

THE WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION

Commission Staff Investigation Report on Explosion and Fire

12312 5th Avenue N.E., Seattle

DOCKET PG-111723

Primary Investigator: Al Jones, Pipeline Safety Engineer

December 26, 2012

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Commission Staff Investigation Report on Explosion and Fire

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I. INTRODUCTION¹

On September 26, 2011, a natural gas explosion and fire destroyed a house located at 12312 5th Avenue N.E., in the Pinehurst neighborhood of Seattle, Washington. The incident involved natural gas pipe owned and operated by Puget Sound Energy (PSE).

The homeowners are Mr. David Ingham and Ms. Hong Ingham, husband and wife. The Inghams were inside the house at the time of the explosion. Ms. Ingham sustained serious physical injuries from the incident. She was treated for burns over an estimated 40% of her body.² Mr. Ingham received first and second degree burns to his upper torso and face.³ Both were admitted to Harborview Medical Center immediately following the incident. He was released from Harborview Medical Center on September 27, 2011.⁴ The couple's home and motor vehicles were destroyed, and the explosion also caused extensive property damage to neighboring homes and other buildings in the area.

The Washington Utilities and Transportation Commission (UTC or commission) has jurisdiction over the safety of the natural gas pipeline facilities at issue, pursuant to RCW 81.88. This report summarizes the investigation of this incident by the staff of the commission.⁵ Mr. Al Jones, commission pipeline safety engineer, is the primary investigator. This report determines the probable cause of the explosion, makes findings of probable violations of commission gas safety rules, and provides commission staff's recommendations for further commission action.

II. EXECUTIVE SUMMARY

Based on the information in this report, it is staff's opinion that the most likely cause of the Ingham house explosion was natural gas leaking from PSE's service pipe located near the foundation of the Inghams' house. The gas leaked through a one-eighth inch diameter hole in Inghams' gas service pipe and migrated into the crawlspace. The gas was ignited from an

¹ This report represents the findings, opinions, conclusions and recommendations of commission staff, and at this time, nothing in this report constitutes a finding, opinion, conclusion or recommendation of the commission. Commission staff understands the commission later will decide what regulatory action, if any, is appropriate. Nothing in this report reflects a finding or conclusion of commission staff that the gas system in the Seattle Pinehurst Area is unsafe.

² Seattle Fire Department Fire Investigator's Scene Report, page 10, Exhibit G to this Report.

³ Seattle Police Department incident report #11-317118, page 5, Exhibit D to this Report.

⁴ Id., page 7.

⁵ Commission staff counsel contacted Mr. David Beninger, the attorney for the victims, Mr. and Ms. Ingham, requesting to interview his clients about the incident. However, no meeting was ever scheduled. Based on the other information staff has gathered, staff is confident in the analysis in this report.

unknown source, causing the explosion and fire, and resulting in injuries to the Inghams and significant damage to property.

The hole in the gas service pipe to the Inghams' house was located where the gas pipe crossed over the sewer pipe that served the house. An electrical arc between the steel gas service pipe⁶ and the iron sewer pipe created the hole in the gas service pipe.

The electrical arcing process was initiated by electricity from a downed power line that energized a fence post and eventually energized PSE's gas distribution pipes in the area.⁷ The electricity caused the metal on the steel pipe at the Ingham house to melt and re-solidify, thus creating the hole.⁸

The hole in the gas pipe serving the Inghams' house is similar to holes in gas pipes found the day before at three other locations in the area. Each hole was caused by the same electrical arcing process.⁹

Though staff considers gas leaking from PSE's service pipe to be the most likely cause of the explosion, we could not eliminate the possibility that the electrical current running through the gas pipe continued into the Inghams' house and caused another gas leak in the Inghams' fuel line, furnace or other facilities.

III. INVESTIGATION AND ANALYSIS

A. Description of the Events Surrounding the Accident

Sunday, September 25, 2011.

Approximately 11:30 a.m.

At approximately 11:30 a.m. on Sunday, during a wind storm, a Seattle City Light high voltage power line broke near the intersection of N.E. 127th Street and 10th Avenue N.E. The severed end

⁶ The information in this sentence about the electrical arc is contained in PSE's Report to Pipeline and Hazardous Materials Safety Administration (PHMSA), page 6, Exhibit H to this Report and PSE's Supplemental Report to PHMSA, page 6, Exhibit I to this Report.

⁷ Commission staff sent a public records request to the City of Seattle seeking its investigative reports (and related documents) regarding the downed power line. The City identified two responsive documents, but did not disclose them based on attorney/client privilege. Letter from Ms. Lizzie Brodeen-Kuo, City of Seattle, to David Lykken, UTC (December 20, 2012).

⁸ SEAL Laboratories - Final Report (attached as Exhibit F), page 3, Summary.

⁹ Id.

of the power line fell to the ground. The line voltage was three phase, 26 kilovolts (kV).¹⁰ The photos below show the power line and the fence.

