Report Reviewing Puget Sound Energy, Inc.'s

Pipe Segment Integrity Study in the Vicinity of the Vasa Park Rectifier (Dated June 21, 2005)

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This report is prepared on behalf of the Staff of the Washington Utilities and Transportation Commission. This report constitutes our review of the above-referenced study conducted by Puget Sound Energy, Inc. (PSE) dated June 21, 2005.

Below we refer to the study as the "PSE Pipe Segment Integrity Study," or simply, "the Study." It has been referred to elsewhere as the "Integrity Study" and the "coating survey."

Overview of the Study

The PSE Pipe Segment Integrity Study is PSE's response to the requirement of the Washington State Utilities and Transportation Commission (the Commission) set forth on page 8, item i of Docket No. PG-041624, Order No. 01 that directs Puget Sound Energy (PSE) to "Conduct a test(s) that will determine the condition of the coating of the coated steel service lines and mains in the area covered by the rectifier (including an assessment of the state of corrosion of such service lines and mains), and provide the results to the Commission upon request."

The PSE Pipe Segment Integrity Study documents the results of the integrity study which, in the words of the Study, "was designed to locate coating holidays on pipelines adjacent to and isolated from nearby pipe that was cathodically protected by the Vasa Park rectifier during the period when the rectifier was misconfigured. PSE designed the study to identify locations that would exhibit corrosion if stray current originating from the pipe connected to the rectifier discharged from the pipe investigated in this study."

Summary of the Study

The Study was undertaken to identify and locate coating holidays. Coating holidays are areas of coating damage which exposes the metal pipe to the soil. Coating holidays were identified[1] by PSE's consultant, CC Technologies Laboratories, Inc. as the cause of the explosion of September 2, 2004 at The Schmitz Residence, 16645 SE 26th Place, Bellevue, WA. Coating holidays make the pipe at the coating holidays more susceptible to damage due to the reversal of the rectifier leads at the Vasa Park rectifier.

The Study investigated 6,000 feet of high pressure main, 9,000 feet of intermediate pressure main and 140 services. We believe the basis for selecting this sample was to select a substantial area closest to the location of the rectifier, because the effects of a cross-wired rectifier would be greater at locations closer to the rectifier.

In the Study, PSE classified indications of coating holidays based on the severity of the survey indication. An "indication" is a survey result that suggests a coating problem at a specific location may exist. The criteria were developed by PSE using the direct current voltage gradient (DCVG) methodology as "minor, moderate or severe." The DVCG methodology is described in more detail below.

A close interval survey (CIS) of pipe to soil potentials was conducted simultaneously to assess cathodic protection levels. Guidelines for prioritizing the action required were based on criteria established by PSE. The CIS is described in more detail below.

Those locations that had indications which PSE prioritized as requiring immediate action were excavated for direct examination of the indication. Those locations that had indications of coating holidays were excavated and examined for signs of corrosion. Locations which showed signs of corrosion on direct examination were characterized in terms of the morphology of the corrosion damage, characteristics of the related corrosion products and soil corrosivity, to assist in determining the cause of the corrosion and metal loss.

Review of the Methodologies

CIS and DCVG are complimentary methods that indirectly measure the effectiveness of primarily the corrosion control (cathodic protection) and the coating condition of the pipe, respectively. CIS surveys are used to identify the levels of protection that exist along pipelines. DCVG in concert with CIS can identify coating defects on metal pipes.

CIS provides a detailed profile of the potential level along the pipeline. The term "potential" means a voltage measurement made using a high impedance voltmeter, where the positive terminal is connected to the pipe or structure being tested and the negative terminal is connected to saturated copper, copper-sulfate reference placed in contact with the soil. This profile can be used to assess the performance of the cathodic protection system and also provides information on the coating system. In a CIS, pipe to soil potentials using portable reference electrodes are recorded at regular intervals along the pipe using a voltmeter with one lead connected to the electrode and

[1] Letter from Kevin C. Garrity, PE of CC Technologies to Charles Gordon, Gordon Murray Tilden LLP, dated February 28, 2005

with the other lead of the voltmeter connected to the pipe (test station or other test point).

