BUILDING EXPLOSION AND FIRE

8701 ARLISS STREET

SILVER SPRING, MARYLAND

ACCIDENT NUMBER – DCA16FP003

PREPARED BY:

WASHINGTON GAS

SUBMITTED TO:

NATIONAL TRANSPORTATION SAFETY BOARD (NTSB)

WASHINGTON GAS
6801 INDUSTRIAL ROAD
SPRINGFIELD VA 22151

JUNE 7, 2017

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ACRONYMS

AGA	American Gas Association
API	American Petroleum Institute
ATF	Bureau of Alcohol Tobacco and Firearms
CFR	Code of Federal Regulation
DOT	Department of Transportation
GTI	Gas Technology Institute
In. W.C.	Inches of Water Column (1 psig equals 27.7 in. w.c.)
LEL	Lower Explosive Limit
NTSB	National Transportation Safety Board
PSMS	Pipeline Safety Management System
SCC	State Corporation Commission
SCFH/SCFM	Standard Cubic Feet per Hour/Minute
WG	Washington Gas

DEFINITIONS

Battery:	Refers to flow equipment installed in a parallel arrangement; as in ‘dual regulators installed in battery’
Delivery Pressure:	The pressure downstream of a service regulator; typically 5-7 in. w.c. (0.20 - 0.25 psig).
Distribution Pressure:	The pressure at which the utility’s distribution mains and services operate for transportation of natural gas supply within local areas.
Exemplar:	A typical example or standard specimen
Fugitive Gas:	Fuel gases that escape from their piping, storage, or utilization systems (i.e., end-use appliances).
Houseline Piping:	Non-Jurisdictional piping that transports gas from the outlet of the meter to the point of end use; piping not designed, constructed, operated or maintained by the gas utility.
Jurisdictional Piping:	The piping and equipment for which Washington Gas is legally responsible, including distribution mains, services, regulators and meters, as well as all associated piping and fittings up to and including the meter outlet swivel.
Kay Management:	The property manager of the Flower Branch Apartment complex, where the incident occurred at 8701 Arliss Street; responsible for the design, operations, and maintenance of all houseline piping and appliances within the Flower Branch Apartment complex.
Main:	A distribution line that serves as a common source of supply for more than one service line.
Mercury-Sealed Regulator:	A regulator which utilizes the weight of a volume of mercury, balanced against the delivery pressure of a regulator to provide overpressure protection; when the delivery pressure exceeds the mercury’s weight, the mercury is displaced and gas is vented to prevent overpressure.
Meter Bank:	A meter set assembly that incorporates multiple meters
Meter Bar:	A metal bar for mounting a gas meter, having fittings at the ends for the inlet and outlet connections of the meter

Meter Set:	Also known as the meter set assembly; the exposed portion of the service line extending from the service line valve to the connection of the customer's fuel line (houseline), including the meter, and (if present) the regulator(s) and relief vent line.
Meter Swivel:	A fitting used to connect a gas meter to a meter bar; typically incorporates one NPT threaded connection and one compression nut connection, with the centerlines of each connecting end parallel but offset
Service Line:	A distribution line that transports gas from a common source of supply to an individual customer, to two adjacent or adjoining residential or small commercial customers, or to multiple residential or small commercial customers served through a meter header or manifold. A service line ends at the outlet of the customer meter or at the connection to a customer's piping, whichever is further downstream, or at the connection to customer piping if there is no meter.
Service Regulator:	A service regulator is the device installed by the utility on a service line that controls the pressure of gas delivered from a higher pressure (distribution pressure) to the pressure provided to the customer. A service regulator may serve one customer or multiple customers through a meter header or manifold.
Thermal Safety Valve:	A valve which is designed to close independently in reaction to external heat, as in the case of fire; typically designed to close when subjected to temperatures of approximately 200 degrees Fahrenheit.

PREFACE

Washington Gas wishes to thank the NTSB for the collaborative manner in which it has worked with us to help determine the facts, conditions, and circumstances regarding this accident. We would also like to acknowledge the parties for the cooperative spirit they have displayed as well.

SECTION 1 - EXECUTIVE SUMMARY

INVESTIGATION SYNOPSIS

A. ACCIDENT DESCRIPTION. On August 10, 2016, about 11:51 p.m. eastern daylight time, an explosion and fire occurred in a 4-story apartment building located at 8701 Arliss Street in the unincorporated community of Silver Spring, Montgomery County, Maryland. The attached, adjacent apartment building at 8703 Arliss Street was also heavily damaged by the fire. The accident resulted in 7 fatalities and 42 injuries. Three firefighters were among those injured. The value associated with damage from the accident, as declared by parties to the investigation, is expected to be more than $1 million.

B. ORIGIN AND CAUSE. Immediately following the accident, the Bureau of Alcohol Tobacco and Firearms (ATF) conducted an Origin and Cause investigation. After gathering available information and evidence -- including witness interviews -- making certain assumptions, and vetting reasonable theories as to cause and origin against the available evidence and assumptions, the ATF concluded that the cause and origin of this accident was UNDETERMINED.

The NTSB launched its investigation on August 17, 2016. Washington Gas immediately accepted the NTSB's invitation to join as a formal party to the investigation, working within NTSB protocols. Through its active and comprehensive participation in the investigation, Washington Gas sought to help further develop relevant facts and to develop and test assumptions, all designed to help the NTSB determine, if possible, the cause and origin of this accident, as well as identify any related key safety protocols. After completion of the NTSB fact gathering, including multiple interviews, completion of the testing and analysis of physical evidence and our own internal reviews of our safety protocols, Washington Gas concurs with the ATF conclusion that the cause and origin of this accident is UNDETERMINED. It is worth noting that while the ATF suggests in its summary redacted report of September 23, 2016 that the NTSB investigation could develop facts leading to a different conclusion, the NTSB investigative findings, as further discussed in this report, serve only to strongly support the ATF conclusion that a probable cause for this accident is UNDETERMINED.

C. OUTLINE OF WASHINGTON GAS'S ANALYSIS OF INVESTIGATIVE RESULTS.

1. **Jurisdictional Piping**: The ATF's working theory that this accident may have been caused by an initial release of natural gas from an open union fitting installed in atmospheric vent piping, concurrent with a gas regulator failure on the jurisdictional meter set piping in the basement level meter/storage room, is not supported by the subsequent investigative evidence, including testing, observed piping deformation, and witness interviews. There is clear physical evidence that is consistent with the union fitting being connected, as it is expected to be***, prior*** to the accident. Long-developed data shows that the failure and venting of a mercury regulator is rare, and the testing in this case has objectively demonstrated

that only one type of failure could be plausible, namely a failure that results in a ***minor*** release of gas at low pressure. Based on the conclusion that this union fitting was connected, the low likelihood of a failure of one of the regulators, and the minimal gas flow from a failed regulator, the open union as the source of fugitive natural gas can be eliminated.

2. **Water Heater Houseline – Basement Level Meter/Storage Room**: There is indisputable evidence of a release of gas in the basement level meter/storage room from a break in the houseline piping at the base of the water heater, resulting in a characteristic burn pattern on the side of the water heater. This break in the houseline is clear evidence of a release of natural gas in the basement and is consistent with a fuel source and gas flow that could support an explosion. As the timing of events has not been established, it is possible that the break in the houseline and fire at the water heater occurred after the initial explosion and prior to the structure collapse that severed the supply of gas to the meter set in the basement level meter/storage room. Determining when this broken houseline occurred cannot be conclusively established by the available evidence.
3. **First Floor Initiating Event**: In addition to the challenges of establishing a supported theory with an initiating event beginning in the basement level meter/storage room, there is evidence and witness accounts that support an initial explosion occurring on the first floor of 8701 Arliss Street, rather than the basement level meter/storage room. That evidence includes blast wave and other investigative findings made by the ATF, witness accounts of reported natural gas

odor, or the lack thereof, and physical destruction and debris fields consistent with a first floor explosion.

D. SAFETY INITIATIVES: Regardless of the undetermined nature of this accident, Washington Gas is pursuing voluntary initiatives consistent with our long-known commitment, always, for improved safety.

1. **Improved safety messaging to customers residing in multi-metered apartments**. While Washington Gas has a robust customer outreach program providing safety messaging to its customers, in the aftermath of this accident Washington Gas will seek to improve the safety awareness of customers when they suspect a release of natural gas. Although customers were aware of the safety concerns raised by a suspected odor of natural gas, and consistently reported such odors to Kay Management company or the Fire Department (via calls to 911), it was not clear to Washington Gas that every customer was aware that they could also report such incidents to Washington Gas. Indeed, there is witness testimony to the contrary.
2. **Construction and Design Standards**. The structural collapse caused a severing of a portion of the Washington Gas service line in the basement level meter/storage room which, due to the location of the service line regulators in the basement level meter/storage room, operated at distribution pressure. The severed service line supported a large fire following the initial incident. Washington Gas will install, whenever feasible, the gas regulators exterior to the buildings on new multi-family construction projects, thus limiting the potential high flow of gas resulting from damage to its interior facilities. Additionally, for legacy multi-

meter sets, Washington Gas, when undertaking the planned replacement of a service line due to age and condition, where feasible, will move regulators that are installed within a building structure to a location outside the building structure, again limiting the potential high flow of gas resulting from damage to its interior facilities. Lastly, Washington Gas will continue its program of installing Thermal Safety Valves on all new construction and on its legacy facilities while performing service line replacement work, for all multi-family housing units. These valves will serve to shut off the flow of gas to the building in the event of a fire engulfing its meter or regulator facilities.

3. **Emergency Response Coordination:** Washington Gas will renew efforts to improve communications between Washington Gas and emergency response agencies to ensure that Washington Gas is alerted each time the jurisdiction receives notice of a possible odor of natural gas so that response can be coordinated.

E. PROPOSED RECOMMENDATIONS: In addition to its voluntary Safety Initiatives, Washington Gas recommends:

1. Fire and Smoke alarms be installed in all storage rooms, utility/meter rooms, and common areas of apartment complexes;
2. The development of County-audited safety checklists for multi-metered apartment complexes that requires periodic self-checks by management companies to ensure compliance with code requirements designed to ensure that flammable or explosive substances are not improperly stored in internal storage rooms; and that

storage practices of equipment, appliances, and other materials in and around gas carrying pipes and appliances does not impose risk to those facilities;

3. In multi-family buildings where the water heater and gas piping is exposed and unprotected from human activities and storage of materials, investigate the use of flexible gas piping ‘pig tails’ between the steel gas houseline and the connection rigidly mounted appliances, such as the water heater control valve found in 8701 Arliss Street. This will eliminate the vulnerable threaded connections that would be subject to significant stress if an unsupported steel houseline serving the appliance is inadvertently bumped or moved;

Photo showing use of flex connector/pig tail between steel house piping and appliance connection

4. Requiring the installation of methane detectors in the gas meter rooms of multi-family (apartment/condo) buildings; and
5. A requirement for Landlords to inform their tenants of safety procedures in case of emergencies, including gas safety and reporting of gas odors.

SECTION 2 - ANALYSIS OF INVESTIGATIVE RESULTS

Introduction and Context for the NTSB Investigation

The NTSB initiated its investigation of this accident on August 17, 2016, following completion of the ATF's Origin and Cause field investigation into the explosion, fire, and 3-story building collapse at 8701 Arliss Street on August 10, 2016, tragically resulting in the death of 7 residents and injury to many others. Washington Gas was asked by the NTSB to join the investigation as a party, and immediately accepted. Washington Gas joined the NTSB investigation with the purpose of providing the NTSB with its operational expertise in the investigation, and to assist in further developing facts, examining hypotheses as to cause, and to establish a confirmed sequence of events leading to this terrible accident, as well as to help the natural gas community better avoid future accidents.

On September 23, 2016, the ATF issued its Confidential Origin and Cause Report ("ATF Report") [1] and found the cause of the accident to be UNDETERMINED. In so doing, the ATF stated, "*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 natural gas in the 8701 Meter Room.*"[2] Washington Gas concurs with the conclusion that the cause of this accident remains UNDETERMINED, even after the follow-on NTSB investigation.

As further outlined in this submission, the additional testing and data collection by the NTSB indicate that certain assumptions made in the early investigation stages regarding the source location of suspected fugitive gas in the basement level meter/storage room are now not

[1] ATF Report at 11.
[2] ATF Report at 11-12.

supported by fact. This submission sets forth the relevant facts established in both the ATF and NTSB investigations, and indicates the assumptions and conclusions supported by the facts. Washington Gas's conclusion remains that there is insufficient available evidence to determine the sequence of events that led to this accident and hence the cause remains UNDETERMINED.

A. <u>Jurisdictional Piping in Basement Level Meter/Storage Room</u>.

<u>Background Facts:</u>

Fact 1: Natural Gas was being delivered to the customers at 8701 Arliss Street by Washington Gas.

Fact 2: There were no leaks found in any of the jurisdictional piping outside of, or in the area of the building at 8701 Arliss Street. All jurisdictional piping was tested, witnessed by the NTSB and party members, up to the point where the service line was severed just inside the meter room in 8701 Arliss Street. Natural gas did not come from the distribution system outside of the building.

Fact 3: Natural gas odorant levels were checked following the incident and found to be adequate under the requirements of the State of Maryland, which are significantly more stringent than the minimum federal safety standard established by CFR 49 Part 192.625. The State of Maryland (COMAR 20.55.09.06) requires "The odorant level throughout the entire company distribution system shall be sufficient so that gas is detectable at 1/10th of the lower explosive limit," whereas the federal minimum standard is 1/5th LEL.

Fact 4: The natural gas distribution system in the area operated at approximately 20 psig, which included the service line into the meter room of 8701 Arliss Street. Just inside the wall of the meter room, the pressure was reduced through two mercury regulators, installed in parallel, to approximately 5.5" water column (equivalent to approximately 0.2 psig). Natural gas was distributed throughout the structure through non-jurisdictional houseline piping which served each resident's furnace and stove, as well as the building's shared water heater.

Fact 5: The natural gas carrying infrastructure within the 8701 Arliss Street building included jurisdictional piping owned and maintained by Washington Gas in the basement level meter/storage room: the interior portion of the distribution gas service line, two gas service regulators, relief vent piping from the regulators to the outside of the building, meter set piping and the typical appurtenances associated with a multi-meter setup, 15 gas meters with individual inlet valves, meter bars and meter swivels. (See Figure 1 for an example of the infrastructure)

The natural gas carrying infrastructure within the building and basement level meter/storage room also included gas carrying infrastructure owned and maintained by the property owner and its management company, Kay Management: the customer's gas houseline piping and appurtenances, the customer gas houseline to the water heater, and the natural gas commercial water heater along with all other end-use appliances.

Figure 1: Exemplar meter and regulator assembly; located in Flower Branch Apartment complex

Fact 6: All components listed above were found damaged, broken, bent, separated, rusted, melted and displaced from their original positioning after the incident. This was noted in the ATF Report as well as observed by party members and documented in photographs. (See Figure 2)

Figure 2: View into basement level meter/storage room of 8701 Arliss Street from grade level post removal of debris

Fact 7: The room that contained the gas meters and water heater was used as a storage area for Kay Management's maintenance operations. A variety of items were stored in this room, including gasoline, gasoline powered equipment, and large heavy objects such as furnaces and central air conditioning compressor units. The remains of a gasoline powered pressure washer and a central air conditioning compressor unit can be seen in the debris in Figure 2. (Appendix 1 – Meter/Storage Room Inventory Provided by Kay Management)

Fact 8: On March 23, 2016, during a "Fire and Life Safety Inspection" by Montgomery County's Division of Fire Prevention and Code Compliance, the management company was cited for storing gasoline inside of the basement level meter/storage room, as well as storing materials which interfered with access to the gas meters and gas service. (Appendix 2 - Montgomery County Fire Code Citation)

Fact 9: Washington Gas did not receive a report of gas odor prior to this accident. In fact, Washington Gas did not receive any inside gas odor call for 8701 Arliss Street for over five years prior to the incident. The most recent such call was received by Washington Gas on February 9, 2011 as an odor complaint. Upon investigation, the source was determined to be a minor leak on an outlet meter swivel fitting which was tightened and repaired by the responding technician that same day.

Fact 10: There was a report of a gas odor called in to Montgomery County Fire and Rescue Service (MCFRS) on July 25, 2016, by the same individual who reported after the incident that he smelled gas just prior to the explosion. The MCFRS responded to the July 25, 2016, odor complaint, investigated the building's interior, as well as the exterior area around 8701 Arliss Street, and did not find any indications of a gas leak. Washington Gas was not notified of, nor called to respond to this reported gas odor.

Fact 11: A Washington Gas representative (Service Technician) was last in the meter room of 8701 Arliss Street on August 26, 2015, reinstating gas service (performing a turn-on) for Apartment 104. The turn-on incorporated all necessary safety checks of the houseline and appliances serving Apartment 104 and removal of a disc[3] in the meter swivel for Apartment 104 to allow gas to safely flow through the houseline to serve the appliances.

Fact 12: Two days before the accident, a Kay Management employee inspected the basement level meter/storage room in 8701 Arliss Street and did not detect any odor of gas or anything amiss with the gas carrying piping or appliance.[4]

Fact 13: There was activity in the meter room the day of the incident as part of the normal work performed by Kay Management Company personnel. "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."[5] There were no reports of a gas odor from the management staff that day.

<u>Analysis of ATF Findings:</u>

The ATF's initial investigative assumptions that there was a separation of the gas union fitting on the regulator relief vent line for one of the natural gas regulators, and concurrent failure of one of the natural gas regulators, are not supported by later investigation, inspection, testing, observed piping deformation, and analysis.

1. From the onset of the investigation, both the ATF and the NTSB recognized: 1) that all of the gas carrying pipe, fittings and appliances impacted by the explosion and building collapse were severely damaged, such that their pre-collapse condition and placement would be difficult to determine (See Figure 2); and 2) that any segment of this damaged piping, any

[3] A meter security disc is a small round plate installed in the meter inlet connection in order to prevent unauthorized and unsafe re-introduction of gas by operation of the meter inlet valve.

[4] National Transportation Safety Board. *Interview of James Clark Melillo*. NTSB Accident No. DCA16FP003, Tr. 46-47, August 20, 2016.

[5] ATF Report at 10.

fitting and any appliance could have been the source of fugitive gas if that piping or fitting was breached, or if that appliance was breached, damaged, improperly maintained or operated.

2. Although the ATF recognized the extensive damage in the basement level meter/storage room prevented investigative determination of the source of fugitive natural gas, there was a clear emphasis on the investigation of a single union fitting connecting the lower regulator's relief port to the atmospheric vent line piped to the building's exterior. This emphasis appears to have rested upon the observation that the union was found separated following the accident without any readily apparent damage to the threads, and an incorrect understanding that a regulator failure coupled with an open vent pipe union would result in high pressure release of gas into the basement level meter/storage room. The ATF, without critical information from further investigation, concluded that the separation of the union observed, post-explosion, also existed pre-explosion. The ATF did not have the benefit of the further facts developed in the course of the inspections and tests developed by the NTSB. Ultimately, the ATF suggested that the follow-on investigation by the NTSB might "possibly provide more data useful to this report."[6]

3. The NTSB investigation has provided more useful data, which is discussed more fully below. The union fitting on the vent piping was closely examined by the NTSB and found to have damaged threads consistent with a forceful separation of the union fitting, such as in an explosion or building collapse. It was further noted that the union nut (female) was somewhat oversized for the union external threaded socket (male), thus contributing to the partial engagement of the threads, and perhaps further facilitating a forceful separation of the

[6] ATF Report at 12.

union by forces applied during and after the explosion. In addition to the findings from inspection of the union fitting, structural damage to the vent pipe and damage to adjacent piping connected to the regulators is also consistent with the type of deformation/deflection to piping that would occur if the union was connected, pre-explosion and pre-collapse. The observed pipe deformation/deflection would not be likely to occur had the union fitting been disconnected, as initially theorized in the early stages of the investigation. This additional data is also discussed more fully below. Based on this additional data, Washington Gas reaches different findings as to the timing of the separation of the union fitting than were offered by the ATF.

