Laboratory Examination Protocol – Line 300 B, MP 286

Natural Gas Transmission Pipeline Failure During Hydrostatic Testing

(Note: based upon NTSB San Bruno protocol with PG&E comments incorporated)

Components covered by this protocol:

Up to 3 sections of 34-inch diameter pipe:

Section 1 – Center Section: Approximately 40 feet long. Contains a longitudinal split that occurred during hydrostatic testing, and a girth weld.

Sections north and south of the above: Examine if/when these become available. These adjacent sections are being made available to gain additional samples of the pipe and weld.

Scope of Proposed Work:

This is a living document and subject to change. Factual information generated during the examination may necessitate a re-evaluation of the work plan.

Work planned:

1) Introduction, safety briefing, review of on-scene observations, operating conditions, information regarding original installation (1950), historic inspection information (including cathodic protection surveys if available – Dave Aguiar).

2) As-received condition:
   a) Document as-received condition and major features including deformation, fractures, cracks, coating condition, and interior and exterior surface condition.
   b) Complete initial as-received photography.
   c) Collect any corrosion or organic residue samples discovered during initial examination for EDS and/or FTIR analysis.
   d) Collect samples for microbial analysis. (Update: not practical for this pipe due to unavailability during required sampling period.)

3) Identify and remove asphalt coating samples from any section for asbestos analysis. Update: Analysis shows that no asbestos precautions are necessary. Fourier-transform infrared spectroscopy (FTIR), thermo-gravimetric analysis (TGA) and differential scanning calorimetry (DSC) as needed. Document locations where samples for the latter tests are taken.

4) Clean all pipe sections:

   Clean fracture surfaces with Alconox detergent, soft-bristle brush, ethanol, forced air, hot air, molded replica application, and/or lint-free towels as appropriate. Protect fracture surfaces with rubber hose, molding compound, or suitable material for subsequent steps.
   a) Clean exterior surface of center section to remove asphalt coating. Loosely adhered material will be removed with plastic scrapers. Strongly adhered material may be removed by brass hammers, steel scrapers, and plastic scraper.
   b) Clean interior surface with shop-vac, hot water with detergent, high-pressure water jet if needed, and dry with forced air, optional application of alcohol.

5) Basic pipe orientation and position measurements:
   a) Identify true top of center pipe section at both ends.
6) Create coordinate reference system. Distances will be measured from south to north (aligned with the flow of gas) with zero reference at top. Mark pipe sections at 1 ft intervals along longitudinal weld with paint pen.
7) As needed for handling, the pipes may be cut into smaller sections, and identification of orientation sufficient to re-create the original orientation shall be applied.
8) Examination of outside surface (south section, center section, and north section):
   a) Document any anomalies [e.g., dents, buckles, gouges, scratches, mandrel or manufacturing marks, scrape marks, wrinkles, pits, crevices, cracks, overall corrosion damage, etc.] that may be present. Lift or roll pipe segments as needed to complete 360˚ inspection. Photo-document all findings.

b) Collect any newly uncovered corrosion deposit samples if required for chemical analysis (EDS, FTIR, etc.). Indicate location of sample taken.

c) Collect any newly discovered samples for microbial analysis if required. Indicate location taken. (As noted before, this does not apply to the current pipe.)

d) Examine exterior surface for mill stamps, tube-turn stamps, or other identifiers.

e) Photo-document the appearance of the welds metal throughout the entire section, inside and outside.

f) Perform visual examination for presence of hard spots, identified by changes in curvature.

9) Examination of inside surface - Document condition and location of inside surface features including any cracks, crevices, scratches, corrosion, oil residues, gouges, mandrel or manufacturing marks, scrape marks, wrinkles, hard spots, etc.. Photo-document all findings. Identify and collect any newly revealed samples for chemical analysis (EDS, FTIR, XRD, etc.).

