EXHIBIT NO. ___(KCG-5)
DOCKET NO. PG-041624
WITNESS: KEVIN C. GARRITY

BEFORE THE
WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION

WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION, **Complainant,** **v.** **PUGET SOUND ENERGY, INC.,** **Respondent.**	**Docket No. PG-041624**

FOURTH EXHIBIT TO THE PREFILED DIRECT TESTIMONY OF
KEVIN C. GARRITY (NONCONFIDENTIAL)
ON BEHALF OF PUGET SOUND ENERGY, INC.

AUGUST 15, 2005

FINAL REPORT

G4434-21G

PREPARED
FOR
GORDON MURRAY TILDEN LLP
SEATTLE, WASHINGTON

ON BEHALF OF
PUGET SOUND ENERGY

SUMMARY REPORT - FAILED SERVICE LINE
BELLEVUE, WASHINGTON

FINAL REPORT
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PREPARED FOR
GORDON MURRAY TILDEN LLP
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ON BEHALF OF
PUGET SOUND ENERGY
BELLEVUE, WASHINGTON

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INTRODUCTION

On September 2, 2004 an explosion and fire destroyed a home located at 16445 SE 26th Place in Bellevue, Washington. The incident was reported to have occurred as a result of gas leaking from an underground natural gas line servicing the residence. The leak and subsequent explosion resulted in the death of Frances Schmitz who was living in the home.

CC Technologies Services Inc. (CC Technologies) has been retained by Gordon Murray Tilden LLP on behalf of Puget Sound Energy (PSE) to perform three tasks in regard to the above incident. The first task was the completion of a metallurgical and corrosion laboratory-based evaluation of a section of the underground natural gas service line. This evaluation and report was completed and issued on February 18, 2005. Secondly, CC Technologies was requested to accumulate, organize and report on the factual history of the service in question to include the leak history in the general area and the history and operation of corrosion protection systems affecting the area. The following report is intended to fulfill this request and will cover both conditions prior to, during and following the incident. CC Technologies has also been retained to provide an opinion as to the cause of the leak that resulted in the incident, which will be the topic of an opinion report to be issued under separate cover.

BACKGROUND

In January 1963 a nominal ¾-inch wrapped steel gas service line was installed at 16645 SE 26th Place, Bellevue, WA. The original service installation records indicate that the service extended sixty feet from a 2-inch intermediate pressure wrapped steel gas main located along SE 26th place. Installation of the service was completed on January 10th, 1963 and the application for gas service was completed January 14th, 1963.

The incident occurred in a housing development dating to the early 1960's. Some homes in the development were originally provided with only electric service while others utilized both gas and electric utilities. This subdivision is located west of Lake Sammamish in Bellevue Washington. 16645 SE 26th Place is located approximately 1,800 feet west of Lake Sammamish at an elevation of approximately 305 feet above sea level. The bulk of the subdivision is included among plats 193.089, 193.090, 194.089, 194.090, 195.089 and 195.090. Figure 1 below shows an aerial view of the site location in Bellevue, WA taken in 2002.

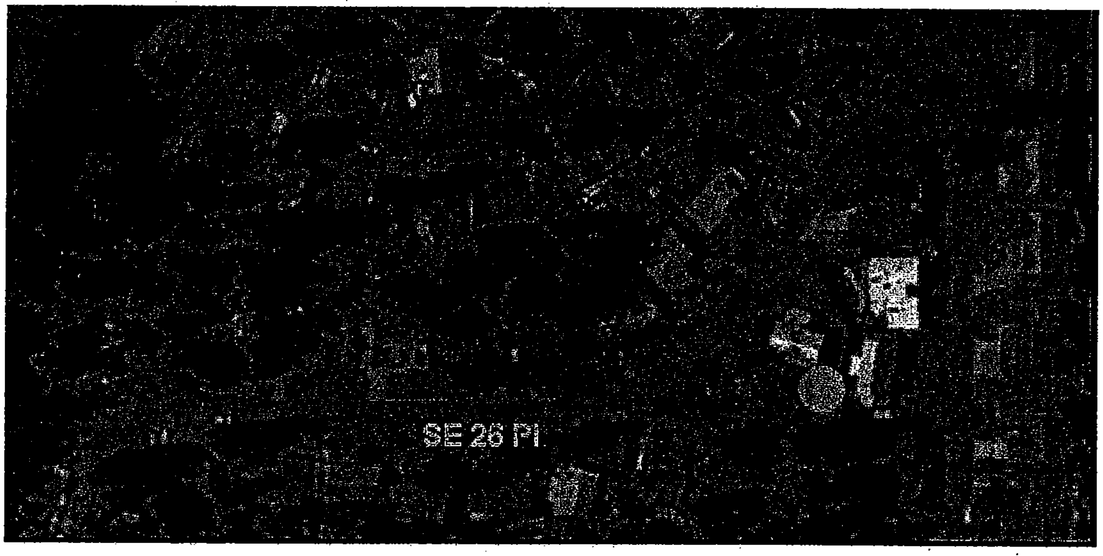

Figure 1. Aerial view of the failure site location in Bellevue, WA (taken in 2002).

