubb insurance company.

[2] Although Kirsner and LPI discussed theories during the ongoing causation analysis, both applied strict adherence of confidentiality by and between their principals - the Department of Public Service, and Con Edison, respectively.

overpressure event in the pipe. Because of the temperature of the steam in the mains, to produce the condensate required to create a condensation-induced water hammer, there had to have been an outside source of water to continuously cool the steam and form condensate within the steam main. A likely source of the water necessary to cool the steam in the main enough to produce condensate was the fire water service line to 135 Fifth Avenue, which was found separated at a coupling after the incident.[3]

As part of Staff's investigation and analysis of Con Edison's operating and maintenance practices and procedures relevant to this incident, Staff observed the following:

- Con Edison's steam housing in the area of the rupture did not have adequate drainage to allow water flow out of the housing. Drainage through this housing had either not been maintained or had been compromised by Con Edison's construction over the years. Specifically, an abandoned Con Edison Steam manhole located near the intersection of 20th Street and Fifth Avenue was found to have significantly impeded the drainage of water from the housing to manhole vault, where it could have been removed from the system and avoided contributing to this incident. This lack of drainage allowed water to remain in the housing, which facilitated the generation of condensate and, therefore, the subcooling of the steam main necessary for condensation-induced water hammer. Although no safety

[3] The building owner of 135 Fifth Avenue disputes that its fire water service was the source of the cool water. However, after Staff confirmed that no City sewer or water service breaks had occurred before and near the rupture, the fire service line appears to be the only possible source of enough water to trigger the subsequent events in the steam system.

requirements exist with respect to abandoned manholes and the steam system, had drainage been added to this vault when it was abandoned, the water accumulation from what appears to be the water service line to 135 Fifth Avenue could have drained instead of collecting in the housing.

- There was severe metal loss on the pipe around the rupture area. The wall loss did not cause the pipe to rupture, but it did contribute to the failure by increasing the likelihood of the pipe rupturing during an overpressure event (such as over-pressurization caused by water hammer).

- Since 2008, Con Edison has installed steam Remote Monitoring System (RMS) at various locations throughout its steam distribution system, including near the incident area. At the time of the rupture, five of the eight RTU boxes[4] in the area were not properly functioning and were not reporting steam trap and manhole water level monitoring data. In particular, the RMS components closest to the rupture site, at the intersection of 20th Street and Fifth Avenue, one block from the rupture, were not functioning. The RMS at that intersection consisted of two RTU boxes with various components attached. One RTU was not working, while each of the RMS components attached to the other RTU box was not reporting useful data. Staff acknowledges the

[4] As detailed further in this report, Con Edison's steam remote-monitoring system consists of various components (trap temperature sensor, float water level detectors, etc.) connected to a remote-terminal unit (RTU) box. The RTU reports back to Con Edison's Steam Control Center. If the RTU box is not functioning, then Con Edison would not receive information from any of the RMS components connected to that RTU box.

difficulty of maintaining electronics in the steam system but believes the current reliability of Con Edison's steam RMS must be improved.

As a result of the investigation, Staff has recommended, and Con Edison agrees to the following Action Items:

1. By September 30, 2021, Con Edison will submit to the Commission's Secretary or Records Access Officer, as appropriate, a revised procedure that requires non-destructive examination of 50 percent of all field welds made on existing steam pipe facilities within a month rather than the 10 percent required by the Commission's regulations. If operational constraints and/or unforeseen circumstances prevent Con Edison from non-destructively examining 50 percent of welds performed in a given month, Con Edison shall submit a report to safety@dps.ny.gov, by the 15th day of the following month, explaining the circumstances and listing the welds that had not been non-destructively examined that month. By September 30, 2022, Con Edison will meet with DPS Staff to review the results of the increased non-destructive examination of field welds and discuss potential changes to the percentage of welds to be non-destructively examined.

2. By September 30, 2021, Con Edison will submit a revised procedure to the Commission's Secretary or Records Access Officer, as appropriate, that: (1) requires Con Edison to monitor the functionality of the Remote Monitoring System ("RMS") float and associated Remote Telemetry Unit ("RTU") box when a pump in a steam manhole is left in continuous operation and, if the RMS is not functioning, perform daily inspections to monitor pump functionality; (2)

identifies a maximum timeframe that a pump can be left in continuous operation; and (3) identifies a timeframe within which a non-working pump will be repaired or replaced.

3. By September 30, 2021, Con Edison will evaluate and submit to the Commission's Secretary or Records Access Officer, as appropriate, a report on the feasibility of inspecting its steam pipe housings for blockages.

4. By September 30, 2021, Con Edison will submit to the Commission's Secretary or Records Access Officer, as appropriate, revised design specifications that include the requirement of drainage continuity through steam main housings for new construction, repairs, and retirement projects.

5. By October 30, 2021, Con Edison will develop and submit to the Commission's Secretary or Records Access Officer, as appropriate,: (1) a steam main rupture risk assessment program and; (2) a steam main inspection program based on the results of its risk assessment and; (3) a remediation plan based on the assessment and preliminary inspection results, including a description of any mitigation actions taken since the start of the assessment and inspection program.

6. Con Edison will evaluate a prototype condensate level detection device. By December 31, 2021, Con Edison will submit to the Commission's Secretary or Records Access Officer, as appropriate, a report reviewing its preliminary findings on the device's performance, reliability, and practicality.

7. Con Edison will evaluate current trap temperature and water level alarming RMS strategies to identify potential enhancements. By December 31, 2021, Con Edison will submit to the Commission's Secretary or Records Access Officer, as appropriate, a report on the feasibility of proceeding with any potential enhancements.

8. Con Edison will evaluate a prototype acoustic/vibration sensing device. By December 31, 2021, Con Edison will submit to the Commission's Secretary or Records Access Officer, as appropriate, a report reviewing its preliminary findings on the device's performance, reliability, and practicality.

9. Con Edison will continue its RMS R&D program to enhance the current design of the RTU and associated devices while continuing to work on improving RMS reliability at critical locations. The Company is developing new prototypes that will seek to improve reliability and will test viable prototypes in the laboratory and field. By January 31, 2022, Con Edison will meet with the Department to review the results of these efforts and discuss potential RMS reliability goals. Con Edison's reliability goals and reporting will apply to critical locations until Con Edison proposes otherwise in a rate case or petition, or the Commission orders otherwise in a proceeding on the record and subject to notice and comment.

10. Con Edison will evaluate the feasibility of reducing steam pressures during portions of the year, including determining which customers require high pressure steam (greater than 100 psig). By September 30, 2021, Con Edison will submit to the Commission's Secretary or

Records Access Officer, as appropriate, a report discussing the results of this assessment.

11. Con Edison will contract with a third-party to study the causes of steam main corrosion and identify mitigation methods. The study will examine the corrosion susceptibility of pipes of varying vintages and include a fracture mechanics evaluation to determine the effect various sized corrosion related flaws have on the structural stability of steam mains. Con Edison will submit the study to the Commission's Secretary or Records Access Officer, as appropriate, by November 30, 2021.

12. Con Edison Steam will evaluate the adoption of American Petroleum Institute Recommended Practice (API RP) 1173 "Pipeline Safety Management Systems." The evaluation will include a baseline assessment/gap analysis of the steam system by a third-party vendor. Con Edison will submit the evaluation results to the Commission's Secretary or Records Access Officer, as appropriate, by March 31, 2022.

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I. Description of Steam System

The Consolidated Edison Company of New York, Inc. steam system extends from the southern tip of Manhattan northward to 96th Street on the West Side, and 89th Street on the East Side. The major uses of steam include space heating, air conditioning, sterilization, and domestic hot water. Currently, the system provides steam to 1,785 accounts. The system is comprised of approximately 91 miles[5] of steam main, with diameters ranging from three inches to thirty-six inches.

The steam system incorporates various piping vintages and designs, some from as early as the 1880's. The network also incorporates thousands of subsurface manhole vaults, which house facilities such as isolation valves, pipe supports, anchors, expansion joints, steam traps and drainage mechanisms.

Con Edison's steam originates at five steam generating stations that it owns. In addition, Con Edison has a long-term contract for steam supply with the Brooklyn Navy Yard Cogeneration Partners, an independent power producer. Steam from the generating stations flows into the steam distribution system through Con Edison's steam transmission mains. The steam transmission mains operate at pressures between 200-280 pounds per square inch gauge (psig), Con Edison has approximately 14 miles of steam transmission mains in its system. From the transmission system, steam enters Con Edison's steam distribution system, which comprises the bulk of the mains within Con Edison's steam system. Steam distribution mains operate at pressures between 125-190 psig, with temperatures ranging from 350°F to a maximum temperature of 413°F.

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[5] Including footage associated with steam services, Con Edison has approximately 105 miles of steam pipe in its steam system

II. Steam System Components

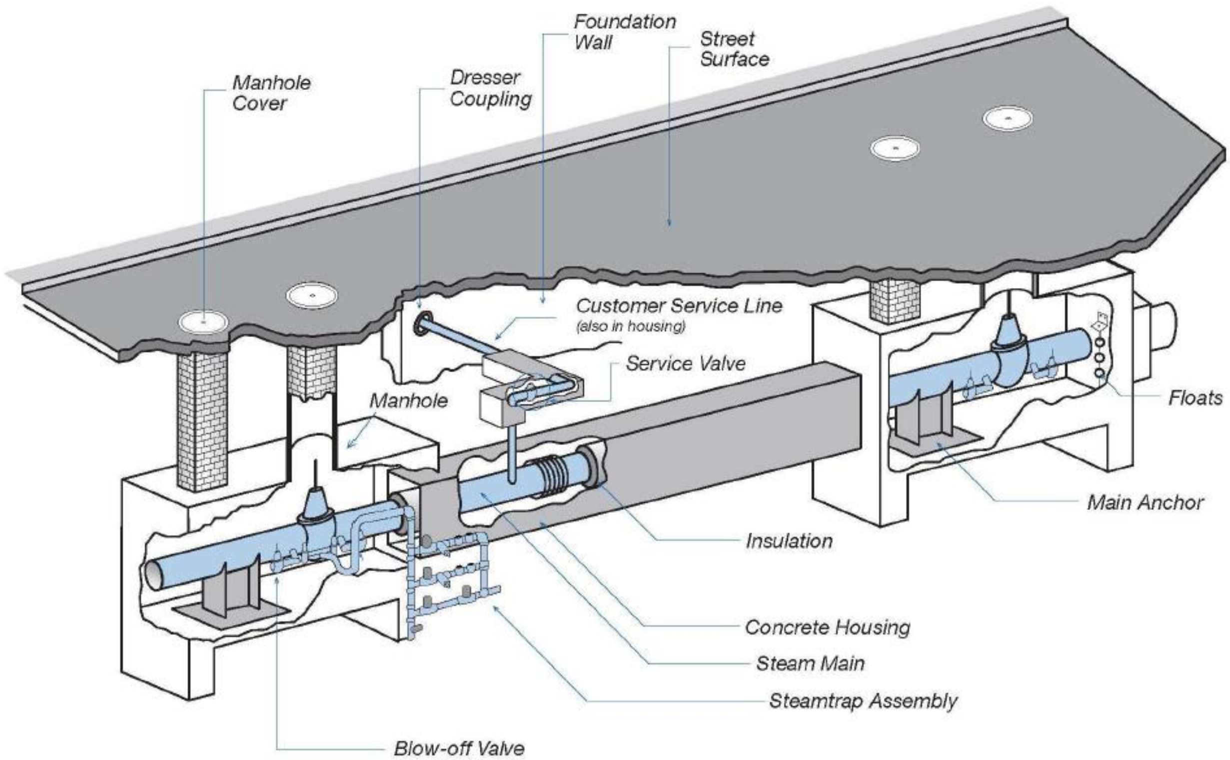

Figure 1 – Sample Layout of Steam System, from Con Edison

Insulation - Piping in the steam system is covered with insulation to minimize heat loss. Prior to 1972, most steam mains were insulated with asbestos. More currently, Con Edison uses glass fiber or aerogel materials for insulation.

