Bureau of Alcohol, Tobacco, Firearms and Explosives

Redacted Origin & Cause Report

On August 10, 2016, the Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF) responded to the accident at 8701 Arliss Street in Silver Spring at the request of the Montgomery County Fire Marshal's Office. On August 11, 2016, the NTSB participated as an observer, while ATF and the Montgomery County Fire and Rescue Service (MCFRS) conducted their fire and arson investigation. On August 18, 2016, at the conclusion of their work, the NTSB conducted an investigation.

On September 23, 2016, the ATF provided the NTSB with its confidential Origin & Cause Report on the condition that the NTSB not disclose any part of the Report without ATF's authorization. The ATF has authorized the NTSB to disclose the following paragraphs, taken verbatim from the ATF Report, subject to redaction of personally identifying information. Any inquiries about the Report or its disclosure should be directed to the ATF's Baltimore Division Counsel, (202) 222-8278.

Ravi Chhatre

Investigator-In-Charge

DCA16FP003

Silver Spring, MD

NARRATIVE:

On August 10, 2016, at approximately 23:55 hours, an explosion and fire occurred at the Flower Branch Apartments located at 8701/8703 Arliss Street (designated "8701" and "8703"), Silver Spring, Maryland (Montgomery County Fire and Rescue Department units were initially dispatched to the neighboring building located at 8644 Piney Branch Road). The explosion and fire destroyed two, attached, fourteen-unit apartment buildings and damaged an adjacent apartment building. At least twenty-seven people were injured, including three firefighters, and seven people were killed as a result of this incident.

Data collection, including the scene examination and witness interviews, was conducted for several days and concluded on August 17, 2016.

SCOPE OF THE INVESTIGATION:

This report relates to an Origin and Cause Determination of an explosion and fire that damaged a multi-unit apartment building located at 8701-8703 Arliss Street, Silver Spring, Maryland on August 10, 2016. The cause was classified as UNDETERMINED.

Investigators gathered available data (information) related to the event and, based on that data, investigators developed and tested hypotheses as to the origin and cause of the explosion. When all reasonable theories had been vetted against the known data, a conclusion was drawn.

ANALYSIS OF BLAST DAMAGE and BLAST WAVE MIGRATION (data collection):

Examination:

For the purposes of this summary, the front of 8701 that faces Arliss Street is listed as Side A (West), Side B (North) is the fire wall between 8701 and 8703, Side C (East) is the wall that faces the courtyard, Side D (South) is the side that faces Piney Branch Road.

Terrace/Basement Level:

The main entrance to building and stairway fed to four doors and were identified for this document as follows:

The meter room was located at the bottom of stairs on the immediate left on the north side. This was the room directly under 8701 Apartment 101 that contained the water heater and the gas meters. The door was a fire door and was painted dark green on the outside and grey on the inside. This door opened inward towards the room. There were no other doors in this room. This door had two locks, a knob lock that was locked and a vertical dead bolt that was not locked.

8701 Apartment #11 (TR 11) was located at the bottom of stairs and to the diagonal left in the northeast quadrant. This was the only apartment on the terrace level for this building. This room was directly under 8701 Apartment #102. This door was a fire door, painted green with a gold door knocker and the number "11" on a plate above the knocker. There was an exterior door to the residence that was painted tan and it was not a fire door. This door was blown from its hinges and was locked at the time of the explosion.

8701 Apartment #12/Management Office was located at the bottom of the stairs to the diagonal

right in the southeast quadrant. This was the rental office for the building and was located directly under 8701 Apartment # 103. There were three doors in this office space. The first door was a fire door and was painted green. It was the access door to the stairway. The door had a locking knob and a vertical deadbolt that was missing.

The second door was an exterior door on the C side (east side) to the office that was painted tan and it was not a fire door. It had a vertical dead bolt and a locking door knob. Both were locked at the time of the blast. The door was still attached to the frame during the initial exam and was covered by fire debris during a later exam.