Figure 2 below shows the general appearance of the soils encountered at the depth of the service line. The 1994 United States Geological Soil Survey Classification describes the soils for the area as being Alderwood soils. These soils are on glacially modified foothills and valleys having slopes of 0 to 65 percent. The average annual precipitation is about 40 inches, and the mean annual temperature is about 50 degrees F. Alderwood series soils are of grayish brown color in the 27 to 60-inch depth range, moderately well-drained soils on uplands, and generally formed under conifers in glacial till. It is a gravelly sandy loam, 40% pebbles, with a cemented pan about 20 to 40 inches below the surface. This pan was formed by the crushing weight of the passing glacier and then covered with the looser till left by the glacial retreat. Alderwood soils have 5 to 10% clay, 5 to 10% organic matter, a pH range of 5.1 to 6.0. Water permeability is 2 to 6 inches per hour, due to the high hardpan.

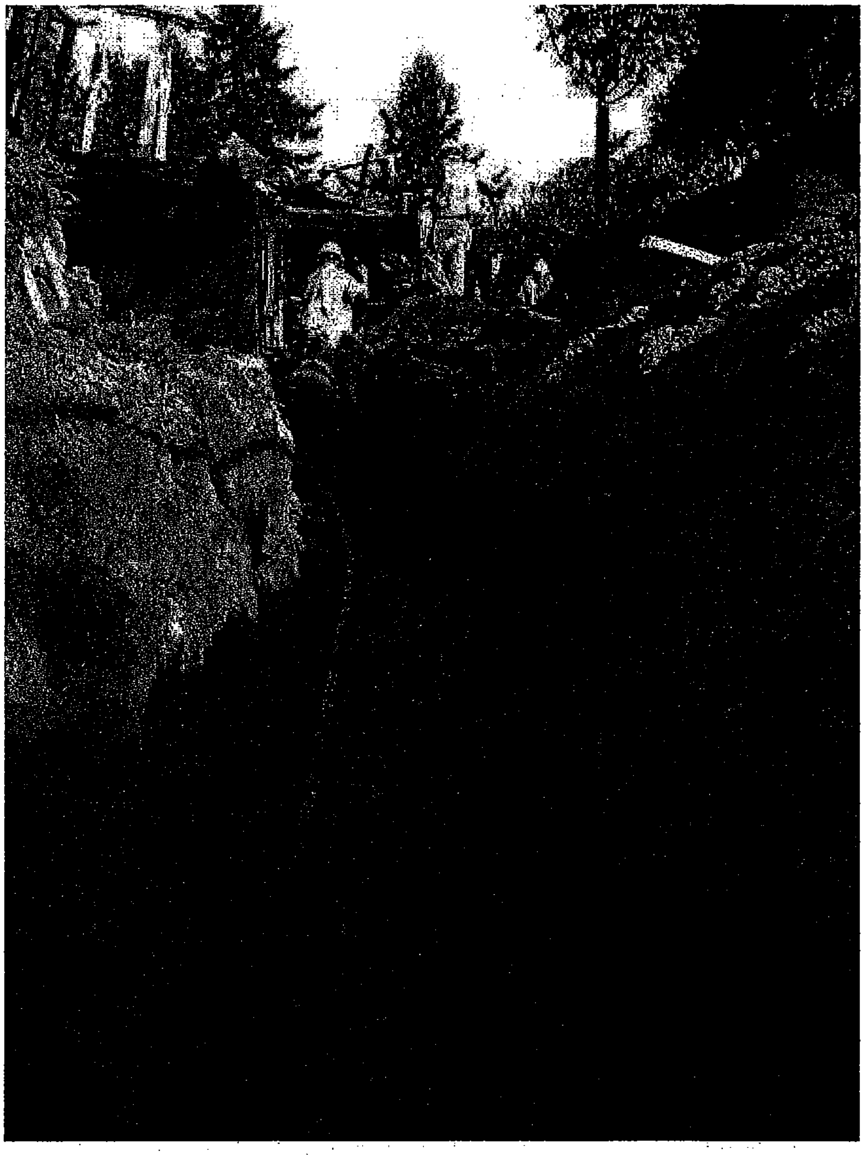

Figure 2. General view of soil conditions encountered at 16645 SE 26th PL, Bellevue, WA.

Cathodic protection was applied to the gas mains in the vicinity of the incident during the early 1980's. The coated and wrapped steel service was installed with no dielectric union at the tie-in to the main. The service therefore, was cathodically protected via the CP sources protecting the main. The predominant CP current source in the vicinity of the Spirit Ridge subdivision is located at SE 43rd Street and 164th Place SE and has been referred to as the Vasa Park rectifier. Figure 3 shows the relative location of the incident and the influencing rectifier. The rectifier is situated approximately 3,240 feet from the incident site. Documents reviewed indicate that this rectifier and ground bed were installed in March 1982. It is reported that supplemental magnesium sacrificial anodes have been installed at various locations during the normal course of pipe excavations and service installations.