Housing – Unlike other underground infrastructure, such as gas mains that can be placed directly in soil, steam mains are encased within a housing with an approximate two-inch air gap between the insulated pipe and housing. The housing provides an annular space for thermal expansion of the piping. Older steam main housing could consist of clay, brick, or cast iron, while modern steam main housing is poured concrete.

Anchors - Anchors are supports welded to the steam main that restrict thermal expansion of the steam main.

Expansion Joints[6] - Expansion joints allow for thermal expansion of the steam main, generally up to eight inches per joint.

Steam Traps / Trap Assemblies - Steam within mains will cool and form condensate. Steam mains are designed so that the condensate will flow to a condensate drain or steam trap line, which then flows to a steam trap allowing its removal from the system. As backup, Con Edison's steam trap piping contains two steam traps. The traps, along with their associated piping, are referred to as a "steam trap assembly." Steam traps are critical to the safe operation of a steam system, since they prevent build-up of condensate within a steam main, which is a precursor to water hammer.

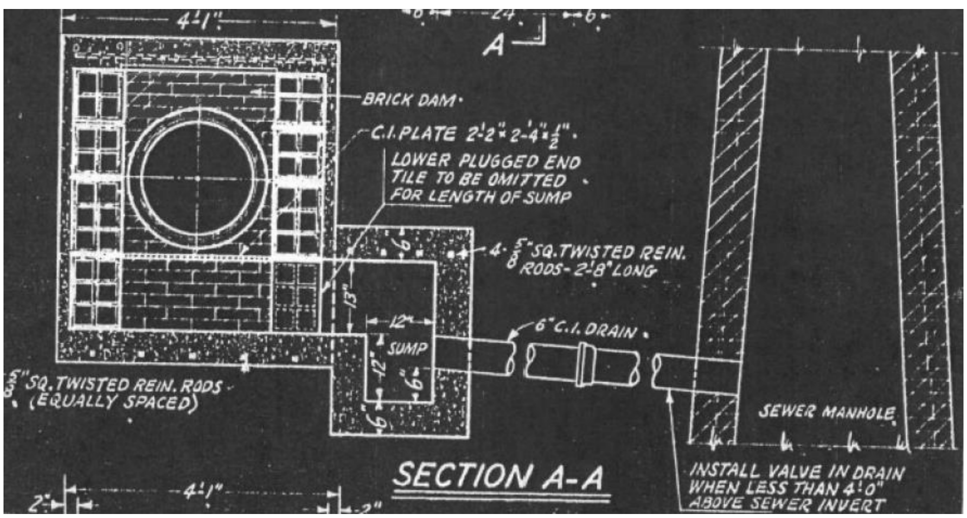

Figure 2 – Layout of Steam Main Housing and Drain, from Con Edison

Unlike steam main condensate, which is internal to the steam main, water that is external to the steam main that infiltrates into the housing is removed to the sewer through drains in the housing (Figure 2) or the housing is designed so that the water will flow to a separate steam manhole. From the

[6] Expansion joints are often referred to as "slip joints." Slip joints are a specific type of expansion joint in which one side of the joint can slide inside the adjacent section of the joint.

steam manhole, water can also drain to the sewer or be removed by a pump to the sewer.

Figure 3 – Photo of Steam Main in Older-Style Housing along Fifth Avenue, between 20th Street and 21st Street. Taken by Staff

III. Location Specifics

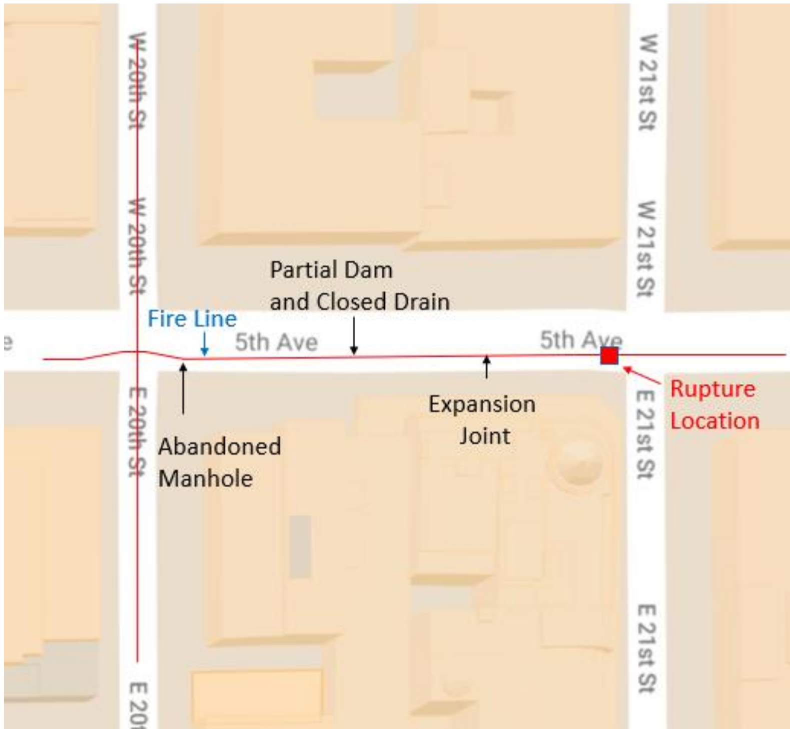

Figure 4 - Layout of Steam Main near Rupture Site

The layout of the steam distribution mains at the intersection of 21st Street and Fifth Avenue, as they existed on July 19, 2018, is shown in Figure 4. The 20-inch main that ruptured ran in a north-south direction along Fifth Avenue, crossing 20th Street, 21st Street, and 22nd Street. The steam main at the intersection of Fifth Avenue and 21st Street, near the rupture location, is approximately 9 feet deep. The section of steam main from 20th Street to 21st Street contains a base anchor and an expansion joint. In addition, within the block between 20th Street to 21st Street is a steam service connection for Building 141 Fifth Avenue. At the intersection of 20th Street and Fifth Avenue, the pipe depth is approximately 14 feet, where it connects to an east-west run of another 20-inch steam main running along 20th Street.

Steam mains are designed such that the pipe is sloped downward, so that condensate within the pipe can flow towards steam traps and be removed from the system. In this rupture location area, steam traps were located approximately one block in each direction from the rupture location. The steam traps are located at the intersection of 20th Street and Fifth Avenue and at the intersection of 22nd Street and Fifth Avenue (not shown in Figure 4). The intersection of 21st Street and Fifth Avenue, near where the incident occurred, was a relative high point on the steam system.

Most of the steam main between 20th Street and 21st Street was installed in 1932. However, small sections of main had been replaced during past operations and maintenance work. For example, adjacent to the rupture location was an anchor that was installed in 1991. Similarly, the expansion joint in this section of main was installed in 2005.

IV. Description of Events

Background on Water Hammer

A water hammer occurs when a steam bubble is trapped within a layer of condensate or steam that has been cooled to the point of condensing to its liquid state. The presence of a sub-cooling layer (or water) outside of the main, such as groundwater or water leaking from a municipal infrastructure facility, can accelerate this process by withdrawing heat from the steam in the main, which increases condensate generation. The forming condensate then cools the steam bubble to the point at which the bubble immediately collapses into condensate. Because steam occupies a larger volume than condensate, the steam's rapid contraction causes the surrounding condensate to rush in and fill the void. Since water is incompressible, the resulting collision generates a high-pressure pulse that transmits through the condensate at magnitudes that can exceed the Specified Minimum Yield Strength (SMYS) of a pipe, leading to its rupture.

In an underground steam system, it is possible for facilities to become submerged by significant rainfall, groundwater, or failure of adjacent water infrastructure. Due to the high heat of the steam system while in operation, any water that comes into contact with an active main or service will instantly boil off, which could release visible vapor at street level, referred to as a vapor condition. If the rate of water encroachment exceeds the boil-off rate that the surface area of the steam facility can maintain, the sub-cooling layer of boiling water can withdraw enough energy from the steam in the main to cause condensation and a water hammer condition.

Steam System Environment July 19th, 2018

On the morning of July 19th, skies were clear, and the temperature fluctuated between 67 to 72 degrees Fahrenheit. Prior to the rupture, the most recent rain event had occurred on the afternoon of July 17th. On July 18th, 2019, Con Edison had performed a manhole inspection at a manhole near to where the rupture would occur, at the intersection of 20th Street and Fifth Avenue, and confirmed that there was no water accumulation present in that manhole.

Notably, during a prior steam incident at Lexington Avenue and 41st Street in 2007, the incident had been preceded by a large amount of rainfall between 6:00 AM and 11:00 AM, which contributed to the 5:56 PM incident. Rainfall, however, does not appear to be a contributing factor to this incident.

Incident Occurrence

On July 19th, 2018, at approximately 6:37 AM, a 20-inch diameter steam pipeline owned and operated by Con Edison ruptured in the Flatiron district of Manhattan near the intersection of 21st Street and Fifth Avenue. The rupture caused debris and escaping steam to break through the pavement, resulting in a crater that was approximately 34 feet (North to South) by 15 feet (East to West). At 6:40 AM, Con Edison steam dispatch noticed a drop in system pressures in the area. CECONY was notified of a possible steam main rupture by the NYC Fire Department also at 6:40 AM. The rupture resulted in a large plume of steam emanating from the incident site.

Figure 5 – Photo of Intersection of 21st Street and Fifth Avenue, Post Rupture. Taken by Con Edison

At approximately the same time, superintendents of nearby buildings observed a large amount of water flooding the basements of 135 Fifth Avenue at 137 Fifth Avenue, with some water entering the basement of 139 Fifth Avenue.