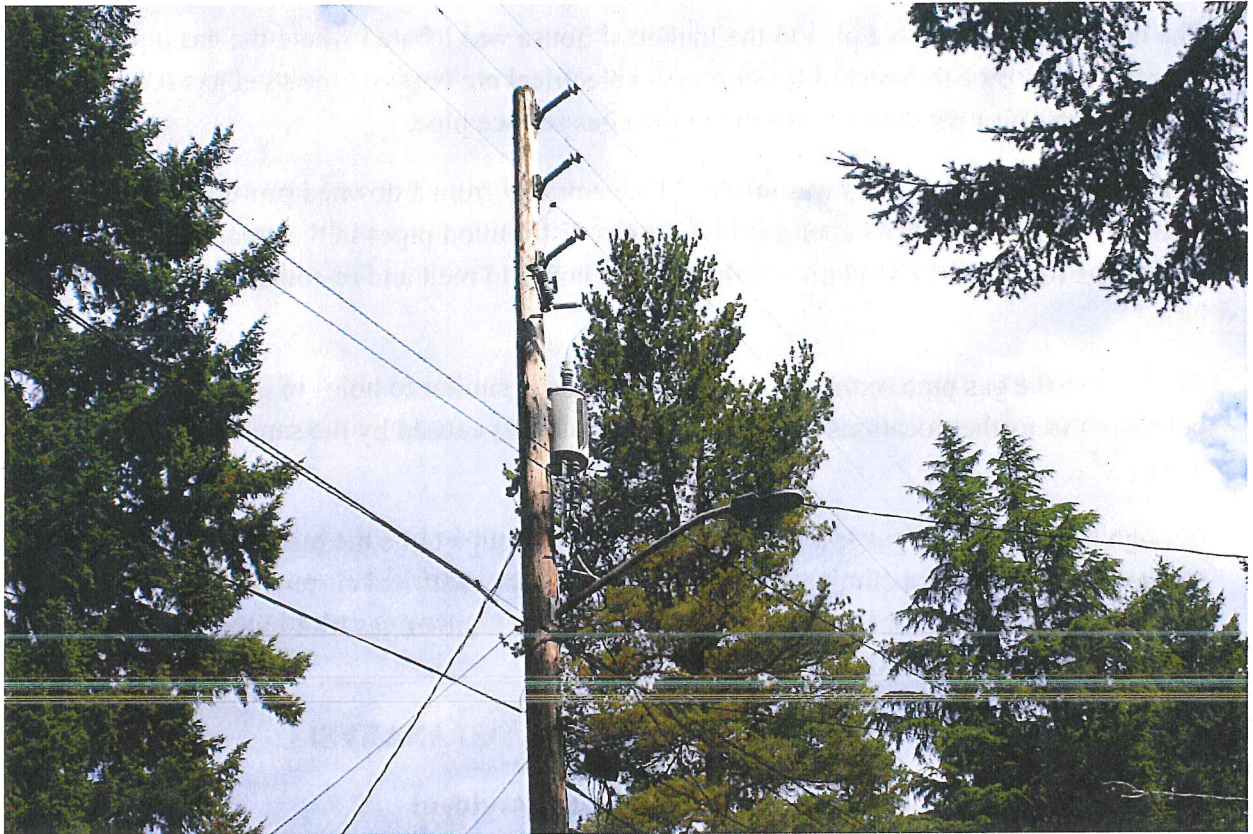


Photo 1: View of high voltage line (top of pole) near the intersection of N.E. 127th Street and 10th Avenue N.E. Photo taken September 30, 2011, by Kuang Chu, UTC engineer.

Electricity from the downed power line energized a metal fence post, arced to an abandoned water pipe near the fence post, traveled through the water pipe and then arced to the gas service pipe at 1016 N.E. 127th Street, approximately 80 feet from the fence post. The vegetation near the base of the fence post caught fire.

The arc energized PSE's gas distribution system throughout the Pinehurst neighborhood.

The electricity in the gas distribution piping in the Pinehurst neighborhood arced to ground at four locations, creating holes in the gas pipe in each location. In each instance, another metal pipe in close proximity to the gas pipe acted as a ground for the electrical current. These other metal pipes included an oil vent pipe, copper water pipes, and for the Inghams, the ductile iron sewer pipe serving their house.

¹⁰ Information in this sentence (other than the photos) was provided by Mr. John Barnett, Manager for Seattle City Light.

Exhibit A to this Report shows the locations of the downed power line and these four damaged gas pipes.



Location of fire at fence

Photo 2: View of where the high voltage line energized the fence post and caused a brush fire. Photo taken September 30, 2011, by Kuang Chu, UTC engineer



Metal chain link fence

Metal fence post

Photo 3: View of fence post, fencing, and fire debris. Photo taken September 30, 2011, by Kuang Chu, UTC engineer

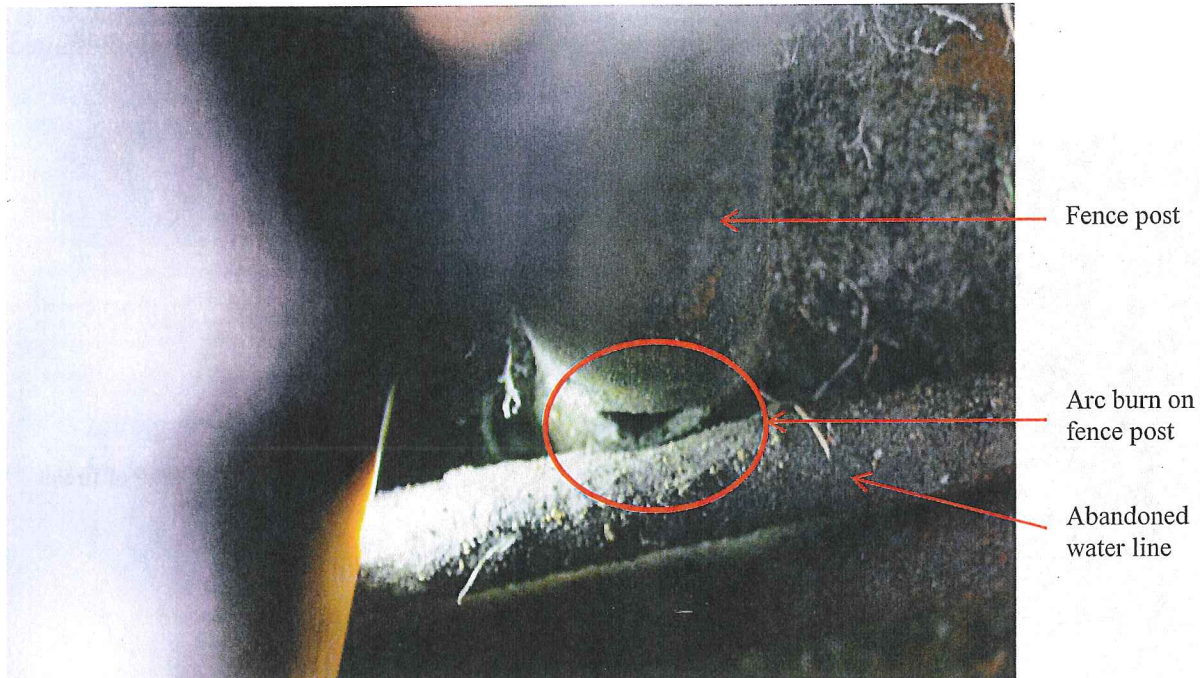


Photo 4: View of where the electrical arc damaged the metal fence post (hole in post) adjacent to the abandoned water pipe. Photo taken October 21, 2011, by Kuang Chu, UTC engineer

At 11:33 a.m. that Sunday the City of Seattle Fire Department received an emergency call reporting the downed power line and fire at the fence line.