The third door was an exterior door on the D side (south side) of the office that was painted tan and it was not a fire door. This was the door nearest to the alarm panel in the office area. It had a vertical dead bolt and a locking door knob. Both were locked at the time of the blast.

The 8701 Maintenance Room was located at the bottom of stairs to the immediate right in the southwest quadrant. This was the maintenance storage and work shop for the rental office and was directly under 8701 Apartment #104. This area was accessible via the office and had two doors. The first door was a fire door and was painted green.

There was an additional door that separated the maintenance area from the rental office area. This door was painted grey and the door and frame were pushed through the wall. This door had a locking knob that was locked at the time of the blast.

The stairwell doors to 8701 Apartment #11, the Rental Office and the Maintenance Room (TR 11, TR 12 and TR 14 respectively) were all blown from their locked positions into their respective rooms. Exact distance was not possible as fire operations moved material prior to examination. Doors were initially examined for the presence of a locked deadbolt or other locking mechanism and all three were found to have been in the locked position at the time of the blast or to have been ripped from the frame in the locked position during the blast.

The Terrace/Basement level hallway included a set of stairs descending from the first floor into the basement. The stairs were positioned along the shared wall with the 8701 Maintenance Room (TR 14). There was a hallway alley in between the stairs and the shared wall with the 8701 Meter Room. The ceiling material appeared to be stucco over a metal lath. The roof to this hallway had damage that appeared to be consistent with a blast wave as each section between the joists was driven up into the spacing.

The stairway was shifted to the south from 8701 Apartment #101 and D side (south side) 8701 Meter Room wall towards 8701 Apartment #104 and the 8701 Maintenance Room. The roof to this stairway had damage that appeared to be consistent with a blast wave as each section between the joists was driven up into the spacing. The loss of support from the D wall (south wall) of 8701 Apartment #101 led to the collapse of the second floor stairway and landing.

There did not appear to be any flame impingement to the Basement/Terrace level hallway or doors. There was slight flame impingement to the stairway ceiling at the junction of stairway and first floor that was consistent with pre-collapse damage.

8701 Apartment #101 had its front entrance facing Arliss Street and was identified by fire operations as side A (west). This was a tan painted door with a door knob lock and a dead bolt. This door was projected across the road and parking lot approximately 300 feet. The dead bolt was bent indicating the door was locked. There was shading and scorching on the interior bottom of the door that was consistent with flash fire damage.

8701 Apartment 102 door was a fire door and was blown from its hinges. It was recovered in the debris pile of the Apartment.

8701 Apartment 103 door was a fire door, painted green with a gold door knocker. This door was blown from its hinges and came to rest on the Apartment balcony.

8701 Apartment 104 door was a tan painted door with a door knob lock and a dead bolt. It remained intact and attached to its frame.

Second Floor:

8701 Apartment 201 door was a fire door. This door was still in its frame and was recovered upside down, still in its frame, partially blocking the entrance to the meter room.

8701 Apartment 202 door was a fire door. This door was still in its frame.

8701 Apartment 203 door was a fire door. This door was still in its frame.

8701 Apartment 204 door was a fire door. This door was recovered from the pile and was still in its frame.

Third Floor:

8701 Apartment 301 door was a fire door. This door was recovered from the pile and was still in its frame.

8701 Apartment 302 door was a fire door. This door was still in its frame, in place.

8701 Apartment 303 door was a fire door. This door was still in its frame, in place.

8701 Apartment 304 door was a fire door. This door was still in its frame, in place.

Blast Damage Below Ground:

There does not appear to be any damage to the A wall (west) below ground level.

According to witness statements, the B side (north) wall of meter room blown into 8703 Apartment #12.

According to witness statements, the C side (east) wall of meter room blew into 8701 Apartment #11 in living room and scene examination shows a partial collapse of the floor above. The framed wall of the bedroom shifted away from the meter room and fell into 8701 Apartment #11 (TR 11) towards the C side (east) wall of the building. The blast caused glass to blow from the outside into the room.