4. Also, the NTSB conducted further investigation and testing of the operational characteristics of the regulators. That laboratory/field testing, demonstrates that the regulators continue to protect the downstream piping from high pressure gas during a failure condition. In addition, in a very rare complete failure of the regulator where the valve seat does not close, the configuration of the two regulators in parallel would immediately result in the activation of both regulators' relief vents. In the scenario sought by the ATF of the open union to the lower regulator, it is undisputed that the upper regulator was connected to the relief vent prior to the incident, therefore, if a complete failure of the regulator had occurred, the venting gas from the upper regulator would have been directed outside by the vent piping creating a strong odor of natural gas as well as an audible noise from the gas rushing from the vent. No odor was reported outside before the accident and none was noted during post-accident interviews. For all the reasons set forth above, and further supported by the analysis that follows, the evidence supports the finding that the union fitting was connected prior to the

accident and that a regulator failure, should such a failure have occurred, did not cause this accident.

Analysis of Facts and Observations Related to the Lower Regulator Vent Piping Union:

It appears that, beyond the ***post***-collapse observation that the union fitting was separated, there is no other evidence to suggest that the union fitting was separated prior to the explosion and collapse. Because there were many threaded fittings which were found separated following the building collapse, it is not reasonable to conclude which of those fittings, if any, were separated prior to the accident without appropriate analysis and support for such a conclusion. The ATF arrived at the determination that the fitting was "disconnected prior to the explosion"[7] based on visual examination of the fitting as found on site, covered in rust (Figure 3A and 3B), post-explosion and fire, and without the aid of any laboratory testing or enhanced observations of the fitting, which proved to be necessary to establish its pre-collapse configuration.

Figure 3A: Lower Union as found on site post explosion

[7] ATF Report at 12.

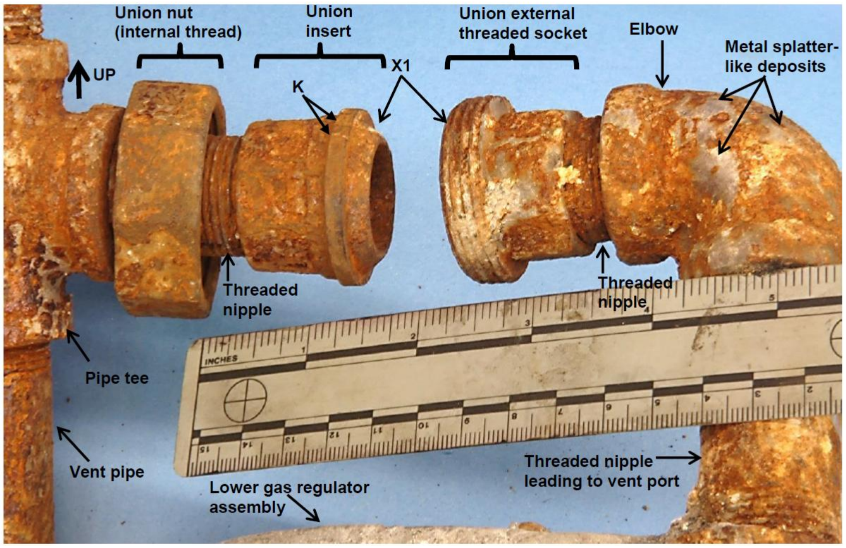


Figure 3B: Lower regulator vent union

The NTSB investigation's close inspection and testing of the regulators, the vent piping and the lower regulator union fitting, revealed numerous factors that support a finding that the union fitting on the vent pipe was connected prior to the explosion/building collapse, and therefore, was not the source of fugitive natural gas that caused the explosion.

Fact 1: The lower portion of the vent pipe was bent inward, towards the wall and opposite of the direction of the tee and nipple that connected it to the lower regulator.

Analysis: For a bend to occur as shown in Figure 4A and 4B, a force would have needed to be applied to the lower section of the vent pipe below the connected tee (W) to the upper regulator. This force could only come from a connected vent line of the lower regulator during the collapse of the building and ensuing collapse of the meter set. The direction of this force is consistent with a force that would result from the meter set collapsing forward and toward the floor, along with the upper regulator connected to the vent line. For an explanation of how this series of events could have occurred, see Figures 4A and 4B.

Figure 4A: Bending evident in lower section of vent line

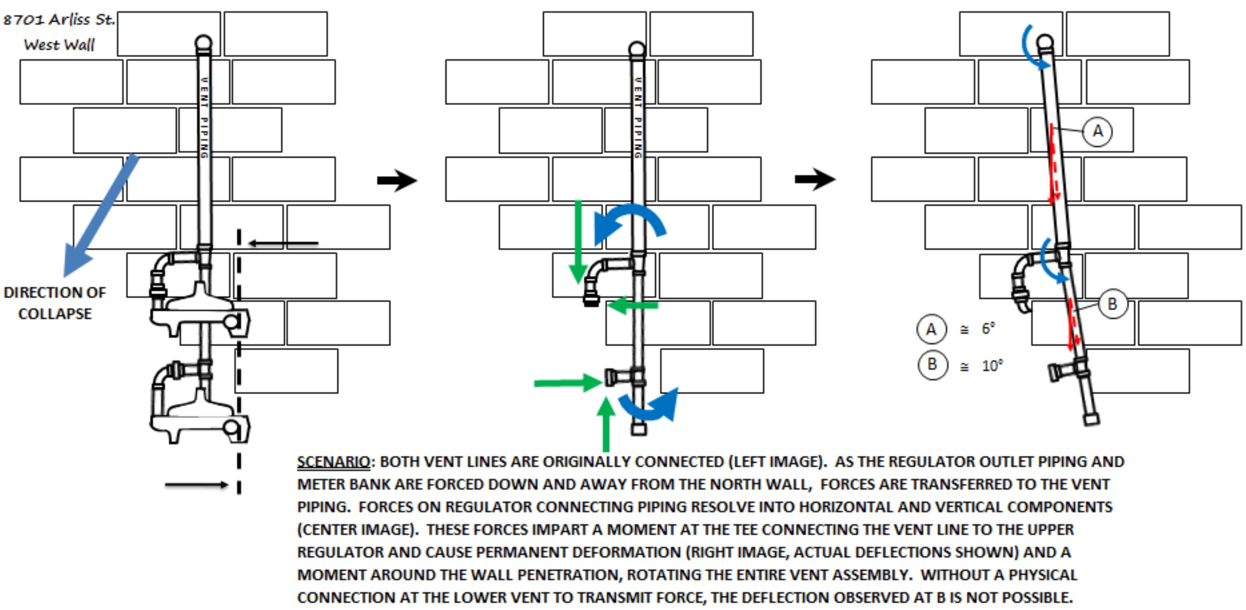


Figure 4B: Before/after image detailing the forces associated with the lower vent line connection where both regulator vent lines are connected prior to damage

Fact 2: The fittings and nipples that led from the regulator to this union fitting were found to be out of line with the vent connection and were rotated clockwise (Angle 'F' in Figure 5).

Analysis: Rotation clockwise would further tighten the fitting into the regulator, which on a 50 year old connection such as this, requires a significant amount of force. If this piping was rotated clockwise by an individual there would have been significant wrench marks on the fittings due to the force required to turn them; no wrench marks were noted. Additionally, an individual seeking to disconnect this union fitting, professional or laymen, regardless of ill-intent or good intent, would ordinarily not do so by forcefully turning the fitting clockwise which would be to further tighten the fitting (virtually everybody knows the phrase "righty-tighty, lefty loosey", with "righty" in this configuration being clockwise). The clockwise rotation of this fitting indicates that it occurred as a result of considerable force, not manual disconnection of the union fitting. Furthermore, the clockwise rotation of this section of piping from the lower regulator to the union appears to be consistent with the forces available during the collapse of the meter set and in the direction consistent with the direction the meter set was forced during the collapse of the building. The application of these available forces is consistent with the union fitting on the vent pipe being connected at the time of the collapse.

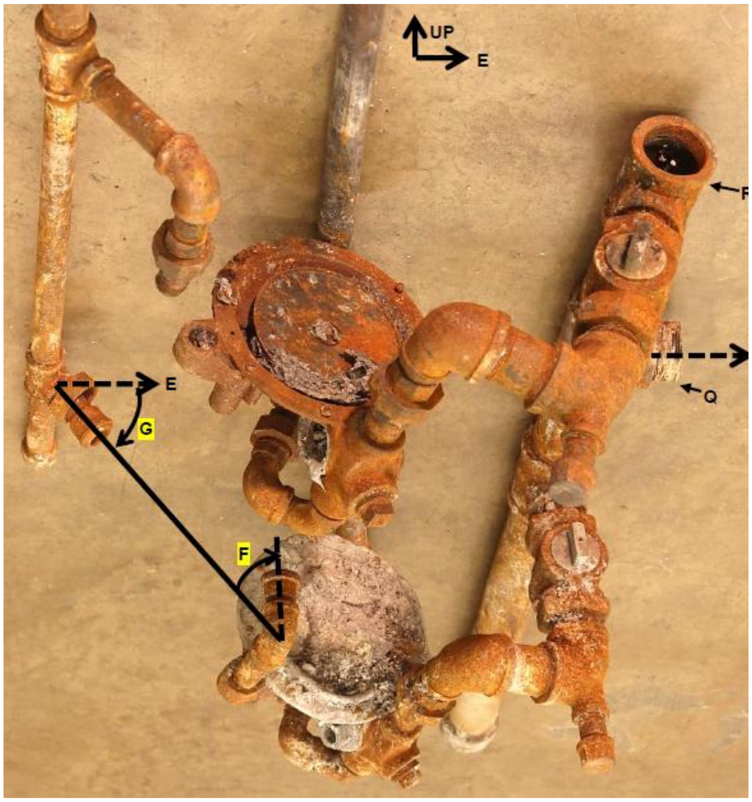


Figure 5: Rotation of vent line segment in lower regulator (Angle 'F')

Fact 3: There is damage to the threads of the lower regulator union fitting as shown in Figure 6, which was observed during the NTSB's more in-depth examination of the lower regulator union fitting.

Analysis: The direction of the damages to the threads are consistent with the fitting being pulled apart by force, and are consistent with the forces that would exist with the collapse of the building and meter set, particularly if there was minimal thread engagement due to the ill-fitting union nut (female).

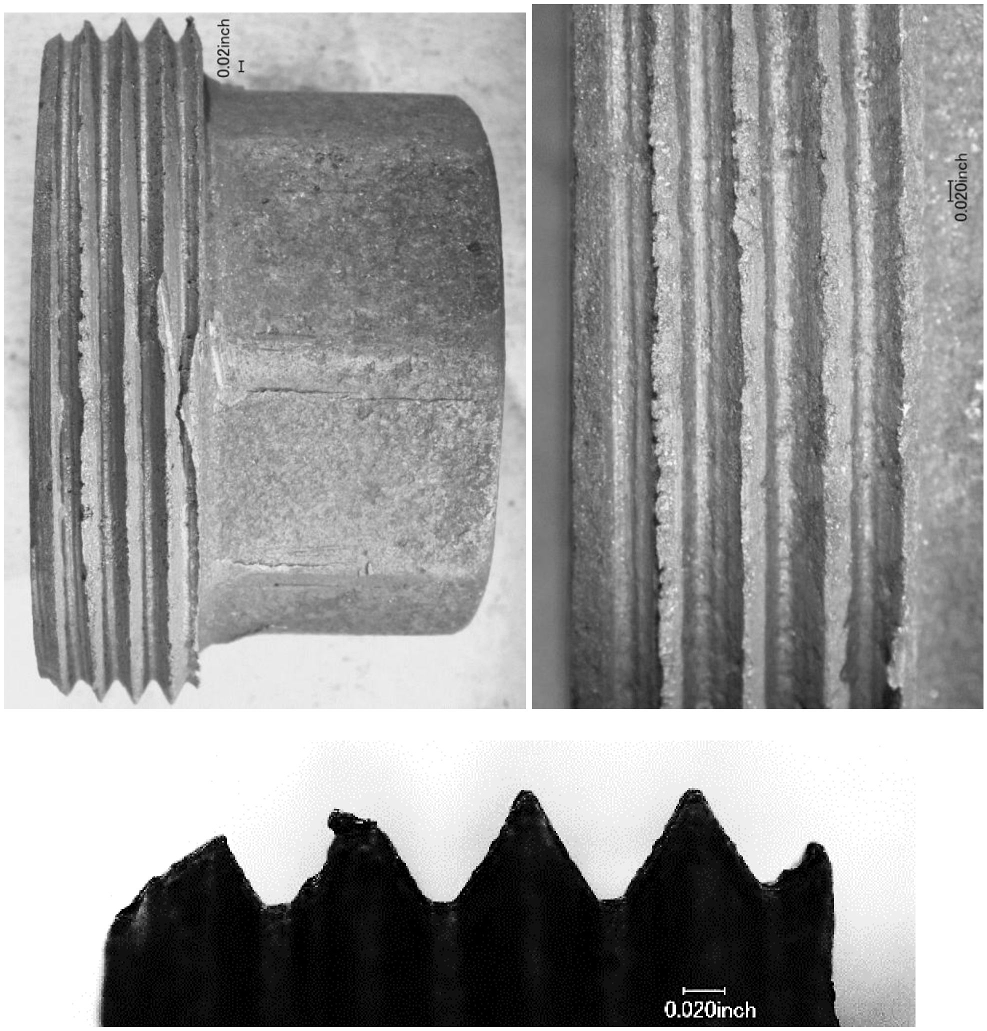


Figure 6: View of the disassembled union external threaded adapter from the lower gas regulator (top left); close-up photograph of the external threads (top right); side profile of external threads (bottom)

Fact 4: During the examination of the lower regulator union fitting in the NTSB lab, the union nut (female) was found to be enlarged resulting in minimal thread engagement with its male counterpart. Where a typical union fitting would have thread engagement at the immediate point of contact between the male and female counterparts (pictured on the left of Figure 7), the threads from the female and male counterparts of the lower regulator union fitting did not engage until 3+ of the 5 threads of the Union External Threaded Socket (male component) were recessed into the Union Nut (female component) as shown in the right side photo of Figure 7.

Analysis: The design of the fitting, accompanied by the purpose it served in the piping arrangement (a component of the non-gas carrying/non-pressurized relief vent piping) would allow a minimally engaged union fitting to serve its purpose, even though its threads were not fully and completely engaged. The forces and extreme heat that were in play following the explosion enabled this fitting, with minimal thread engagement, to expand and separate. It is important to note that the x-ray of the upper union fitting shown in the *Materials Laboratory Factual Report*[8] (See Figure 8), which had normal immediate thread engagement, only has three threads engaged when fully connected. An investigation based on full knowledge of all the relevant facts, including the minimal thread engagement of the lower union, the oversized nut, and the thread damage found, could not reliably conclude that the lower union must have been separated pre-explosion, pre-collapse. The ATF did not have the benefit of these facts.

Figure 7: Disparity in fitment; Comparison of the point of thread engagement of a typical union fitting (left) versus the point of engagement found with the lower regulator union fitting (right).

[8] National Transportation Safety Board. *Materials Laboratory Factual Report No. 16-097*. NTSB Number DCA16FP003. Washington, DC 2016 at 42.

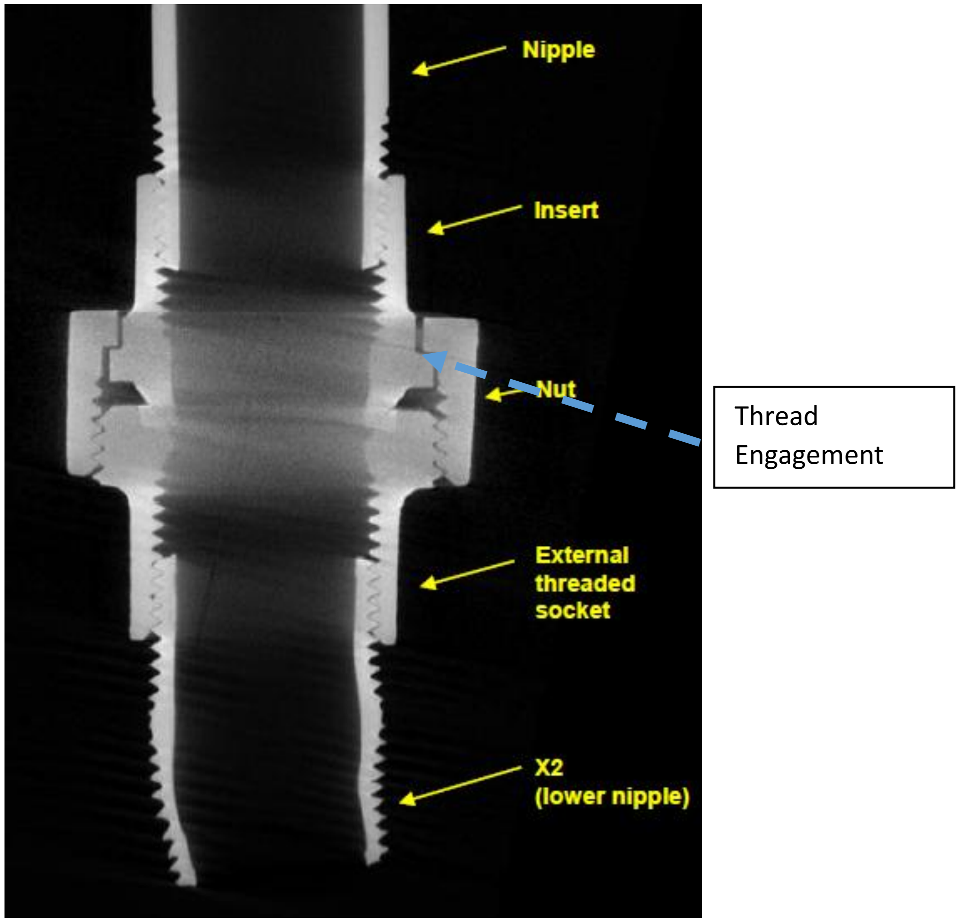


Figure 8: X-ray showing upper vent union coupling nut thread engagement

It is most reasonable to conclude that the incomplete thread engagement and observed thread damage, coupled with the enlarged female nut, is consistent with the union separating under the force of the collapsing meter set, especially when considering the potential for further heat expansion of the enlarged nut from the ensuing fire.