Sunday Afternoon

Later that Sunday afternoon, PSE received gas leak reports regarding three of its natural gas service pipes in the Pinehurst neighborhood, as follows:

1. 1:37 p.m., 12040 8th Avenue N.E. – gas pipe crossing abandoned oil vent pipe - the home owner reported to PSE a gas odor outside, near the meter.¹¹
2. 1:54 p.m., 913 N.E. 122nd Street – gas pipe crossing a water service pipe. A report from the Seattle Public Utilities crew that arrived at the scene stated:

campbejd 09/25/11 03:42 PM – when we arrived we noticed water bubbling up out of asph street by curb kind of spraying. When we got out we smelled strong gas smell, we had orc call p.s.e. right away¹².

¹¹ Information contained in this paragraph is from PSE’s “Gas Respond to Odor/Emergency” report, provided by PSE in its response to staff Data Request 01.01.

¹² Information contained in this paragraph is from Seattle Public Utilities Work Order Details Report, WO#2912486.

The City could not repair the water leak until the gas leak was controlled.¹³

3. 7:55 p.m., 1020 N.E. 127th Street (See photo below) – gas service pipe crossing abandoned water pipe - Heath Consultants, a leak survey team working for PSE, reported to a PSE dispatcher an immediate leak repair where the electrical energy first entered the gas distribution system. This location is near where the electrical wire fell on the steel fence post.



Photo 5: View of service pipe at 1020 N.E. 127th Street, where the high voltage passed from the abandoned water pipe (rust colored line with a hole) to the gas service pipe (green coated pipe). The damaged gas service pipe had been removed at the time this photo was taken. Photo taken October 20, 2011 by David Cullom, UTC engineer.

Sunday Afternoon and Evening – Special Leak Surveys

On Sunday, beginning at approximately 5:30 p.m., at PSE's direction, Heath Consultants (Heath),¹⁴ conducted a leak survey on steel wrapped mains and services, after PSE discovered

¹³ Id.

¹⁴ Heath Consultants is a subcontractor of PSE. PSE is responsible for compliance with pipeline safety rules, including rules applicable to leak surveys.

the leaks were caused by electrical arcing on the steel gas pipe at 12040 8th Avenue N.E. and 913 N.E. 122nd Street. “PSE instructed Heath Consultants to perform a gas detection survey of identified wrapped steel gas piping...”¹⁵

The boundary of this first special leak survey was 5th Avenue N.E. to 12th Avenue N.E. and N.E. 115th Street to N.E. 130th Street, which encompassed both of the two previously reported gas leaks. This survey boundary is shown in Exhibit B by the red rectangle, approximately 0.28 square miles.

Beginning at approximately 9:30 p.m. Sunday, also at PSE’s direction, Heath conducted a second leak survey, after identifying the leak at 1020 N.E. 127th Street (see Photo 5 above), which also was caused by electrical arcing. “PSE instructed Heath Consultants to perform a gas detection survey of identified gas piping located in the public rights-of-way accessible to a vehicle ...”¹⁶

The area for this second leak survey was expanded from the first leak survey (as shown in Exhibit B by the yellow rectangle) to include approximately 0.66 square miles. The survey was between 5th Avenue N.E. to 15th Avenue N.E. and N.E. 105th Street to N.E. 130th Street. This second leak survey was conducted using vehicle-mounted mobile survey units, and it surveyed gas pipe located in the public right of way and accessible to vehicles. If gas was detected, the leak surveyors were to stop and conduct further investigation. This meant that service connections between the gas pipe in the street and houses and buildings were not covered routinely by this leak survey. This second leak survey was completed at approximately 3:00 a.m. on Monday, September 26, 2011, with no additional leaks found.¹⁷

The gas main serving three homes on the private drive where the Inghams’ home is located is not shown on the map used in these leak surveys. The map has a short line that intersects the gas main located under 5th Avenue N.E. Apparently, this short line is intended to indicate that a gas facility extends into the private drive and serves three addresses; one address is the Inghams’ home (the house numbers are listed on the map).

In both of these leak surveys, the Heath personnel used colored highlighter pens to mark the mains and services they surveyed or circled the area on plat maps that they surveyed. However, Heath personnel did not mark or circle the gas main and the services to the Inghams’ home and the other two homes in the private drive.¹⁸ In addition, the map Heath used for the first leak survey shows a hand drawing of the main located under the private drive and the services that are

¹⁵ PSE response to staff Data Request 2.27.

¹⁶ Id.

¹⁷ The information in this paragraph is based on PSE’s response to staff Data Requests 2.04 and 2.27.

¹⁸ PSE response to staff Data Request 2.31.

circled with an asterisk symbol (Exhibit C to this Report). An asterisk on the margin of the map has a handwritten note that states:

9/26/11 drawn in 1:45 pm Monday after conversation w/Rick Elkin based on field locates was not surveyed.¹⁹

Staff concludes that Heath failed to leak survey either the service pipes to the three homes in the Inghams' private drive or the gas main located under the private drive.

Monday, September 26, 2011

At approximately 6:00 a.m. Monday, a natural gas explosion and fire destroyed the home of Mr. and Ms. Ingham. The Inghams received aid from a neighbor and were transported by the Seattle Fire Department to Harborview Hospital Burn Center, where they were admitted. They both survived the incident.

Photo 6, below, is a photograph showing the Ingram's property after the explosion and fire:



Photo 6: View of Inghams' home looking west. Photo taken September 26, 2011, by Kuang Chu, UTC engineer.

Police interview

Later that day (Monday), Detective Randy Curtis of the Seattle Police Department Bomb Squad interviewed Mr. Ingham at the Hospital. His report (Exhibit D to this Report) states that

¹⁹ The information in this paragraph is based on PSE's response to staff Data Request 2.02.