The D wall (south) had a hole approximately 4'x8' in the upper corner of the D side (south). The hole was between the metal support framing and the A wall (west). The fire door was blown from its hinges and through the Management Office door.

An examination of the debris in meter room shows that the ceiling of the meter room underneath 8701 Apartment #101 bedroom shows heaving, radiating out from A/B corner wall area (northwest). Due to the extent of collapse, investigators were unable to determine a center point. Debris analysis shows flooring with parquet tiles facing up and kitchen debris, under flooring with parquet tiles facing down, indicating that the floor heaved upwards trapping the debris between the layers.

Above Ground:

According to witness statements and the initial police dash camera video, the A side (west) of 8701 Apartment #101 was completely blown out during the initial explosion, with the door landing across the street and parking lot. The front door to 8701 (main building entrance) was completely blown out with the door frames and the glass in the street. The forward progression of the doors was stopped by parked cars on Arliss Street.

According to witness statements, the D side (south) wall of 8701 Apartment #101 was blown out and into hallway moving the stairway and railing during the initial explosion. Witnesses reported having to climb over the debris to exit the building.

8701 Apartment 101 ceiling appears to collapse above the bedroom area, allowing the collapse of the Apartment 201 floor. Scene processing shows the female occupant of Apartment 201 and a bed drop into the 8701 Meter Room, on top of the gas meters. Additionally, the resident of 8701 Apartment 101 was recovered from under the floor of 8701 Apartment 101 in the debris pile just in front of the meter bank.

Investigators were unable to determine if the B (north) or C (east) walls of 8701 Apartments 201 or 301 were breached by the blast.

The D (south) wall of 201 and 301 was believed to be intact pre-fire and eventually collapsed due to structural support failure.

Blast Wave Progression

The blast appears to have progressed from the A/B (northwest) corner of the 8701 Meter Room. The wave progression was described in two phases, below and above grade.

Below grade:

The blast wave appears to have radiated from an area near the gas meters. On the A/B (northwest) side where the gas meters were mounted, the B (north) wall was blown into the 8703 Apartment #12 with, according to witness statements, an immediate rush of flame.

On the C (east) side, the blast wave impacted the block wall and pushed it outward, collapsing the wall and driving an interior wall of Apartment #11 onto the occupants of a bed.

On the D (south) side the blast wave impacted the wall and blew out a 4'x8' section of the block wall midline to ceiling, approximately four feet from the door frame and towards the C/D (southeast) corner. This initial push also blew the 8701 Meter Room door from its frame and into the door of the 8701 Management Office.

That pressure wave then continued into the stairwell pressing the stucco and lath into the gaps between the joists and on the stairwell into the backside of the steps. The pressure wave also blew the doors from 8701 Apartment #11 and the 8701 Maintenance Room into their respective rooms as well as blowing out windows and/or glass. There did not appear to be any flame impingement with this blast wave.

Above Ground:

The above ground wave appears to have emerged from the floor of 8701 Apartment 101, directly above the Meter Room, and impact the 8701 Apartment 101 A (west) wall driving it outward. The

B (north) wall appears to have breached and received fire. The C (east) wall appeared to hold and maintain its integrity. The D (south) wall was blown outward into the common hallway.

The doors to 8701 Apartments 102 and 103, which open into the D (south) wall hallway, were both blown from their hinges and into their respective apartments.

Support removal of the A (west) wall of 8701 Apartment #101 appeared to have caused the collapse of the A (west) side of 8701 Apartments #201 and 301, ejecting occupants out of the building westward towards Arliss Street.

WEATHER (obtained from Weather Underground):

The weather at the time of the incident was approximately 80 °F with clear skies and calm winds.