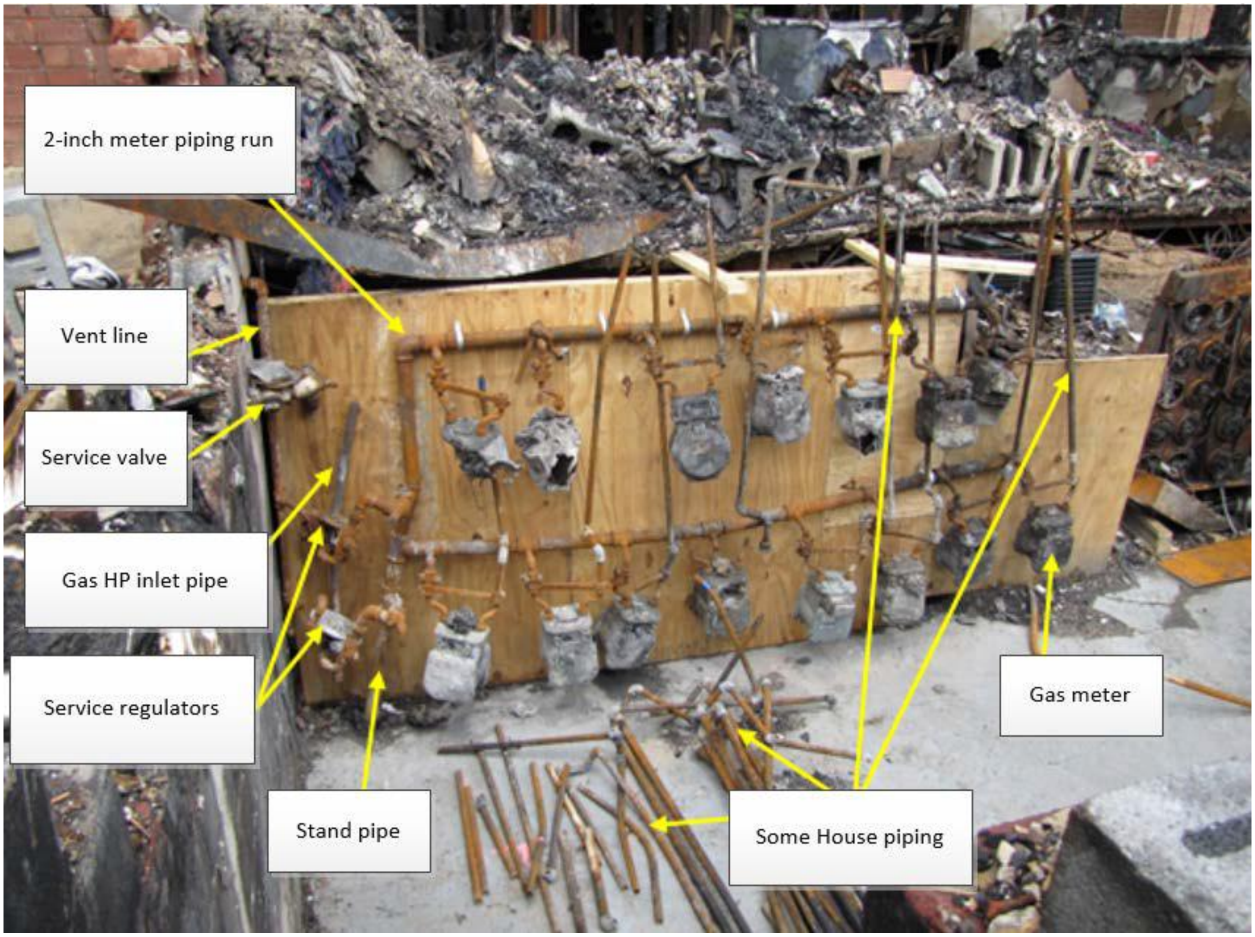


Figure 9: Meter set and house piping as reconstructed by ATF post accident clean up.

Conclusion: When considered together with all the developed observations and data, as well as the testing and analysis conducted, these facts are consistent with the union fitting on the vent pipe being connected prior to the explosion and the ensuing building collapse. The fact that the union was found separated post-accident, as were numerous other fittings as shown in Figure 9, is a result of the forces associated with the collapsing building and meter set acting on a threaded union fitting with minimal thread engagement due to a difference in size between the male and female components.

This is an important conclusion. The connected union could not have been the source of suspected fugitive natural gas in the basement level meter/storage room of 8701 Arliss Street. If, as the physical evidence now suggests, the union fitting was connected, any failure of the regulator would have vented gas only to the outside of the building.

Analysis of Facts and Observations Related to the Mercury Regulators:

Even when assuming that the union was open prior the accident, the conclusion remains the same. In order for a disconnected relief vent pipe to release gas, it would also require the simultaneous failure of the regulator to the point where it vents gas through its relief device. Discovery, testing, and observation confirm that the flow rates developed by a credible regulator failure would: 1) be unlikely to result in natural gas accumulation to the limits of explosive concentrations within the basement in the available time frame established by the ATF; or 2) vent a significant volume of gas to the outside through the vent pipe with an audible noise from the gas rushing from the vent. There were no reports of any indications of venting outside of the building. No witnesses reported an odor of natural gas outside the building. The witness that smelled gas inside the building in the stairwell prior to the explosion specifically stated that he did not smell gas outside when he exited the building, also just prior to the explosion.

Mercury Regulator History and Operation:

Throughout the 1940s and 1950s, Washington Gas installed mercury-sealed service regulators manufactured by the Reynolds Gas Regulator Company, est. 1892. The majority of installations utilized one of three model numbers:

1. Model 30, #1, ¼” orifice
2. Model 30, #3, $^{7}/_{8}$” orifice
3. Model 10, #1, ¼” orifice

Mercury-sealed regulators, commonly called “mercury regulators”, are known for their consistent performance and steady delivery pressures. Washington Gas has approximately

125,000 mercury regulators still in service today that are reliably delivering gas per the specifications and pressure settings they were installed under.

The regulators used at 8701 Arliss St, were Model 30, #1 units. A picture of this regulator type is shown below:

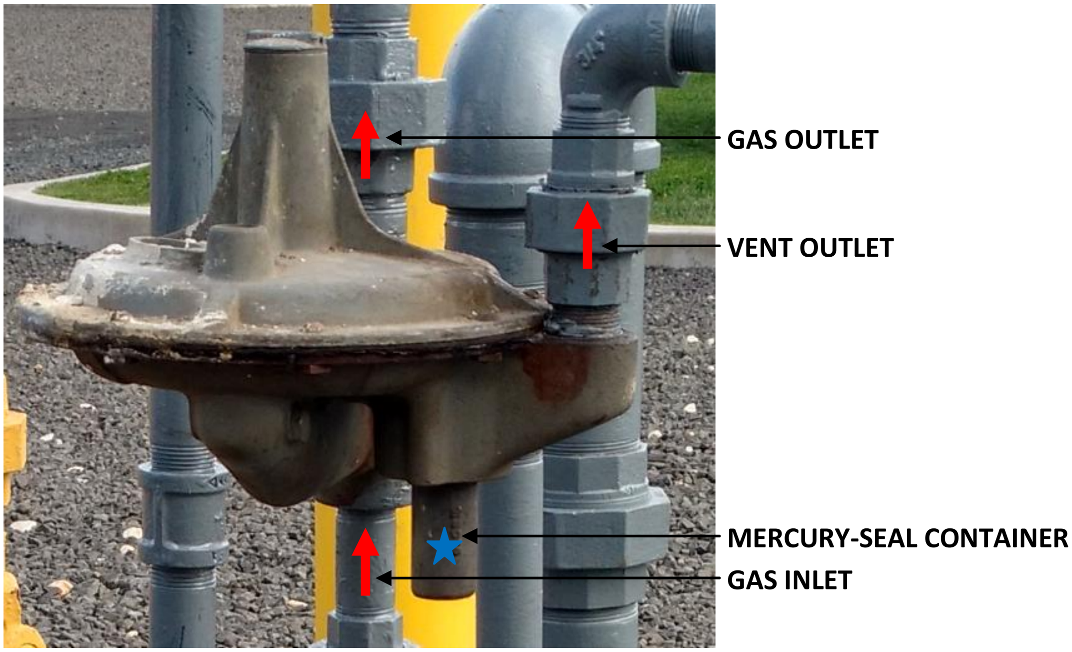


Figure 10: Mercury-Sealed Regulator

The mercury regulator's reliability is based on simple construction and a minimal number of moving parts, comprised of the following:

1. Spring – Used to adjust natural gas delivery pressure
2. Leather Diaphragm and Metal Diaphragm Plate (a disk) – Serves as the pressure sensing element and translates pressure into a force to counterbalance the force of the spring
3. Rubber Valve Seat – Acts to provide a positive shutoff under no-flow conditions
4. Linkages – Transmit the motion of the Diaphragm to the Valve Seat

5. Orifice – Serves as the passageway for distribution gas; pressure reduction occurs as gas flows through the orifice
6. Mercury seal - A tube extending into a cup for the storage of mercury and a sufficient amount of mercury to provide overpressure protection

See the cross-sectional image below for an illustration of the basic parts of a mercury regulator.

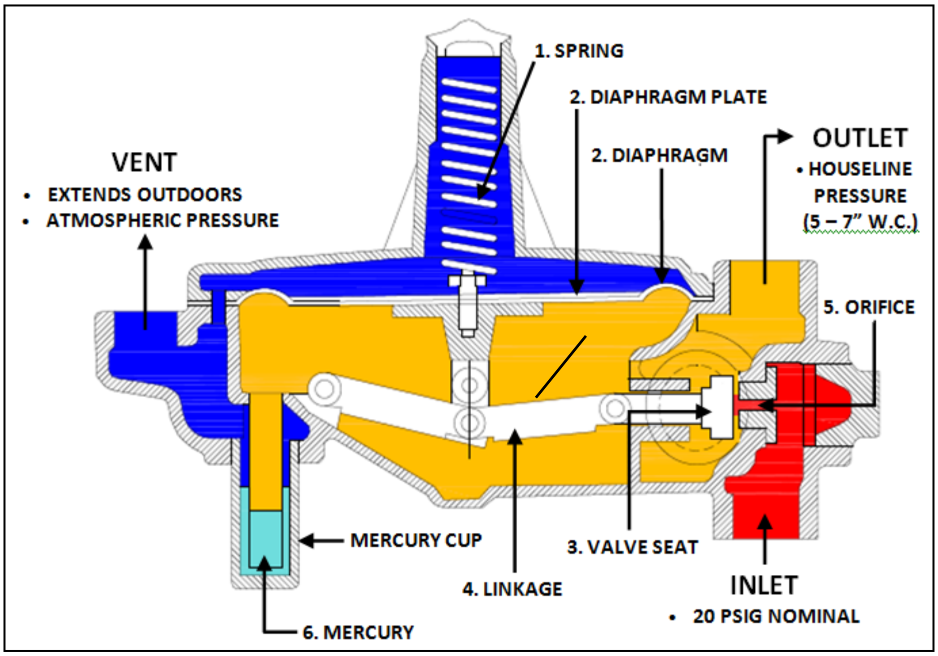


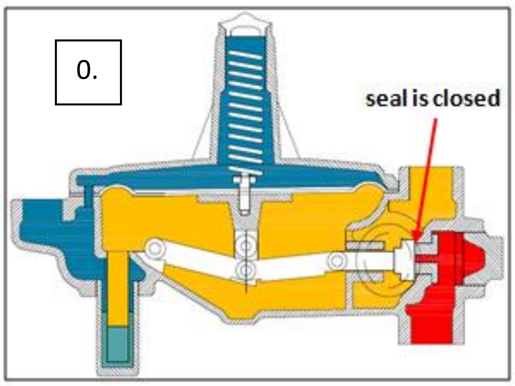
Figure 11: Mercury Regulator Cross-Section

The spring, diaphragm, and diaphragm plate control the movement of the valve seat. As downstream pressure drops below a pre-determined setting known as a "set point," due to demand from the customer, the spring force pushes on the diaphragm and diaphragm plate which in turn pulls the valve seat away from the orifice to allow more gas to enter the body of the regulator and house piping.

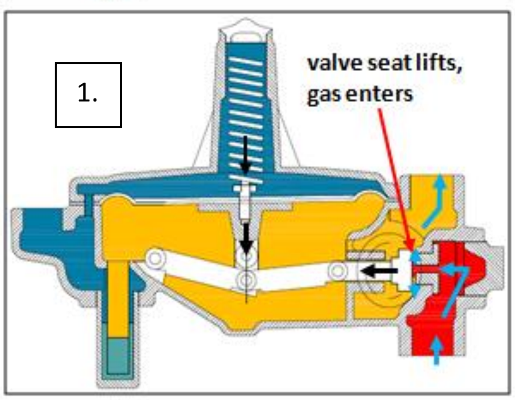
The regulator's vent line is separated from gas by means of a column of mercury called the "mercury seal." Gas pressure forces mercury down the tube, then up and out of the cup if the pressure within the house piping ever exceeds the weight of the column of mercury (typically set at 14 in. w.c., equivalent to approximately 0.5 psig) during what is known as an “overpressure” event or “venting.” It should be noted that an overpressure/venting event is rare, and results in a small flow of gas through the vent. If the regulator is located indoors, the vent is connected to vent piping that terminates outdoors so that a passerby can smell gas and alert the gas utility or building management.

The diagrams below, along with a brief explanation, depict the operation of a mercury regulator:

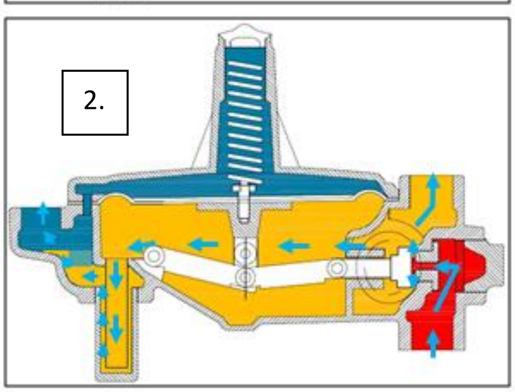
REGULATOR OPERATION



0. <u>Starting Point:</u> Closed Regulator with no Gas Demand from Appliances. Houseline pressure is at the regulator setpoint, i.e., the gas pressure within the yellow region is at 5.5 in. w.c. (equivalent to approx. 0.2 psig), nominally. The upward force against the diaphragm, caused by gas pressure, is balanced by the downward force against the diaphragm, caused by the spring force.



1. <u>Houseline Demand</u>: An appliance demands gas, so pressure within the houseline decreases, i.e., pressure in the yellow region drops below the regulator set point because gas is being consumed. The downward force of the spring overcomes the upward force against the diaphragm (due to houseline gas pressure). The valve seat moves away from the orifice, and inlet gas enters the regulator chamber and houseline, raising the houseline pressure and moving the diaphragm upwards until a seal is created again.



2. <u>Overpressure Event:</u> The demand for gas from the appliance stops, but a positive seal is not maintained between the valve seat and the orifice. Gas continues to flow into the houseline until the pressure reaches a level equivalent to the height of the mercury column within the mercury cup. This is, nominally, about 14 in. w.c., corresponding to a mercury column height of about 1”. The pressure of the houseline gas overcomes the mercury, forcing the mercury upwards into the area above the cup, and allowing the gas to escape through the vent line. As gas exits the vent line, the houseline pressure stabilizes.

Supporting facts and analysis:

Fact 1: The two mercury regulators that served 8701 Arliss Street were examined and disassembled in the NTSB lab. Both were heavily damaged by the fire. Aluminum components melted, but observation of some key components was accomplished. In both regulators, the valve seat was intact and connected to the lever arm. In both regulators, the operating lever arms were intact, indicating a failure of these key components did not occur (Figure 12), nor does Washington Gas have any historical evidence or testimony that these components have ever been found to have failed.

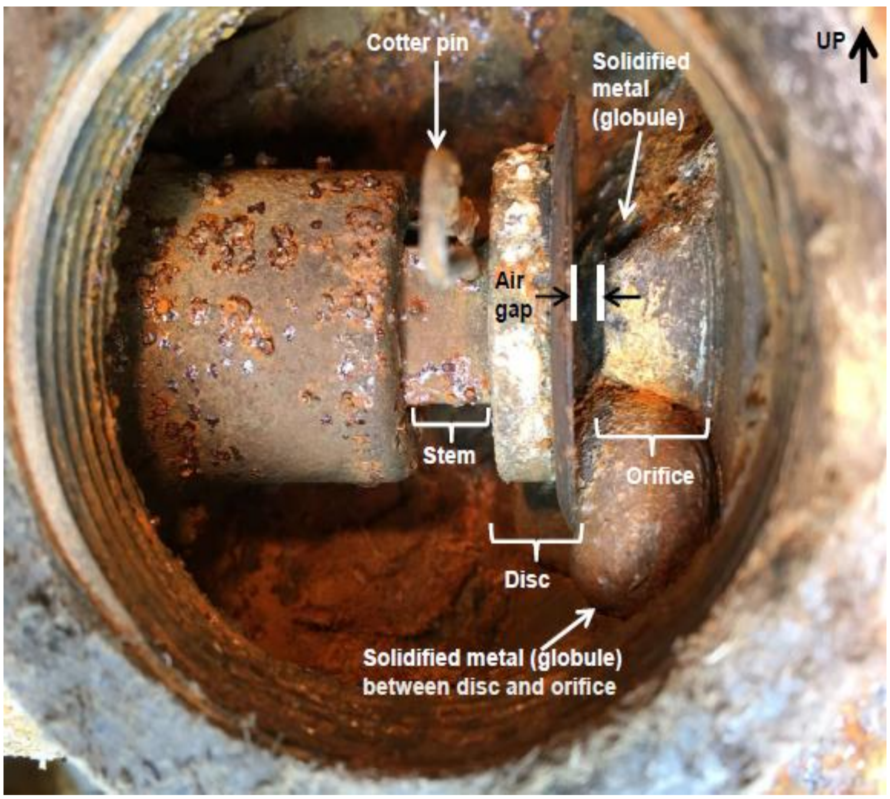


Figure 12: Lower gas regulator valve seat area

Fact 2: The party members observed, tested and disassembled three exemplar mercury regulators of the same vintage and type that were in 8701 Arliss Street. The exemplar regulators were removed from separate buildings in the Flower Branch Apartment complex (8642 and 8674 Piney Branch Road). They were found to be in working order. One of the exemplar regulators had experienced loss of some of its mercury in shipping, and thus was venting gas through the mercury relief device during operational testing, yet was functioning normally as to pressure regulation. The exemplar regulators were later disassembled in the lab and all components were found to be in good condition and operating normally. The diaphragms in the mercury regulators were comprised of leather material and were found to be pliable and in excellent condition. The valve seats were also observed to be in good condition.

Analysis: Observation, testing, and disassembly of the two mercury regulators in 8701 Arliss Street, as well as the exemplar mercury regulators, reveals no evidence to indicate an inherent structural or functional issue with the two mercury regulators in 8701 Arliss Street.

Fact 3: As noted in the investigation, there are three basic failure modes in which a mercury regulator can vent gas through its relief port, all of which were demonstrated through field testing at Washington Gas' Springfield Training Center. (Appendices 4 and 5: Exemplar Mercury Regulator Test Report and Mercury Regulator Battery Test Protocol and Report, respectively)

A) The regulator cannot stop the flow of gas due to contamination of the seat, seat wear, or a blockage between the valve seat and the orifice.

In this situation, the valve seat does not create a gas tight seal with the orifice, allowing the gas to flow through the regulator, exceeding the customer's appliance consumption downstream. In this case, the pressure will slowly rise until it overcomes the weight of the column of mercury in the mercury cup and gas bubbles through the mercury and out of the relief vent. The mercury in the mercury cup is typically filled to a level that equates to 14 in. w.c. of weight (equivalent to approximately 0.5 psig). The downstream pressure in the customer's house piping will be maintained at or below the pressure of the relief setting (14 in. w.c. in this case; 0.5 psig). See Figure 13 for an illustration of this failure mode (gas flow indicated by green arrows). This was demonstrated during the field test held at the Washington Gas Springfield Training Center on May 31, 2017, detailed in Appendix 5, in which gas escaped through the vent at approximately 165 SCFH. During testing, the relief capacity of a single regulator was adequate to limit the houseline pressure to a maximum of 8.5 in. w.c. (0.3 psig) in this failure mode.