Mr. Ingham said that on Sunday, his wife told him she smelled gas, but he did not. He said he walked outside and did not smell gas there either, and he checked around the meter set outside the house and the crawl space. He also said his wife had placed moth balls in the house to control a spider infestation²⁰. The Inghams did not report a possible gas leak.²¹

According to his report, Detective Curtis was advised by Sgt. Hansen that Seattle Fire Department personnel and PSE employees were notified of a possible gas leak on Sunday, September 25, 2011, by a neighbor(s) of the Inghams.²² However, staff was unable to confirm this. Staff requested PSE to supply all odor calls for Sunday, September 25, 2011, and PSE's response identified no odor calls that day for the immediate area around the Inghams' private drive, either to PSE or the Seattle Fire Department.²³ Also, staff engineer Mr. Jones interviewed the Inghams' neighbors to the north, south, east, and west. They reported they did not smell the odor of gas and they did not know of any neighbor that smelled gas in the neighborhood on Sunday, September 25, 2011, the day before the explosion.²⁴

Additional Leak Surveys

After the incident, PSE directed Heath to conduct four extended leak survey using vehicle mounted and foot units. These surveys were completed over several weeks. The first extended leak survey began on September 26, 2011, between Meridian Avenue N. to 15th Avenue N.E. and N. 165th Street to N. 105th Street. The second extended leak survey began on September 28, 2011, using the same methods and survey area. The areas of these extended leak surveys are shown in Exhibit B by the green rectangle, approximately three square miles. Heath conducted two other extended leak surveys beginning on October 10, 2011, and October 17, 2011, respectively, using reduced survey areas.²⁵

In addition, on September 26, 2011 at 10:29 a.m., PSE completed a gas leak survey for residual gas over the Inghams' service pipe and found zero percent gas in the air over the service pipe and

²⁰ The odor from the moth balls placed in the house may have affected Mr. Ingham's ability to smell natural gas.

²¹ Information contained in this paragraph is from the Seattle Police Department incident report #11-317118, page 6 contained in Exhibit D of the Report.

²² Id.

²³ PSE response to staff Data Request 2.23.

²⁴ Commission Pipeline Safety Engineer Mr. Al Jones interviewed the Inghams' neighbors to the north, south, east, and west. Mr. Evan Gullacson's home at 12314 5th Ave NE faces the east side of Inghams' gas meter. Mr. Gullacson said his family was at home on Sunday, September 25, 2011, and had guests over to watch a Seahawk game. Mr. Gullacson reported that neither he nor his guests detected the odor of natural gas in the atmosphere. On the day of the incident, Mr. and Mrs. Gullacson provided a place for the Inghams to wash and sheets to cover their injuries. The home owners located adjacent to the Inghams' home to the north, south and west reported they detected no gas odors on Sunday, September 25, 2011. The addresses of the other home owners interviewed are: north – 521 NE 124 St, south – 518 NE 123 St, and west – 12316 5th Ave NE.

²⁵ The information in this paragraph is based on PSE response to staff Data Request 2.02.

100 percent gas at the pipe riser.²⁶ A black plastic ground cover was in place on the east side of the Ingham house where the gas meter was located, covered with a “Beauty Bark”-like material typically used for weed control. The fact that PSE found zero percent gas over the service pipe suggests the plastic covering above the pipe may have prevented the gas from escaping, except where the gas pipe riser came above the ground surface.

Excavation and Removal of the Gas Service

On the afternoon of the incident, PSE excavated the three quarter inch steel service pipe located along the east side of the Inghams’ house. The gas service pipe was located approximately twelve inches from the house’s concrete foundation wall and ran parallel to the wall. The pipe crossed over the sewer pipe and continued below ground approximately two more feet to the vertical gas service riser pipe. The riser pipe was connected to the gas regulator and meter. The gas service pipe, service riser, regulator and meter were removed and taken to PSE’s secure storage facilities.²⁷

As a result of the explosion, the regulator and meter were bent over and the Inghams’ gas fuel line from the meter to the house was detached from the meter. Photo 7, on the next page, shows the sewer pipe, gas service pipe, service riser, regulator and meter as they were situated after the explosion.

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²⁶ PSE response to staff Data Request 1.01, which included the PSE Leak Work Order No. N0039501 for 12312 5th Avenue N.E., dated 9/26/2012.

²⁷ PSE response to staff Data Request 2.25 describes in detail how the pipe was handled from removal to testing. Staff concludes the pipe was tested in the same condition it was in at the time of removal.

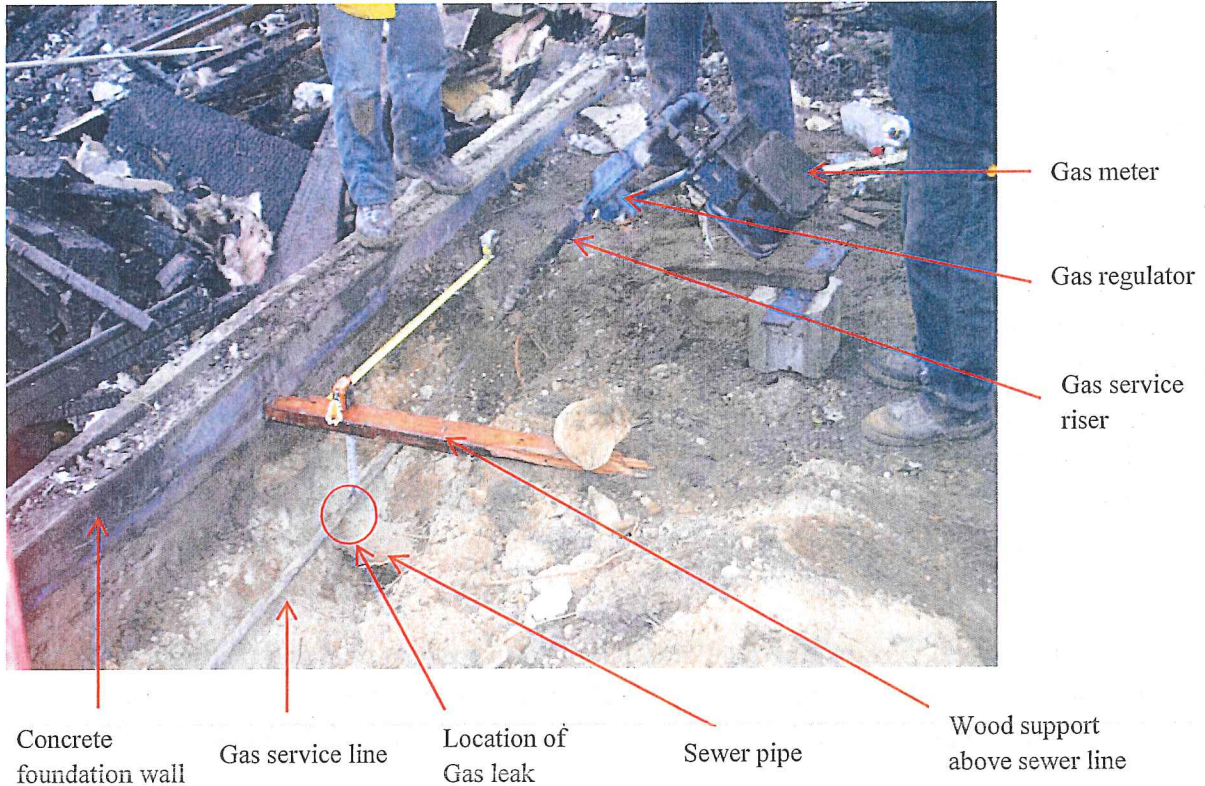


Photo 7: View of east foundation wall, location of service pipe, and meter set.-Photo taken September 26, 2011, by Al Jones, UTC engineer.