DATA ANALYSIS:

Investigators determined the incident was an explosion that resulted in fire as opposed to a fire that resulted in an explosion. The data does not support a fire event occurring before the explosion. None of the witnesses, including witnesses who detected the odor of natural gas, detected smoke and/or fire before the explosion. [redacted], who was present in the building walked past the doors for every apartment, on every level, in 8701, including the front doors for 8701-101 and 8701-104 as he exited out the front of the building, immediately prior to the explosion. He detected neither smoke nor other evidence of a fire prior to the explosion. It is unlikely a hostile fire of a size capable of damaging the natural gas system to the point of failure would have gone unnoticed given the circumstances. Even if that had been the case, it is unlikely an explosion would have resulted from damage to the system as, in the event of a hostile fire in the presence of a breach in the natural gas system, the fugitive gas[1] would ignite before it could accumulate in a compartment and form an explosive mixture.

An analysis of the remains of apartments in both 8701 and 8703 revealed no fire, heat or smoke damage that could not be attributed to the burning of natural gas and/or collapsed structural components and building contents on the north side of 8701 and the travel of fire from the north side of 8701 upwards and outwards throughout the remains of the two buildings.

A report from the resident of Apartment 8701-203 of a smoke detector sounding in the distance before he went to bed the night of the explosion could not be substantiated with other witnesses including [redacted], who walked the entire building immediately prior to the explosion and stated he did not hear a smoke detector sounding nor smell smoke.

Having determined this is an explosion investigation, investigators determined the explosion is the result of the ignition of fugitive natural gas[2] confined in the 8701 Meter Room. Several witnesses

[1] NFPA 921 – Guide for Fire and Explosive Investigations (2014 ed.) mentions “fugitive gases” in § 10.1.1 stating, "Fuel gases that escape from their piping, storage, or utilization systems can serve as easily ignited fuels for fires and explosions. These gases are commonly referred to as *fugitive gases."*

[2] NFPA 921 - Guide for Fire and Explosion Investigations (2014 ed.) § 10.2.I states, "Natural gas is a naturally occurring largely hydrocarbon gas product recovered by drilling wells into underground pockets, often in association with crude petroleum. Although exact percentages differ with geographic areas and there are no standards that specify its composition, natural gas is mostly methane, with lesser amounts of nitrogen, ethane, propane, and with traces of butane, pentane, hexane, carbon dioxide, and oxygen. The percentages may vary widely and have been reported in mixtures that range from 72 percent to 95 percent methane, 3 percent to 13 percent ethane, <l percent to 4 percent propane, and <l percent nitrogen. Undiluted

describe smelling an odor of natural gas in the hours and days prior to the explosion. Several witnesses, including [redacted], also reported smelling natural gas at varying intervals in the days and weeks leading up to the explosion. Additionally, [redacted] reported smelling natural gas in the basement immediately prior to the explosion.

The area of origin is the 8701 Meter Room located in the northwest quadrant of the basement/terrace level of 8701 as detailed in the "Analysis of Blast Damage and Blast Wave Migration" section of this report. The debris field consisted of building materials and contents spread in a pattern consistent with the debris field originating from the northwest quadrant of 8701 Arliss Street. The front door to Apartment 8701-101 was found to be amongst the farthest objects thrown from the building. The highest concentration of debris, which consisted of both structural materials and contents such as clothing was directly in front of the northwest quadrant of 8701. Moreover, the debris field was generally limited to the line of sight away from the northwest quadrant of 8701.

Vehicles parked within the line of sight of the northwest quadrant of 8701 exhibited damage consistent with being in the flight path of projected building materials and contents. Said building materials and contents traveled with enough velocity to cause damage to the affected vehicles. Vehicles parked farther from the northwest quadrant exhibited less damage than vehicles parked closer. Vehicles parked outside of the line of sight of the northwest quadrant were spared this type of damage.

A debris field on the east side of the structure was of a lesser severity, in both quantity of contents and distance of travel, than the aforementioned debris field on the west. However, it, too, extended from the northern half of 8701.