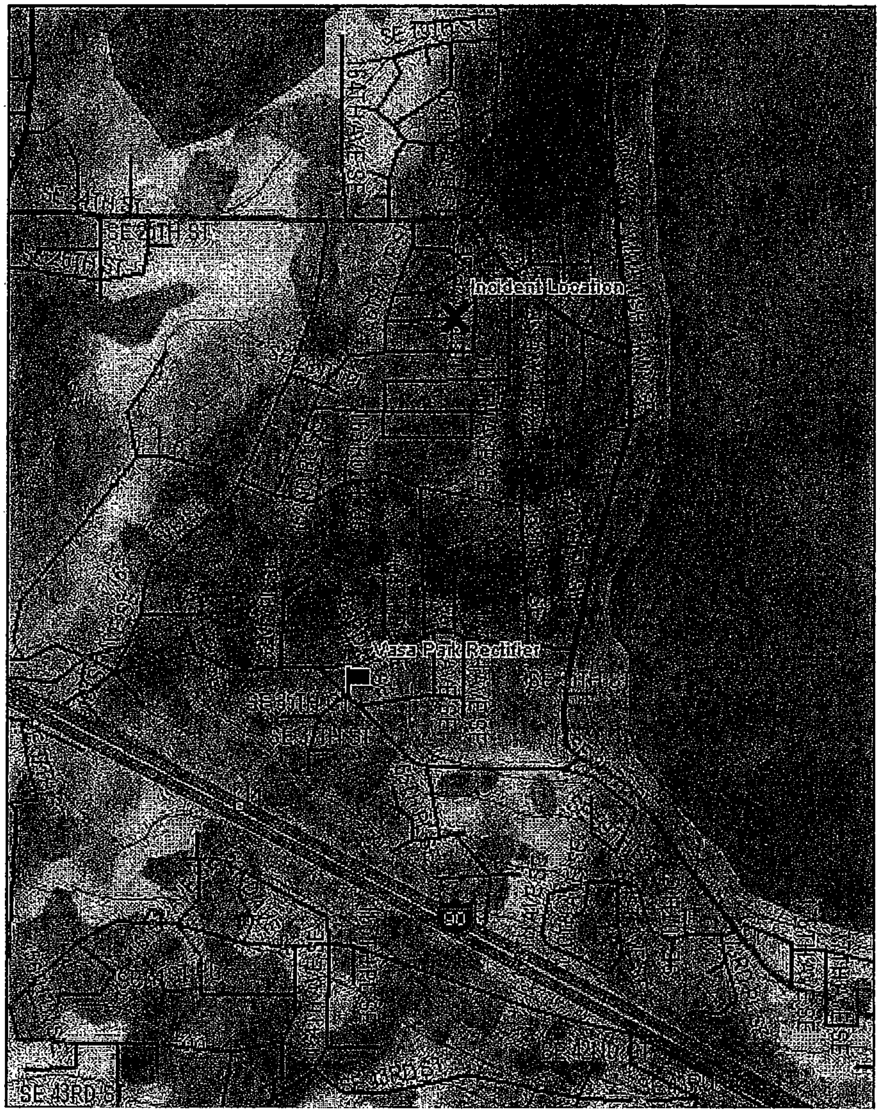

Figure 3. Map depicting Incident location and influencing rectifier.

Since the early 1980's the effectiveness of the cathodic protection system has been monitored through the use of leak surveys as is permitted in the Code of Federal Regulations (49 CFR) Part 192.457 and Part 192.465.[1] Three corrosion leaks had had been detected in the area of the Spirit Ridge system in the 10 years preceding the incident. In addition to the leak surveys the system is monitored through annual surveys where pipe-to-soil potential measurements are collected at test points identified throughout the system to evaluate the effectiveness of the CP.

Until the summer of 2004, no significant corrosion or corrosion protection related conditions were noted in the area.

EVENTS LEADING UP TO THE INCIDENT

In the summer and fall of 2003 an annual cathodic protection survey was conducted in the Spirit Ridge area. Over sixty test points were investigated in the Spirit Ridge vicinity during the survey. The results of that survey are summarized in Table 1 below and shown graphically in Figure 4. Test stations highlighted in yellow lie directly in the Spirit Ridge area plats. The data indicate that throughout this area of the system at the time of these tests the CP system was operating at a level sufficient to meet the industry recognized criteria for effective CP in the Spirit Ridge area (See Appendix B for CP criteria listed in 49 CFR Part 192).

[1] See Appendix A.

Table 1. Summary of 2003 Annual Test Point Cathodic Protection Survey for the Spirit Ridge Area

Test Station Identification	*Plat*	*Pipe-to-Soil On Potential (-mV vs. CSE)*	*Survey Date*
3700	200.097	1107	August-03
3702	196.092	1286	August-03
3703	196.093	1243	August-03
3704	200.098	1363	August-03
3705	193.090	1637	August-03
3706	194.090	1731	August-03
3707	199.097	1036	August-03
3708	200.090	1182	August-03
28022	193.090	1690	August-03
28023	194.090	1331	August-03
28027	194.090	1392	August-03
28029	194.090	1663	August-03
28030	193.090	1268	August-03
28054	195.090	1368	August-03
28279	193.087	1220	July-03
28306	195.090	1317	August-03
28307	195.090	1420	July-03
28828	200.097	1180	August-03
28994	199.097	1217	August-03
28996	195.088	921	August-03
29028	196.092	1359	August-03
29053	197.093	1303	August-03
29055	197.093	1281	August-03
29269	194.087	1140	July-03
29298	198.094	1160	August-03
32433	193.090	1255	August-03
32506	196.091	1449	August-03
32868	193.090	1693	August-03
32870	194.090	1663	August-03
32871	194.090	1331	August-03
33771	193.090	1600	August-03
33772	193.090	1618	August-03
34114	194.090	1427	August-03
34162	195.089	1608	August-03
34287	199.097	1378	August-03
36119	196.091	1457	August-03
39689	199.100	1255	August-03
40360	196.085	1351	August-03
41378	199.100	1120	August-03
41379	199.100	1283	August-03
44675	195.087	966	August-03