Emergency Response and Notification

Con Edison first responders were dispatched at 6:42 AM, arriving on location at 6:50 AM. A Steam System Emergency and a Steam Hands-Off Day[7] were declared at 7:03 AM. Staff was notified of a potential rupture at 7:20 AM. The National Response Center (NRC), Department of Environmental Conservation (DEC), and Department of Environmental Protection (DEP) were all notified by 7:27 AM. Con Edison also briefed NYC Emergency Personnel[8] and first responders from the Occupational Safety and Health Administration (OSHA), Environmental Protection Agency (EPA), and Metropolitan Transportation Authority (MTA).

Con Edison mechanics were able to partially isolate the main by 7:34 AM, by shutting four nearby valves to decrease pressure. At 8:33 AM, Con Edison declared the incident a 'full-scale level corporate emergency'[9], and later determined that the area would be treated as an asbestos cleanup site. The ruptured section of steam main was completely isolated by 9:34 AM, via the closure of seven additional valves, totaling eleven valves needed for complete isolation. Steam continued to escape from the rupture location until the main was completely isolated.

Asbestos Cleanup

Prior to 1972, steam mains were mostly insulated with asbestos. Currently, Con Edison opportunistically removes asbestos insulation from steam mains during steam work that

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[7] A steam hands-off day is when Con Edison stops all non-essential steam work and devotes all resources to the emergency.

[8] NYC Emergency Personnel included members of the NYPD, FDNY, Office of Emergency Management, Department of Health, Department of Transportation, and Department of Buildings.

[9] CECONY Corporate Instruction 260-4, *Corporate Response to Incidents and Emergencies*, defines a "Full-Scale" level incident as one "that involves widespread need for Company forces in one or multiple service areas and which could include support from outside the Company."

requires the main to be excavated, such as pipe replacement or repairs. Right now, of the 105 miles of steam pipe throughout the system, approximately 72.5 miles are covered with asbestos insulation. Since asbestos insulation is present throughout most of the steam system, asbestos contamination of the air and the surrounding buildings, sidewalks, streets, vehicles, and materials is a constant concern during a rupture. Therefore, when Staff arrived on location, responding agencies, which included NYCDEP, NYC Office of Emergency Management (NYC OEM), NYPD, FDNY, and Con Edison, were establishing a "hot zone"[10] around the rupture crater. The designated hot zone was large enough to encompass all areas potentially contaminated with asbestos, including the area surrounding Fifth Avenue from 19th street to midway past 21st Street. Forty-nine buildings were evacuated the day of the rupture due to potential asbestos contamination/exposure.

[10] A hot zone is the area with actual or potential contamination and the highest potential for exposure to hazardous substances.

Figure 6 – Map of buildings affected by rupture. From NYC OEM, for location identification purpose only; distinguishing colors may be ignored.

Soon after the rupture, DEP and Con Edison began taking air and bulk solids samples within the hot zone to test for the presence of asbestos. No one was allowed into the rupture crater area without the specified respirator and personal protective equipment (PPE). Initial tests of air samples from the hot zone, however, showed no asbestos presence; however, the bulk sampling of soil from the rupture crater confirmed that the debris was contaminated by an elevated level of asbestos. Four of the bulk samples contained less than 1% asbestos, while one sample showed 1.5% asbestos. Since one sample contained greater than one percent asbestos, the rupture site was treated as an asbestos clean-up site. In the month following the incident, of the 2,000 air samples taken by Con Edison, 82 contained detectable concentrations of asbestos. Eleven of the 82 samples containing asbestos exhibited levels greater than the Asbestos Hazard Emergency Response Act 70 s/mm^2 clearance criteria[11]; all 11 samples had been taken in the direct vicinity of the crater on July 20th and 21st. As of July 26th, NYC DEP had taken more than 1,700 air readings in the area surrounding the rupture site and did not find significant levels of asbestos in any of the readings.[12]

Because of the evacuation, the 49 buildings were evacuated on the day of the incident due to the risk of potential asbestos exposure. Residents were unable to enter the buildings until those buildings had been tested and cleared for asbestos. Approximately 500 residents from 249 residential units were temporarily displaced as a result of potential asbestos contamination of their buildings.[13] The environmental agencies on-site ultimately determined that a total of 45 buildings needed to be tested for asbestos. By July 26, 2019, 36 buildings had been tested and cleared for re-entry. Because the remaining buildings were closer to the rupture site and required more extensive cleanup efforts before being cleared for re-entry, by July 30, 2019, only one building (141 Fifth Avenue)

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[11] From "Con Edison Part 420 Report," posted in DMM Case 18-S 0448 on August 20, 2018, "The United States Environmental Protection Agency's AHERA clearance level of 70 structures per square millimeter (70 S/mm2) is based on the level at which the Agency considers a space appropriate to return to general occupancy following an asbestos abatement. The Agency developed criteria for the AHERA standard in 1987 for air monitoring inside schools. Since there is no regulatory asbestos threshold for clearance of ambient (outdoor) air quality, regulatory agencies use the AHERA standard as a reference point."

[12] July 26, 2018 Press Release from the City of New York "Update on the City's Response to the Manhattan Steam Main Explosion"

[13] July 19, 2018 Press Release from the City of New York "Update on the City's Response to the Manhattan Steam Main Explosion"

was pending clearance for re-entry.

Facades for multiple buildings along and surrounding Fifth Avenue between 19th and 21st Street needed to be cleaned due to potential exposure to asbestos debris. Con Edison employed an average of 200 asbestos handlers in the days following the incident to facilitate clean-up activities. Fifth Avenue from 19th Street to 21st Street was closed to the public following the incident, along with surrounding side streets. By July 23rd, Fifth Avenue was opened to limited traffic. On July 28th, the west side of Fifth Avenue was open to pedestrian traffic. Con Edison's asbestos remediation costs totaled $7.2 million dollars.

During the clean-up, Con Edison set up outreach locations at Broadway and East 19th Street, Broadway and East 22nd Street, and at The Clinton School, where affected individuals could dispose of contaminated possessions, request information on the status of clean-up and restoration, and file claims for losses. Con Edison and the City of New York maintained websites with updates available to the public.

Impact on Gas Facilities

The steam main rupture also affected Con Edison's gas facilities, although the steam main was more than six feet below surface level, with more than three feet of clearance between the 24-inch and 6-inch gas mains, which run parallel to the steam main and the steam main, itself. Upon initial inspection, CECONY found no gas odors or gas leak readings associated with the incident; gas system pressures in the area were found to be stable and within normal ranges.

On the evening after the rupture, at 6:57 PM on July 19th, Con Edison gas crews entered the area near the rupture wearing HAZMAT suits and found readings of 23% gas-in-air. Con Edison, however, did not find readings within subsurface structures or residences. Gas readings were traced to a leak on a nearby, six-inch, low-pressure steel gas main. The main was isolated at 9:59 PM; isolation of the gas main resulted interruption of gas service to five buildings. By August 9th, the main was repaired and gas to four out of the five buildings had been gas restored.

Impact on Electric Facilities

The rupture affected several electric networks in the vicinity of the incident: four primary 13 kV feeders to the Madison Square and Chelsea networks were lost. Combined with the damage to the secondary network, three services were affected: electric service to two locations were interrupted, while the third location was placed on load restrictions. To prevent additional service interruptions, the Company declared a "Condition Yellow"[14] on July 19th and reduced voltage by 5% on its Madison Square and Chelsea networks. The "Condition Yellow" was ended the same day by 6:22 PM. Service was restored to the three customers by July 24th.

Impact on Steam Facilities

Steam service to 27 buildings was affected by the rupture and subsequent isolation of the steam system in the area of the rupture. Sixteen of these buildings were restored within 24 hours of the incident; ten more customers were restored by July 28th. The last customer, 145 Fifth Avenue, was directly adjacent to the rupture site. CECONY installed a temporary service to this customer on August 9th, after DEP cleared the building for occupancy.

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[14] Con Edison declares a "Condition Yellow" when the next contingency (excluding substation breaker failure) either will result in an outage to more than 15,000 customers or will result in electric distribution equipment being loaded above emergency ratings.

V. Material and Evidence Recovery

Security of Evidence

As the asbestos hot zone decreased to the area immediately surrounding the crater, identifying underground facilities and materials within the crater for the purpose of determining the root cause of the rupture became a priority. To assist Con Edison in this endeavor, Con Edison contracted with a third-party evidentiary company, CFI, which was responsible for preserving and cataloguing pertinent pieces of evidence from the incident site. CFI catalogued each piece of evidence with an item identification number and brief description of the item, with Staff witnessing much of this process. The entire rupture site was videotaped with a digital recorder.

Evidence Recovery

The asbestos abatement process slowed the rate of evidence recovery. The ruptured section of the steam main was inaccessible for over two weeks due to the amount of asbestos-contaminated debris. Evidence collection and removal also slowed the pace of excavation. In addition, the size of the rupture pit required sheeting and shoring be installed to ensure that workers could safely work in the trench.

From July 25th to July 29th, nearby steam traps, expansion joints, pumps, steam remote monitoring system components, and other facilities deemed pertinent to the investigation were documented in place, removed, and retained by CFI. Staff witnessed the removal of the facilities.

On July 27th, a mobile robotic video camera was inserted into the pipe at an opening near 139 Fifth Avenue, approximately 90 feet south of the rupture. The camera traveled northward towards the intersection of Fifth Avenue and East 21st Street, and encountered the fish-mouth rupture at the 6-o'clock position on the pipe. The rupture was submerged in water, but evidence of an opening in the pipe was clearly visible.

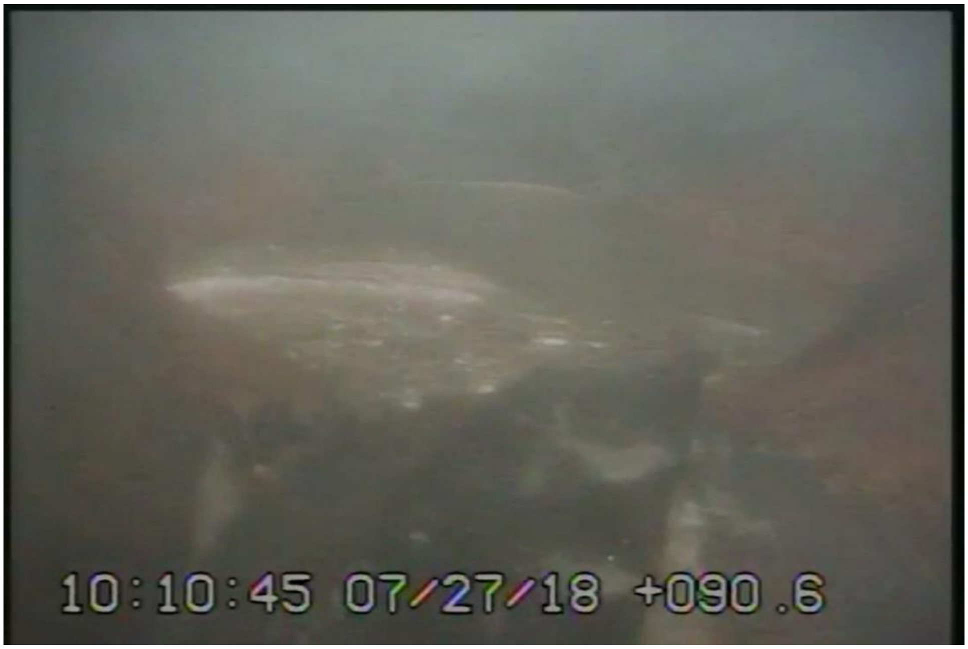

Figure 7 – Screen capture of rupture site from inside main from ULC Robotics Video

After locating the rupture, the robot returned to the deployment point and proceeded south. Upon reaching the intersection of 20th Street and Fifth Ave, the robot was unable to continue due to the steep downward grade of the steam main offset.