In the Study, PSE placed electrodes on the ground at five-foot intervals over the main and three-foot intervals over services. The intent was to determine the efficacy of protection on the pipeline on a finer scale than can be determined simply by monitoring pipe to soil potentials at relatively widely spaced test points.

DCVG also uses measurements of surface pipe to soil potential to investigate the pipe's coating condition. When a DC current is applied to a pipeline, as with a cathodic protection system, ground voltage gradients are created due to current flow through the electrically resistive soil. The term "ground voltage gradient" means a voltage difference as measured between two points in the soil as a result of the current flow.

Well coated pipelines have a high resistance to soil. However, at locations where there are coating defects, current can flow through the soil to be picked up by the pipe. In the vicinity of these defects, measurable voltage gradients can be detected at ground level using two electrodes in contact with the soil and measured using a voltmeter. Large defects have large current flows and large voltage gradients. Comparing the voltage drop in the soil with the applied potential shift can assess severity of coating defects.

Critique of the Methodologies

It is well accepted by the corrosion control and pipeline industries that test point measurements at random test posts are insufficient to judge the overall condition and efficacy of protection of the pipeline. As a result, CIS and DCVG have become common practice in the industries. While there is no doubt that both CIS and DCVG are widely used, there are limitations to each application.

Pipe Size Affect on DCVG Survey Technique: The effect of small pipe diameter (e.g., less than 2-inch) on DCVG technique, such as encountered on service lines or laterals, is not known. This is simply a sensitivity issue since small pipes and with even smaller coating holidays result in small voltage gradients. It is not widely accepted that DCVG can be accurately applied to small diameter service lateral piping.

On page 3 of the Study, PSE mentions that the purpose for the confirmatory examinations was to assess the effect of pipe size on the indication measurement obtained through DCVG. So, according to PSE: "Excavations were performed to confirm correlation of coating holiday size to voltage gradient measurement, three for each of minor, moderate, severe, and no indication."

In the conclusions portion of the Study on page 9, PSE states that "that the IR measurement is inversely proportional to the pipe size." An "IR measurement" is a voltage measurement. "I" means current and "R" means resistence. "I" times "R" equals "V" which is volts. PSE goes on to state that "These relationships of IR measurement to holiday size, current flow, and pipe size support the criteria used at PSE that assigns severity of DCVG indications based on IR *without specifying pipe size* [emphasis added].” In other words, the first of these PSE quoted statements indicates that IR measurement is inversely proportional to the pipe size, yet the second PSE quoted statement indicates that IR measurements are not based on pipe size. These are contradictory statements.

Pipe-to-Soil Measurements on Paving Without Hole-Drilling: Some of the survey was conducted in areas where the pipe centerline was underneath paving. The question is: “Can valid measurements be made through paving without drilling holes to promote electrode contact for the CIS/DCVG testing?” On page 9 of the Study, PSE states that testing was done to determine if valid measurements could be obtained through paving without drilling holes to reduce contact resistance between the electrode and the earth. Our suggestion was to re-survey regions with questionable data using a voltmeter with variable input impedance, and this suggestion was accepted by PSE as a modification to the protocol. If the pipe to soil readings did not change as a function of input impedance, then pipe to soil readings were valid. If the readings changed, then contact resistance of the electrode was an issue. Although this suggested methodology was reflected in the Study protocols, we assume that this was consistently applied throughout the survey.

Critique of the PSE Study

In the industry, the DCVG method is not well established for small diameter pipe. It should be used cautiously or sparingly in evaluating small diameter piping such as the services, which is where the leak and explosion at 16645 SE 26th Place, Bellevue, WA occurred, and it should be used in concert with other methods in the evaluation and maintenance of a piping system.

It is our opinion that the PSE Study is written in a manner that obscures the actual findings of the integrity assessment, and it does not adequately address the impact of the findings.

Our opinion is based on the results of the assessment showing that the coating is at or nearing the end of its life-cycle. The Study shows that the pipe is backfilled in rocks, which damage the coating and shields cathodic protection current. The Study shows that soil resistivity variations in orders of magnitude likely contribute to corrosion and failures. Finally, and most importantly, the Study found two leaks out of only 34 completed excavations; which is 5.8% of the locations excavated.