44676	196.085	1078	August-03
44677	196.085	1313	August-03
44678	196.085	1219	August-03
44679	194.087	1093	August-03
44681	194.087	950	June-03
44682	200.084	1252	August-03
44683	196.085	1189	August-03
44685	200.084	1109	August-03
48627	200.086	1100	August-03
48825	195.089	1380	October-03
48870	200.084	1050	October-03
29667	198.094	1281	August-03
34172	196.091	1359	August-03
34283	199.097	1357	August-03
34284	200.098	1200	August-03
34285	200.098	1220	August-03
34288	200.095	1290	August-03
34289	198.093	1219	August-03
34290	196.090	1485	August-03
34291	196.090	1410	August-03
34292	196.090	1408	August-03
44664	201.083	1332	August-03

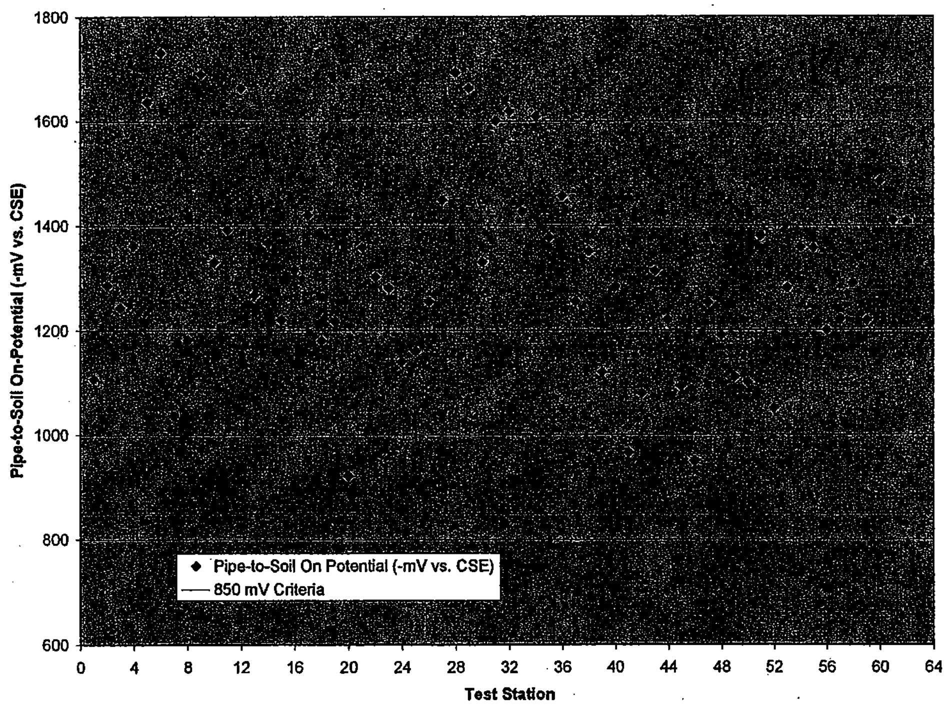

Figure 4. Pipe-to-soil potentials from the 2003 annual survey of the Spirit Ridge area.

In addition to annual CP test point surveys and the leak surveys conducted in the area, the Vasa Park rectifier was monitored on a bi-monthly schedule as is required by 49 CFR Part 192.465.[2] These readings from 2003 and leading up to the incident are summarized in Table 2. Also included in the table is the circuit resistance calculated by dividing the rectifier output voltage by the output current. This value is useful in monitoring the condition of the ground bed as well as assessing general changes to the cathodic protection system network.

Table 2 indicates that from February of 2003 through April of 2004 the rectifier was operating under consistent circuit conditions with an average circuit resistance of 1.07 ohms.

Table 2. Vasa Park Rectifier Bi-Monthly Test Reads and Calculated Circuit Resistance

Date	Rectifier Setting (%)	DC Output (Amps)	DC Output (Volts)	Circuit Resistance (Ohms)
February-03	9	3.90	4.0	1.03
April-03	9	3.80	4.0	1.05
June-03	9	3.40	4.0	1.18
August-03	10	4.60	5.0	1.09
October-03	10	4.40	5.0	1.14
December-03	10	4.90	5.0	1.02
February-04	10	4.60	5.0	1.09
April-04	10	4.00	4.0	1.00
June-04	12	2.60	4.0	1.54

Additional information related to the operation and effectiveness of the cathodic protection system in the vicinity of Spirit Ridge can also be gained through a review of exposed pipe condition reports (EPCR's). These reports are required by 49 CFR 192.459[3] to be completed at any time a regulated pipeline is exposed and include observations made with regard to any observed external corrosion and also include information related to the effectiveness of the cathodic protection system through recording pipe-to-soil potentials at the excavation locations. In the months prior to the incident, five EPCR's were completed in the Spirit Ridge area. Pertinent information from these reports is summarized in Table 3.