Hypotheses involving the explosion originating from a building quadrant other than the northwest quadrant of 8701 were falsified by the data. Had the explosion occurred in another quadrant of 8701 or 8703, such as the southeast quadrant, one would expect the debris field to travel outward from that quadrant. Hypotheses involving the explosion originating on the exterior of the building were falsified by the data. Had the explosion occurred on the exterior of the building, such as outside in front of the northwest quadrant of 8701, one would expect the contents of the building to be blown farther into the building.

A hypothesis of the explosion originating in 8701 Apartment #101 was falsified by the data. The concrete floor that separated the 8701 Meter room from 8701 Apartment #101 was found to be flipped over onto itself as if blown upwards from below. Had the explosion originated in 8701 Apartment #101, the flooring would have been blown downward into the meter room, maintaining its orientation with the wooden parquet flooring on the top and the concrete ceiling of the 8701 Meter Room on the bottom. Large sections of concrete flooring were found during the scene excavation in the opposite orientation.

The damage associated with 8703 Arliss Street is consistent with exposure to an explosion and subsequent fire that occurred in 8701 Arliss Street. Fire, heat and collapse damage in 8703 was most severe along the wall shared with the northwest quadrant of 8701 and decreased in severity

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natural gas is lighter than air. Depending on the exact composition, it has a specific gravity (air) (vapor density) of 0.59 to 0.72, a lower explosive limit (LEL) of 3.9 percent to 4.5 percent, and an upper explosive limit (UEL) of 14.5 percent to 15 percent. A flammable mixture has a vapor density of 0.96 to 0.98. Its ignition temperature is 482°C to 632°C (900°F to 1170°F).

as distance increased away from this area. The shared wall separating Apartment 8703-12 and the 8701 Meter Room was blown into Apartment 8703-12 away from the 8701 Meter Room. Fire, heat and smoke damage to the Apartment along the wall shared with 8701 are consistent with exposure to a fire involving natural gas and the debris pile on the north end of 8701.

[redacted], a resident of 8701-304 located on the southwest quadrant, stated he arrived home from work less than an hour before the explosion. He stated he did not smell natural gas at that time. Just prior to the explosion, he exited Apartment 8701-304 to take out the trash. He stated he smelled natural gas as he was descending the stairs and followed the smell to the bottom of the stairwell to the Basement/Terrace Level where the meter room is located. He added the smell of natural gas was strongest in the Basement/Terrace Level. He stated he was on the phone with his girlfriend at the time, a phone call that was timestamped to have begun at 23:47 hours and lasted for three minutes. He described hearing the sound he equated to that of escaping natural gas coming from apartment 8701-11 or the Management Office which were located on the northeast and southeast comers of the Basement/Terrace Level of 8701 respectively.

A release of natural gas from Apartment 8701-11 is inconsistent with the data. The resident of Apartment 8701-11 was home at the time of the explosion and reported no odor of natural gas. It is unlikely somebody outside the closed door to Apartment 8701-11 would smell natural gas while the resident within Apartment 8701-11 would not, had the natural gas been originating from 8701-11. Also, an explosion originating in 8701-11 is inconsistent with the data obtained from the scene examination.

A release of natural gas from the Management Office (also known as 8701-12 and located on the southeast quadrant of the Terrace/Basement Level) is inconsistent with the data obtained from the scene examination.

The Maintenance Room (located on the southwest comer of the Terrace/Basement Level had natural gas piping running along the ceiling from the Meter Room to the Apartments above, however, this piping did not exhibit damage associated with a pre-incident leak. Also, an explosion originating in the 8701 Maintenance Room is inconsistent with the data obtained from the scene examination.

The noise described by [redacted] as the sound of escaping natural gas could be natural gas escaping from a failure in the system in the Meter Room and echoing in the hallway where the witness was located. It was determined the Meter Room contained the main natural gas feed for the building which, after testing in the exemplar building located at 8709 Arliss Street with an exemplar system flowing an inert gas at a high flow, was determined to be the only natural gas source capable of the volume of noise described by the witness.