Located on the top surface of the sewer pipe were dark spots or ash-like material from the electrical arc. There were no visible signs of general corrosion or corrosion pitting on the sewer pipe surface.

On the PSE gas service pipe, the coating was missing on the lower half of the pipe where the hole was located. There were no visible signs of general corrosion or corrosion pitting on the exposed metal surface of the gas service pipe (see Photo 8, below). The wall thickness of the service pipe was approximately one-eighth inch which is within an acceptable wall thickness range for a pipe of this age. The hole in the service pipe was cone-shaped. The exterior and interior diameters of the hole were approximately one-fourth inch and one-eighth inch, respectively.

Photo 8, on the next page, is a photograph that shows the bottom surface of the section of the Inghams' gas service pipe that was located above the sewer pipe, with the through-wall hole in the pipe.



Photo 8: View of the hole in gas service pipe to Inghams' home located on bottom side of the pipe where it crossed over the sewer pipe. Photo taken September 26, 2011, by Al Jones, UTC engineer.

B. The Incident Site

1. The Inghams' House

The Inghams' property is located within the city limits of Seattle, in a residential neighborhood known as the Pinehurst District. It is the second lot east of 5th Avenue N.E., and it is accessible via a private one-lane paved road. On the property were a house and an attached, south-facing garage for two motor vehicles.

The Inghams' house was a single story, 1650 square foot, rambler-style, stick-framed residence built in the 1960's.²⁸ The house was supported by concrete foundation walls that did not have air vents. The ground in the crawl space was paved with concrete. The height of the crawl space varied from two to three feet and contained the heating ducts for the gas furnace. Typically, a gas furnace has a dedicated cold air return duct to circulate the air from the living space to the furnace. In this instance, the entire crawl space was used as the cold air return from the living space to the gas furnace.²⁹ The Inghams' furnace was designed to circulate cold air from the living space through openings in the floor into the crawlspace. Any gas entering the crawlspace could have moved into the living space of the house.

²⁸ Information in this sentence was obtained from King County Assessor's records.

²⁹ Seattle Police Department incident report #11-317118, page 6.

2. The Inghams' Fuel Pipe

The Inghams were PSE gas customers at the time of the incident. They used the gas to operate a furnace and hot water tank.

Gas pipe connected the Inghams' furnace and hot water tank to PSE's meter. This is commonly referred to as the customer's "fuel line." The fuel line would be owned by the Inghams because the outlet of PSE's gas meter marks the dividing line between PSE's facilities and the customer's facilities.

The Inghams' fuel line passed through the concrete foundation wall below the ground surface, and connected to PSE's meter above the ground surface. The fuel line's entry point through the foundation wall appeared to have been hammered through, shattering the concrete on the inside wall surface and reducing the wall thickness. This is a possible entry point for the gas to migrate into the crawl space. Photo 9, below, is a photograph showing the entry of the fuel line into the crawlspace of the Ingham house.



Photo 9: View of the gas fuel pipe entry into crawl space through east foundation wall. The vertical saw cuts in the concrete wall were made after the incident. Photo taken October 18, 2011, by Dennis Ritter, UTC engineer

C. PSE's Underground Facilities Near the Incident Site

PSE Facilities Serving the Inghams' House

In 1961, the year the Inghams' house was built, PSE installed the gas main under the private drive serving the Inghams' house and the service pipe from the main to the house.³⁰

PSE had three gas customers on this private road; the Inghams, and the neighbors on either side of the Inghams' property to the east and west. These three houses are shown on Exhibit A to this Report.³¹

The PSE service pipe to the Inghams' house entered the Inghams' property near the southeast corner. In the area where the hole in the pipe was located, the distance from the top of the gas service pipe to the ground surface was approximately 12 inches.

As shown in Exhibit E to this report and Photo 7, above, the Inghams' gas service pipe crossed over a four-inch ductile iron sewer pipe approximately eighteen feet from the southeast corner of the house. The riser for the gas regulator and meter was located approximately two feet north of the sewer pipe. Where the pipes crossed, there was approximately a one inch separation between the top of the sewer pipe and the bottom of the gas service pipe. The hole was located on the bottom of the gas service pipe directly above the top of the sewer pipe.

Facilities Serving the Other Houses With Damaged Gas Pipes

As we explained earlier, on the day before the explosion, a power line severed and came down in the Pinehurst neighborhood, and that same day, PSE received reports of damage to three of its gas service pipes in the area. PSE installed gas facilities at two of those locations in 1965³² and at the third location in 1966.³³

D. PSE's Periodic Leak Surveys, Cathodic Protection System and Odorant System

1. Periodic Leak Surveys

Commission rules require PSE to conduct leak surveys of its gas distribution system in residential areas at least once every five calendar years, at intervals not exceeding 63 months.³⁴

³⁰ Installation of main: PSE Plat maps #176.070 and #176.071, provided in response to staff Data Request 2.16. Installation of service pipe: PSE's customer service D-4 Card (PSE Form 1193), provided in PSE response to staff Data Request 1.04.

³¹ This drawing was prepared by Mr. Al Jones, UTC engineer.

³² The year of gas service installation is contained in PSE response to staff Data Request 1.04.

³³ Id.

³⁴ WAC 480-93-180, with reference to 49 C.F.R. § 192.723.