[2] See Appendix A.
[3] See Appendix A.

Table 3. Exposed Pipe Condition Reports from the Spirit Ridge Area Prior to the Incident of September 2, 2004.

EPCR Date	Plat	Address	Corrosion Condition	Pipe-to-Soil Potential As Found (-mV vs. CSE)	Pipe-to-Soil Potential As Left (-mV vs. CSE)
4/19/2004	195.090	3240 164 PL SE	No Pitting	1200	1200
4/30/2004	195.087	14200 SE Eastgate Way		500	500
5/7/2004	195.088	15600 SE Eastgate Way	No Pitting	600	600
6/30/2004	195.090	3234 164 AVE SE	No Pitting	1100	1100
8/9/2004	194.090	2621 171 AVE SE	No Pitting	900	900

Two of these reports indicate pipe-to-soil potentials less negative than the industry accepted criteria for effective CP (-850 mV CSE). These two reports triggered an investigation into why the potentials were not meeting criteria. The other potentials collected on the EPCR reports indicate that the cathodic protection system was functioning properly and providing sufficient CP to polarize the structures investigated to potentials in excess of the industry accepted criteria for adequate protection.

Other PSE investigations taking place southeast of the Spirit Ridge subdivision in the months preceding the incident revealed low pipe-to-soil potentials. These investigations were the result of the construction of a sound wall along the Interstate 90 corridor. The investigation was undertaken to insure that the construction activities associated with the sound wall installation had not caused any third party damage to the pipeline in the area. This investigation conducted in April and May of 2004 revealed low pipe-to-soil potentials (-700 to -800 mV) in the area of the sound wall construction further continuing the investigation of the cause of the low reads. It was suspected that a portion of the cathodically protected portion of the PSE system had inadvertently been shorted to an unprotected PSE or foreign structure resulting in the low potentials. In an attempt to locate the area where the suspected short existed, the CP technician began to systematically disconnect portions of the system. This approach was intended to narrow down the location of the short to a disconnected segment.

Changes such as these (isolation of individual pipe segments from the CP system) cause a change in the electrical network associated with the cathodic protection system. These changes also result in obvious changes in the operating conditions of the impressed current sources protecting the area. This is observed in the bi-monthly rectifier reads (Table 2) where the June 2004 readings show a significant change in output current though no change in the rectifier settings occurred. This decrease in current output (and corresponding increase in circuit resistance) is consistent with the troubleshooting undertaken whereby a portion of the system was disconnected from the

CP circuit. These activities are consistent with standard practices used to investigate low pipe-to-soil potentials in gas distribution systems.

On June 21, 2004 the CP technician troubleshooting the low readings in the vicinity of Spirit Ridge discovered a flange intended to isolate an unprotected portion of the system from the cathodically protected portion of the system in a shorted condition. Believing that this was the likely cause of the low potential readings in the area, a work order was created to replace the insulating joint in an effort to remedy the low potentials and the CP investigation was suspended

Throughout July and much of August the on-going investigation at the sound wall installation site and additional EPCR's indicated pipe-to-soil potentials in the protective range (more negative than -850mV vs. CSE). On August 30, 2004 an EPCR in the Spirit Ridge area showed pipe-to-soil potentials of 0 mV.[4] Pipe-to-soil potentials of this magnitude on coated or bare carbon steel buried piping are indicative of either stray current interference (that is, current flow from a foreign source that is collecting on and discharging from the structure being measured) or an indication of an impressed current source (rectifier) operating with the output polarity reversed. Readings of this nature are also considered an abnormal operating condition and as required by the regulations should be reported and investigated immediately. Additional testing conducted on September 1, 2004 at an excavation in the southern part of the Spirit Ridge area also indicated pipe-to-soil potentials of 0 mV.

The 0 mV readings were reported as "low readings" to the CP technician who had discovered the shorted flange in June of 2004. Believing that the "low readings" were consistent with his prior findings, and with the knowledge that a work order had been prepared to address the shorted flange, no further investigative steps were taken at that time.

FOLLOWING THE INCIDENT

On the morning of September 2, 2004 PSE personnel were responding to a reported odor of gas in the Spirit Ridge subdivision. While meeting with the concerned neighbors and while searching for the leak, the explosion and fire at 16445 SE 26th Place occurred. PSE personnel spent much of the remainder of the day insuring that the incident scene was safe. A team of investigators assembled from the Bellevue Fire Department, PSE and the Washington State Utilities and Transportation Commission (WUTC) identified the source of the gas leak as the ¾-inch service line supplying gas to

[4] The type of meter used by PSE personnel to record pipe-to-soil potentials during the EPCR indicate potentials in one polarity (consistent with industry standards), therefore a positive pipe-to-soil potential could be indicated by a 0 mV reading.