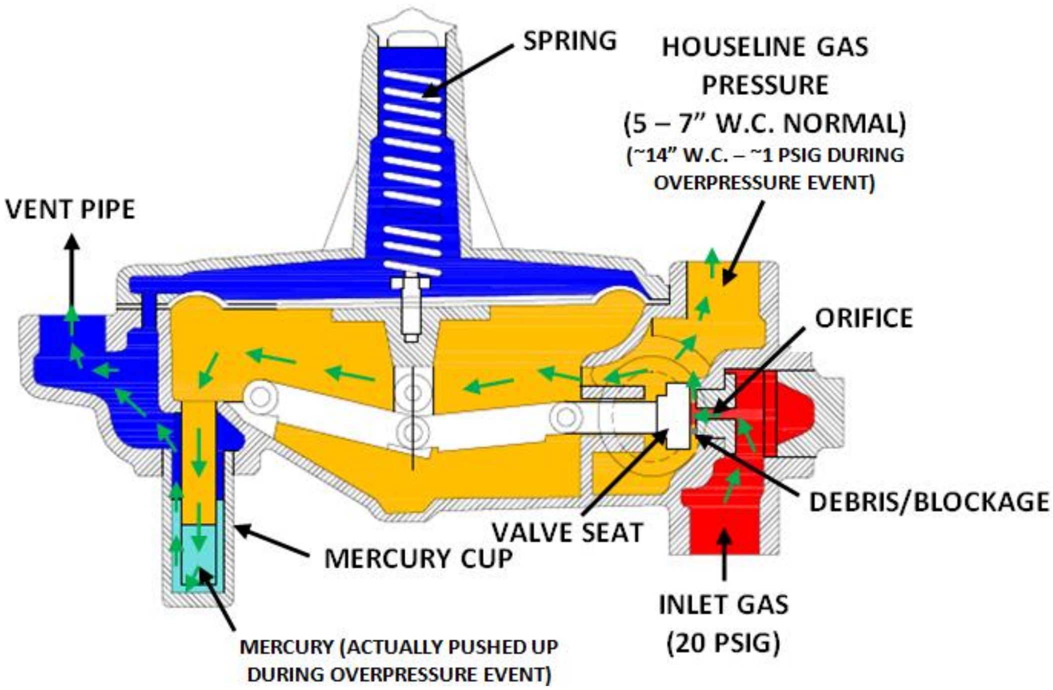


Figure 13: Orifice Blockage or Valve Seat Wear Schematic

B) The mercury is displaced from the mercury cup and allows the gas in the regulator to escape through the relief vent.

The circumstance of mercury being displaced is caused by individuals (HVAC Contractors/homeowners) unfamiliar with the intricacies of the mercury regulator who (a) modify the regulator installation and tilt it or, (b) shut off gas to the regulator, then reintroduce gas too quickly, both of which force mercury out of the cup. In these cases, the regulator continues to operate and control the pressure to its set point (5 to 7 in. w.c.; 0.2 psig), supplying gas to customers' appliances while gas vents out through the relief vent due to the lack of mercury to retain it. This was demonstrated during the field test held at the Washington Gas Springfield Training Center on October 12, 2016, as detailed in Appendix 4, in which gas escaped through the vent at approximately 330 SCFH. See Figure 14 for an illustration of this failure mode (gas flow indicated by green arrows).

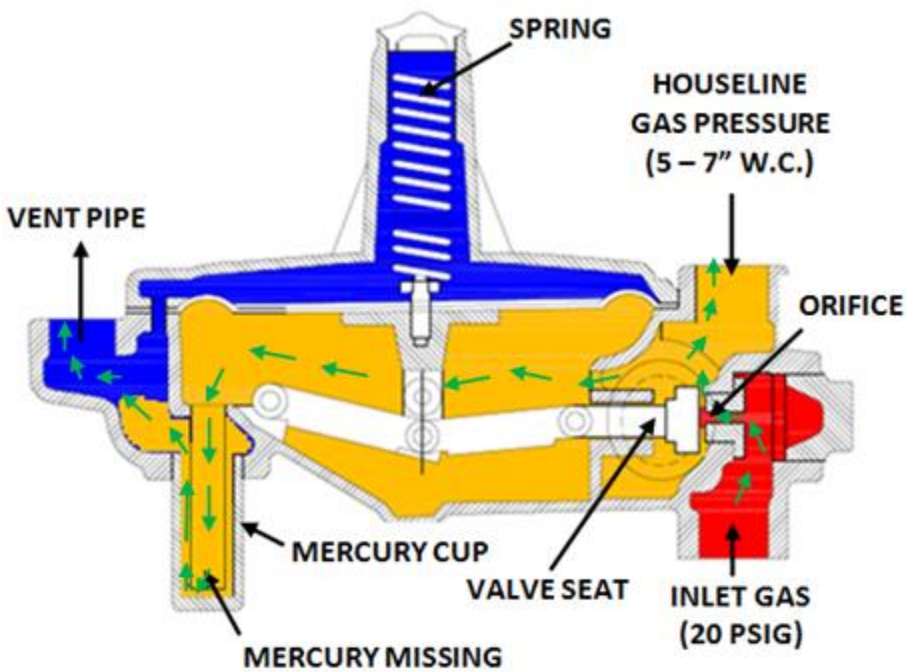


Figure 14: Missing Mercury Schematic

C) The regulator fails causing valve seat to go open. This could be caused by the linkage breaking or the diaphragm tearing.

In this case, the valve seat is forced away from the orifice, gas flows through the regulator, and into the houseline, restricted by the size of the orifice (1/4" in the case of the mercury regulators at 8701 Arliss Street). The regulator is designed to handle this failure mode and will relieve the volume of gas coming into the regulator through the mercury relief cup and relief vent. During testing of a single regulator, the relief device maintained the pressure in the regulator and house piping to 6 psig or less during this type of failure. In a parallel regulator set up as was utilized in 8701 Arliss Street, the relief devices from both regulators are engaged in limiting the downstream pressure of the houseline for the protection of connected piping and appliances. As the downstream pressure increases beyond the weight of the column of mercury, the regulators will vent the gas. The typical mercury regulator is configured to relieve at approximately 14 in. w.c. (0.5 psig). In the case of a failure as described in this section, both regulators' relief valves will activate and vent gas. This was demonstrated in the regulator testing conducted at the Washington Gas Training Center on May 31, 2017, detailed in Appendix 5. See Figure 15 for an illustration of this failure mode (gas flow indicated by green arrows). During the field test, gas escaped through both vents at a combined rate of approximately 2,200 SCFH and the audible rush of gas from the vent was readily apparent. During testing, the combined relief capacity of both regulators was adequate to limit the houseline pressure to 1.75 psig in this failure mode. A detailed depiction of the regulator vent piping arrangement is presented in Appendix 5: Washington Gas Mercury Regulator Battery Test Protocol and Report, May 30, 2017.

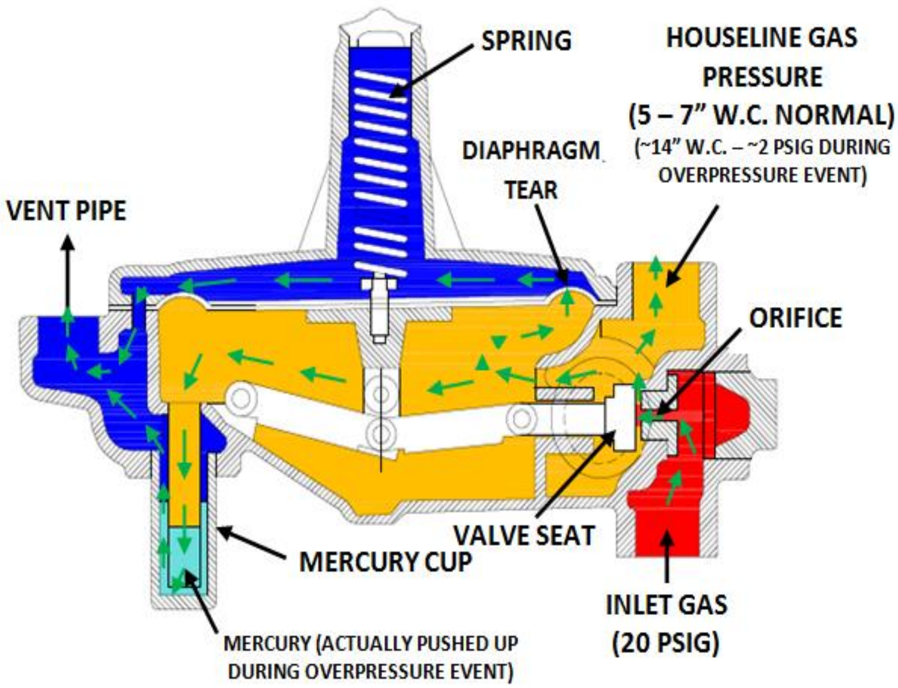


Figure 15: Diaphragm Tear Schematic

Analysis: There was no indication that either of the two mercury regulators were removed at any time, nor any indication that they were turned off and then turned back on, so as to have displaced the mercury from the cup (Failure Mode B, above).

Under Failure Mode B, the regulator will continue to vent gas until the gas supply is turned off. There were no reports of a gas odor in the basement level storage/meter room the day of the incident, therefore the displacement of the mercury from the cup would have had to be done knowingly by the last individual leaving the meter room that day, of which there is no evidence. This would have also resulted in gas venting at approximately 330 SCFH, for approximately 5-1/2 hours between the time the basement level meter/storage room was locked and the time the explosion occurred. Thus the heavy odor of leaking gas would have been reported by individuals in and around the meter room at some time prior to the incident. Failure Mode B is therefore not credible.

The examination of the regulators from 8701 Arliss Street post accident demonstrated that the linkages and valve seat were intact. The leather diaphragms from the exemplar regulators removed from 8642 and 8674 Arliss Street were found in excellent condition, which suggests the diaphragms from the regulators in 8701 Arliss Street would be in like condition. Field testing of an exemplar regulator assembly consistent with what was used in 8701 Arliss Street was conducted to simulate Failure Mode C (a full failure by purposely cutting the diaphragm). Testing demonstrated the fact that both regulators vent gas through their relief ports. This being the case, this type of regulator failure would have resulted in the release of a high volume of gas to the outside of the building through the relief vent piping from the upper regulator, creating a strong gas odor and an audible release of gas escaping the vent outside of 8701 Arliss Street. There were no reports of a gas odor outside of 8701 Arliss Street. These facts make Failure Mode C implausible.

Therefore, the only possible scenario where the regulators would be the source of gas into the basement level meter/storage room, where gas would not have been venting during the day while the room was open, and where gas would not have also been venting outside the building through the relief vent, would be a circumstance where the union fitting of the lower regulator was open and disconnected from the vent pipe and the lower regulator simultaneously failed due to some type of obstruction between the valve seat and the orifice (Failure Mode A above). This type of regulator failure is very rare, less than 0.1% annually from Washington Gas' experience and records.[9] In addition, as demonstrated through field testing, the gas relief flow rate from this type of failure would only be approximately 165 SCFH, assuming no downstream appliances are using gas. Testing demonstrated that flow rates in this range do not produce notable sound. This flow rate drops considerably when appliances are consuming natural gas. At these flow rates, it would take a considerable amount of time to fill the basement level meter/storage room with gas to a concentration exceeding the lower explosive limit, particularly without people noticing the smell of gas inside and outside of the building as the room has vented window openings near the ceiling, a door, and various openings in the basement ceiling. In addition, the demonstrated flow rate from the regulator with this type of failure is in a range that is less than or equivalent to the flow that would occur from the many other noted piping breaches found in the jurisdictional and houseline gas piping found after the explosion. Figure 16 - Table 1 compares the flow rate of the gas relieving from a 'Mode A' failure of the mercury regulator with estimated flow rates of other various open or broken fuel lines found in the gas system within the basement of 8701 Arliss Street after the incident.

[9] National Transportation Safety Board. *Operations Group Factual Report Accident No. DCA 16F003*, Washington, DC 2016 at 22-24; less than 631 failures noted over a population of approximately 137,174 regulators during the period October 2011 to September 2016.

Figure 16 - Table 1: Calculated Flow Rates

Piping or Component	Inner Diameter (in)	Flow Rate (SCFH)	Method of Determination	Time to Fill 1600-ft^3 room* (h)
1" Pipe	1.049	**2561**	**Calculation**	**0.3**
3/4" Pipe	0.824	**1359**		**0.7**
1/2" Pipe	0.622	**650**		**1.4**
Meter Swivel**	0.547	**1613**		**0.6**
Failed Mercury Regulator***	N/A	**165**	**Empirical**	**5.4**
Cracked 1/2" Pipe****	0.622	**264**	**Calculation**	**3.4**
Upstream P	14.92	psia		
Downstream P	14.7	psia		
Pressure Drop through Pipe	0.22	psia	6	in. w.c.
Specific Gravity	0.6		**Cr (SG factor)**	0.627
Absolute Temperature	535	°R		
Viscosity	0.012	centipoise		
Length of Pipe	10	feet		

Calculations Based on the Low Pressure Sizing Equation within NFPA 54 Annex B.5, 2015 ed.

*Time based on a 10% leak escape rate through room vent and 50% gas occupation of the total room volume.

** Meter Swivel Capacity based on an effective swivel length of 1 foot.

***Reflects failed-open regulator with 0.034 inch-diameter metal rod placed between valve seat and orifice, tested 5/31/2017.

**** Based on 1/16" wide crack spanning half of the pipe circumference, with 6 in. w.c. pressure, 10 ft. upstream of leak.

In Figure 16, included in the table, are calculated times it would take each gas flow rate to produce enough natural gas to reach an explosive atmosphere (LEL) within the basement level meter/storage room in 8701 Arliss Street. The calculation is based on the time it takes to fill the room 50% with gas considering a loss rate of 10% where gas would vent out of the room through various openings. This conservative assumption considers that with 50% of the room occupied with gas, it can be reasonably expected that some sample volume within the room will span 5 – 15% gas-in-air, and assumes it will find a source of ignition. The chart shows that a regulator failure relieving gas at 165 SCFH directly into the room would take approximately 5 ½ hours to reach an explosive atmosphere, yet the water heater fuel line ("1/2" pipe" in Table 1) which was found broken and separated at the control valve, with obvious signs of leaking, would create an explosive atmosphere in the room in under 1½ hours. If we consider the houseline to the water heater as only being cracked at the control valve prior to the incident ("Cracked 1/2" pipe" in Table 1), that would take approximately 3 hours to fill the room with gas to an explosive atmosphere. The room was vacated and locked by the Kay Management maintenance staff at 6:04 PM with no report of a gas odor. This creates only a 5 ½ hour window for gas to start leaking and accumulate in the basement level meter/storage room. It is reasonable to assume, the longer the duration of leaking gas the more opportunity for people to detect the smell of gas in and around 8701 Arliss Street. It is not reasonable to conclude that a regulator failed just moments after the room was vacated, then vented gas into the room with an open window near the ceiling (where gas would accumulate first) for over 5 hours in an active 14 unit apartment building, on a warm summer evening, without anyone detecting the odor of natural gas until moments before the accident.

Conclusion: The mercury regulator was not the source of fugitive gas that caused the initial explosion. The ATF's assumption regarding the possibility of a high pressure/high volume source of gas associated with a regulator failure has been demonstrably shown to be unsupported by physical evidence. Furthermore, a regulator venting scenario would require the lower regulator vent pipe to be simultaneously disconnected from the regulator; yet physical evidence and testing through the investigation are consistent with the vent pipe union being connected prior to the incident. The only plausible failure of the regulator that would vent gas solely into the basement produces a low pressure flow at a maximum rate of 165 SCFH; not the source of high pressure gas noted by the ATF. At this flow rate, it would take over 5 ½ hours to put enough gas into the room to create an explosive atmosphere, significantly more time than required via a release of natural gas from any other disconnected or broken fitting found within the basement level meter/storage room. Subsequently, all possible breaches in the building's gas system must have equal consideration and should be assessed within the timing constraints built in to the known sequence of events. Due to the destruction and damage of the piping within the building, the timing of any of these failures cannot be conclusively determined and therefore the source of the fugitive natural gas is indeterminable.

B. Houseline/Water Heater in Basement Level Meter/Storage Room

The physical evidence suggests that the only obvious and known source of leaking gas at 8701 Arliss Street prior to the building collapse and destruction of the jurisdictional piping serving the building was a fractured houseline serving the water heater located in the basement level meter/storage room.

The water heater was located in the Northeast quadrant of the basement level meter/storage room, and was found to have a full diameter, complete thickness fracture of the ½-inch gas houseline fitting where it connected to the inlet of the thermostat controller of the water heater at the base of the appliance. Additionally, the evidence clearly shows that the jurisdictional service line, meter set and houseline piping to the water heater were intact when that fitting fracture occurred, which could have allowed natural gas to have flowed freely into the basement level meter/storage room.

Analysis of Facts and Observations Related to the Fractured Houseline Serving the Water Heater:

Fact 1: The water heater had no standing pilot. The ignition system for the water heater was subject to activation, irrespective of the presence of a combustible atmosphere. The ATF correctly noted that the normal operation of the pilot light mechanism "could allow natural gas to have accumulated to an explosive mixture in its presence and ignite when the water heater activated."[10]

Fact 2: Water heater exhibited a U-shaped burn pattern covering nearly half of the outside surface of the heater, located above the thermostat/controller unit (See Figure 17). This burn pattern obviously resulted from a natural gas fed fire with a point of origin for the fuel consistent with the "full diameter, complete thickness fracture where the piping connects to the inlet on the thermostat controller of the heater unit."[11] (See Figure 18)

[10] ATF Report at 11.
[11] National Transportation Safety Board. *Materials Laboratory Factual Report No. 16-100*. NTSB Accident No. DCA16FP003. Washington, DC 2016 at 2.

Fact 3: The melting of the controller components on top of the control valve is consistent with a fire originating from the damaged ½-inch houseline (Figure 18). The ATF cited this control valve as a potential source of the fugitive natural gas in the 8701 Arliss Street basement level meter/storage room, and concluded that "The control valve for the water heater was found to be partially melted such that an examination for failure was inconclusive."[12]

Fact 4: The cracked or severed ½-inch houseline serving the water heater would create a gas flow rate of between 264 to 650 SCFH, enough to create and explosive atmosphere within 1.4 to 3.4 hours. (See calculations in Figure 16 - Table 1)

Figure 17: Water heater burn pattern

[12] ATF Report at 10.

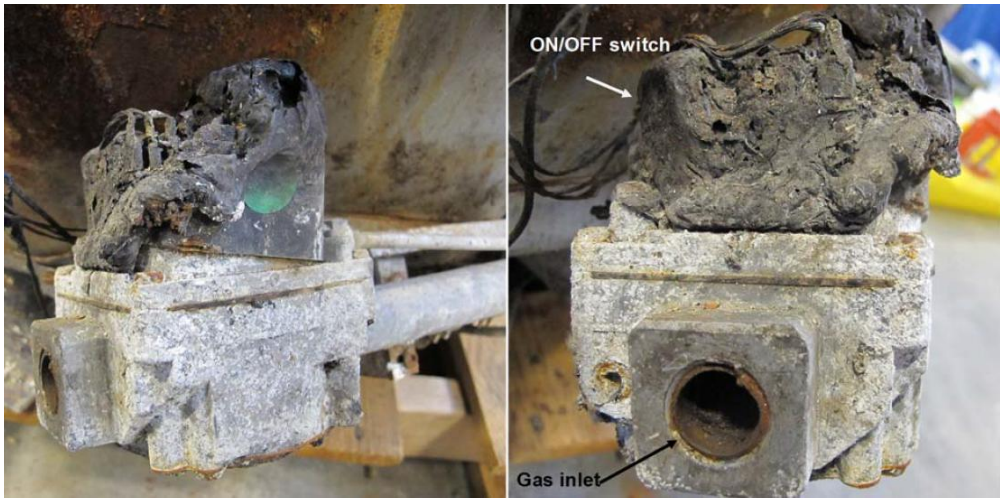


Figure 18: Water heater fuel control valve

Analysis: The evidence of the fractured houseline to the water heater, coupled with the characteristic burn pattern emanating from the location of the fracture is consistent with a finding that the houseline fracture and water heater fire occurred while the jurisdictional natural gas piping supply system to the water heater was still intact. An intact jurisdictional supply system would allow natural gas to flow to the point of fracture, where it would be released as fugitive natural gas at the base of the water heater. The burn pattern on the water heater indicates that, prior to the collapsing building severing the jurisdictional service line, the fugitive gas escaping at the base of the water heater ignited. That gas burned for a sufficient period of time to leave the burn pattern spreading in a "U" from the base as it climbed up the water heater.