Once sheeting and shoring of the rupture location was completed, the ruptured section of the steam main was exposed on the evening of August 6th. On August 7th, the 'as-found' condition of the pipe was documented and allowed to be viewed by interested parties, including Staff. The same day, the ruptured section was cut-out by Con Edison crews and retained by CFI.

At Staff's request, the other sections of 20-inch steam pipe running from the intersection of East 20th Street to East 21st (approximately 300 feet of steam main) were also retained by CFI. This removal and replacement of the steam main required the work on the street to continue into September.

Description of Ruptured Section of Pipe

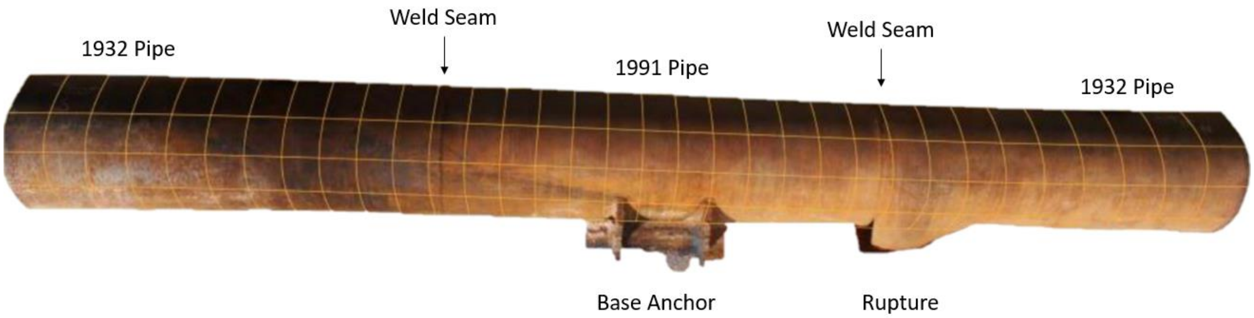

Figure 8 - Photo of Steam Pipe, from Affiliated (Rotated to Show Pipe in Same Orientation as Found in Ground)

Figure 8 shows the removed section of ruptured steam main. The majority of the 20-inch steam main along Fifth Avenue, between 20th and 21st Street, was installed in 1932. Since then, small sections of the steam main within this block had been replaced due to prior Con Edison operations and maintenance work. In the removed section containing the rupture, a 64.5-inch piece of pipe had been installed in 1991 between two sections of pipe installed in 1932. The 1991 pipe was installed to accommodate the installation of an anchor (shown in Figure 8) at this location. Anchors are used in tandem with expansion joints to allow for controlled linear expansion of the steam main due to thermal expansion.

As shown in Figure 8, the area where the steam main ruptured is located on the 1932 pipe, abutting where the pipe is joined to 1991 pipe. The rupture is confined to the 1932 pipe and extends along the weld joining the 1932 pipe to the 1991 pipe. See Figure 9.

Figure 9 - Close-up of Rupture on Pipe, Taken by Affiliated

VI. Metallurgical Analysis

DPS retained Affiliated MRD Services (Affiliated) services independently, under a Memorandum of Understanding between Staff and Con Edison, to perform the metallurgical testing and metallurgical analysis of the ruptured section of pipe. On October 6, 2018, Affiliated sent out for comment to interested parties a draft protocol of the proposed metallurgical examination and testing procedure. The examination process allowed interested parties to view the ruptured section of the pipe at CFI's facilities on October 22, 2018, as well as witness metallurgical evaluation and mechanical testing in November 2018.

During metallurgical testing in November 2018, sections of the steam main near the rupture were cut to be used as samples for tensile, Charpy V-notch, and bend tests - which Staff witnessed. The tests confirmed that the pipe's tensile strength, ductility, and fracture toughness were consistent with pipe manufactured circa 1932. Material testing and chemical analysis results showed that the pipe met the mechanical property and chemical composition requirements of ASTM A53-30 "Standard for Welded Seamless Steel Pipe," a pipe standard in use when the pipe was installed in 1932. Similar testing found that the 1991 pipe met the 1991 requirements of ASTM A53-88a Grade A pipe.

Affiliated's report notes that there was significant wall loss at the bottom (6 o'clock position) of the steam main. Affiliated characterizes the corrosion as being consistent with "corrosion-erosion". Affiliated states that such damage was consistent with condensate sitting at the bottom of the pipe and churning with steam flow as a result of turbulent steam flow. This process would have occurred over time during normal steam operations. LPI, in its report, states that the damage was consistent with flow-accelerated corrosion (FAC), due to the smooth and scalloped appearance of the corrosion on the pipe surface. FAC is a mechanism by which a metal's protective oxide layer is removed by a fast-moving fluid. The metal corrodes to recreate its oxide layer but loses material in the process. In this case, both terms ("corrosion-erosion" and "flow-accelerated corrosion) describe a similar cause for the corrosion observed at the bottom of the pipe – steam condensate was able to puddle near the pipe weld and movement from the steam flow caused the material loss observed at the bottom of the bottom. The condensate accumulation was made more likely because this area of the pipe has a flat slope and the weld bead on the inside of the pipe provided an area for the condensate to collect.

The lowest remaining wall thickness measurement in the corrosion area was 0.06-inches, significantly thinner than the pipe's nominal wall thickness of 0.375-inches. Although the lowest remaining wall thickness reading was 0.06-inches, this reading was 4 inches away from where the pipe ruptured. Wall thicknesses along the rupture were around 0.134 inches. Therefore, although Affiliated's report states that the corroded wall section was near the initiation site of the rupture; the wall loss was not the cause of the rupture.

Figure 10 – Flow-Accelerated Corrosion on Bottom of Pipe, Taken by Affiliated

Radiographic testing was performed on the two pipe welds joining the 1932 pipe and 1991 pipe. Affiliated notes that radiographic testing found defects on the welds, such as inadequate penetration, slag inclusions, and porosity. The defects on the welds would have caused the welds to not meet the code requirements of API 1104, 17th Edition.[15] However, Affiliated concludes that the weld defects were not causal to the incident, as the rupture did not originate at the weld. Affiliated's analyses show that the rupture had initiated in the 1932 pipe and then propagated along the welds, instead of continuing into the 1991 pipe. Staff notes that the steam regulations in 16 NYCRR Part 420.9(d) require Con Edison to

[15] The 17th Edition of API 1104 was the edition of the specification that was current in 1991.

nondestructively test 10% of new field welds made on existing steam facilities in each calendar month. However, this weld was installed on February 16, 1991, prior to when 16 NYCRR Part 420.9(d) came into effect on March 6, 1991.[16] Staff recommends and Con Edison agrees, that Con Edison will submit a revised procedure that requires non-destructive examination of 50% rather than the 10% required by Code of new field welds made on existing steam pipe facilities within a month.

In its report, Affiliated concludes that a localized overpressurization event from an excessive internal pressure pulse caused the observed failure mode of the steam main. Affiliated characterizes the failure as initiating at the bottom of the 1932 pipe, translating along the axis of the pipe, until it reaches the weld, at which point it propagates along the heat-affected zone of the weld. Affiliated describes the rupture as a 'fish-mouth' configuration (see Figure 9), exhibiting plastic deformation. Plastic deformation indicates that the pipe failed due to an overpressure event, since it indicates that the pipe exceeded its yield strength.[17]

In addition to its analysis of the pipe failure mode, Affiliated also provides further evidence that the pipe failure was due to an overpressure event: the pipe exhibited notable bulging around the circumference of the 1932 pipe, continuing

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[16] Though not required by the regulations at the time, Staff asked Con Edison whether it had performed nondestructive examination of the weld in February 1991. Con Edison stated that it does not have nondestructive records from that time period, and therefore cannot determine whether the weld was subject to nondestructive examination.

[17] As compared to other failure modes, such as fatigue mode failure, in which the material could fail below its yield strength.

into the 1991 pipe, in the area where the pipe ruptured. The bulging around the pipe provides strong evidence that the pipe was subjected to a local overpressure condition (for example, water hammer), since the surrounding pipe likely would not have exhibited bulging if it had failed at normal steam system operating pressures. In addition, microscopic examination of the rupture location shows grain flow in the direction of applied stresses, providing further evidence that the pipe had plastically deformed and exceeded its yield strength.

To further determine whether the pipe had ruptured due to an overpressure condition, Staff requested that additional engineering analysis be performed. Affiliated subcontracted Gilad Marine Facilities Engineering (GMFE) to perform calculations based on the API 579 Fitness for Service specifications and Mechanical Solutions, Inc. (MSI) to perform a finite element analysis.[18] Based on the API 579 calculations, GMFE found that the pipeline would be suitable for operating pressures up to 297 psig, which is greater than the steam system maximum operating pressure of 200 psig in this area.[19] In addition, GMFE conducted a pipe stress analysis using CAESAR II software to determine if existing stresses on the pipeline were

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[18] Finite element analysis is a numerical method that allows stresses on pipelines to be calculated over complex objects

[19] Kirsner states in its report that the pipe would not have passed the API 579 Level 1 Fitness-for-Service analysis due to the less than 20% remaining wall thickness reading on the pipe. Con Edison disputes this, stating that the finite element analysis shows the pipe would not have ruptured until 775 psig and the finite element analysis serves as a Level 3 analysis under API 579. Staff notes that the primary purpose of the API 579 evaluation was to use the calculations within the standard to determine if the pipeline could operate at intended pressures at the time of the incident, not as an evaluation to determine if the pipe was fit for future use.

excessive. GMFE found that pipe stresses remained low for the pipeline when subjected to operating and expansion load.

Affiliated subcontracted MSI to perform a finite element analysis to calculate the pressure necessary to cause the pipe to burst, based on the measured wall thicknesses on the ruptured pipe section. MSI's report states that the wall of the steam pipe would begin to yield at 136 psi in localized areas, but strains remained low until approximately 500 psi, suggesting that the pipe had significant pressure-carrying capability up to that point. MSI calculates the burst pressure to be 775 psi. The results also support the conclusion that the pipe ruptured because of a local over-pressurization event: the weakest portion of the steam main experienced the greatest amount of plastic deformation.