Another source of the noise heard by the witness could be that of running water through the building's water pipes. During the scene excavation but prior to the water being completely shut off to 8701, investigators temporarily halted the scene examination to investigate a noise that sounded like that of escaping natural gas. It was determined the noise was that of water flowing through a pipe in the remains of 8701-11. Additionally, after the interview with [redacted] investigators heard a similar noise in the exemplar building originating from 8709-11 or 8709-12. Therefore, investigators could not conclude, based on [redacted] interview alone, the source of the noise heard immediately prior to the explosion.

The resident of 8701-11, the apartment to the east of the 8701 Meter Room, did not smell natural gas, nor did he hear natural gas escaping prior to the explosion. His statement is consistent with the scene examination in that the wall shared with the 8701 Meter Room is blown out to the east into his apartment. Damage to apartment 8701-11 was mostly limited to blast and collapse damage from the direction of the 8701 Meter Room. Apartment 8701-11's hallway/stairwell door was blown into the apartment as opposed to being blown out of the apartment. Had the explosion originated in Apartment 8701-11, one would expect the hallway/stairwell door to be blown out and away from Apartment 8701-11 as opposed to being blown in. One would also expect the walls enclosing Apartment 8701-11 to be blown out as opposed to blown in as was observed with the wall separating apartment 8701-11 from the 8701 Meter Room. Moreover, one would expect the residents of Apartment 8701-11, who were relatively uninjured, to be seriously injured or killed as result of an explosion of this magnitude originating in the apartment they were occupying.

It is also worth noting the only stairwell/hallway door observed to be blown outwards away from its respective room (as opposed to being blown inward) was the stairwell/hallway door to the 8701 Meter Room. The door to the 8701 Meter Room was found in the 8701 Main Administrative office across the hallway from the 8701 Meter Room. The balance of the stairwell/hallway doors in building 8701 (that were separated from their respective frames) were found blown into their respective rooms.

With the area of explosion origin being identified as the 8701 Meter room in the Basement/Terrace Level, investigators identified potential first fuels. Two potential first fuels capable of causing an explosion were identified and included gasoline and natural gas. Hypotheses involving gasoline as a first fuel were falsified by the data during the investigation. Hypotheses involving explosives and/or the presence of a clandestine drug laboratory were falsified by the available data. Investigators concluded the first fuel ignited was fugitive natural gas.

Investigators found no data to support the presence of explosives in the 8701 Meter Room. Investigators found no data to support the presence of a clandestine drug laboratory in the 8701 Meter Room.

The data does not support gasoline being the first fuel involved in this incident. Although a gasoline powered appliance was excavated during the scene processing and the tank appeared to have exhibited damage, the cap remained in place and a quantity of gasoline remained in the tank. A partially-melted, portable, plastic gasoline container was excavated in the southeast quadrant. The remains of the container were approximately half full and the cap was in place. Given the nature of the 8701 Meter Room serving, also, as a storage room by the apartment complex maintenance provides an innocent explanation for the presence of gasoline and gasoline containers in this room. Additionally, the containers were observed to be in a condition one would expect stowed gasoline containers and gasoline appliances to be found.

A section of wooden panel (parquet) flooring tested positive for the presence of gasoline. This section of wooden panel (parquet) flooring was found on a loose section of flooring that had apparently fallen from 8701 Apartment #101 into the 8701 Meter Room during the incident and was present during suppression operations[3]. Samples of wooden panel (parquet) flooring taken from sections of 8701 Apartment #101's floor that had not fallen into the basement tested negative

[3] In an article published in the Fire and Arson Investigator -Journal of the International Association of Arson Investigators in July 2016 stated that "ignitable liquids in a flooded compartment can be re-distributed to other materials within the compartment."

for the presence of gasoline. This is consistent with the flooring testing positive for gasoline coming into contact with gasoline in the 8701 Meter Room during the incident and not as a result of gasoline being present in 8701 Apartment #101.