the residence. Buried more than 18 inches below ground level near the foundation, investigators discovered a corrosion perforation in the service upstream of its connection with the gas meter. While processing the scene, investigators also discovered evidence that the ground directly above the gas line had been used as a small drainage area for a sink located in the lower level of the home. Instead of having a normal plumbing system in place, a pipe had been diverted through the foundation wall so that any materials poured down the drain would flow out of the residence onto the soil above the gas service line. The investigators concluded that this situation may have contributed to the failure of the line. The presence of the pipe in the wall of the foundation may have also contributed to the incident, as gas that escaped the service line would have an easy avenue to enter the house via the drain.[5]

In the course of the investigation, multiple EPCR's in the Spirit Ridge area indicated pipe-to-soil potentials of 0 mV. On September 3, 2004, as part of the on-going investigation, the Vasa Park rectifier was investigated and it was determined that the rectifier outputs had been reversed. In addition to the reversed output wiring, the cable connecting the high-pressure system (HP) to the rectifier in the junction box beneath the rectifier was found disconnected. These findings would indicate that only the continuous intermediate pressure (IP) piping within the Spirit Ridge area was subjected to the potential deleterious effects of the polarity reversal.

Upon finding these conditions, the rectifier polarity reversal was immediately corrected. Subsequent EPCR's on the Spirit Ridge system revealed pipe-to-soil potentials in the -1400 to -2000 mV CSE range indicative of satisfaction of industry recognized criteria for adequate cathodic protection.

Two days following the incident a team of PSE leadership decided that the company should take more visible steps to ensure that the piping system in the Spirit Ridge area was indeed safe. A leak survey of the area commenced along with targeted communications to the residents. The leak survey was conducted over a large geographic area exceeding the area of the system presumed to be under the influence of the Vasa Park rectifier.

As the leak surveys continued during the months of September and October 2004, an increase in leaks was observed on the portion of the system connected to the Vasa Park rectifier. As of January 25, 2005, a total of 23 additional external corrosion leaks have been detected during this investigative program in the Spirit Ridge neighborhood. Figure 5 below shows the approximate location of these leaks within the Spirit Ridge area. To alleviate the publics concerns over the safety of the system, PSE officials decided in November to replace all of the steel mains and services.

[5] This description of the investigation is paraphrased from the City of Bellevue Fire Departments News Release related to the incident dated September 4, 2004

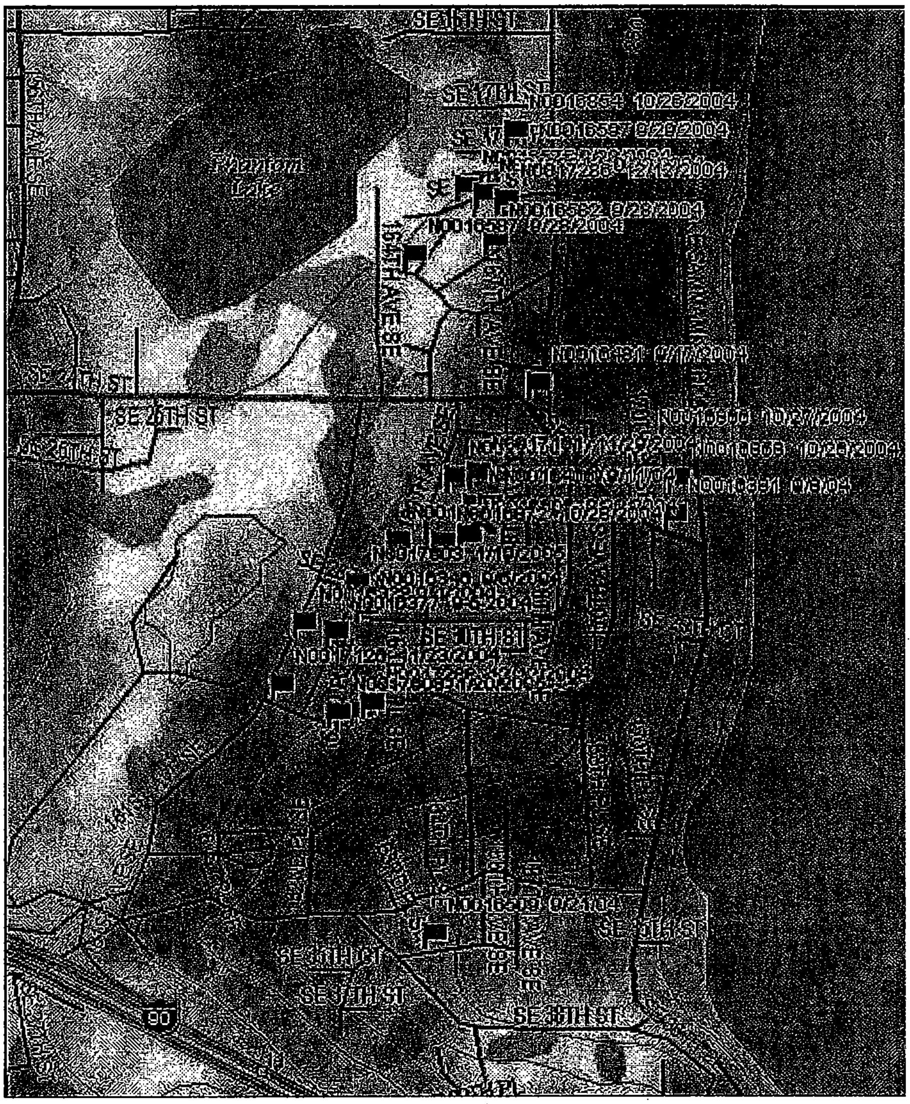

Figure 5. Approximate locations of identified leaks in the Spirit Ridge Vicinity.