Therefore, the analyses performed show the cause of the pipe rupture was due to a local overpressure condition. Given that local steam pressure sensors in the area did not show steam main pressure exceeding 167 psig[20] at the time of the incident, Staff investigated the most likely source of the overpressure condition in the steam pipeline – a water hammer condition. As detailed in the next section of this report, Staff ultimately concluded that water hammer was the only plausible cause of the overpressure condition.

VII. Water Hammer Analysis

To investigate the water hammer component of the rupture, Staff contracted with water hammer specialist Kirsner Consulting Engineering, Inc. (Kirsner). Kirsner concludes that a condensation-induced water hammer (CIWH) would be the only

[20] The nearest pressure sensor is the South Gramercy Park Pressure Sensor. The highest reading observed within 24 hours of the incident was 166.41 psig at 9:55 AM on July 18th.

possible explanation for the overpressure condition that resulted in the steam pipe rupture.

Water hammer, in general, is the pressure surge caused when a fluid is forced to change direction suddenly. A common example of water hammer is when a valve is closed suddenly in a water line. CIWH is a specific type of water hammer that can occur in a steam system. CIWH, or rapid steam bubble collapse, occurs in steam systems when a steam bubble becomes entrapped in subcooled condensate. The steam bubble rapidly cools and collapses, causing condensate to rush in to fill the void. The collision of the condensate results in an overpressure condition. Water hammer in a large steam system can cause pressures in excess of 1,000 psig.

One of the conditions necessary for CIWH to occur is the presence of large amounts of condensate inside the steam main, enough to fill up at least 50% of the main. In addition, the condensate within the steam main must be "subcooled," which means that the condensate must be at least 72 degrees Fahrenheit cooler than the surrounding steam.

The only release of enough cool water was identified at the fire water service line to 135 Fifth Avenue, which was found separated after the rupture, and is the likely source of the water that would have to have been needed to cool the steam main enough to produce large amounts of condensate. Kirsner notes that the water from the water service line could provide the cooling necessary to generate enough condensate and create the "subcooling" condition necessary for a water hammer event.[21]

<u>Drainage Through Housing</u>

[21] Staff checked with the City of New York and confirmed that no sewer or water mains in the area had broken nor significant leaks found

As explained previously, an external source of water that infiltrated into the steam main housing and the configuration of the steam main housing allowed water to build up around the steam main. The housing directly underneath the water service was a newer style concrete housing, installed in 2005. However, approximately 10 feet north of the fire line are older cast iron housings (circa 1932). The cast iron domes for the older housing were found corroded to the point that there were holes in the top of the housings (see Figure 11). It appears that water could have entered the steam housing through holes in these cast iron housings.

Figure 11 – Cast Iron Housing Removed from Rupture Site, Image Taken by Staff

Steam mains are generally designed to allow water to drain from the steam main housing. That is, housings are usually designed with a slope, so that gravity will pull any water that enters the housing out, by flowing downward into manhole vaults. In addition, housings may contain drains that allow water to flow directly into the sewer.

Kirsner notes that Con Edison's steam mains did not allow for adequate drainage of the condensate from the steam main housing. The restrictions on adequate drainage in the area of this steam housing include, first, approximately 105 feet south of the rupture location (in front of 139 Fifth Avenue), there was a partial dam and drain. The partial dam went up to at least the bottom of the steam main, though it did not fully enclose the housing. Kirsner states that the dam was intended to collect water that infiltrated the housing. The collected water would then be removed to the sewer via a drain in a sump next to the dam. The drain was found to be in a closed position after the incident, thus preventing water from being removed from the dam and potentially allowing water to collect in the housing at this point, which could cause the water to impinge the steam main.

The second location that would cause water to collect in the housing was located 183 feet south of the rupture location, near the intersection of 20th Street and Fifth Avenue. At this location, there was a manhole vault that was abandoned by Con Edison in 2005. When Con Edison abandoned this manhole vault, it did not install a means of allowing drainage to flow through the housing into manhole vaults at 20th Street and Fifth Avenue, where the water could be removed. The abandoned manhole vault encircled the entire steam drain and acted as another blockage that prevented water from draining out of the housing, also allowing water to submerge and cool the steam main.

Kirsner also notes that, based on Con Edison's constructions drawings, it is unclear how the drainage from the older-style housings was connected to the newer concrete housings.

A video obtained from the Verizon store at 139 Fifth Avenue shows a plume of steam vapor from a valve access cover in front of the store (see Figure 12 below). The steam vapor starts at 4:17 AM and ends at approximately 5:44 AM. The video provides strong evidence that water had infiltrated the steam housing, began boiling off and cooling the main, and then stopped once the main had subcooled and the condensate stratified to the point where the outer surface of the main was no longer hot enough to boil off the water. This cooling resulted in the condensate necessary to cause the water hammer condition.

Figure 12 - Screen capture of steam leaking from valve access cover at 4:56 AM

<u>Method of Water Hammer</u>

Based on the known facts, the water hammer formed was a less conventional type of water hammer, what Kirsner terms "The Two-Opposing Slug CIWH." In the conventional water hammer scenario, one end of the pipe is completely filled with subcooled condensate. A single slug, which is a mass of water that blocks or impairs steam flow in the pipe, entraps a steam bubble within the subcooled condensate. The bubble then rapidly collapses, resulting in a water hammer.

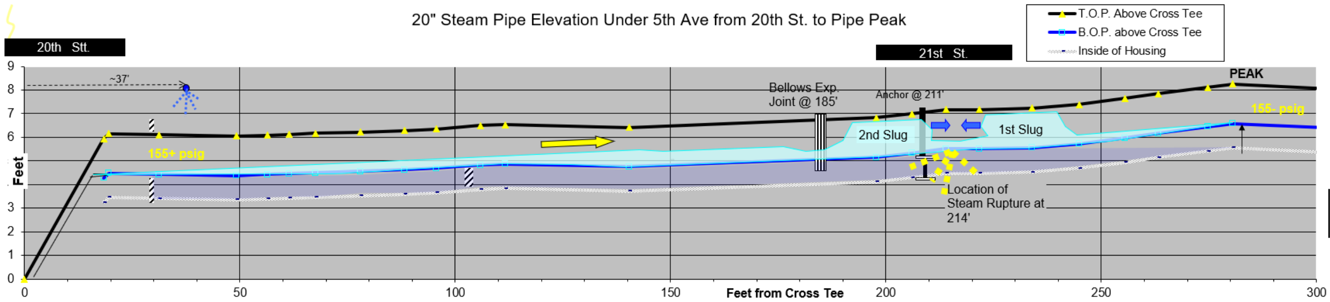

Figure 13 – Diagram of Two-Opposing Slug Water Hammer Mechanism (From Kirsner Report)

In the Flatiron Steam Incident, the most likely cause of the water hammer was two opposing slugs colliding into each other. As shown in Figure 13, two slugs entrap a bubble of steam. The trapped steam suddenly condenses and collapses, causing the two slugs to collide into each other causing water hammer. Kirsner concludes that this is the most likely cause of the CIWH at 21st and Fifth Avenue for two reasons.

First, for the more common water hammer scenario to occur, conditions must exist for subcooled condensate to build up and completely fill the pipe. Because the rupture occurred in the middle of a section of steam pipe run and near a relative high point, cool water accumulation could not occur here because there was no apparent area at which subcooled condensate would hold to fill the pipe. Second, there is an expansion joint 30 feet south of the incident location, so if water had filled the pipe, the resulting pressure wave would flow through to the expansion joint and damaged it.[22] However, upon examination during the investigation, the expansion joint exhibited no significant damage. Because neither of these conditions

[22] Expansion joints, such as the one located on East 21st and Fifth Avenue, contain bellows which allow for the expansion and contraction of the fitting. However, prior experience has shown that bellows are susceptible to damage if near a water hammer event

occurred, Kirsner discounted the traditional causes of water hammer. What Kirsner calls the "Two-Opposing Slug CIWH" creates a highly localized overpressure event, thus explaining the lack of damage to the expansion joint.

Though not noted in Kirsner's report, additional evidence that a water hammer caused the rupture is that steam RMS temperature sensors on steam traps from 22nd Street and Fifth Avenue show that the upper trap inlet temperature had decreased from approximately 360 degrees Fahrenheit to 351 degrees Fahrenheit in the upper trap inlet temperature, at approximately 4:30 AM to 5:00 AM on the morning of July 19th. While this is not a sufficient temperature to warn of an imminent or likely damaging water hammer, in retrospect, one explanation for this temperature decrease is that the large amount of condensate created was being pushed north by steam flows towards the traps at 22nd Street and Fifth Avenue and cooling those traps.

Wall Loss, Consideration of Other Scenarios, and Recommendations by Kirsner

Kirsner notes that the pipe in the rupture area was significantly thinned. Approximately 6 inches away from where pipe had ruptured, the 0.375-inch nominal wall thickness of the pipe had a remaining wall thickness of 0.06-inches, measured at the lowest point. Although Kirsner concludes that the steam main failed as a result of a water hammer event, as opposed to the steam main failing due to normal operating pressures in the steam system, Kirsner identifies the wall loss due to corrosion in the pipe wall as a concern. In its report, Kirsner recommends that Con Edison investigate all instances of wall loss in its stock of 1932 and older pipe.

Kirsner also considered other ways the water hammer might have occurred but ruled them both out. For instance, Kirsner considered whether the water hammer was caused by a steam trap failure. Kirsner rejected this possibility because post-incident testing did not show the steam traps at Fifth Avenue & 20th Street and traps at Fifth Avenue & 22nd Street were blocked. The second possibility Kirsner tested was whether the steam traps became overwhelmed by condensate. For this to occur, given that Con Edison's steam traps had more than adequate capacity, Kirsner concluded that for the steam traps to be overwhelmed there would have needed to be an implausibly high rate of condensate generation.

Kirsner concluded his report by making three recommendations to Con Edison. First, Con Edison must refocus on securing workable drain paths from steam pipe housings. Second, Con Edison must investigate and remediate instances of wall loss in its stock of vintage steam pipe. Lastly, Con Edison should investigate the feasibility of reducing the steam pressure system during the summer months. In making the third recommendation, Kirsner notes that reducing steam pressures in the system would reduce the magnitude of a water hammer event.

Discussion of Kirsner Engineering Recommendations

Kirsner's first recommendation states that Con Edison must refocus on securing workable drain paths from steam pipe housings. Staff recommends and Con Edison agrees, that Con submit to the Secretary of the Commission revised design specifications that include the requirements of drainage continuity through steam main housings for new construction, repairs, and retirement projects. Since the lack of drainage through a previously abandoned manhole was a contributing factor to this event, the revised specifications will ensure that new steam construction has adequate drainage through steam housings.

Con Edison should also examine the feasibility of assessing the steam housings for blockages during either its steam system assessment (detailed further in this section) or during other opportunistic moments when the steam main housing is exposed (for example, during construction or repairs). An example of this could include inspecting the housing with a camera probe. However, Staff does acknowledge the difficulty in assessing the housing. For example, the space in the housings is limited and most of Con Edison's mains within the housings are covered with asbestos; therefore, anything removed would be treated as contaminated. Staff recommends and Con Edison agrees that, by September 30, 2021, Con Edison will evaluate and submit to the Records Access Officer a confidential report on the feasibility of inspecting its steam pipe housings for blockages.