For gasoline to have been a first fuel, a person would have to enter the 8701 Meter Room to pour gasoline throughout the room. There was no data, such as empty gasoline tanks with their caps removed, to support the hypothesis of somebody pouring gasoline in the 8701 Meter Room prior to the explosion. Related to that hypothesis, there was no data to support a gasoline being accidentally spilled in the 8701 Meter Room. Given the damage observed to the contents of the 8701 Meter Room, including the discovery of a damaged yet capped gasoline container, the remains of empty gasoline containers would have been identified by the investigators during the scene excavation. None were found.

Additionally, the alarm data concluded the door to the 8701 Meter Room was alarmed and that the alarm had been set by a maintenance crew member at 18:04 hours. The alarm was later disarmed on two separate occasions at two-minute intervals by Montgomery County Police Officer [redacted] during the course of his overtime assignment as property security and was set for the night at 20:42 hours. Had somebody entered the meter room prior to the explosion, the alarm would have sounded and recorded the violation.

Neither Officer [redacted], nor [redacted] stated they smelled gasoline in the building prior to the explosion. [redacted] was specific in his statement when asked to differentiate between the smell of natural gas and the smell of gasoline. [redacted] stated he smelled natural gas. Additionally, the resident of 8701 apartment 301 stated they smelled natural gas minutes prior to the explosion.

Sources of natural gas in the 8701 Meter Room involve the main natural gas feed, natural gas meter bank, an 81-gallon water heater and the associated piping. The control valve for the water heater was found to be partially melted such that an examination for failure was inconclusive. Investigators were also not able to conclusively determine the pre-explosion status of all of the connections for the gas meters on the meter bank.[4]

The examination of the meter bank revealed a disconnected three-part union on the vent pipe between the regulators and the exterior. One function of a connected vent pipe is to expel natural gas to the exterior of the building in the event of a regulator failure. If the regulator was to fail in this instance, the natural gas would have likely vented into the 8701 Meter Room, not to the exterior of the building as designed.[5] [6] It should also be noted, of the sources of fugitive natural gas mentioned, the only source capable of a relatively high flow would be a failed regulator

[4] NFPA 921 -Guide for Fire and Explosion Investigations (2014 ed.) § 10.9.4.5 states, "The malfunction and leaking of gas appliances or gas utilization controls, such as valves, regulators, and meters, can also produce fugitive gas. . ."

[5] NFPA 921 - Guide for Fire and Explosion Investigations (2014 ed.) § 10.9.4.4 states, "A common source of large quantities of fugitive gas is open, uncapped pipes and outlets. . ."

[6] NFPA 921 - Guide for Fire and Explosion Investigations (2014 ed.) § 10.9.4.6 states, "Failures in gas regulators most often fall into one of three categories: faults with the internal diaphragm, faults with the rubberlike seal that controls the input of gas into the regulator, or faults with vents. Each of these fault categories can result in the regulator's failing to reduce the outlet pressure to acceptable levels or producing fugitive gases."

venting into the 8701 Meter Room through the disconnected vent pipe. Several witnesses also reported post-explosion fire in the comer of the 8701 Meter Room occupied by the regulators. This was also an area of the most intense fire damage observed in the 8701 Meter Room during the scene examination. That being said, investigators were unable to establish a satisfactory timeline based on the available data to differentiate between a high-flow natural gas release (such as what would be possible with a regulator failure) and a low-flow natural gas release (such as what would be possible with the failure of the meter bank, water heater, or associated piping). Future testing of the involved natural gas regulators, meter bank, water heater, and associated piping may provide useful information capable of overcoming this data shortfall.