Extensive additional testing of the cathodic protection system was also conducted in September and October of 2004. This testing confirmed that the HP system was not connected to the Spirit Ridge IP piping and further confirmed that the North Lake Sammamish leg of the piping was not connected to the Spirit Ridge IP piping. These findings support that only the IP piping in the Spirit Ridge area could have been adversely affected by the inadvertent rectifier reversal.

In addition to the investigative testing performed on the Spirit Ridge piping in September and October 2004, PSE undertook a system wide investigation of all like and similar cathodic protection rectifier units to ascertain whether any additional units had been mis-wired. No additional wiring reversals were found during this investigation.

In addition, to prevent future inadvertent mis-wiring, PSE assured that all rectifier units and associated wiring had permanent labeling.

Sampling of Service Risers

As a part of the on-going investigation into the incident and in response to inquiries by the WUTC inspectors regarding the risers in the area, PSE has undertaken a program of removal and inspection of a sample of risers from the Spirit Ridge subdivision. To date a total of five risers have been excavated, removed and visually inspected.

While premature to draw conclusions, none of the service risers removed and inspected to date show abnormal corrosion.

Additional risers will be inspected and possibly removed for further analysis. These findings will be supplemented accordingly.

APPENDIX A

Excerpts of 49 CFR Part 192

Subpart I - Requirements for Corrosion Control

Sec. 192.457 External corrosion control: Buried or submerged pipelines installed before August 1, 1971.

(a) Except for buried piping at compressor, regulator, and measuring stations, each buried or submerged transmission line installed before August 1, 1971, that has an effective external coating must be cathodically protected along the entire area that is effectively coated, in accordance with this subpart. For the purposes of this subpart, a pipeline does not have an effective external coating if its cathodic protection current requirements are substantially the same as if it were bare. The operator shall make tests to determine the cathodic protection current requirements.

(b) Except for cast iron or ductile iron, each of the following buried or submerged pipelines installed before August 1, 1971, must be cathodically protected in accordance with this subpart in areas in which active corrosion is found:

(1) Bare or ineffectively coated transmission lines.

(2) Bare or coated pipes at compressor, regulator, and measuring stations.

(3) Bare or coated distribution lines.

[Amdt. 192-4, 36 FR 12302, June 30, 1971, as amended by Amdt. 192-33, 43 FR 39390, Sept. 5, 1978; Amdt. 192-93, 68 FR 53900, Sept. 15, 2003]

Sec. 192.465 External corrosion control: Monitoring.

(a) Each pipeline that is under cathodic protection must be tested at least once each calendar year, but with intervals not exceeding 15 months, to determine whether the cathodic protection meets the requirements of Sec. 192.463. However, if tests at those intervals are impractical for separately protected short sections of mains or transmission lines, not in excess of 100 feet (30 meters), or separately protected service lines, these pipelines may be surveyed on a sampling basis. At least 10 percent of these protected structures, distributed over the entire system must be surveyed each calendar year, with a different 10 percent checked each subsequent year, so that the entire system is tested in each 10-year period.

(b) Each cathodic protection rectifier or other impressed current power source must be inspected six times each calendar year, but with intervals not exceeding 2\1/2\ months, to insure that it is operating.

(c) Each reverse current switch, each diode, and each interference bond whose failure would jeopardize structure protection must be electrically checked for proper performance six times each calendar year, but with intervals not exceeding 2\1/2\ months. Each other interference bond must be checked at least once each calendar year, but with intervals not exceeding 15 months.

(d) Each operator shall take prompt remedial action to correct any deficiencies indicated by the monitoring.

(e) After the initial evaluation required by Sec. Sec. 192.455(b) and (c) and 192.457(b), each operator must, not less than every 3 years at intervals not exceeding 39 months, reevaluate its unprotected pipelines and cathodically protect them in accordance with this subpart in areas in which active corrosion is found. The operator must determine the areas of active corrosion by electrical survey. However, on distribution lines and where an electrical survey is impractical on transmission lines, areas of active corrosion may be determined by other means that include review and analysis of leak repair and inspection records, corrosion monitoring records, exposed pipe inspection records, and the pipeline environment. In this section:

(1) Active corrosion means continuing corrosion which, unless controlled, could result in a condition that is detrimental to public safety.

(2) Electrical survey means a series of closely spaced pipe-to-soil readings over a pipeline that are subsequently analyzed to identify locations where a corrosive current is leaving the pipeline.

(3) Pipeline environment includes soil resistivity (high or low), soil moisture (wet or dry), soil contaminants that may promote corrosive activity, and other known conditions that could affect the probability of active corrosion.