Finally, as part of its steam main assessment program, Con Edison should also identify and determine if there are any dams, abandoned structures, and other facilities that could impair drainage through its steam main housings. By examining potential obstructions or gaps to its housing drainage as part of its steam system assessment, Con Edison would address Kirsner's first recommendation regarding steam main housings.

Kirsner's second recommendation states that Con Edison must investigate and remediate instances of wall loss in its stock of vintage steam pipe, noting that all 1932 and older pipe must be checked. In making this recommendation, Kirsner cites the wall loss on the 1932 vintage pipe at the rupture site. While Staff agrees with Kirsner's concerns regarding the wall loss on the pipe, Staff notes that, in this instance, the thinner pipe did not cause the rupture; the pipe still required an overpressure event far greater than the maximum operating pressure to rupture. At most, the wall loss is a contributing factor to the event in that it reduced the strength of the pipe and increased the likelihood that the pipe might rupture during an otherwise-caused overpressure event. As noted by Kirsner, water hammer events often result in pressures over 1,000 psig, which is at least 800 psig more than the maximum operating pressure of this steam pipe. For example, Staff's report[23] estimates that the estimated water hammer during the 2007 41st Street and Lexington Avenue event resulted in pressures of at least 1,060 psig. For the Flatiron steam incident, MSI calculates, through finite element analysis, that the pressure required to burst the pipe would need to have been at least 775 psi. So, due to the wall loss in the pipe, the pipe was able to rupture from a lower magnitude water hammer event, but it still required an overpressure event far greater than the 200 psig maximum operating pressure in the steam system.

Staff has requested that Con Edison also assess for internal corrosion on the rest of the 1932 pipe retained from Fifth Avenue. Affiliated performed the assessment for internal corrosion on April 4th and April 5th, 2019. The internal corrosion assessment identified other areas of pitting and material loss, though it is unclear whether this corrosion was also caused by flow-accelerated corrosion. To further analyze the causes of the noted wall loss in the steam system, Staff recommends and Con Edison agrees, that Con Edison will contract with a third-party to study the causes of steam main corrosion and identify mitigation methods. The report will be submitted by November 30, 2021. Kirsner's second recommendation notes that all the 1932 and older pipe in Con Edison steam system must be assessed. However, Kirsner does not address why the corrosion would be limited to only 1932 and older pipe in Con Edison's steam system. Therefore, as part of the third-party

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[23] Case 07-S-0984, Consolidated Edison Company of New York Inc. – Steam Pipe Rupture, Report on Steam Pipeline Rupture 41st Street & Lexington Avenue Consolidated Edison Company of New York. Inc. (issued February 13, 2008) (2008 Report).

corrosion study, Con Edison will examine the susceptibility of pipe vintage on corrosion.

Staff notes that the corrosion-erosion or flow accelerated corrosion noted on the pipe appears more related to the pipe configuration (e.g. pipe slope, proximity to welds, etc.) than the pipe vintage. Near the rupture location, the pipe slope was flat[24] and there was a weld bead. Both assisted in allowing condensate to pool. Therefore, Staff modifies Kirsner's recommendation and believes Con Edison should identify criteria to assess for corrosion of Con Edison's steam pipe throughout its entire steam system.

On August 17th, 2019, Con Edison presented its Steam System Assessment Plan to Staff as a follow-up to the Company's own investigation of this incident. Con Edison filed an "Investigation Summary and Action Plan" (Con Edison Plan) on January 22nd, 2020.[25] In addition, Con Edison has agreed to develop and submit to the Records Access Officer by October 20, 2020, a steam main rupture risk assessment program, a steam main inspection program based on the results of the risk assessment, and a remediation plan based on the assessment and preliminary inspection results. As part of the submitted steam main rupture risk assessment program, Con Edison will use existing data, such as pipe geometry, leak history, steam flow direction, insulation type, etc., to identify steam mains that are higher risk. Con

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[24] Survey measurements show that the steam pipe from East 21st Street to East 20th Street, along 5th Avenue, was sloped downward to allow condensate to drain towards manholes. However, the pipe slope was flat in a short section near the rupture area.

[25] Case 18-S-0448, Consolidated Edison Company of New York, Inc. – Steam Rupture, Investigation Summary and Action Plan (filed January 22, 2020).

Edison will identify which of those mains are to be inspected proactively, using technology such as robotic camera inspection. The inspection will allow Con Edison to assess the condition of its steam mains and to determine if there any other locations with excessive corrosion or areas that need further investigation for any other reason. Con Edison's steam system assessment would address Kirsner's second recommendation to investigate the condition of steam mains in its system.

As part of its steam system risk rupture assessment plan, Con Edison should identify conditions on its steam system that require remediation. Examples of conditions requiring remediation would include severe corrosion, and undrained low points in the steam mains, etc. Con Edison should also examine if additional steam trap assemblies are needed and at which any locations based on the results of the findings of the steam system assessment.

Kirsner's third recommendation states that Con Edison should investigate the feasibility of reducing steam pressure in the steam distribution system to operate well below 155 psig during summer months. Kirsner proposes reducing steam pressures to 67 psig. Staff supports this recommendation but notes that the feasibility of it may be limited by steam air conditioning customers, who require minimum pressures of 125 psig in the summer. Therefore, as part of the feasibility assessment, Con Edison should address those customers that require high steam pressures. Con Edison should also expand its feasibility assessment to other parts of the year, instead of limiting it to the summer months. Staff recommends, and Con Edison agrees, that Con Edison will evaluate the feasibility of reducing steam pressures during portions of the year, including determining which customers require high pressure steam (greater than 100 psig). By September 30, 2021, Con Edison will submit to the

Records Access Officer a confidential report discussing the results of this assessment.

VIII. Steam Remote Monitoring System (RMS)

East 41st Street and Lexington Avenue Incident In 2007

Prior to the steam main rupture in Flatiron, the most recent major incident on Con Edison's steam system occurred in 2007 at the intersection of East 41st Street and Lexington Avenue. Staff performed an investigation and issued the 2008 Report. The Lexington Avenue steam incident occurred at approximately 5:56 PM on Wednesday, July 18, 2007, when a 20-inch diameter steam pipeline owned and operated by Con Edison ruptured, making a crater at the intersection of 41st Street and Lexington Avenue in Manhattan. The rupture resulted in one fatality and two serious injuries.

Staff determined the cause of the 2007 rupture to be CIWH, which had been triggered by heavy rainfall accumulation in a steam manhole. One of the primary causal factors that contributed to the incident were obstructed traps in the area, which were unable to remove excessive condensate from the steam main, facilitating the conditions for a water hammer event.

In the 2008 Report, Staff recommended that Con Edison conduct feasibility analyses for a remote monitoring system to detect real-time water infiltration into subsurface structures containing steam pipeline facilities, and that the Company conduct a feasibility analysis on systems to detect condensate levels within steam piping at specific locations identified based on history of excessive condensate formation requiring actions to alleviate potentially unsafe conditions. The

Commission ordered Con Edison to implement Staff's recommendations in its February 13, 2008 Order.[26]

Progress of Remote Monitoring System (RMS) Technology

In response to Staff's recommendations in Case 07-S-0984 in 2008, CECONY designed and developed its RMS that same year. The RMS was meant to alert Con Edison to conditions that, if left uncorrected, could result in a possible water hammer or a hazardous condition.

Con Edison's remote monitoring system consists primarily of two components: manhole floats/pump manhole floats and trap temperature sensors.

Manhole Floats/Pump Manhole Floats - A cause of the 41st Street and Lexington Avenue incident was a steam main in a deep location had become submerged in water, resulting in the build-up condensate inside the steam main. As a result, Con Edison developed a "float" sensor for its RMS system. The float sensors would be placed inside critical Con Edison manholes and would trigger an alarm at Con Edison's steam control if the float detected water levels building up to "low," "medium," or "high" levels inside the manhole. The purpose of the float sensor is to give Con Edison advance notice if water levels are reaching levels that could impinge the steam main contained in those structures.

Con Edison also places floats in manholes that contain a pump, which it refers to as "pump manhole floats." These floats function the same way as typical manhole floats. Both alarm as water levels reach "low," "medium" or "high" levels in the structure. But, when placed in a pump manhole, the water

[26] Case 07-S-0984, supra, Order Directing the Company to Implement Staff Recommendations or Show Cause (issued February 13, 2008).

level alarms also indicate that the pump is not working or that the pump is being overwhelmed by water, since there is water building up in the structure.

Figure 14 – Photo of Manhole Float, Taken by Staff

Figure 15 – Photo of Trap Assembly During Testing on November 1st, 2018, Taken by Staff

<u>Traps</u> – Because one of the contributing factors to the 2007 incident were traps that were blocked, trap temperature sensors were installed throughout the RMS system to indicate the functionality of the traps. A trap that has been obstructed will cool down as the trapped steam condenses in the piping (a "cold trap" condition). If the trap temperature drops below 300 degrees, Con Edison will receive an alarm from the trap temperature sensor, since it indicates that the trap may not be functioning.

Each of these components are connected to a remote telemetric unit (RTU) box which, in theory, communicates back to Con Edison Steam Control. Con Edison currently has approximately 895 RTUs in its steam RMS system.

Figure 16 – Photo of Remote Telemetry Unit (RTU) Box

<u>RMS Reliability at Incident Area</u>

Due to the high heat and humidity intrinsic to a steam system, reliability of the RMS system, in general, has been problematic since its initial installation. Con Edison has made continuous improvements over the years, however, to improve the reliability of its RMS system. Each component has undergone numerous iterations. For example, for the RTU boxes, the Company transitioned from polycarbonate enclosures in 2008 to fiberglass reinforced polyester enclosures in 2015 because the polycarbonate material became brittle to the point of collapse from the heat cycling typically seen within the steam manholes. Similarly, in 2011, the Company moved from wired communications to wireless cellular antennae communications.

Since January 2016, CECONY has maintained an internal Key Performance Indicator (KPI) metric for tracking RMS Reliability. Reliability has been determined by an RTU box successfully communicating with the Con Edison's steam Control Center. The target reliability of the RMS system as part of this metric was 90%. Con Edison recorded an average of 86%, 93%, and 91% performance in this metric in 2016, 2017, and the first half of 2018, respectively.