Fact 5: The basement level meter/storage room at 8701 Arliss Street was subject to different uses than the equivalent rooms in the remainder of the complex. In some cases, the uses in the 8701 Arliss Street basement level meter/storage room were in violation of applicable building safety code. (See Appendix 2 - Montgomery County Fire Code Citation) The storage uses were occurring in the space around the meter and regulator assembly as well as the house piping. Relatively large, unwieldy, and heavy objects such as central air conditioning units and furnaces were being stored and stacked in sufficient proximity to the water heater and its fuel supply piping, to cause the Montgomery County building authorities to cite Kay Management for its violation of code by interfering with access to the utilities in the basement level meter/storage room, including the natural gas equipment. Kay Management personnel confirmed that such storage was taking place at the time of accident, observing on August 8th, two days before the accident, as many as 8 furnaces and multiple air conditioning units positioned within 2-3 feet of the water heater.[13]

Fact 6: The room arrangement in other buildings in the complex provided for a security cage around the hot water heater and its supply piping which protected it from other uses occurring in the room. (See Figure 19) No protection was provided for the water heater or, more importantly, it's associated gas supply piping in the basement level meter/storage room at 8701 Arliss Street.

Fact 7: There was an unsupported section of house piping from the ceiling to the ½-inch connection at the water heater control valve providing fuel supply to the water heater. (See Figure 20) This unsupported piping run can act as a significant

[13] Appendix 3 – National Transportation Safety Board. *Interview of Eduardo Hildago*. NTSB Accident No. DCA16FP003, Tr. 20:21-22:17, August 27, 2016.

lever arm capable of transmitting and multiplying any force applied to the house piping system to the observed point of failure at the fuel control valve.

Figure 19: Photo of meter room in 8703 Arliss Street; Protective cage around water heater

Figure 20: Water heater from 8701 Arliss Street; placed during ATF reconstruction, with fuel supply piping segment severed at elbow where pipe then ran up to connect to pipe at ceiling.

Analysis: The unsupported houseline and gas control valve were exposed and vulnerable to unintentional damage from the storage activities that are acknowledged to have regularly occurred in the basement level meter/storage room, that were occurring at the time of the accident, and that had been officially cited as a violation of county code. The crack discovered in the fuel supply piping is consistent with forces applied to the unsupported sections of house piping to the fuel control valve.

Factual Gaps:

1. Cause and time of origination of the full circumference fracture of houseline serving the water heater was not determined by either the ATF or through the NTSB investigation.

2. The period of time during which the jurisdictional piping was intact and feeding fuel to the crack at the water heater has not been identified within the sequence of events immediate to the explosion and collapse of the structure.

3. "Due to the damage to the natural gas regulators, natural gas meter bank and the water heater, investigators were not able to determine the failure that led to the release of natural gas in the basement level meter/storage room of 8701 Arliss Street."[14]

Analysis: Assuming fugitive natural gas was the fuel source for the initial explosion, the available evidence does not support a determination of the sequence or timeline of events that identified the source of an initial release of fugitive gas that could have led to the explosion and collapse of 8701 Arliss Street.

Conclusions:

1. The nature of the burn pattern exhibited on the water heater is consistent with a low pressure fuel supply which indicates that the natural gas regulators in 8701 Arliss Street were operating to reduce fuel pressure after the fracture in the houseline at the base of the water heater occurred.

[14] ATF Report at 11-12.

2. A definitive cause of the full circumference fracture was not determined, and a timeline for when it occurred is also undetermined. While it is possible that activity that was regularly occurring in the basement level meter/storage room including the regular movement and storage of relatively large heavy objects such as central air conditioners and furnaces, could have inadvertently strained the unprotected water heater piping leading to its failure, there is no definitive evidence as to cause of the fractured ½-inch fuel supply line to the water heater.

3. Although the available facts do indicate the fracture in the houseline to the water heater is the only obvious evidence of a gas leak, and could have been a source of fugitive natural gas in the basement level meter/storage room prior to the severing and damage to jurisdictional service line and associated gas supply equipment, the overall available evidence is insufficient to support determination of a timeline or sequence of events leading to the accident. The cause of the accident is UNDETERMINED.

C. <u>First Floor Initiating Event</u>

The ATF Report stated, "A hypothesis of the explosion originating in 8701 Apartment 101 was falsified by data."[15] However, based upon the analysis set forth below, the factual support relied upon to categorically rule out a first floor initiating event appears insufficient. Facts developed in the NTSB investigation, appear to support a hypothesis that an initial explosion could have originated in 8701 Arliss Street, Apartment 101, leading to a 3-story collapse of the building, and causing a

[15] ATF Report at 7.

severe degree of damage to the gas carrying facilities in the basement level meter/storage, resulting in further release of gas, ignition and ensuing damage. While it is acknowledged that the available evidence does not support a definitive timeline, sequence or cause for this accident, it is important that the findings and observations that are reached are vetted against all the facts that have been established.

It is evident from the ATF Report that a significant focus of its on-site investigation was the basement level meter/storage room. As stated earlier in this report, the ATF investigators reached an assumption, which Washington Gas believes is not supported by the evidence, that the union fitting had been separated prior to the explosion. Relying upon that assumption, as well as evidence of significant destruction in the basement level meter/storage room, perhaps explains the ATF ruling out the first floor event as initially causative without more in-depth analysis.

The follow-on NTSB investigation, however, had the benefit of time in developing additional facts, analyzing available evidence, and vetting facts against theory to better assess a given theory's strength or weakness. Facts developed in the follow-on NTSB investigation, including witness statements, are not only consistent with a potential initial explosion on the first floor, but may affirmatively contradict an initial explosion in the basement level meter/storage room. Although the entirety of the ATF investigation was not shared with Washington Gas, it is important to note that of the established facts shared in the ATF Report, none definitively contradict the hypothesis of an initiating explosion on the first floor. Consequently, the first floor should not be ruled out as a source of possible fugitive natural gas, or as the location of the initial explosion which led to the catastrophic collapse of 8701 Arliss Street into the basement level meter/storage room and the gas carrying facilities located there.

Analysis of Facts and Observations that support the theory that the first floor could have been the location of the explosion:

Fact 1: The only suspected odor of gas, prior to the initial explosion, was detected by a witness inside the building as he was descending from the third floor. He stated that he traced the odor to the landing area of the first floor, including the open stairwells ascending and descending from the first floor landing to the basement, with his perception being that the smell became stronger as he descended. This same witness then immediately exited the building to throw out his trash and stated that he did not smell natural gas outside the building as he walked along the front (west) side of 8701 Arliss Street toward the community trash collection point.[16] It should be noted that his path toward the collection point took him directly past the vented window of the basement level meter/storage room and the regulator vent discharge.

Fact 2: A witness located in the front of the 8701 Arliss Street observed what he described as the explosion occurring in and coming from the first floor Apartment 101. The witness stated: "there was a flash, there was shock wave. The apartment that was on top of the apartment that blew up, basically it went down on the building. Basically it's a building that has I think, two or three…floors."[17] He continued "I must tell you that the explosion came from the apartment on the first

[16] National Transportation Safety Board. *Interview of Adraine Boye*. NTSB Accident No. DCA16FP003, Tr. 48:20-49:1, November 15, 2016.

[17] National Transportation Safety Board. *Interview of Patrick Francisque*. NTSB Accident No. DCA16FP003, Tr. 16:4-8, November 15, 2016.

floor. There were two apartments on top of it that basically went down on it."[18] According to the ATF Report, multiple witnesses, as well as police dash cam footage, confirm that the "(west) of 8701 Apartment 101 was completely blown out during the initial explosion."[19]

Fact 3: The steel door to 8701 Arliss Street Apartment 101, which was dead-bolt locked at the time of explosion, was blown laterally away from the front of 8701 Arliss Street, approximately 300 feet directly outward and west from building 8701 (See Figure 21). Other debris was forcefully blown laterally westward from the first floor level directly into parked vehicles out in front of 8701 Arliss Street.[20]

Figure 21: 8701 Arliss St, Apartment 101, externally facing fire door

[18] National Transportation Safety Board. *Interview of Patrick Francisque*. NTSB Accident No. DCA16FP003, Tr. 16:11-13, November 15, 2016.
[19] ATF Report at 5.
[20] ATF Report at 7.

Fact 4: Other first floor damage, fully noted in the blast analysis of the ATF report, while not ruling out an initial event in the basement level meter/storage room, are also consistent with an initial explosive event occurring on the first floor. Some of those notable findings include:

a. "The stairway was shifted south from 8701 Apartment 101…"[21]

b. "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."[22]

c. "8701 Apartment 102 door was a fire door and was blown from its hinges."[23]

d. "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."[24] The Apartment 103 balcony is located to the rear, east side, of 8701 building. (See Appendix 4 - Floor plan of 8701 and 8703 Arliss Street)

e. "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."[25]

f. "According to witness statements and the initial police dash camera video, the A side (west) of 8701 Apartment 101 was completely blown

[21] ATF Report at 3.
[22] ATF Report at 3.
[23] ATF Report at 4.
[24] ATF Report at 4.
[25] ATF Report at 5.

out during the initial explosion, with the door landing across the street and parking lot."[26]

g. "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 toward Arliss Street."[27]

Facts that detract from the theory that the first floor was the location of the explosion:

1. Blast wave damage in the basement level consistent with an explosive event in the meter/storage room.[28]
2. According to the ATF Report, "…..the resident of 8701 Arliss Street Apartment 101 was recovered from under the floor of 8701 Apartment 101 in the debris pile just in front of the meter bank."[29]
3. Sections of the concrete floor that separated the 8701 basement level meter/storage room from the 8701 Arliss Street Apartment 101 were found to be flipped over, such that the parquet flooring of Apartment 101 were found facing downward, rather than upward.[30]

Factual Gaps:

1. The available evidence does not permit investigators to determine a timeline or sequence of events leading to this accident, or describing the sequence of forces that resulted in the eventual locations and positions of debris, doors, walls, or sections of flooring, following the accident.

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[26] ATF Report at 5.
[27] ATF Report at 6.
[28] ATF Report at 7.
[29] ATF Report at 7.
[30] ATF Report at 7.

Analysis: In its Report, the ATF cited only the sections of concrete floor that were found flipped over for its conclusion ruling out the first floor as the location of the "the explosion."[31] Because there would seem to be other plausible explanations for sections of the Apartment 101 concrete/parquet floor being flipped over on itself at various stages of an accident of this nature, that single fact would seem to be insufficient to definitively rule out the first floor as the location of a potential initiating event. One such explanation, which is supported by witness testimony, is that there was more than one explosion or explosive event.

A secondary forceful ignition, detonation or explosive event should have occurred if the initiating explosion resulted in an eventual severing of the 20 psig line in the basement level meter/storage room. The severed service line would have immediately put a large amount of gas into the confined space of the basement under the collapsing structure. A forceful explosion on the first floor could have impacted the numerous natural gas lines running along the ceiling of the meter/storage room, including the line serving the water heater. A second powerful event in the basement, the ignition of the gas escaping from the broken 1-inch service line at 20 psig, with a calculated flow rate of over 30,000 SCFH, could have resulted in the blast wave and debris field described by the ATF in the basement level of both 8701 and 8703 Arliss Street. That such forces could also have flipped various sections of collapsing flooring seems plausible.

Interestingly, a secondary explosion was described by one witness, the same witness who initially said he smelled gas inside 8701 Arliss Street moments before the initial explosion. In his interview with the NTSB he was definitive in this particular exchange regarding a second explosion[32]:

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[31] ATF Report at 7.
[32] NTSB Accident No. DCA16FP003. *Interview of Adraine Boye,* Tr. 18:13-20, November 15, 2016.

Q. I know you heard the first. You said you heard the first explosion.

A. Right.

Q. Was there any other explosion after that?

A. After the fact, maybe like when the firefighters came and stuff, like, yeah, it was an explosion.

Q. So there was a second explosion?

A. Yah, but not like the same one, not like the first one. The first one was louder than the others. I think like the other was just like, I'm guessing, from the apartments, I don't know – but, yeah.

The materials stored in the basement level meter/storage room appeared to be in the locations where they were prior to the explosion and building collapse. If indeed the explosion was initiated in the basement, without the floors above to obstruct the movement of these objects, it seems that these objects would have been forced away from the explosion. This was not the case. In addition, the natural gas odorant evidence is inconsistent with an initiating event occurring in the basement level meter/storage room, and thus would also seem to indicate that the first floor cannot be ruled out as a source of fugitive natural gas. Both the ATF and the NTSB focused upon witness testimony regarding smelling natural gas in the relevant time periods before this accident. Washington Gas injects odorant into its gas so that customers and persons near escaping gas can smell it and call Washington Gas or 911 to address any suspected leak.

The ATF and NTSB interviewed a witness who reported to have smelled a suspected odor of natural gas inside the building prior to the explosion. Prior to the explosion, the witness stated that he smelled a strong odor of natural gas inside the building that seemed to grow stronger as he came down the steps from the third floor. As noted earlier in this report, upon noting the odor of gas inside the building, the witness immediately exited the building to throw out his trash. Pursuant to NTSB questioning, he confirmed that he did not smell natural gas outside the building as he walked along the front (west) side of 8701 Arliss Street toward the community trash collection point.[33] It should be noted that his path toward the collection point took him directly past the vented window of the basement level meter/storage room.

Although Washington Gas did not have access to all of the investigative interviews, we are unaware of any other witness identified by the ATF report, or identified to Washington Gas in the NTSB follow-on investigation that reported smelling an outside odor of gas in front of (west) 8701 Arliss Street prior to the explosion. In addition to the witness identified above, there were at least two other witnesses reported to have been sitting on or near air conditioning units immediately in front of the west wall of 8701 Arliss Street, Apartment 101. Thus, it is fair to conclude that had there been fugitive natural gas outside of 8701 Arliss Street, it would have been detected by the witnesses who were known to be outside of 8701 Arliss Street in the time prior to the explosion, including the one primary witness who had just previously identified the odor of natural gas inside the building.

The absence of an odor of natural gas outside the building potentially rules out the basement level meter/storage room as the initial source of fugitive natural gas in this accident. The basement level meter/storage room was constructed with vented wooden windows with cheeseboard-type holes allowing air to pass freely into and out of the basement level meter/storage room. If the initial explosion was caused by fugitive natural gas from the basement level meter/storage room that sufficiently filled the basement level meter/storage room (gas is lighter than air) before igniting, then that same fugitive natural gas, with its odorant,

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[33]NTSB Accident No. DCA16FP003. *Interview of Adraine Boye*. NTSB Accident No. DCA16FP003, Tr. at 48:20-49:1, November 15, 2016.

would have likely passed through the vented windows to the front (west) side of 8701 Arliss Street at ground level. Because it was "80 degrees with clear skies and calm winds,"[34] the odorant would have likely been detected outside before the explosion.

Conclusion: The available evidence in this case cannot rule out that both the source of possible fugitive natural gas, as well as the initial explosive event leading to the collapse and fire in 8701, occurred in the first floor of 8701 Arliss Street, Apartment 101. Because that cannot be ruled out, neither can it be reasonably concluded that the source of suspected fugitive natural gas, as well as the initial explosive event, occurred in the basement level meter/storage room. For these reasons, and the other reasons set forth in this submission, the cause and origin of this tragic accident is UNDETERMINED.

[34] ATF Report at 6.

SECTION 3 - INVESTIGATION STANDARD OF PROBABLE CAUSE

Standard for Probable Cause:

Throughout this investigation, Washington Gas sought to identify conclusive facts and evidence that would support an investigative theory or theories as to the "probable cause" of this accident. Washington Gas is mindful of the NTSB admonition that "Mere suspicion, inference, and conjecture must not suffice."[35] Further, Washington Gas concurs with Chairman Hall's congressional testimony in the matter of TWA Flight 800, "The only thing worse than not waking up and giving the answer would be to wake up and give incorrect information or the wrong answer."[36]

The concern of a wrong answer in any investigation of this nature is that it may lead to wrong recommendations. Safety recommendations based on wrong conclusions not only fail to meet a central purpose of the NTSB investigation -- reducing the likelihood of future accidents -- but may actually serve to alter or divert needed attention on safety improvements and initiatives that are demonstrated to improve safety and reduce accidents.

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[35] *United Airlines Flight 585, Boeing 737-291, N999UA, Uncontrolled Collision With Terrain for Undetermined Reasons Four Miles South of Colorado Springs Municipal Airport, Colorado Springs, Colorado, Mar. 3, 1991,* NTSB Aircraft Accident Report 92/06 (PB92-910407, Dec. 8, 1992, p. 102.

[36] Testimony of NTSB Chairman James Hall before the House Committee on Transportation and Infrastructure, Subcommittee on Aviation, regarding TWA Flight 800, July 10, 1997.

SECTION 4 – CONCLUSION

The ATF conducted an Origin and Cause investigation. After gathering available information and evidence -- including witness interviews -- making certain assumptions, and vetting reasonable theories as to cause and origin against the available evidence and assumptions, the ATF concluded that the cause and origin of this accident was UNDETERMINED.

The NTSB initiated its investigation on August 17, 2016. Washington Gas immediately accepted the NTSB's invitation to join as a formal party to the investigation, working within NTSB protocols. Through its active and comprehensive participation in the investigation, Washington Gas sought to help further develop relevant facts and to develop and test assumptions, all designed to help the NTSB determine, if possible, the cause and origin of this accident, as well as identify any related key safety protocols. After completion of the NTSB fact gathering, including multiple interviews, completion of the testing and analysis of physical evidence and our own internal reviews of our safety protocols, Washington Gas concurs with the ATF conclusion that the cause and origin of this accident is UNDETERMINED.

It is worth noting that while the ATF suggests in its summary redacted report of September 23, 2016 that the NTSB investigation could develop facts leading to a different conclusion, the NTSB investigative findings, as further discussed in this report, serve only to strongly support the ATF conclusion that a probable cause for this accident is UNDETERMINED.

SECTION 5 – WASHINGTON GAS SAFETY INITIATIVES

Washington Gas is fully committed to safety. The Company is acutely aware that the regulations under which it operates represent the *minimum* standard for safety and remains alert for opportunities to enhance public safety. Several examples of Washington Gas's commitment to exceed minimum standards in pursuit of pipeline safety are discussed below:

Pipeline Safety Management System Implementation: In July 2015, the American Petroleum Institute Recommended Practice 1173 (API RP 1173) outlining a Pipeline Safety Management System (PSMS) was released. Washington Gas is an active member of the American Gas Association (AGA) and agrees that by implementing voluntary programs, the industry is greatly benefited. To that end, we have been collaborating since early 2015 in AGA's Pilot Group that is developing guidelines to help fellow gas operators also implement API RP 1173. Additionally, we are participating in AGA's PSMS Discussion Group that connects in a broader way with AGA members to other organizations that are interested in exchanging information about PSMS.

Commitment to Research and Development: Since 2015, Washington Gas has been engaged in the industry's exploration of reliable residential gas detection technology, through its involvement with the Gas Technology Institute's (GTI) Operations Technology Development collaborative, particularly the Residential Methane Detector Program. The purpose of the program's initiatives is to create a "comprehensive program for achieving full customer adoption of cost effective, reliable, accurate and readily available residential methane detectors." The program comprises technology development and evaluation, codes and standards development, stakeholder engagement and economic and market analysis. In addition, Washington Gas is currently supporting a field pilot program to evaluate the commercially available detectors that performed well during an earlier laboratory evaluation.