PSE Operating Standards require leak surveys over mains and services every three years, not to exceed 39 months.³⁵

The last leak survey PSE conducted in the area prior to the incident was on December 5, 2008.³⁶ The leak survey map did not indicate any gas leaks found on the main or service pipe to Inghams' home.³⁷ The hand-written markings on the map indicate that this periodic leak survey included the gas main serving the Inghams' private drive and the service lines to the Inghams' house and the other two houses located there.³⁸

2. *Cathodic Protection*

Cathodic protection (CP) involves impressing a small electrical current onto metal pipe to maintain the integrity of the metal. Commission rules require PSE to cathodically protect its steel pipe. To assure the system is working properly, commission rules require PSE to take CP readings once every calendar year, at intervals not exceeding 15 months.³⁹

Staff reviewed PSE's CP records for its CP test sites within a mile radius of the Inghams' house. Eight test sites were involved. Staff reviewed the records dated from January 1, 2006, to October 7, 2011.

During that period, PSE took 78 CP voltage readings.⁴⁰ Each reading met the required minimum of -850 mV.⁴¹

PSE's gas distribution system is designed with insulated connections to isolate electrical current from adjoining pipe sections for CP maintenance. Each CP area is isolated from adjoining areas to permit PSE to locate problems in the CP system.

Normally, the insulated connections are provided by a nonmetallic connection in the gas pipe. Adjoining gas pipe with different CP areas are bonded together with a heavy gauge wire connection across the insulators. PSE exposed the main at an insulated connection in the Pinehurst area and found the wire bond damaged from heat generated from the current flow

³⁵ PSE Procedure 2625.1100, Table 4-1, Leakage Survey Frequency Schedule.

³⁶ PSE response to staff Data Request 2.24.

³⁷ Id.

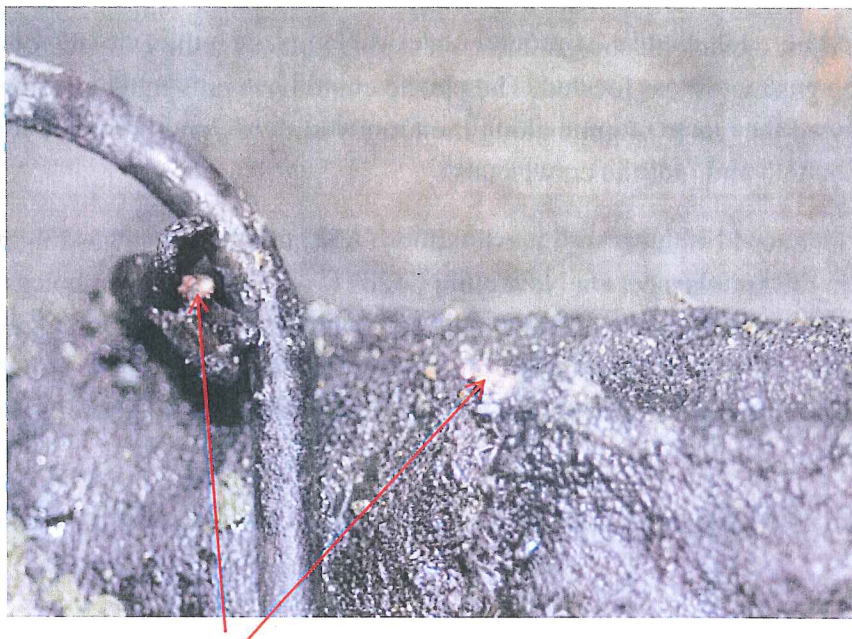
³⁸ Id.

³⁹ WAC 480-93-110 (5).

⁴⁰ The PSE's cathodic protection test sites which staff reviewed include test sites with the following identification numbers: TS-034519, PS-0015, TS-002790, TS-002793, TS-002794, TS-002803, TS-056245, and TS-029064.

⁴¹ WAC 480-93-180, with reference to 49 C.F.R. §192. 463 - External Corrosion Control: Cathodic Protection.

through the wire. Photo 10, below, is a photograph of the damaged bond wire PSE exposed.⁴² Approximately two inches of the wire was melted.



Damaged section of wire between the above end points

Photo 10: View of the damaged bond wire connection at gas main connection. About 2” of wire was melted. Photo taken October 25, 2011, by David Cullom, UTC engineer.

3. *Odorant Systems*

Gas leaking from a PSE gas service pipe should emit a strong “rotten eggs” smell, caused by the presence of an odorant called “mercaptan.” Commission rules require gas companies such as PSE to use an odorant as a method of warning the public of a gas leak.⁴³

The PSE’s odorator unit (OD-0006) serving the Pinehurst neighborhood is located at the North Seattle Gate Station, near Woodinville, approximately 20 miles from the incident site. PSE reported that it evaluates six odorant test sites monthly for the area served by that odorator unit. Odorant reads taken from gas pipelines in the Pinehurst neighborhood on September 26 and 27, 2011, indicated an odorant level well above minimum standards.⁴⁴

⁴² This bond wire was located at 10th Avenue N.E. and 125th Avenue N.E.

⁴³ WAC 480-93-180 Plans and Procedures and Title 49: Part 192. 625 – Odorization of Gas.

⁴⁴ PSE response to staff Data Request 2.22.

E. Testing⁴⁵

1. Advanced Engineering Investigations

As we noted earlier, a black plastic ground cover was in place on the east side of the Ingham house where the gas meter was located. The plastic could have prevented gas from escaping into the air and allowed the gas to migrate along the foundation wall, and under the foundation footing and floor slab and into the crawlspace.

PSE retained Advanced Engineering Investigations (AEI) to investigate gas migration under the concrete floor in the crawlspace. On November 8, 2011, AEI drilled seven holes through the concrete floor slab approximately one and half feet from the east foundation wall and injected gas into the soil on the exterior side of the foundation. The investigation was to determine the potential of gas migrating into the crawlspace. During the test, natural gas migrated to the crawlspace.^{46 47}

Photo 11, on the next page, is a photograph taken during the AEI test of gas migration.

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⁴⁵ In addition to Advanced Engineering Investigations and SEAL Laboratories, PSE retained Investigative Sciences, which tested infiltration where the Inghams' sewer pipe and fuel pipe each penetrated the foundation wall. Investigative Sciences did not prepare a written report of this test. Commission staff reviewed the field notes from this test, but could not interpret them. PSE provided the field notes in response to staff Data Request 2.26.

⁴⁶ Mr. Scott Rukke, UTC engineer, witnessed the test. A mixture of gas in air at 40% of the lower explosive limit (LEL) was injected in a pipe located outside the foundation wall. Gas readings were taken at seven holes in the concrete floor and along cracks and seams at the foundation prior to the start of the gas flow and after the start of the gas flow to determine points on entry into the crawlspace. Mr. Rukke observed a reading of 10% LEL of gas at hole number 5, which was directly adjacent to the leaking service pipe and sewer penetration of the foundation. He concluded that gas had migrated and entered the crawlspace at several locations along the foundation wall.