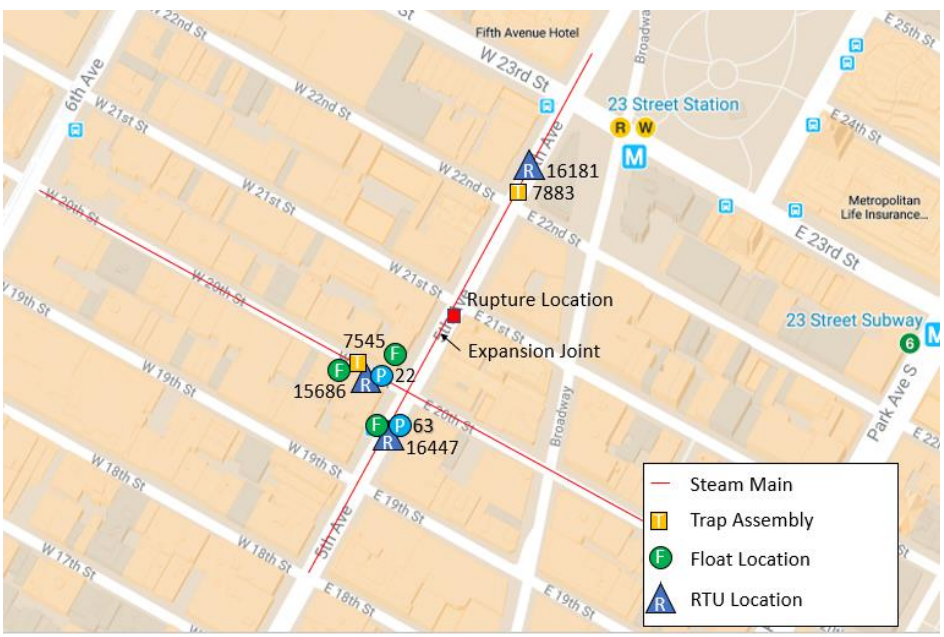

Figure 17 - Map of Equipment Tested from 20th Street and Fifth Avenue

Despite this seemingly high measure of performance, much of the RMS in the Flatiron area near 21st Street and Fifth

Avenue was not functioning at the time of the incident. For instance, of the eight RTU boxes in the area of the rupture, five were not reporting correctly at the time of the incident.[27]

The part of the RMS system in the immediate area of the incident was two RTU boxes (#15686 and #16447) near the intersection of East 20th Street and Fifth Avenue, as shown in Figure 17. Data showed that RTU #15686 had not been transmitting information since before July 5th, 2018.[28] Testing on November 1, 2018 confirmed that the RTU was not functioning. RTU #15686 was connected to manhole float #MVMH1006 and pump manhole float #PMH7642. The two floats were not retained by Con Edison, therefore the functionality of the two float devices could not be tested. Even if the floats had been tested and found functional, the information they provide would not have transmitted to Con Edison since RTU #15686 was not functioning. In addition to the floats, Con Edison had a trap temperature RMS attached to RTU #15686. The trap temperature thermocouple was not tested, as it was connected to a non-reporting RTU.[29]

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[27] The following RTUs in the area were not reporting on the date of the incident: 15686, 15746, 15750, 16199, and 16206.

[28] Due to the transition of the RMS system from REMMS (Remote Monitoring and Manhole System) to Supervisory Control and Data Acquisition (SCADA,), Con Edison was unable to provide RMS data prior to July 5th, 2018.

[29] Although the RTUs were not reporting correctly, it is unlikely the information they provide would have prevented the rupture. The path of water through the steam housings was blocked by the abandoned manhole, therefore this would impede water from flowing into manholes at the intersection of East 20th Street and Fifth Avenue that contained float water level monitoring. In addition, the pump in the nearest manhole (Pump #63) was found functional after the event. Water that did make its way to the manhole would have been removed by the pump.

RTU MH	As Found Condition	Test Result	Address	Equipment Manhole	Equipment Monitored	Status at Time of Incident	Test Result
15686	Malfunctioning	Malfunctioning	20ST W/O FIFTH AVE	MVMH10067	Water Level Sensor	Not Communicating with RTU	Not Retained
				DMH10471	Trap Station		Not Tested
				PMH7642	Pump Water Level Sensor		Not Retained
16447	Operational	Operational	FIFTH AVE S/O 20ST	MVMH8253	Water Level Sensor	Communicating, but Components Not Sending Useful Data	Only Top Float Could be Tested – Top Float Functional
				PMH10559	Pump Water Level Sensor		Testing Indicated Some Wiring Issues – At High Float Water Level, Appears to Function
16181	Operational	Not Tested	FIFTH AVE N/O 22ST	TMH7883	Trap Station	Communicating with RTU	Not Tested
				DMH7879	Water Level Sensor		

Figure 18 – Summary Table of Test Results, From Staff

RTU #16447 was the other RTU at the intersection of East 20th Street and Fifth Avenue. Two RMS components were attached to the RTU, manhole float #MVMH8253 and pump manhole float #PMH10559. During testing on November 1, 2018, manhole float #MVMH8253 was found to be partially defective. The wires for the bottom and middle floats were found damaged within the float body; therefore, only the top float was able to be tested. The top float was found functional during testing on November 1, 2018. The other float, pump manhole float #PMH10559, indicated some issues with wiring during testing on November 1, 2018. Specifically, the "low" water level float did not register when submerged in water at the "low" level but registered when submerged at "high" water level (along with "medium" and "high" level floats). The "medium" water level float registered properly when submerged at that level. Testing from November 1st, 2018 shows some functionality to both floats, at least at "high" water level alarms.

Staff reviewed the RMS data transmitted by RTU #16447 immediately prior to the incident. Both floats #MVMH8253 and #PMH10559 appeared to be in an error state on the morning of July 19th and in the weeks prior to the incident. Even though testing showed some functionality to each of the floats, the float water level RMS was not sending useful data to Con Edison.

RTU #16181 was located further north of the incident at the intersection of 22nd Street and Fifth Avenue. RTU #16181 was not tested post-incident, but the RTU was functioning at the time of the incident (as evidenced by data Con Edison received and recorded) and the two components appeared to be transmitting valid data. In fact, as noted earlier in this report, the RMS trap temperature sensors at this location showed trap temperatures decreasing from 360 degrees Fahrenheit to 351 degrees Fahrenheit in the upper trap inlet from 4:30 AM to 5:00 AM, a possible indication of large amounts of condensate entering the traps, but not enough of a change to warrant an active response from Con Edison.

After the incident, Con Edison reported that its RMS reliability KPI only addressed the reliability of the RTU boxes, it did not address the reliability of each individual component connected to the RTU box. For example, RTU #16447 was functioning, but both components (floats #MVMH8253 and #PMH10559) connected to the RTU box were not reporting useful data. In Con Edison's metric, it would have counted as functioning. In January 2019, the Company changed its metric to account for the functioning of float and temperature sensor components attached to the RTU box.

RMS Action Items

Steam RMS is an important means of continuous monitoring of the steam system. It can alert Con Edison to abnormal conditions on its steam system in real-time before those conditions develop into a possible incident. While Staff acknowledges the difficulty in maintaining electronics in Con Edison's steam system environment, Con Edison must take actions to ensure that each component (RTU, floats, trap temperature monitoring) of its steam RMS system is functioning and sending valid data. For long term reliability, this would primarily entail improvement to RMS component designs such that they can withstand the steam system environment, but short-term actions might include more crews assigned to replace RMS components and shortened intervals between repairs.

In the Con Edison Plan, Con Edison identifies measures it will take to improve the reliability of its steam RMS. As part of the Con Edison Plan and the agreement reached in this case, Con Edison will continue its RMS R&D program to enhance the current design of the remote telemetry unit ("RTU") and associated devices while continuing to work on improving RMS reliability at critical locations. The Company is developing new prototypes that will seek to improve reliability and will test viable prototypes in the laboratory and field. By January 31, 2022, Con Edison will meet with DPS Staff to review the results of these efforts and discuss potential RMS reliability goals.

Currently, Con Edison's current steam RMS system does not directly measure levels of condensate inside steam pipes. As such, it only provides Con Edison indirect warnings of the precursors to water hammer. For example, float sensors indicate if there is water building-up in vaults, which could ultimately impinge the steam main and cause excess condensate generation. But, Con Edison does not have RMS components that would directly monitor if there were excessively high levels of condensate within the steam main.

Recommendation 12 in the 2008 Report states that "Con Edison must also conduct feasibility analyses on systems to detect condensate levels within steam piping at specific locations identified based on history of excessive condensate formation requiring actions to alleviate potentially unsafe conditions." Con Edison has made efforts over the past ten years to find technologies that could directly measure the levels of condensate. Con Edison is currently exploring two technologies that could provide real-time monitoring of conditions within the steam main itself. As part of the Con Edison Plan and as part of Con Edison's agreement with Staff in this case, Con Edison will evaluate a prototype acoustic/vibration sensing device and, additionally, Con Edison will evaluate a prototype condensate level detection device. By December 31, 2020, Con Edison will submit to the Records Access Officer a confidential report reviewing its preliminary findings on each device's performance, reliability, and practicality.

In the meantime, Con Edison may be able to use its existing RMS components to provide better warnings of water hammer. For example, the existing trap temperature data monitors at East 22nd Street and Fifth Avenue did provide an indirect indication of condensate in the steam main. The event on July 19, 2018 resulted in excess condensate flowing towards the traps at East 22nd Street and Fifth Avenue. As such, the traps showed lower temperature. The temperature decrease was not significant enough to alert Con Edison to this event, but shows that Con Edison may be able to modify existing RMS alarms for steam trap temperature to function as an indicator for excessive condensate accumulation in steam mains. As part of the Con Edison Plan and the Staff's agreement with the Company in this case, Con Edison is evaluating current trap temperature and water level alarming strategies to identify potential enhancements the Company can make. By December 31, 2021, Con Edison will submit to the Records Access Officer a confidential report on the feasibility of proceeding with any potential enhancements.

IX. Status of Traps and Pumps

In addition to testing the RMS components on November 1st, 2018, the stream traps nearest to the incident location were tested. These included the steam traps at East 20th & Fifth Avenue and at East 22nd & Fifth Avenue.

Testing did not show any blockages in either of the steam trap assemblies. During testing on November 1st, the steam traps at East 20th Street and Fifth Avenue failed in the open position ("blowing"). While this is an abnormal operating condition for the traps, in this state, the traps would still be removing condensate from the main. Testing showed the steam traps at East 22nd and Fifth Avenue to be operating normally. Radiographic and boroscopic examination did not show any blockages and obstructions in either of the trap assemblies. There is no evidence to suggest that steam traps problems contributed to this incident.

In addition to traps, two pumps one block from the rupture, at the intersection of East 20th and Fifth Avenue (Pump #22 and Pump #63), were in place. Both pumps were in "continuous operation" at the time of the incident, meaning that the pumps were continuously running. Pumps used by Con Edison are normally connected to floats (the same type of floats used by its steam RMS) to control the on/off cycling of the pump, which helps lengthen the life of the pump. When these pumps were installed, however, they were placed in continuous operation. For each pump, Con Edison states, the pumps were placed into continuous operation because Con Edison did not have floats available at the time of the installation.

Con Edison states that Pump #22 was placed into service on June 8, 2018 to replace a pump that was found not functioning during an inspection on the same day. The nonfunctioning pump being replaced had been placed into continuous operation on April 24, 2018, less than two months earlier.