[Amdt. 192-4, 36 FR 12302, June 30, 1971, as amended by Amdt. 192-33, 43 FR 39390, Sept. 5, 1978; Amdt. 192-35A, 45 FR 23441, Apr. 7, 1980; Amdt. 192-85, 63 FR 37504, July 13, 1998; Amdt. 192-93, 68 FR 53900, Sept. 15, 2003]

Sec. 192.459 External corrosion control: Examination of buried pipeline when exposed.

Whenever an operator has knowledge that any portion of a buried pipeline is exposed, the exposed portion must be examined for evidence of external corrosion if the pipe is bare, or if the coating is deteriorated. If external corrosion requiring remedial action under
Sec. Sec. 192.483 through 192.489 is found, the operator shall investigate circumferentially and longitudinally beyond the exposed portion (by visual examination, indirect method, or both) to determine whether additional corrosion requiring remedial action exists in the vicinity of the exposed portion.

[Amdt. 192-87, 64 FR 56981, Oct. 22, 1999]

APPENDIX B

Appendix D to 49 CFR Part 192

Appendix D to Part 192--Criteria for Cathodic Protection and Determination of Measurements

I. Criteria for cathodic protection-- A. Steel, cast iron, and ductile iron structures. (1) A negative (cathodic) voltage of at least 0.85 volt, with reference to a saturated copper-copper sulfate half cell. Determination of this voltage must be made with the protective current applied, and in accordance with sections II and IV of this appendix.

(2) A negative (cathodic) voltage shift of at least 300 millivolts. Determination of this voltage shift must be made with the protective current applied, and in accordance with sections II and IV of this appendix. This criterion of voltage shift applies to structures not in contact with metals of different anodic potentials.

(3) A minimum negative (cathodic) polarization voltage shift of 100 millivolts. This polarization voltage shift must be determined in accordance with sections III and IV of this appendix.

(4) A voltage at least as negative (cathodic) as that originally established at the beginning of the Tafel segment of the E-log-I curve. This voltage must be measured in accordance with section IV of this appendix.

(5) A net protective current from the electrolyte into the structure surface as measured by an earth current technique applied at predetermined current discharge (anodic) points of the structure.

B. Aluminum structures. (1) Except as provided in paragraphs (3) and (4) of this paragraph, a minimum negative (cathodic) voltage shift of 150 millivolts, produced by the application of protective current. The voltage shift must be determined in accordance with sections II and IV of this appendix.

(2) Except as provided in paragraphs (3) and (4) of this paragraph, a minimum negative (cathodic) polarization voltage shift of 100 millivolts. This polarization voltage shift must be determined in accordance with sections III and IV of this appendix.

(3) Notwithstanding the alternative minimum criteria in paragraphs (1) and (2) of this paragraph, aluminum, if cathodically protected at voltages in excess of 1.20 volts as measured with reference to a copper-copper sulfate half cell, in accordance with section IV of this appendix, and compensated for the voltage (IR) drops other than those across the structure-electrolyte boundary may suffer corrosion resulting from the build-up of alkali on the metal surface. A voltage in excess of 1.20 volts may not be used unless previous test results indicate no appreciable corrosion will occur in the particular environment.

(4) Since aluminum may suffer from corrosion under high pH conditions, and since application of cathodic protection tends to increase the pH at the metal surface, careful investigation or testing must be made before applying cathodic protection to stop pitting attack on aluminum structures in environments with a natural pH in excess of 8.

C. Copper structures. A minimum negative (cathodic) polarization voltage shift of 100 millivolts. This polarization voltage shift must be determined in accordance with sections III and IV of this appendix.

D. Metals of different anodic potentials. A negative (cathodic) voltage, measured in accordance with section IV of this appendix, equal to that required for the most anodic metal in the system must be maintained. If amphoteric structures are involved that could be damaged by high alkalinity covered by paragraphs (3) and (4) of paragraph B of this section, they must be electrically isolated with insulating flanges, or the equivalent.

II. Interpretation of voltage measurement. Voltage (IR) drops other than those across the structure-electrolyte boundary must be considered for valid interpretation of the voltage measurement in paragraphs A(1) and (2) and paragraph B(1) of section I of this appendix.

III. Determination of polarization voltage shift. The polarization voltage shift must be determined by interrupting the protective current and measuring the polarization decay. When the current is initially interrupted, an immediate voltage shift occurs. The voltage reading after the immediate shift must be used as the base reading from which to measure polarization decay in paragraphs A(3), B(2), and C of section I of this appendix.

IV. Reference half cells. A. Except as provided in paragraphs B and C of this section, negative (cathodic) voltage must be measured between the structure surface and a saturated copper-copper sulfate half cell contacting the electrolyte.

B. Other standard reference half cells may be substituted for the saturated cooper-copper sulfate half cell. Two commonly used reference half cells are listed below along with their voltage equivalent to -0.85 volt as referred to a saturated copper-copper sulfate half cell:

(1) Saturated KCl calomel half cell: -0.78 volt.

(2) Silver-silver chloride half cell used in sea water: -0.80 volt.

C. In addition to the standard reference half cells, an alternate metallic material or structure may be used in place of the saturated copper-copper sulfate half cell if its potential stability is assured and if its voltage equivalent referred to a saturated copper-copper sulfate half cell is established.

[Amdt. 192-4, 36 FR 12305, June 30, 1971]