⁴⁷ AEI's detailed filed notes are contained in PSE's response to staff Data Request 2.26. According to PSE's response, AEI did not prepare a written report on its investigation.



Photo 11: View of the east foundation wall (looking south) and the crawspace concrete floor (right of the wall). The white plastic pipe at the base of the wall was supplied for use in the test. Photo taken November 8, 2011, by Scott Rukke, UTC engineer.

2. SEAL Laboratories

PSE retained Scanning Electron Analysis Laboratories, Inc. (SEAL Laboratories) of El Segundo, California to make an independent determination of the root cause of the service pipe leaks. Before PSE retained Seal Laboratories, commission staff reviewed and confirmed the proposed protocols for the metallurgical examination of the four PSE gas service pipes.

On December 11, 2011, Dr. Arun Kumar, PhD and President of SEAL Laboratories, performed the metallurgical tests at MDE, Inc. in Seattle. MDE, Inc. is an engineering firm specializing in failure analysis. Dr. Kumar conducted the tests in Seattle to accommodate the interested parties.

On February 27, 2012, the commission received Dr. Kumar's metallurgical testing report. A copy is included as Exhibit F to this Report. We refer to Dr. Kumar's report as the SEAL Laboratories - Final Report.

Dr. Kumar analyzed the following service pipes that were damaged:⁴⁸

12040 8th Avenue N.E. – gas service pipe crossing abandoned oil vent pipe,

913 N.E. 122nd Street – gas service pipe crossing a copper water service pipe,

⁴⁸ Exhibit F, SEAL Laboratories - Final Report, page 1.

1016 N.E. 127th Street – gas service pipe crossing abandoned water pipe, and
12312 5th Avenue N.E. (Ingham residence) – a gas service pipe to the Ingham home that
crossed a 4-inch diameter ductile sewer pipe.

According to the SEAL laboratories – Final Report, the PSE service pipe serving the Inghams’
home had a through-wall hole approximately one-quarter inch in diameter, and located on the
bottom of the pipe.⁴⁹ The report states:

In summary, metallurgical examination and analysis of all the four (4) steel gas
pipes revealed holes created by arcing process since the hole surface revealed
melted and re-solidified material with no fracture features. The holes varied in
size and were created from outside and inside. The holes were not caused by a
corrosion process. The pipe material revealed no metallurgical defect⁵⁰.

IV. CONCLUSIONS

Based on its investigation, commission staff concludes that the explosion at the Ingham house
most likely was caused by gas leaking from a hole in the PSE gas service pipe located next to the
Inghams’ house.

As the gas escaped through the hole, the soil surrounding the Inghams’ service pipe allowed gas
to migrate to the surface, along the pipe and in the soil adjacent the concrete foundation wall of
their house. Test performed after the incident demonstrated that gas could migrate between the
foundation wall and the floor slab or around the wall penetration for the sewer pipe and gas pipe,
and thus gas could have accumulated in the crawl space. The crawl space of the Inghams’ house
had no outside vents, so the gas did not escape to the outside. The cold air return vents in the
floor could provide a path for gas to migrate from the crawl space to the living area. When an
ignition source⁵¹ was supplied, the resulting explosion and fire caused significant personal
injuries and property damage.

The hole in the PSE service pipe serving the Inghams’ house was caused by an electricity arcing
process that was initiated by a downed Seattle City Light power line. The day before the
explosion, the power line was severed, fell and energized a metal fence post, an abandoned
buried metal pipe, and finally, PSE’s gas distribution piping.

⁴⁹ Id., page 3.

⁵⁰ Id., page 3, Summary.

⁵¹ Examples of common sources of a spark include a light switch, pilot light and electrical motor.

The hole in the Inghams' service pipe was consistent with the holes in three other PSE gas service pipes in the area. Each pipe had another metal pipe in close proximity that acted as a ground. The holes in these pipes were caused by the same electrical arcing process. When the electricity was discharged from the energized gas pipe to the other nearby metal pipe, the electricity became grounded, electricity arced from the gas pipe to the ground, and this arc of electricity created a hole in each gas pipe.

For the Inghams' gas service line, the path to ground was the metal sewer pipe directly below the PSE service pipe.

The metallurgical analysis shows a melting and re-solidification of the metal caused by an electrical arcing process. The holes in each of the gas pipes analyzed showed a shiny, smooth and regularly shaped hole, with no blisters or flaking. This is entirely consistent with the electrical arcing phenomenon discussed above.

This eliminates corrosion as a cause of the holes in these pipes, because corrosion by oxidation of a ferric metal reduces the metal to a lower state of energy, such as ferrous oxide, and it results in a condition that is irregular in shape, reddish brown in color, blisters and easily flakes off. That was not the situation here.

We also eliminated PSE's cathodic protection system as a source for the electricity that caused the arcing process, because the cathodic protection system uses a very small current that is not sufficient to create an arc. The only known electrical source of any significant magnitude existing at the time of the incident was the downed power line. The holes in the pipes adjacent to the fence post are consistent with the same electrical arcing process discussed in this Report.

We could not eliminate the possibility that the electrical current running through the gas pipe continued into the Inghams' house and caused another gas leak, in the Inghams' fuel line, furnace or other facilities.

V. PROBABLE VIOLATIONS AND RECOMMENDATIONS

Based on this investigation, commission staff makes the following findings of probable violations of commission gas safety rules, codified in WAC 480-93, and makes the following recommendations.

A. Probable Violations

WAC 480-93-188(4) states: Special leak surveys must be conducted under the following circumstances: ... (d) In areas and at times of unusual activity, such as earthquake, floods, and explosions; ...

Findings: On September 25, 2012, the day before the explosion, PSE properly and promptly initiated two special leak surveys after discovering unusual activity, i.e., the pipeline damage at various locations within the Pinehurst neighborhood. PSE established reasonable boundaries for the area of each of these special leak surveys.