The two leaks were given only cursory mention in the Study. Specifically, on page 4, PSE states that there are reportedly “Two of the four sites with pitting [that] had minor leakage associated with the corrosion.” However, the only mention in the Study with respect to corrosion related leaks—a critical peace of information in a corrosion study—is an ambiguous reference under the “root cause” column of Appendix B, Table 1, “List of Examination Sites,” that states: “Pitting through pipe wall.”

Under the portion of the Study entitled: “Assessment of Four Examination Sites,” on pages 7 and 8, there is no mention of the leaks for Examination Sites 28 and 31 at all.

The close interval survey (CIS) and direct current voltage gradient (DCVG) test methods can give indications of the pipeline system's overall corrosion condition if combined with: record review (old pipe, aged coal tar coating); maintenance excavations (showing inappropriate rock backfill); and comprehensive leak testing. The Study does not include this analysis, though results of the Study, which include the discovery of two leaks on the pipe, confirm why such measures should have been implemented by PSE in accordance with standard industry practice for operation and maintenance of their piping system. Accordingly, PSE should add this review to complete the assessment process.

The Study also produces more questions than it answers:

1. If the DCVG was found to be effective, then why was it employed by PSE only recently, as stated by PSE staff during field testing conducted during the Study, and not on a routine basis and if so, what is its effectiveness on small diameter pipe?

2. There are numerous references to third-party damage in the Study, though if this is the case, then why wasn't third-party pipe damage addressed earlier than now (as evidenced by its prevalence through portions of pipe in the Study), for example, when it was discovered during previous excavation work?

3. There is a discussion on page 4 of the Study stating, "…soils with resistivity changes of an order of magnitude or more may drive corrosion cells on pipeline traversing those regions." This being the case, and knowing that soil resistivity in the area varies by one and even two orders of magnitude, why wasn't more investigation work done on the pipelines at low resistivity areas?

4. Why were the leaks at Examination Site 28 and 31 not found during the normal course of leak testing? Is PSE conducting sufficient leak testing so that possibly dangerous leaks can be found and repaired?

5. Numerous references are made in the Study to rocks damaging the pipe coating. Since rock-damage coating will result in decreased CP levels, and in some cases, will shield the pipe from protective current, why wasn't this issue addressed before now?

Conclusions

We agree with the statement on the last paragraph on Page 10 of the Study, which points out that the stray current affects caused by the reversed leads on the rectifier could not have caused leaking on the pipe at any significant distance from the rectifier. Specifically, it alone could not have caused the leak that resulted in the explosion at 16645 SE 26th Place, Bellevue, WA.

However, as noted above, many other factors identified in the assessment could have contributed to the corrosion, and subsequent failures of the pipe at that location and at other locations not yet known.

We also agree with the statement on page 11 of the Study, first paragraph, “The investigation found nothing unique about this pipe. The corrosion processes acting on the pipe are not unusual and are typical of those to be expected at any other location in the gas distribution system.” We therefore believe that the integrity of the system in the Study is compromised, and that remedial measures must be taken to insure continued, reliable service. Annual leak surveys are recommended, as well as initiating a program where pipe sections are prioritized for repair, re-coating, or replacement, as required.

It follows from the Study that the rest of the PSE system of this vintage and characteristics (*e.g.,* impressed current cathodic protection implemented several years after installation) will have the same problems:

1. Undetected leaks (as in the case of the Excavation Sites 28 and 31)
2. Coal tar enamel or similar coatings which have outlived their life cycle.
3. Non-select backfill with rocks that are damaging to the pipeline coating and shielding the pipe from cathodic protection current.
4. Widely varying soil resistivities of two orders of magnitude or more, which as stated on page 4 “may drive corrosion cells on pipeline traversing those regions.”
5. Third-party damage may affect many portions of the pipelines.
6. The approximately 50 feet of pipe that was excavated and examined suggests coating damage and/or pitting will exist on similar lengths of segments of pipe as studied (6,000 feet of High Pressure, 9,000 feet of Intermediate Pressure, and 140 service lines.)

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