Pump #63 was replaced on June 18, 2018. The pump it was replacing was found to be not working during an inspection two days prior, on June 16, 2018.

Based on a review of the manual for the pumps used by Con Edison, Staff found that the pump used for Pump #22 is designed to be submerged and is not intended to "run dry."[30] Staff notes that Con Edison heavily modifies that pump model used as Pump #22 to better accommodate usage in the steam system. However, Staff still recommends that, if a pump in a steam manhole is left in continuous operation, Con Edison must ensure that the float and RMS in that pump manhole is functioning. If the float and RMS are not functioning, Con Edison should be required to perform daily inspections to ensure the pump is functioning. In addition, Staff recommends that Con Edison modify its operations and maintenance procedures to identify a timeframe in which a pump must be replaced if that pump is found not functioning and a maximum timeframe that a pump can be left in continuous operation. Con Edison agrees with these recommendations and will be submitting revised procedures by September 30, 2021 to the Secretary of the Commission.

Pump #22 was inspected on July 18th, 2018, one day prior to the incident. Con Edison's inspection documentation notes that Pump #22 was operating at the time. After the incident, both Pump #22 and Pump #63 were inspected when they were removed from the system on July 27, 2018. Pump #22 was found inoperable at the time, but Pump #63 was found

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[30] The manufacturer's manual for the pump used for Pump #63 states that the pump has dry running capabilities.

functioning. Both pumps were tested on November 1st, 2018. Similarly, Pump #22 was found inoperable during the testing, while Pump #63 was functioning.

X. Review of Steam System Operation and Maintenance Requirements

Staff reviewed records associated with Con Edison's periodic inspections required by the Commission's steam regulations contained in 16 NYCRR Part 420 "Distribution of Steam."

Regulation 16 NYCRR Part 420.8(a) requires steam traps and trap piping assemblies to be inspected for general condition and proper operation at least six times each calendar year, at intervals not exceeding ten weeks. Staff found that traps at 20th Street and Fifth Avenue were inspected most recently on January 16, 2018, March 19, 2018, and May 22, 2018. Steam traps at 22nd Street and Fifth Avenue were inspected most recently on January 3, 2018, February 28, 2018, May 2, 2018, and July 5, 2018. For both trap assemblies, recent inspections did not exceed the timeframes mandated by 16 NYCRR § 420.8(a). As noted in the previous section, post-incident testing on November 1, 2018 did not find traps to be obstructed or blocked.

Regulation 16 NYCRR § 420.8(c) requires accessible expansion joints to be inspected twice each calendar year at intervals not exceeding 30 weeks. Within the section of 20-inch steam main from 20th Street to 22st Street, there was one accessible expansion joint located between 21st Street and 22nd Street, approximately 138 feet north of the rupture location. The expansion joint was most recently inspected on January 15, 2018 and July 15, 2017. Inspections for the expansion joint were timely, within timeframes mandated by 16 NYCRR § 420.8(c) and those inspections did not show excessive joint expansion or contraction. Another expansion joint was located approximately

30 feet south of the rupture location, but this expansion joint was buried and not accessible, and therefore was not required by the regulation to be inspected. For both expansion joints, post-incident inspection did not show evidence of excessive expansion or contraction causing damage to the expansion joint.

Soon after the 41st Street and Lexington Avenue incident in 2007, Con Edison implemented S-11974 – "Rain Response Procedure." As part of the procedure, if the rain event trigger of ¾" of rain in a 3-hour period is met, then Con Edison will commence a vapor survey and inspection of priority structures. The most recent rainfall had been on July 17th, two days prior to the event, and met the rain response trigger. A Con Edison inspection of the manhole containing Pump #22 on July 18th showed no accumulation of water within the steam facility.

XI. Public Comment

DPS received one public comment in this case on September 22, 2018. The commenter stated that he was covered in debris from the steam explosion on July 19, 2018. In response to Con Edison's 30-day incident report posted on August 20, 2018, the commenter stated that Con Edison's report did not address the risk of direct body exposure to the bulk material tested at the site. The commenter requests that the Commission require Con Edison to perform a more thorough assessment of the conditions at the site and the possible health and detrimental effects to individuals from those conditions.

The Commission's regulations relating to steam (16 NYCRR Part 420) contain two subparts pertaining to asbestos. The first, 16 NYCRR §420.12 "Reports of incidents and interruptions," only addresses asbestos in so far as each steam corporation must report and file with the Department incidents that result in an airborne release of asbestos. The second, 16

NYCRR § 420.15 "Asbestos control," requires that each steam corporation have procedures to eliminate asbestos from accessible steam facilities, control and eliminate asbestos during any steam facility failure, and follow applicable rules and regulations regarding the removal, handling and disposal of asbestos materials. An assessment of the health impacts of asbestos is a review outside the expertise of the Department. Therefore, Staff recommends the comments be directed to the New York City Department of Environmental Protection or other environmental agency.

XII. Post-Incident Steam Leaks

Prior to the incident, Con Edison did not have any records of existing steam leaks at the intersection of East 20th Street and Fifth Avenue nor near the rupture intersection at East 21st and Fifth Avenue.

During post-incident investigation activities, interested parties, however, noted a slight steam vapor in the trench near the intersection of East 20th Street and Fifth Avenue. On November 14th, 2018, Con Edison identified a steam leak at that intersection. Con Edison traced the leak to a weld on the steam main. Con Edison repaired the weld leak on March 4th, 2019. After the weld repair, Con Edison identified a second leak near the anchor just south of the intersection of 20th Street and Fifth Avenue. Con Edison repaired the second leak on May 1st, 2019. During the second half of 2019, Con Edison raised the steam main at this intersection due to a high water table. While the noted steam leaks could have been present at the time of the incident, they would not have contributed to the water hammer-type event that caused the incident.

XIII. American Petroleum Institute (API) Recommended Practice (RP) 1173 Pipeline Safety Management Systems

In July 2015, the American Petroleum Institute released API RP 1173 "Pipeline Safety Management Systems." The recommended practice promotes a pipeline safety culture and provides a framework for operators to manage risk, adopt an environment of continuous learning, and improve pipeline safety. The recommended practice was originally developed for the hazardous liquid and natural gas pipeline industry, but Staff believes that Con Edison Steam would be able to adopt much of the standard to their operations. Staff recommends, and Con Edison agrees, that Con Edison Steam will evaluate the adoption of American Petroleum Institute Recommended Practice (API RP) 1173 "Pipeline Safety Management Systems." The confidential evaluation will include a baseline assessment/gap analysis of the steam system by a third-party vendor. Con Edison will submit the evaluation results confidentially to the Records Access Officer by March 31, 2022.

XIV. Action Items

1. By September 30, 2021, Con Edison will submit to the Commission's Secretary or Records Access Officer, as appropriate, a revised procedure that requires non-destructive examination of 50 percent of all field welds made on existing steam pipe facilities within a month rather than the 10 percent required by the Commission's regulations. If operational constraints and/or unforeseen circumstances prevent Con Edison from non-destructively examining 50 percent of welds performed in a given month, Con Edison shall submit a report to safety@dps.ny.gov, by the 15th day of the following month, explaining the

circumstances and listing the welds that had not been non-destructively examined that month. By September 30, 2022, Con Edison will meet with DPS Staff to review the results of the increased non-destructive examination of field welds and discuss potential changes to the percentage of welds to be non-destructively examined.

2. By September 30, 2021, Con Edison will submit a revised procedure to the Commission’s Secretary or Records Access Officer, as appropriate, that: (1) requires Con Edison to monitor the functionality of the Remote Monitoring System (“RMS”) float and associated Remote Telemetry Unit (“RTU”) box when a pump in a steam manhole is left in continuous operation and, if the RMS is not functioning, perform daily inspections to monitor pump functionality; (2) identifies a maximum timeframe that a pump can be left in continuous operation; and (3) identifies a timeframe within which a non-working pump will be repaired or replaced.

3. By September 30, 2021, Con Edison will evaluate and submit to the Commission’s Secretary or Records Access Officer, as appropriate, a report on the feasibility of inspecting its steam pipe housings for blockages.

4. By September 30, 2021, Con Edison will submit to the Commission’s Secretary or Records Access Officer, as appropriate, revised design specifications that include the requirement of drainage continuity through steam main housings for new construction, repairs, and retirement projects.

5. By October 30, 2021, Con Edison will develop and submit to the Commission’s Secretary or Records Access Officer, as appropriate,: (1) a steam main rupture risk assessment program and; (2) a steam main inspection program based on the results of its risk assessment and; (3) a remediation plan based on the assessment and preliminary inspection results, including a description of any mitigation actions taken since the start of the assessment and inspection program.

6. Con Edison will evaluate a prototype condensate level detection device. By December 31, 2021, Con Edison will submit to the Commission’s Secretary or Records Access Officer, as appropriate, a report reviewing its preliminary findings on the device’s performance, reliability, and practicality.

7. Con Edison will evaluate current trap temperature and water level alarming RMS strategies to identify potential enhancements. By December 31, 2021, Con Edison will submit to the Commission’s Secretary or Records Access Officer, as appropriate, a report on the feasibility of proceeding with any potential enhancements.

8. Con Edison will evaluate a prototype acoustic/vibration sensing device. By December 31, 2021, Con Edison will submit to the Commission’s Secretary or Records Access Officer, as appropriate, a report reviewing its preliminary findings on the device’s performance, reliability, and practicality.

9. Con Edison will continue its RMS R&D program to enhance the current design of the RTU and associated devices while

continuing to work on improving RMS reliability at critical locations. The Company is developing new prototypes that will seek to improve reliability and will test viable prototypes in the laboratory and field. By January 31, 2022, Con Edison will meet with the Department to review the results of these efforts and discuss potential RMS reliability goals. Con Edison's reliability goals and reporting will apply to critical locations until Con Edison proposes otherwise in a rate case or petition, or the Commission orders otherwise in a proceeding on the record and subject to notice and comment.

10. Con Edison will evaluate the feasibility of reducing steam pressures during portions of the year, including determining which customers require high pressure steam (greater than 100 psig). By September 30, 2021, Con Edison will submit to the Commission's Secretary or Records Access Officer, as appropriate, a report discussing the results of this assessment.

11. Con Edison will contract with a third-party to study the causes of steam main corrosion and identify mitigation methods. The study will examine the corrosion susceptibility of pipes of varying vintages and include a fracture mechanics evaluation to determine the effect various sized corrosion related flaws have on the structural stability of steam mains. Con Edison will submit the study to the Commission's Secretary or Records Access Officer, as appropriate, by November 30, 2021.

12. Con Edison Steam will evaluate the adoption of American Petroleum Institute Recommended Practice (API RP) 1173 "Pipeline Safety Management Systems." The evaluation will

include a baseline assessment/gap analysis of the steam system by a third-party vendor. Con Edison will submit the evaluation results to the Commission’s Secretary or Records Access Officer, as appropriate, by March 31, 2022.