However, PSE violated WAC 480-93-188 in the following respects:

1. In the first special leak survey, which started at approximately 5:30 p.m. on September 25, 2012, PSE failed to survey all of PSE's gas facilities located in the area of the special leak survey. In particular, PSE failed to survey the gas main located under the Inghams' private drive and the service lines serving the Inghams' house and the two houses next door.
2. In the second special leak survey, which started at 9:30 p.m. on September 25, 2012, PSE failed to survey all of PSE's gas facilities located in the area of the special leak survey. In particular, PSE limited this leak survey to a "mobile" survey which surveyed gas pipe located in the public right of way and accessible to vehicles. PSE failed to survey gas services located in the area of this second special leak survey but not in the public right of way and accessible to vehicles, and PSE failed to survey the gas main located under the private drive where the Inghams' house was located. The private drive is a paved road that was accessible to survey vehicles.

B. Recommendations

1. Staff recommends the commission initiate a complaint for penalties for the above-described violations of WAC 480-93-188(4).
2. Staff recommends PSE consider installing mitigation devices on its pipeline where fault currents from electrical source voltage levels lower than 115kV.⁵² PSE's Operation & Maintenance Manual has an operating standard for - Electrical Isolation and Grounding Requirements (2600.1400). The standard states:

Where a pipeline is located close to electrical transmission tower footing, ground cables or counterpoise, or in other areas where fault currents or unusual risk of lightning may be anticipated, the pipeline shall be provided with protection against damage from fault currents or lightning. Protective measures shall also be taken at insulating devices.

This standard applies to electrical sources 115 kV or greater.

Staff will consider whether this is an issue the commission should address by a rule.

⁵² Additional information is available from NACE Standard Recommended Practice (RP0177-2000) – Mitigation of Alternating Current and Lightning Effects on Metallic Structures and Corrosion Control Systems.

APPENDIX

Persons Interviewed and Data Requests Issued

Commission staff meetings and interviews in the course of its investigation included:

- September 26, 2011 – Commission engineer Al Jones met with Captain Ricardo Castro from the Seattle Fire Department’s Fire Investigation Unit to discuss the condition of injured persons, evacuation of neighborhoods, making the area safe, extent of damage to properties, and identifying the parties involved in the investigation.
- September 27, 2011 - Al Jones met with Ken Brown, PSE manager at the Factoria storage unit, to examine the four damaged gas pipes, i.e., from 1016 N.E. 127th St, 913 N.E. 122nd St, 12040 8th Avenue N.E., and 12312 5th Avenue N.E..
- October 10, 2011 - Al Jones and Joe Subsits, commission engineers, met with John Barnett PE, Manager Distribution Engineering for City of Seattle City Light and Joe Groshong, Assistant City Attorney for Seattle. The meeting took place in Olympia and it included a review of Seattle City Light’s electrical distribution system and how a tree limb damaged a high voltage electrical line that fell on was ground to a metal fence post.
- October 13, 2011 - Al Jones met with John Barnett and Rich Eilman, Risk & Claims Advisors, Seattle Public Utilities, and Rick Scott, Director of Seattle Public Utilities. The meeting was in Seattle and the purpose was to examine the damaged copper water pipe removed from 913 N.E. 122nd Street.
- October 20, 2011 at N.E. 127th Street between 10th and 12th Avenue N.E. – Staff field investigation to locate and examine ground fault damage with Mr. Ronnie Liem from Investigative Sciences. Mr. Liem is a PSE consultant in forensic engineering and scientific services. Also, John Barnett and Gary Maehara, Legal Affairs for Seattle Public Utilities met with commission staff to review events and answer questions. Al Jones and David Cullom, commission engineers, attended.
- October 21, 25, 26, 28, 2011 – Staff field investigation examined damaged gas piping and bond wires at N.E. 127th Street between 10th and 12th Avenue N.E. Ronnie Liem from Investigative Sciences and David Cullom, commission engineer, were also present.

- November 8, 2011 - meeting at the incident site to investigate the potential gas migration in the area of the leak. Scott Rukke, commission engineer, attended. PSE retained Advanced Engineering Investigations to conduct the test.
- November 17, 2011 - Al Jones and Joe Subsits, commission engineers, met with John Barnett, Manager Distribution Engineering for City of Seattle City Light and Joe Groshong, Assistant City Attorney. The meeting took place in Seattle and the purpose was to review Seattle Public Utilities' electrical distribution maps, location of switches activated during the ground fault incident, and damaged transmission line.
- December 20, 2011 - At MDE, Inc. to witness the metallurgical test by Dr. Arun Kumar of Seal Laboratories; El Segundo, California. The following people attended: Glenn Johnson and Gwen Johnson of Q-Global, John Biskey of Biskey's Forensic Engineering, Jeremy Hailey of NW Corrosion, Victoria Liem of Forensic Engineering and Scientific Services, Ed Iskra of Unified Investigation, Bryan Templeton of CASE Forensic, Doug Barovsky and Keith Cline of MDE, Matt Prece of Gordon Tilden, Stephanie Silva and Jace McMaste of PSE, Jack Prestrud of Seattle City Light, Craig Evezicu of Evezicu, and Kuang Chu and Al Jones, commission engineers.
- September 10, 2012 - Al Jones, commission engineer met with the following PSE employees: Duane Henderson, Manager, Gas System Integrity; Cheryl McGrath, Manager, Gas Compliance & Regulatory Audits; John Klippert, Manager, Gas System Operations; David Moffett, Supervisor, Corrosion, and Michelle Gallardo, Engineer, Gas System Integrity. During the meeting, the Exhibit B - Leak Survey Map was reviewed, and the following data requests were reviewed: No. 01.15 for the chain of custody document for Pinehurst incident and current location of collected pipe components, No. 02.23 for Gas odor calls received Sunday, Sept 25, 2011, and No. 02.24 for the last leak survey that was part of the 5-year cycle for the private road to Inghams' home and service pipe.
- December 16, 2012 – Al Jones, commission engineer, met with the persons whose homes are adjacent to the Inghams' property, located at 12314 5th Ave NE. Home owners located to the north at 521 NE 124 St, south at 518 NE 123 St, and west at 12316 5th Ave NE.

Commission staff also issued data requests to PSE seeking information applicable to the incident and what occurred afterward, such as PSE documentation of: security of the evidence, gas leak surveys, gas concentration in the soil, odorant level in main, gas pressure in the main, photographs, and exposed pipe condition including depth of cover. PSE responded to these

requests. Staff also asked for the investigative reports from the first responders and the City of Seattle.⁵³

⁵³ See footnote 7.