Damage Prevention: Washington Gas has maintained its status as a national leader in damage prevention and we continue to improve on our programs year after year, working with all stakeholders in managing third party damages from excavation. The Common Ground Alliance just published it 2016 ranking of the best damage prevention results by state. Virginia was ranked number 1, with Maryland being ranked number 2. Washington Gas is the driver of these results in both states.

Frequent Leak Surveys of the Distribution System: Washington Gas performs surveys across its entire distribution system every three years as opposed to the five year standard set by federal regulation.

Vent-Limited Regulators: Washington Gas challenged the status quo of standard service regulator designs which vent natural gas to safely deal with an overpressure occurrence and sought a regulator that would simply shut itself down in the case of abnormal operation or an over-pressurization. Washington Gas identified and sourced a regulator that was being used in Europe which fails closed instead of venting any significant quantity of natural gas. Working with the Virginia SCC, we began a pilot program in Virginia installing and testing these regulators in service applications. Today we have over 7,500 in service and use these regulators for residential homes where adequate clearance around windows, intakes and sources of ignition make it a challenge to safely install a regulator which incorporates a vent. Many other operators are now piloting the use of these regulators for their systems.

Thermal Safety Valves: Natural gas meters and regulators are installed at or inside the buildings they serve. In the course of reviewing practices and technologies for the safety of our customers, emergency responders, and our employees, Washington Gas recognized that our facilities are often involved, secondarily, in structure fires. The fires impact our meters and regulators thus releasing gas and intensifying an already dangerous situation. This then requires personnel to approach the fire and shut off the gas valve or otherwise interrupt the flow through the gas line. Washington Gas searched for and found a thermally activated valve that could be installed on the service line, just prior to the regulator and meter. This device automatically shuts off the flow of gas when impacted by the heat of the fire. Washington Gas is in the process of field testing these devices and updating our standard practices to include them on all multi-family houses, apartment buildings and condos; further noted under Initiative 2, below.

Additional Safety Initiatives: Regardless of the undetermined nature of this accident, Washington Gas is pursuing the following voluntary initiatives consistent with our long-known commitment, always, for improved safety.

1. **Improved safety messaging to customers residing in multi-metered apartments**. While Washington Gas has a robust customer outreach program providing safety messaging to its customers, in the aftermath of this accident Washington Gas will seek to improve the safety awareness of customers when they suspect a release of natural gas. Although customers were aware of the safety concerns raised by a suspected odor of natural gas, and consistently reported such odors to Kay Management Company or the Fire Department, it was not clear to Washington Gas that every customer knew they could also report such incidents to Washington Gas. Indeed, there is witness testimony to the contrary.

2. <u>Construction and Design Standards</u>. The structural collapse caused a severing of a portion of the Washington Gas service line, which operated at distribution pressure. This damaged service line supported a large fire following the initial incident. Washington Gas will install, whenever possible, the gas regulators exterior to the buildings on new multi-family construction projects, thus limiting the potential high flow of gas resulting from damage to its interior facilities. Additionally, for legacy multi-meter sets, Washington Gas, when undertaking the replacement of a service line due to age and condition, where possible, will move regulators that are installed within a building structure to a location outside the building structure, again limiting the potential high flow of gas resulting from damage to its interior facilities. Lastly, Washington Gas will continue its program of installing Thermal Safety Valves on all new construction and on its legacy facilities while performing service line replacement work, for all multi-family housing units. These valves will serve to shut off the flow of gas to houselines in the event of a fire engulfing its meter or regulator facilities.

3. <u>Emergency Response Coordination</u>. Washington Gas will renew efforts to improve communications between Washington Gas and emergency response agencies to ensure that Washington Gas is alerted each time the jurisdiction receives notice of a possible odor of natural gas so that response can be coordinated.

SECTION 6 – PROPOSED RECOMMENDATIONS

<u>PROPOSED RECOMMENDATIONS</u>:

In addition to its voluntary Safety Initiatives, Washington Gas recommends:

1. Fire and Smoke alarms in all storage rooms, utility/meter rooms, and common areas of apartment complexes;
2. The development of County-audited safety checklists for multi-metered apartment complexes that requires periodic self-checks by management companies to ensure compliance with code requirements designed to ensure that flammable or explosive substances are not improperly stored in internal storage rooms; and that storage practices of equipment, appliances, and other materials in and around gas carrying pipes and appliances does not impose risk to those facilities;
3. In multi-family buildings where the water heater and gas piping is exposed and unprotected from human activities and storage of materials, investigate the use of flexible gas piping 'pig tails' between the steel gas houseline and the connection of rigidly mounted appliances, such as the water heater control valve found in 8701 Arliss Street. This will eliminate the vulnerable threaded connections that would be subject to significant stress if an unsupported steel houseline serving the appliance is inadvertently bumped or moved;
4. Requiring methane detector installations in the gas meter rooms of multi-family (apartment/condo) buildings; and
5. A requirement for Landlords to inform their tenants of safety procedures in case of emergencies, including gas safety and reporting of gas odors.

APPENDICES

APPENDIX 1

Meter/Storage Room Inventory Provided by Kay Management

8701 Meter Rm Inventory

Aprox Quantity	Item Discription
7 to 8	Gas Furnance
3 to 4	A\C Condenser
7 to 8	A Coils for A\C
1	Roll copper a\C pipe
1	Roll B\X Wire
1	Roll Romex Wiire
20	3\4 x10' PVC Pipe
4 to 6	Condenser Pump
5 to 6	Box Fans
2	Portable A\Cs
2	Case Spray Nine
2	Case Windex
10	Bath Room Mirror
2	Case Paper Towels
1	Case Toilet Paper
20	File Boxes
5	Salt Spreader
2	Boxes Air Freshener
8	Cases Brown Caulk
3	Ceiling Fans
5 each	Top&bottom Ref. Gaskets
4	Range Tops
3 to 4	A\C Pans
4	Thermo Couplings(Oven)
7	Yelloow Boots
7	Rain Coats
1	Box Shoe Booties
2	Box Pipe Insulation
1	Box Floor Tile
1	Dehumidifier
2	Case Return Grill A\C
1	File Cabinet
1	Trash Can Full Snow Shovels
1	New Chain Saw in Box
1	Back Pack Blower almost Empty
1	Pressure Washer Almost Empty
1	1Gal Gas Can Empty

APPENDIX 2

Montgomery County Fire Code Citation

1 of 3

DEPARTMENT OF PERMITTING SERVICES
DIVISION OF FIRE PREVENTION AND CODE COMPLIANCE
255 Rockville Pike, 2nd Floor, Rockville, MD 20850
240-777-2457

Monday May 9, 2016

Inspection Type 916B
Staff Hours 4.50

MAYRA PINTO
FLOWER BRANCH APARTMENTS - OFFICE
8628 PINEY BRANCH RD
SILVER SPRING MD 20910

An inspection of your facility, on Wednesday March 23, 2016 revealed the violations listed below for the property located at

8628 PINEY BRANCH RD
SILVER SPRING MD 20910

ORDER TO COMPLY: Since these conditions are contrary to law, you must correct them upon receipt of this notice.

Violation Code	Article	Division	Page	Count
COMMENT COMMENT			0	0

A FIRE AND LIFE SAFETY INSPECTION OF ENTIRE COMPLEX, WHICH INCLUDES.
(8701-8711 ARLISS ST, 8851-8857 GARLAND AVE AND 8628-8674 PINEY BRANCH RD)

EXITS- OK
EXTINGUISHERS- OK
SYSTEMS INSPECTION- OK
STORAGE- SEE BELOW
UTILITY ACCESS- SEE BELOW
LAUNDRY DOORS- SEE BELOW
KNOX BOX- SEE BELOW

ALL DEFICIENT ITEMS MUST BE CORRECTED WITHIN 30 DAYS OF THIS INSPECTION

Repaired 05/06/2016

Violation Code	Article	Division	Page	Count
NFPA 1 / UTILITY RM STORE Combustible Storage in Utility	10	19.5.1	0	0

Combustible material shall not be stored in boiler rooms, mechanical rooms, or electrical equipment rooms.

1. REMOVE ALL GAS POWERED ITEMS OUT OF STORAGE ROOMS IN THE BUILDINGS. RECOMMEND THE PURCHASE OF AN EQUIPMENT SHED TO HOUSE ALL THOSE ITEMS AND THEIR FUEL CANS.

2. PAINT STORAGE ROOM NEED TO HAVE A VENT SYSTEM INSTALLED TO PREVENT THE HIGH

05/09/2016 09:31 Page 1

APPENDIX 2

Montgomery County Fire Code Citation

2 of 3

DEPARTMENT OF PERMITTING SERVICES
DIVISION OF FIRE PREVENTION AND CODE COMPLIANCE
255 Rockville Pike, 2nd Floor, Rockville, MD 20850
240-777-2457

Monday May 9, 2016

Inspection Type 916B
Staff Hours 4.50

MAYRA PINTO
FLOWER BRANCH APARTMENTS - OFFICE
8628 PINEY BRANCH RD
SILVER SPRING MD 20910

CONCENTRATION OF FUME BUILDUP.

Repaired 05/06/2016

MCFSC CH 22.92 Access to Utilities 0 0

In other than individual dwelling units no person shall place, keep or store any material on or before any gas or electric meter or any shut-off for gas service, electrical service or water service the presence of which would interfere with the ability of the fire department to shut off the utility.

YOU MUST MAINTAIN A CLEAR 3 FOOT SURROUNDING AREA AROUND ALL UTILITIES.

Repaired 05/06/2016

NFPA 1 / DOOR CLOSING Self Closing Device 12 4.6.9.2 0 0

Fire door assemblies shall be visually inspected from both sides to assess the overall condition of the door assembly. As a minimum, the following items shall be verified: The self-closing device is operational, that is, the active door completely closes when operated from the full open position.

YOU MUST REMOVE ANY AND ALL DEVICES THAT PREVENT THE LAUNDRY ROOM DOORS FROM CLOSING AND LATCHING PROPERLY. LAUNDRY ROOMS ARE A HIGH FIRE RISK.

Repaired 05/06/2016

NFPA 1 / KNOX BOX Add or Correct Knox Box Keys in Box 18 2.2.3 0 0

The owner or occupant of a structure or area, with required fire department access as specified in 18.2.2.1 or 18.2.2.2, shall notify the AHJ when the access is modified in a manner that could prevent fire department access.

KEYS ARE MISSING FOR THE KNOX BOX LOCATED @ BUILDING 8656 PINEY BRANCH RD. THIS IS A LARGE GAP IN ACCESS COVERAGE.

Repaired 05/06/2016

APPENDIX 2

Montgomery County Fire Code Citation

3 of 3

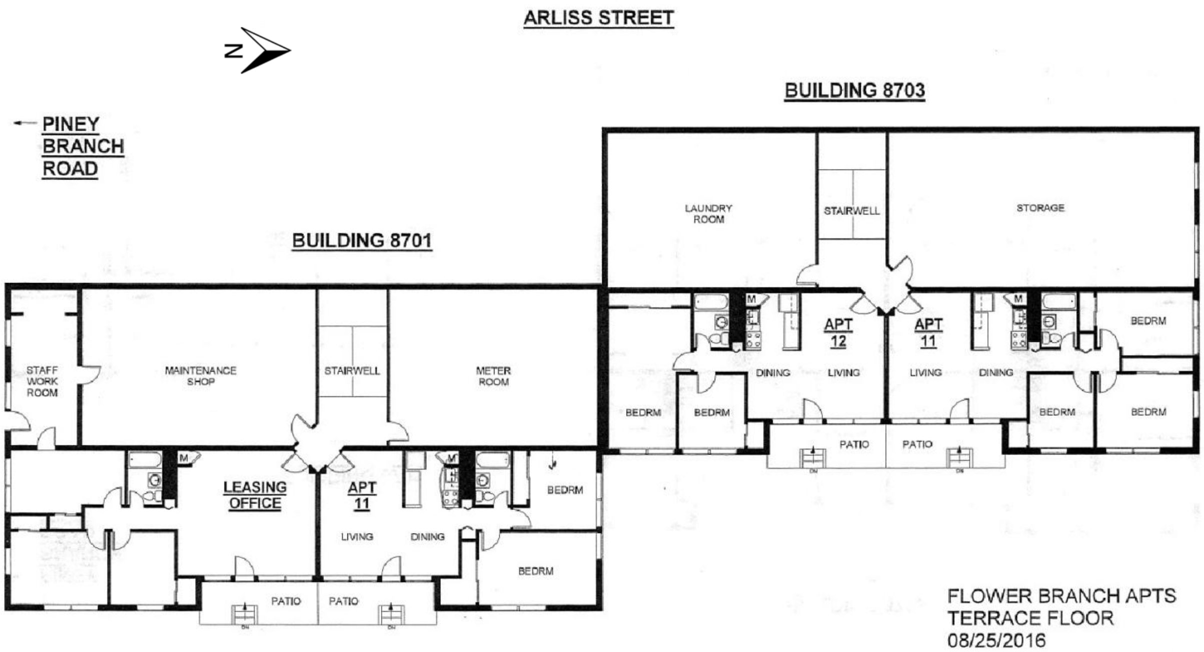
DEPARTMENT OF PERMITTING SERVICES
DIVISION OF FIRE PREVENTION AND CODE COMPLIANCE
255 Rockville Pike, 2nd Floor, Rockville, MD 20850
240-777-2457

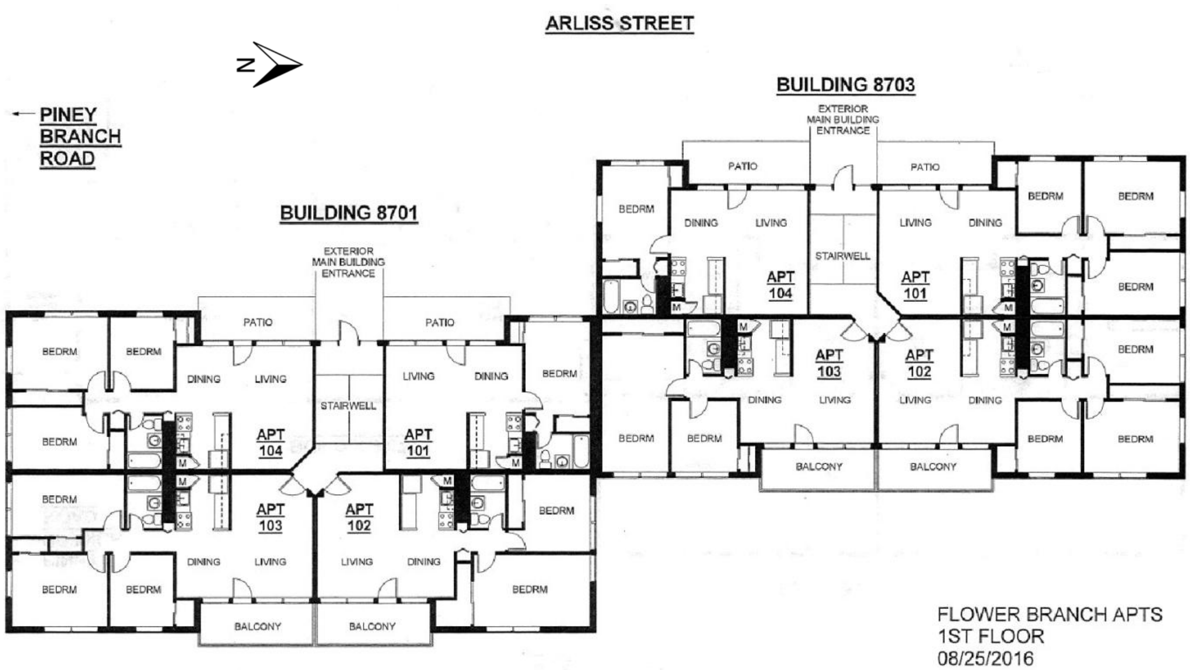
______________________	X______________________
Thorn, Maynard	**MAYRA PINTO**
Inspector	**Responsible Party**

The owner/occupant in receipt of this NOV may request a time extension to correct the noted code violations beyond the timeframe specified in this NOV. An extension request is made by contacting the issuing inspector and providing specific information as to the nature of the request. The inspector may grant the request upon gaining the approval of a Fire Code Enforcement supervisor.

APPENDIX 3

Floor Plan of 8701 and 8703 Arliss Street





APPENDIX 4

Exemplar Mercury Regulator Test Report

(8 pages)

EXEMPLAR MERCURY REGULATOR TEST REPORT Page 1 / 8	
Revision Date: November 22, 2016	**Report No.TR-2016-1.0**
Reference: O&M Section 5121, "Testing and Adjusting Service Regulators"	
Purpose: To summarize mercury regulator exemplar testing performed at the Washington Gas Springfield Center on Wednesday, October 12. Reference NTSB DCA16FP003.	

1. **BACKGROUND & INTRODUCTION:** On Wednesday, October 12, 2016, representatives from the National Transportation Safety Board (NTSB), Maryland Public Service Commission (MDPSC), Montgomery County, Maryland Fire Department, and Washington Gas participated in mercury regulator performance testing at the Washington Gas Outdoor Training Facility situated behind 6803 Industrial Road, Springfield, VA. Performance testing was conducted in accordance with the protocol stated within the NTSB Memo to Washington Gas dated September 26, 2016 (attached).

   Three mercury regulators removed from 8642 (2) and 8674 (1) Piney Branch Rd. were subjected to function testing, mercury content measurement, and relief vent flow measurement.

   One Schlumberger B-39, ¼" orifice regulator removed from 8674 Piney Branch Rd. was also subjected to function testing and relief vent flow measurement.

2. **TESTING**

   2.1 The Function Test. Function testing involves simulating loads (a "load" is the gas demanded by the customer's equipment, usually measured in flowrate) by flowing gas through standard orifices (holes) on a testing apparatus known as a "load tester". Gas flows through individual orifices after the gas pressure is reduced by the regulator. The test is typically begun with adjustment of the regulator so that it delivers the desired set pressure (e.g., 5.5" w.c.) when flowing through the "low load" orifice. Load testing pass/fail criteria are summarized in Table 5121-1 of the Washington Gas Operations and Maintenance Manual (O&M), pictured below in Figure 1.

   Function Testing determines:

   2.1.1 If regulators deliver accurate pressures (maintain set point) when there is a small demand from a single customer. A single residential furnace rated at 50,000 Btu/h would represent a small demand, or "low load".

   2.1.2 If regulators can maintain sufficient delivery pressure when a higher load is demanded. The simultaneous operation of a typical furnace, water heater, and range would represent a "high load".

   2.1.3 If regulators "lock-up", or shut off the flow of gas when demand for gas stops; before commissioning, regulators must not allow the passage of gas when customer equipment does not require it.

PREPARED BY JWW
DATE 11 22 2016

EXEMPLAR MERCURY REGULATOR
TEST REPORT

Revision Date: November 22, 2016	Report No.TR-2016-1.0
Reference: O&M Section 5121, "Testing and Adjusting Service Regulators"	
Purpose: To summarize mercury regulator exemplar testing performed at the Washington Gas Springfield Center on Wednesday, October 12. Reference NTSB DCA16FP003.	

2.2 Testing during NTSB Evaulation. Each exemplar regulator was subjected to a modified function test; delivery pressure was not adjusted on low load. The as-received pressure setting, high-load, and lock-up pressures were recorded, and performance details noted. The regulators were tested on a 20 psig system, as described within the TEST PROTOCOL dated October 11, 2016 (attached). See Table 1.

2.3 Mercury Content Measurement. Mercury (liquid) forms a seal between gas within the regulator body and the vent line. A column of mercury is exposed to downstream, or houseline, pressure. The mercury column is located within the regulator's "mercury cup", which includes a small diptube. When the houseline pressure is higher than the pressure provided by the height of the mercury column, the mercury is driven into a reservoir above the cup. At this point, gas is allowed to escape through the vent piping. This scenario is shown below in Figure 2.