Fugitive natural gas accumulating in the 8701 Meter Room, reaching its Lower Explosive Limit in the presence of a competent ignition source such as an open flame or electric arc would cause an explosion originating in the 8701 Meter Room such as that evidenced in this incident.[7]

Competent ignition sources for natural gas are plentiful in an environment such as an apartment building. Open flames, such as the burners on a water heater, are a competent ignition source of natural gas as is a static electric arc.[8] The presence of a natural gas-fired water heater in the 8701 Meter Room cannot be ignored as a potential ignition source. The water heater is of a design that does not involve a standing pilot light. It only produces an open flame when in operation. This could allow natural gas to have accumulated to an explosive mixture in its presence and ignite when the water heater activated. While this hypothesis seems likely, flammable gases, such as natural gas, may travel a considerable distance from their original point of release before reaching a competent ignition source.[9] [10] [11]

CONCLUSION:

Given the damage to the natural gas regulators, natural gas meter bank and the water heater, investigators were not able to immediately determine the failure that led to the release of fugitive

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[7] NFPA 921 - Guide for Fire and Explosion Investigations (2014 ed.) §5.2.3.2.2 states "Lower Explosive Limit (Lower Flammable Limit). The minimum percentage of fuel in air (by volume) in which combustion can occur is the lower explosive limit (LEL) of the material. In a mixture that is below its LEL no combustion will occur. This is because below the LEL there are insufficient fuel molecules in the mixture. The mixture is said to be "too lean."

[8] NFPA 921 -Guide for Fire and Explosion Investigations (2014 ed.) §19.3.2. l states, "Potential sources of ignition for gases, vapors, or dusts include open flames, arcs from motors and switches, electric ignitors, standing pilots or flames in gas appliances, hot surfaces, and static electricity.

[9] NFPA 921 - Guide for Fire and Explosion Investigations (2014 ed.) §l 9. l .3 states, "The ignition source will be at or near the point of origin at the time of ignition, although in some circumstances, such as the ignition of flammable vapors, the two may not appear to coincide. . .

[10] NFPA 921 - Guide for Fire and Explosion Investigations (2014 ed.) § 19.4.2.2 states, "Flammable gases or liquid vapors, such as those from gasoline, may travel a considerable distance from their original point of release before reaching a competent ignition source. Only under specific conditions will ignition take place, the most important condition being concentration within the flammable limits and an ignition source of sufficient energy located in the flammable mixture.

[11] NFPA 921 - Guide for Fire and Explosion Investigations (2014 ed.) § l 9.4.4.3 states, "There are times when there is no physical evidence of the ignition source found at the origin, but where an ignition sequence can logically be inferred using other data. . . The following are examples of situations that lend themselves to formulating an ignition scenario when the ignition source is not found during the examination of the fire scene. . . (A) Diffuse fuel explosion and flash fires."

natural gas in the 8701 Meter Room. What is known is the three part union connecting the regulators to the vent pipe was disconnected prior to the explosion, thus, bypassing a safety feature of this system. The person who disconnected the vent pipe, as well as his/her intentions in doing so, are as of yet to be determined. With the unknown circumstances involving the disconnection of the vent pipe as well as the ongoing National Transportation Safety Board (NTSB) investigation which will possibly provide more data useful to this report, this explosion is to be classified at this time as UNDETERMINED.[12] [13]

[12] NFPA 921 - Guide for Fire and Explosion Investigations (2014 ed.) §20. l.4 defines "Undetermined Fire Cause" as, "Whenever the cause cannot be proven to an acceptable level of certainty, the proper classification is undetermined as follows: (A) Undetermined fire causes include those fires that have not yet been investigated or those that have been investigated, or are under investigation, and have insufficient information to classify further. However, the fire might still be under investigation and the cause may be determined later with the introduction or discovery of new information."

[13] If additional information/data becomes available, investigators reserve the right to evaluate the impact, if any, of the information/data and the right to revise an opinions and/or conclusions that may be relevant based on the new information/data.