Table 5121-1. Regulator Function Test Specifications

Regulator Type		Regulator	Low-Load Delivery Pressure	High-Load Min Delivery Pressure	Lock-Up Max Pressure	Load Tester 12443 (Old) Orifice (Drill Size)		Load Tester 3188883 (New) Orifice (Drill Size)	
						Low-Load	High-Load	Low-Load	High-Load
Residential	Standard	Mercury	5.5" w.c	5.0" w.c	7.5" w.c	#34	None 1.Remove Cap 2.Flow Gas through Valve	#46	#37
		Legacy (B42R, etc.)	7.0" w.c.	6.5" w.c.	9.0" w.c.				
		Pietro Fiorentini FE-Series	7.0" w.c.	6.5" w.c.	11.0" w.c.				

Figure 1. Regulator Load Test Pass/Fail Criteria. Mercury Regulator info. Underlined.

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EXEMPLAR MERCURY REGULATOR TEST REPORT Page 3 / 8	
Revision Date: November 22, 2016	**Report No.TR-2016-1.0**
Reference: O&M Section 5121, "Testing and Adjusting Service Regulators"	
Purpose: To summarize mercury regulator exemplar testing performed at the Washington Gas Springfield Center on Wednesday, October 12. Reference NTSB DCA16FP003.	

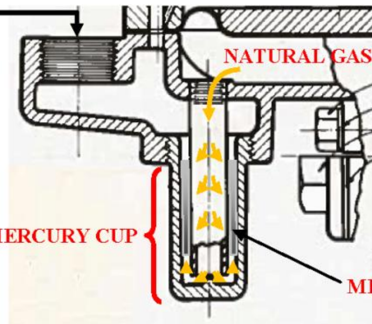

Figure 2.
Mercury Column (silver) being Driven Upwards within Cup by High Houseline Pressure

2.2.1 Mercury Height and Weight Measurement. Using a nail as a measuring device, the height of mercury within each exemplar regulator cup was marked on the nail and measured. It should be noted that the height within the cup during normal operation will be different from the reported values due to displacement by the volume of the diptube. Also, the weight of mercury within each regulator was measured. It should be noted that some mercury may have escaped from the cup during shipping and handling activity. Mercury content is noted within Table 2 of this report.

2.3 Relief Valve Flow Testing. When mercury is removed from a regulator, gas can escape freely through the cup and out of the vent line. After mercury content was measured in each exemplar regulator, mercury was disposed of and the cup reinstalled. The regulator was shut-in, such that no gas could escape through the outlet; all gas was directed through the vent piping. Gas flows were measured and corrected to standard temperature and pressure using the formula provided within the TEST PROTOCOL. Flowrates are reported within Table 3. It should be noted that relief valve flow testing was performed on all exemplar regulators, instead of just one regulator as planned within the TEST PROTOCOL.

Flowrates were measured using rotameters, compensated for temperature and pressure as described within the TEST PROTOCOL.

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EXEMPLAR MERCURY REGULATOR
TEST REPORT

Revision Date: November 22, 2016	Report No.TR-2016-1.0
Reference: O&M Section 5121, "Testing and Adjusting Service Regulators"	
Purpose: To summarize mercury regulator exemplar testing performed at the Washington Gas Springfield Center on Wednesday, October 12. Reference NTSB DCA16FP003.	

Exemplar Regulator	System Pressure (psig)	Initial Delivery Pressure (inches w.c.)	Low-Load (inches w.c.)	High-Load (inches w.c.)	Lock-Up (inches w.c.)	Notes
1	20.1	6.1	6.1*	6.1	6.4	Gas flowed through vent during testing
2	20.2	5.6	5.6*	5.4	6.8	No flow through vent pipe
3	20.4	5.3	5.3*	5.1	6.7	No flow through vent pipe
4	20.4	5.7	5.7*	5.3	5.8	No flow through vent pipe

Table 1. Regulator Function Test (Load Test) Data
*** The regulator was not adjusted to 5.5" w.c. The evaluation determined set point drift at high load and lock-up only.**

Exemplar Regulator	Height of Mercury within Cup (cm.)	Weight of Mercury + Condensate (oz)
1	1.3*	0.375*
2	1.5	1.25
3	1.2	1.25
4	N/A	N/A

Table 2. Exemplar Regulator Mercury Data

**The weight of the mercury/condensate mix from Exemplar regulator #1 was significantly lower than that of regulator #'s 2 and 3. This is attributed to more mercury content within #2 and 3, and more condensate content within #1.*

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TEST REPORT

Revision Date: November 22, 2016	Report No.TR-2016-1.0
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Purpose: To summarize mercury regulator exemplar testing performed at the Washington Gas Springfield Center on Wednesday, October 12. Reference NTSB DCA16FP003.	

Exemplar Regulator	System Pressure (psig)	Ambient Temperature, T (°F)	Flow through Vent, observed Q_{obs} (CFH)	Pressure Downstream of Rotameter, P_{act} (psig)	Flow through Vent, corrected Q_{corr} (SCFH)
1	20.1	61	197	11.8	344
2	20.5	64	163	18.9	320
3	20.5	65	184	13.4	330
4	20.4	65	260	2.4*	360

Table 3. Relief Vent Flowrate Data
***B-39 regulator seat removed during testing, representing system failure mode not expected in field**

3. OBSERVATIONS:

3.1 Load testing.

- Exemplar regulator #1 continuously vented gas during load testing; gas was able to travel around the mercury seal in the as-received condition.
- Exemplar regulators #2 through #4 did not vent during load testing.
- The maximum allowable pressure drift during high load testing is -0.5" w.c. from low load delivery per the Washington Gas O&M (see Figure 1). All regulators maintained set point pressure within this range.
- The maximum allowable lock up pressure is 2" w.c. above low load delivery. All regulators locked-up within this range.

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EXEMPLAR MERCURY REGULATOR TEST REPORT Page 6 / 8	
Revision Date: November 22, 2016	**Report No.TR-2016-1.0**
Reference: O&M Section 5121, "Testing and Adjusting Service Regulators"	
Purpose: To summarize mercury regulator exemplar testing performed at the Washington Gas Springfield Center on Wednesday, October 12. Reference NTSB DCA16FP003.	

3.2 Mercury Content Measurement.

- The contents within the mercury cup were not exclusively mercury. Dark fluid was mixed among elemental, silver colored mercury. The dark fluid resembled natural gas condensate, which can collect within the pipeline system over many years of operation.
- Manufacturer's literature states that 1 oz. of mercury will seal 6.9" of water column. Exemplar regulators #2 and #3 had 1.25 oz. of fluid, and did not vent during normal load testing. Exemplar regulator #1, with 0.375 oz of fluid, continuously vented during load testing.
- Mercury drops were noted around the regulator inlet and outlet during disassembly, suggesting that mercury may have exited the cup during operation, shipping, or handling activity.

3.3 Relief Valve Flow Testing.

- The average mercury regulator flowrate through the vent piping was 331 SCFH.
- After the mercury was drained and the cup reinstalled, the system was shut-in to direct all gas through the vent line. Flow rates within Table 3 are based on this arrangement. At one point, gas was allowed to divert through the load tester (while venting) for the purpose of a qualitative observation. The outlet pressure from the regulator was maintained near the set point, suggesting that customer loads may be supported during a large relief event.
    - Consider a typical winter customer load of 100 SCFH. If 5.5" w.c. is delivered through the regulator, a 100-ft. houseline would see a 0.5" w.c. drop[1], and a 250-ft. houseline would see a 1.15" w.c. drop. Appliances at the end of this houseline would perform normally in a situation such as this.
- In order to force gas through the vent downstream of the B-39 regulator, the valve seat was completely removed. This represents removal of a large flow restriction, and would not accurately reflect a field scenario.

3.4 Test Setup. The test setup is pictured in Figures 3 and 4.

[1] Values were calculated based on National Gas Fuel Code (NFPA 54) Pipe Sizing Equations.

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TEST REPORT

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Reference: O&M Section 5121, "Testing and Adjusting Service Regulators"	
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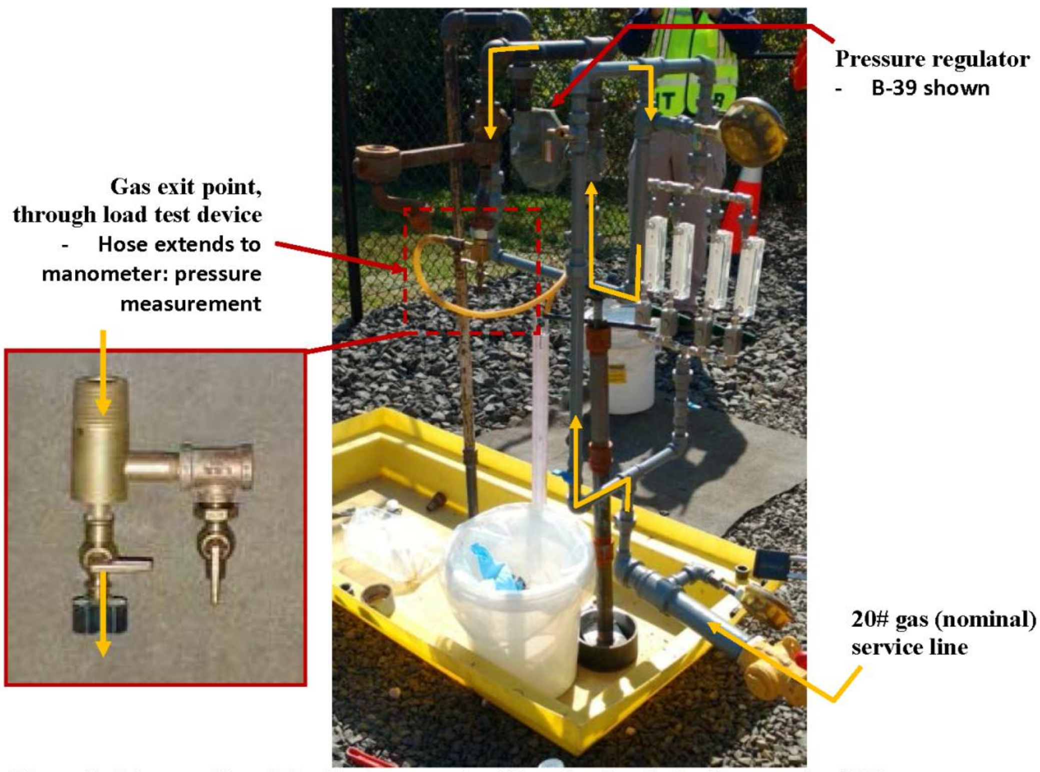

Figure 3. Mercury Regulator Test Apparatus, View 1 – Gas Path, Shown using Yellow Arrows, is Directed through the Meter Bypass, for Load Testing

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Revision Date: November 22, 2016	**Report No.TR-2016-1.0**
Reference: O&M Section 5121, "Testing and Adjusting Service Regulators"	
Purpose: To summarize mercury regulator exemplar testing performed at the Washington Gas Springfield Center on Wednesday, October 12. Reference NTSB DCA16FP003.	

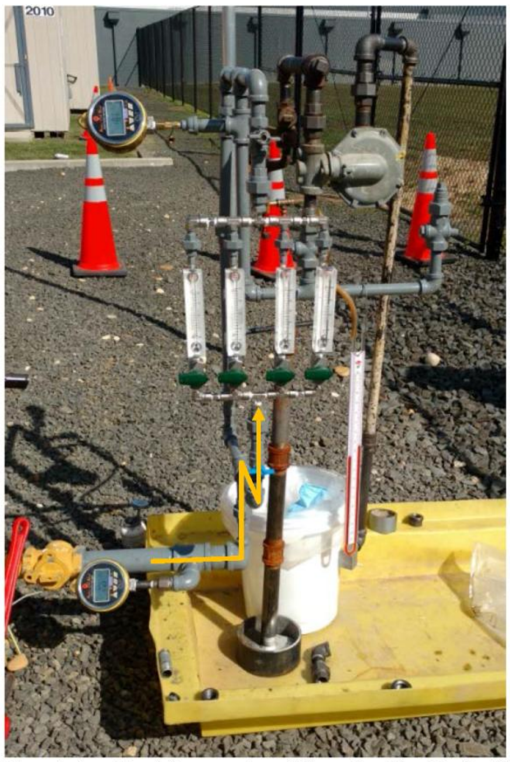

Figure 4. Mercury Regulator Test Apparatus, View 2 – Gas Path, Shown Using Yellow Arrow, is Directed towards the Rotameters, as Used during Relief Valve Flow Testing

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DATE 11 22 2016	

APPENDIX 5

Mercury Regulator Battery Test Protocol and Report

(15 Pages)

Washington Gas

TEST PLAN

MERCURY REGULATOR
BATTERY TEST PROTOCOL

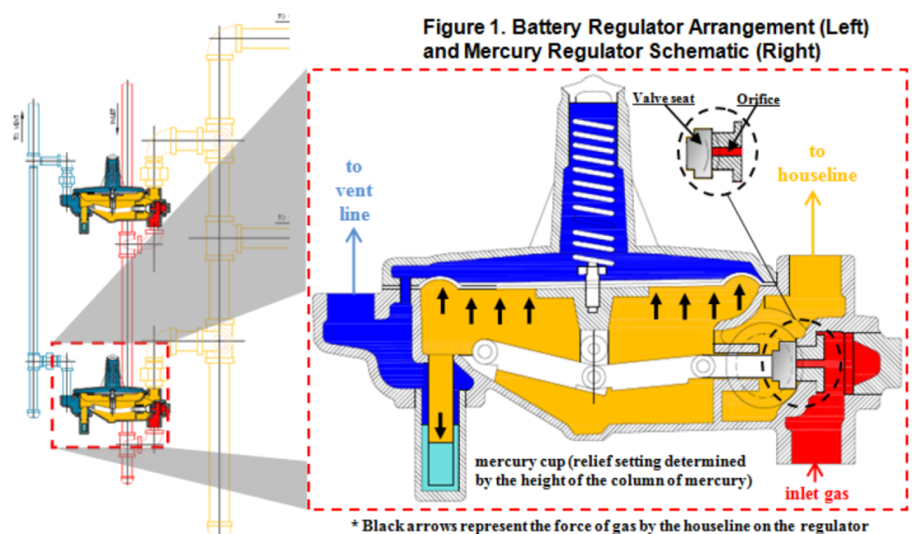
Revision Date: May 30, 2017	Revision P – 2017 – 4.0
Reference: N/A	
Purpose: To outline a test protocol for testing two functioning mercury regulators arranged in parallel.	

1. **INTRODUCTION:** The pressure-reducing regulators serving 8701 Arliss St, Silver Spring, MD were arranged in a parallel configuration: a single, 1” (nominal pipe size, or NPS) diameter pipe supplied two regulators with a maximum system pressure of 20 pound per square inch, gauge, nominal (psig) natural gas. Both regulators provided a supply of natural gas to utilization equipment such as cooking ranges, furnaces, and a water heater.

   Additionally, each regulator relief – a device that limits gas pressure within the customer’s piping, or “houseline”, below a predetermined “relief setting” – were manifold together and exited the building through a common pipe, or “vent line”, which directed any relieving gas outdoors. The relief setting was determined by the height of a column of mercury, which separated the houseline from the vent line. The vent line was made up of ¾” and 1” NPS pipe and fittings.

   This parallel dual-regulator system, known at Washington Gas as a “battery” arrangement, is based on the concurrent operation of each regulator, for both normal operations and overpressure relief. Both regulators contribute to the delivery of gas according to the demands of the houseline, and both regulators contribute to the relief, or venting, of gas in the event that the houseline pressure exceeds relief settings. See Figure 1 and subsection 2.1 of this report for more information.

Figure 1. Battery Regulator Arrangement (Left) and Mercury Regulator Schematic (Right)



* Black arrows represent the force of gas by the houseline on the regulator diaphragm (upwards) and mercury column (downwards)

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DATE: 05 05 2017

MERCURY REGULATOR
BATTERY TEST PROTOCOL

Revision Date: May 30, 2017	Revision P – 2017 – 4.0
Reference: N/A	
Purpose: To outline a test protocol for testing two functioning mercury regulators arranged in parallel.	

Washington Gas will be conducting tests on a battery regulator assembly within its "Pipetown" facility at 6803 Industrial Rd, Springfield, VA. The purpose of testing is to evaluate the response of the system to specific regulator "failure modes". These failure modes are listed below. The left hand column, indexed 2.2 through 2.4, corresponds to detailed discussions in paragraphs 2.2 through 2.4 of this report, respectively.

Ind.	Regulator Failure	Description	Result
2.2	Valve seat deterioration, orifice scoring, or foreign material between the orifice and valve seat	The valve seat, which is normally a smooth rubber surface, is scored or eroded, the rubber seat may exhibit a divot or small gouge, the edge of the orifice may be slightly deformed, or foreign material blocks the seat from fully sealing to the inlet orifice.	This failure mode typically results in a small flow of gas escaping past the valve seat and entering the houseline. Under low/no consumption conditions, a slow buildup of gas pressure may occur within the houseline until it overcomes the mercury column (see Figure 1). At this point, gas will escape through the vent line. [Typical houseline relieving pressure: 14" w.c.]
2.3	The level of mercury within the cup is lower than required to maintain the desired relief setpoint.(approximately 14" wc)	Mercury may be displaced or removed during activation by a pressure surge into the regulator , or by mishandling / tilting Normal houseline delivery pressure may overcome the resistance provided by the remaining column of mercury.	Gas will exit through the vent line during normal operation. However, the regulator will continue to deliver gas to the houseline at its intended set point. [Typical houseline pressure: 5.5" to 7" wc]
2.4	Diaphragm tear or linkage failure	The leather or rubber diaphragm develops a tear or hole, or the linkages that control the position of the valve seat (the distance to the orifice) become bound or disconnected. The regulator may be forced into the open position. Gas will constantly vent.	If the valve position is permanently open, the gas will travel downstream until houseline pressure overcomes the mercury seal, at which point it will travel out the vent line. [Typical houseline pressure: < 2 psig]
2.5	Spring breakage	The regulator spring breaks, leaving no tension against the diaphragm. The regulator will be forced into the closed position.	If the valve is permanently closed, gas will not be delivered downstream. Gas flow will be shut off. [Typical houseline pressure: 0]

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DATE: 05 05 2017

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Revision Date: May 30, 2017	**Revision P – 2017 – 4.0**
Reference: N/A	
Purpose: To outline a test protocol for testing two functioning mercury regulators arranged in parallel.	

2. **TESTING.** Two tests will be performed on the assembly in Pipetown. A schematic of the test rack is shown at the bottom of this report in Figure 4. Subsection 2.1 describes in more detail the battery regulator theory of operation. Each subsequent subsection describes specific test details.

2.1 Battery Regulator Arrangement | Theory of Normal Operation: Each regulator in battery is set to deliver slightly different pressures to avoid instable gas delivery (which would result when one regulator senses and reacts to the action of the other at an equivalent houseline pressure). The regulator set to deliver higher pressure, i.e., the regulator with a higher "set point", is the most active regulator under normal operations. For example, consider two regulators:

2.1.1 Regulator #1 (top): 5.5" w.c. flowing set point (about 0.20 psig)

2.1.2 Regulator #2 (bottom): 6.0" w.c. flowing set point (about 0.22 psig)

Both regulators will remain closed when no demand for gas exists within the houseline; the houseline pressure will remain at about 6.0" w.c. When gas is demanded from an appliance, the houseline pressure will drop below the setpoint of regulator #2, and the regulator will open. The houseline pressure will be slightly lower than the set point due to the minor decrease in pressure that occurs due to the regulator operating characteristic known as "droop". Droop (also known as proportional band or offset) is a decrease in outlet pressure caused by an increase in flow rate through a pressure-reducing regulator. When the outlet pressure drops due to a demand for gas, the regulator with a higher set point will open first in an effort to maintain the gas pressure inside the houseline to its set point. Both regulators will open only when gas demand is high enough to drop the houseline pressure below the lower regulator's set point.

The vent line remains inactive during normal operation. When the houseline demands gas, pressure drops within the houseline, so the regulator(s) respond by moving its (their) valve seat away from the orifice. Once the houseline pressure rises to the regulator set point, the valve seat closes against the orifice. The vent line is free of gas during this entire operation.

The vent line becomes operational only when:

- the valve seat does not (completely) seal against the orifice

AND

- the houseline pressure rises above the regulator's relief setting

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Reference: N/A	
Purpose: To outline a test protocol for testing two functioning mercury regulators arranged in parallel.	

Above the relief setting, gas pressure pushes the mercury upwards, out of the mercury cup and into the space just underneath the vent outlet. The relief setting is typically 14" w.c. (nominally)*.

Both regulator vents sense the same houseline pressure, as shown in Figure 1. Either regulator can relieve the system, or expel gas, when the houseline pressure rises above its relief setting. In this manner, both Regulator #1 <u>and</u> Regulator #2 may relieve gas in the event that Regulator #1 <u>or</u> Regulator #2 fails with an incomplete seal between the valve seat and the orifice.

* It should be noted that, during an earlier test at the Washington Gas Pipetown facility on 4/21/2017, a mercury regulator did not relieve with 1 psig on the houseline. Due to the out-of-spec regulator (regulators are expected to relieve when about 14" w.c., or ½-psi is present), the test was postponed until more regulators could be obtained for additional overpressure testing.

2.2 <u>Regulator Relief Test | Disruption of seal between the valve seat and orifice</u>: *The purpose of this test is to characterize the response of a regulator to a small disruption at the regulator seal between the valve seat and orifice, and the venting that follows.*

A disruption of the seal between the valve seat and the orifice (small amount of valve seat deterioration, orifice scoring, or foreign material between the orifice and valve seat) will result in the houseline pressure slowly rising until it overcomes the relief setting of the regulator. As downstream pressure builds to overcome the relief setpoint, gas will travel through the vent line and exit through the vent outlet, outdoors. In order to model this phenomenon, a small needle will be taped across the valve seat. This will prevent the seat from sealing against the orifice. This action should cause the houseline pressure to rise from ~5.5 – 6.0" w.c. to the relief setting. The small flow of gas that will vent through the relief device should mirror the small amount of gas flowing past a disrupted valve seat-orifice seal. The houseline pressure and vent flow rate will be measured Both a no-flow condition ("no houseline demand") and a low-load condition will be modeled.. The houseline will initially be "shut-in", meaning there will be no demand or flow within the houseline. A small gas demand will then be placed on the houseline to demonstrate the effect of flow. A "low-load" representative of a small 50,000 Btu furnace will be placed on the houseline by opening up a small passageway equivalent to the size of a #34 drill bit. A single regulator will be used for the test. See Figure 2 for a schematic of this failure mode. The following data will be collected:

MERCURY REGULATOR
BATTERY TEST PROTOCOL

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Reference: N/A	
Purpose: To outline a test protocol for testing two functioning mercury regulators arranged in parallel.	

Regulator (top or bottom):___________

Regulator set point: ___________

No Houseline Demand		Low-Load Houseline Demand	
Relief Pressure, or "Relief Setting" (" w.c.)	Relief Flowrate through vent line (CFH)	Houseline Pressure with "Low-Load" (" w.c.)	Relief Flowrate through vent line (CFH)

Notes (smell, sound, etc.):____

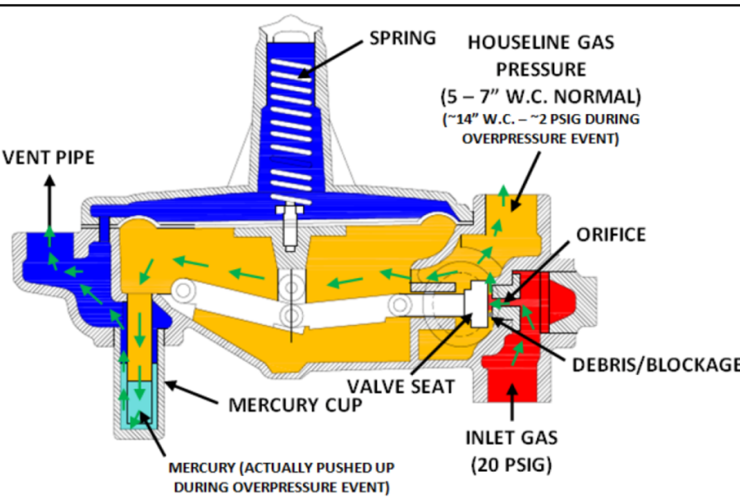

Figure 2. Disruption of seal between the valve seat and orifice – gas flow indicated by green arrows.

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2.3 Regulator Relief Test | Low-Mercury Level: *This test was conducted at the Washington Gas Pipetown facility on October 12, 2016.*

When the mercury level is low, such that the relief setting is lower than the houseline delivery set point of the regulator, gas will constantly escape through the vent line. During the Washington Gas test on 10/12/2016, regulators - whose mercury was completely removed - vented an average of 331 standard cubic feet per hour (CFH). It was noted during testing that the regulators continued to deliver standard pressures to the houseline, even while venting. See Washington Gas "Exemplar Mercury Regulator Test Report" dated 11/22/2016 for details.

2.4 Regulator Relief Test | Diaphragm Tear: *The purpose of this test is to evaluate the response of a regulator system (in battery) to a potentially "wide-open" failure, i.e., a scenario where the valve seat pulls away from the orifice, allowing gas to freely flow around the seat, into the houseline, and out of the vent line.*

A ruptured, or torn, regulator diaphragm may result in the regulator spring forcing the linkages connected to the valve seat to move the valve seat away from the orifice, leaving a gap for gas to flow into the regulator and house piping, resulting in an increase in the downstream pressure. The tear would have to be significant enough so that the increased force above the diaphragm – due to pressure from gas travelling into the chamber above the diaphragm – combined with the force of the spring, exceeds that of the houseline pressure. The downstream pressure may increase until the relief vents of one, or both, of the regulators activate (at approximately 14" wc) and then will stabilize at a pressure where the volume of gas entering the regulator is equal to the volume forced out through the vent plus any demand for gas. This will be demonstrated by removing the cover from one of the regulators and then cutting a 1" long slit through the diaphragm. The response of each regulator's vent line and the houseline pressures will be measured with both no demand on the houseline and a low-load, analogous to the test described in subsection 2.2. See Figure 3 for a schematic of this failure mode. The following data will be collected:

MERCURY REGULATOR
BATTERY TEST PROTOCOL

Revision Date: May 30, 2017	Revision P – 2017 – 4.0
Reference: N/A	
Purpose: To outline a test protocol for testing two functioning mercury regulators arranged in parallel.	

"Torn" Regulator (top or bottom):___________

No Houseline Demand			Low-Load Houseline Demand		
Houseline Pressure (" w.c.)	Relief Flowrate Top Vent** (CFH)	Relief Flowrate Bottom Vent** (CFH)	Houseline Pressure (" w.c.)	Relief Flowrate Top Vent (CFH)	Relief Flowrate Bottom Vent (CFH)

* * Vent flow rates are contingent upon the houseline pressure. The houseline pressure serves as a driving force behind the gas escaping through the vent line.

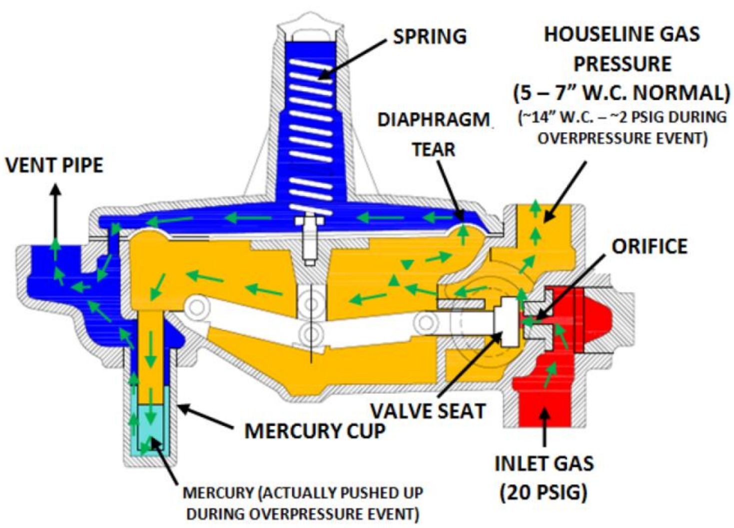

Figure 3. Diaphragm Tear – potential gas flow indicated by green arrows.

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Reference: N/A	
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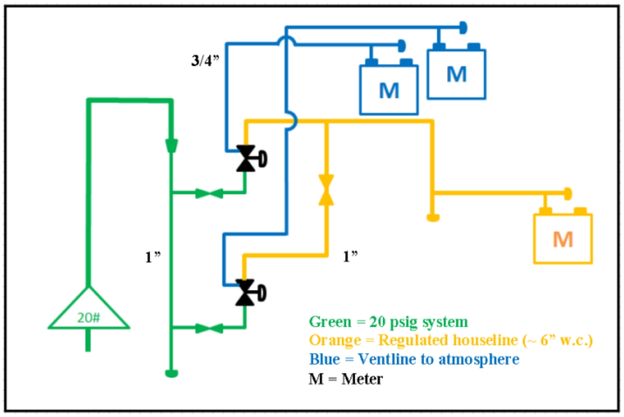

Figure 4. Washington Gas Mercury Regulator Battery Test Rack Schematic

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MERCURY REGULATOR **BATTERY TEST REPORT** Page 1 / 7	
Revision Date: June 5, 2017	**Revision: TR-2017-1.0**
Reference: Washington Gas "Mercury Regulator Battery Test Protocol", dated May 30, 2017	
Purpose: To summarize mercury regulator testing performed at the Washington Gas Springfield Center on Wednesday, May 31, 2017.	

1. **INTRODUCTION:** On Wednesday May 31, 2017, representatives from the National Transportation Safety Board (NTSB), Maryland Public Service Commission (MDPSC), and Washington Gas (WG) participated testing at WG's facility in Springfield, VA. Two functioning mercury regulators were extracted from the field and installed in a piping assembly supplied by a 20 pound per square inch, gauge (psig) distribution system. The mercury regulators were of the same make and model as those used within 8701 Arliss St, Silver Spring, MD (Reynolds Model 30 No. 1). The regulators were arranged in battery, or parallel. As such, both regulators are supplied by a common pipe. Also, both regulators can contribute to venting gas out of the building if the houseline is subjected to an overpressure event. Reference the Washington Gas "Mercury Regulator Battery Test Protocol" (dated May 30, 2017) for further explanations of the mercury regulator's function and operation. See Figure 1 below:

Figure 1. Battery Test Arrangement

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MERCURY REGULATOR BATTERY TEST REPORT Page 2 / 7	
Revision Date: June 5, 2017	**Revision: TR-2017-1.0**
Reference: Washington Gas "Mercury Regulator Battery Test Protocol", dated May 30, 2017	
Purpose: To summarize mercury regulator testing performed at the Washington Gas Springfield Center on Wednesday, May 31, 2017.	

2. TEST RESULTS. As described within the WG Mercury Regulator Battery Test Protocol, the goal of the test was to evaluate the as-received performance of each regulator, and then to characterize the response of the system to two separate overpressure events. The initial evaluation assessed the normal delivery pressure of either regulator, known as "upper" or "lower" depending on its relative position within the battery arrangement. The regulator with the higher set point is more active, and will open first when gas is consumed by downstream appliances. Next, the more active regulator was intentionally failed by disrupting the seal between the downstream houseline and the higher pressure inlet gas supply. This was accomplished by placing a pin between the regulator's valve seat and orifice. After this, the pin was removed and the leather diaphragm within the regulator was torn. The diaphragm separates the upper chamber of the regulator, where the spring resides, from the lower chamber, where houseline-pressure gas is located. Each test, and test results, is described below:

2.1 Initial Evaluation | Characterization of the System As-Received: *The purpose of this test was to confirm that both regulators were functioning, and to determine which regulator was the "active" regulator within the system.*

Each regulator was subjected to a "load test" to determine the set points of each regulator. Set points were determined by flowing a "low-load", or about 50 standard cubic feet per hour (SCFH) of gas, nominally, through the houseline and measuring delivery pressures with a water-filled manometer. A manometer is also known as a "U-gauge".

Regulator (Year of Manufacture): Upper (1960) **Regulator set point**: 5.6" w.c.

Regulator (Year of Manufacture): Lower (1957) **Regulator set point**: 5.7" w.c.

It should be noted that the system "locked-up" at 6.4" w.c. and did not vent any gas when the houseline was shut-in, i.e., was not consuming any gas. Therefore, the mercury levels within each regulator were sufficient for normal operation, and the regulators were considered fully functional.

The lower regulator was the "active" regulator within the system, and subsequently forced to fail in two separate scenarios.

2.2 Regulator Relief Test | Disruption of seal between the valve seat and orifice[1]: *The purpose of this test was to characterize the response of the regulator system (in*

[1] See Appendix for a discussion of an earlier overpressure test conducted at the Washington Gas Springfield facility on April 21, 2017.

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DATE:	06 05 2017

battery) to a small disruption at the regulator seal between the valve seat and orifice, and to measure any venting that followed.

In order for a regulator to properly seal off the downstream system (the houseline) from the upstream system, the regulator's orifice needs to contact the valve seat continuously around its circumference. A disruption of this seal will allow a steady stream of gas to enter the houseline, raising its pressure until it overcomes the resistance provided by the column of mercury. Gas then escapes through the regulator vent. During the test, a pin with a diameter of 0.020" was taped across the valve seat's sealing area. The houseline system was locked-in, and its pressure increased until it reached 11.5" w.c.. At this point, the pressure held steady. No flow passed through the vent line; the orifice sealed against the valve seat, despite the presence of debris. See Figure 2.


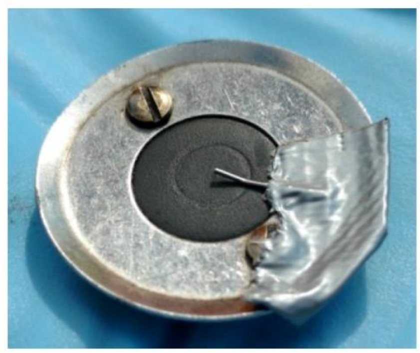

Figure 2. 0.020" Diameter Pin Taped Across Valve Seat (Left). Deformed Pin on Valve Seat, Removed After Regulator Lock-Up (Right).

The 0.020" pin was removed and replaced by a larger pin, 0.034" in diameter. As gas was introduced to the system, the valve seat was not able to seal against the orifice. The houseline was shut-in, and gas proceeded to vent through the (lower) regulator's vent line. A single vent was sufficient to maintain a steady-downstream pressure. In other words, the upper vent did not activate during this scenario; only the lower vent was active. After houseline pressures and vent flowrates were measured, a small flow was introduced within the houseline. Gas continued to vent. The vent flowrate and houseline pressures were measured in both scenarios. Results are listed within Table 1.

No Houseline Demand		Low-Load Houseline Demand	
Relief Pressure, or "Relief Setting" (" w.c.)	Relief Flowrate through vent line (CFH)	Houseline Pressure with "Low-Load" (" w.c.)	Relief Flowrate through vent line (CFH)
8 – 8.5" w.c.	165	7 – 7.5" w.c.	51

Table 1. Valve Seat Obstruction Failure Test Data

2.3 Regulator Relief Test | Diaphragm Tear: *The purpose of this test was to evaluate the response of the regulator system (in battery) to a "wide-open" failure, i.e., a scenario where the valve seat pulls away from the orifice, allowing gas to freely flow around the seat, into the houseline, and out of the vent line.*

In order to force a regulator "wide-open", the lower regulator's leather diaphragm was torn. This forced houseline pressure above the lower chamber of the regulator, allowing the regulator's spring to drive the diaphragm plate downwards, forcing the linkages to pull the valve seat away from the orifice. See Figure 3 for an image of the torn diaphragm. With the regulator wide-open, a steady stream of gas was delivered into the houseline. Both regulator vents engaged in order to maintain the houseline pressure below 2 psig. The vent flowrates and houseline pressures were recorded with both the houseline shut-in and with a small, 50 SCFH (nominal) demand. Data is summarized within Table 2 below.

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Figure 3. Torn Leather Diaphragm

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Torn Regulator (upper or lower): Upper

No Houseline Demand			Low-Load Houseline Demand		
Houseline Pressure (psig)	Relief Flowrate Top Vent** (SCFH)	Relief Flowrate Bottom Vent** (SCFH)	Houseline Pressure (" w.c.)	Relief Flowrate Top Vent (SCFH)	Relief Flowrate Bottom Vent (SCFH)
1.75*	**1,170**	**1,020**	**1.6**	**1,020**	**900**
Combined Flowrate	**2,190**		**Combined Flowrate**	**1,920**	

** The vent lines were metered with AC-250 diaphragm meters. These meters were necessary for flowrate determination, however, they did act as a slight restriction within the vent line. Meters are never present on vent lines within an actual installation. With the meters removed, the houseline pressure within a shut-in system dropped to 1.5 psig.*

Table 2. Diaphragm Tear Failure Test Data

3. OBSERVATIONS AND CONCLUSIONS. A mercury regulator can still operate adequately with a small amount of debris on its valve seat surface. This was evident from the test with the 0.020"-diameter pin; the lower regulator was able to seal against inlet gas when a pin was placed across its valve seat. Once the debris size reaches a critical shape and size, however, the valve seat is unable to achieve a complete seal. A small amount of gas will escape through the vent line. This was evident from the test with the 0.034"-pin; the lower regulator was not able to seal against inlet gas when a pin was placed across its valve seat. The measured flowrate through the vent line – with no houseline demand – was 165 SCFH. This flowrate is lower than that observed on October 12, 2016, when 331 SCFH flowed through the vent line of a regulator with its mercury removed.

The noises emitted at the vent line outlet were noticeably different: the valve seat disruption resulted in a barely noticeable sound, while the diaphragm tear resulted in a clear, resonant rush.

The valve seat disruption represents the most common failure mode of a regulator. The second test, of a torn diaphragm, is extremely rare. There have been no known occurrences of a torn diaphragm on a mercury regulator. During testing, the amount of gas vented was significantly higher than during the seat disruption. With no houseline demand, the measured flowrate (combined) through the vents was 2,190 SCFH.

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Washington Gas
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APPENDIX

APRIL 21, 2017 OVERPRESSURE TEST DISCUSSION. On April 21, 2017, representatives from the NTSB and Washington Gas met at the WG facility in Springfield, VA to assess the response of a mercury regulator to an overpressure event. The mercury regulator had been extracted from WG's Virginia territory, and was fully functional at the time of removal. The regulator was transported to Springfield, VA and installed within the test assembly (Figure 1). The downstream pressure was increased by effectively strengthening the regulator's spring; washers were placed above the spring, increasing the overall spring weight and forcing the downstream pressure upwards. The downstream (houseline) pressure increased until it reached 1 psig, at which time the test was cancelled due to an out of specification regulator.

The exact cause of the high houseline pressure is unknown. The regulator was subjected to a lot of shipping and handling, which may have caused mercury to be displaced internally. Additionally, debris from the unfastening process at the customer's site may have migrated into the regulator chamber at some point, blocking the venting mechanism.

Finally, the actual overpressure simulation, caused by weighting the spring, was ultimately considered unrealistic. Therefore, future tests - subsequently conducted on May 31, 2017 - only evaluated a disrupted seal and torn diaphragm.

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