10) Pipe dimensional measurements:

a) Measure circumference of each pipe segment at both ends. Measure ovalization of pipe (where possible) at each girth weld.

b) Measure miters on all pieces if present. Note: May not be practical due to ovalization, fracture, and/or buckling.

c) Measure wall thickness of each segment by ultrasound at 12 locations around the circumference of the pipe spaces at even intervals. Also measure at locations that are visibly thick or thin. Any corrosion found shall be mapped with the PG&E H-form process, using a grid for measurement.

d) Measure circumferential distance of longitudinal seams from true top.

e) Any corrosion or other service related progression found shall be cause for a full H-form inspection. (For this pipe, no evidence of progression was found before Hydro testing and backfill work were completed.)

11) Examination of Fractures

a) Measure dimensions and locations of longitudinal and circumferential fractures as appropriate.

b) Examine fracture surfaces for chevrons or other features indicating crack propagation direction. Document location and indicated direction of features.

c) Identify and document suspect origin area(s).

d) Determine and document fracture sequencing as necessary.

12) Nondestructive Evaluations (NDE). Note: Surfaces to be evaluated by NDT may need to be prepared by abrasive blasting, solvent cleaning, or other means required to prepare a suitable surface. Fracture surfaces will be protected prior to abrasive

blasting with adhesive tape, rubber molding compound, rubber hose, or other suitable material. NDE shall be performed on all pipe segments.

a) Magnetic particle inspection (MPI) of center pipe section and north and south pipe sections. MPI should be performed by the wet fluorescent method per PG&E standard inspection process.

b) Visual inspection of all longitudinal and girth welds by American Welding Society (AWS) certified welding inspector in accordance with 1956 API visual standard and to current visual standard. An AWS API concentration is desirable.

c) 100% radiography of girth welds and longitudinal seam welds as needed in accordance with API 1104 is required. Report results in accordance with API 5L and 1104, using versions closest to installation date as well as current version

13) Document and photograph surface condition in areas treated by abrasive blasting, solvent cleaning, etc.

14) Identify and remove (if required) samples from any newly uncovered corrosion deposits on exterior surface for chemical analysis (EDS, FTIR, XRD, etc.). Identify and remove (if required) samples from any newly uncovered anomalies, such as gouges, mandrel or manufacturing marks, scrape marks, wrinkles, etc.

15) Removal of samples for laboratory phase. Mark areas for cutting with consensus from the Group (stake-holders). Cutting methods may include oxy-fuel torch, plasma torch, portable band saw, reciprocating saw, or plunge cutting with abrasive cutting wheel as-required. Torch cuts will be at least 12 inches from the fracture surface and torch cuts shall be kept away from any other feature of interest such as gage sections of potential tensile specimens. [Where necessary, the cut exclusion distance may be reduced after evaluation.] Cut pieces will be labeled with paint pen, engraving tool, and/or placed in labeled sample bags. Samples will be labeled in such a way to retain information on gas flow direction and location along the pipe section, and to facilitate a virtual reassembly. Fracture faces and adjacent surfaces will be covered with heat treating blanket cloth or other material to protect surfaces from torch spatter or debris. Areas to be removed include:

a) The fracture initiation site(s) for stereomicroscope, SEM examination (both halves), and metallographic examination;

b) Suspect areas from DSAW longitudinal seams for metallographic examination, and defect characterization;

c) Representative areas from girth welds for metallographic examination;

d) Metallographic examination of base metal locations of interest, near and away from the initiation and propagation locations;

e) Other suspected features of interest that may have played a role in the initiation or propagation of the failure. Perform metallographic, SEM, or other testing as deemed appropriate.

16) Photo-document pieces cut out of the pipe segments.

17) Clean fracture surfaces and exterior surfaces of sectioned pieces with lint-free towels, alcohol, acetone, Alconox detergent, and/or a soft-bristle brush as appropriate.

18) Photo-document cleaned piece.

19) Protect remaining fracture surfaces and other areas of possible interest which have not been removed for initial examination, by use of moisture exclusion material similar to WD-40.

20) Using an optical stereomicroscope and/or macro scope, conduct a fractographic examination of the fracture surfaces, documenting fracture features and inspecting for evidence of origin areas. Examine and document interior and exterior surfaces adjacent to fracture surfaces.

21) Scanning Electron Microscopy (SEM)
   a) Identify areas for additional examination by SEM, and cut selected area out with band saw or abrasive cutting wheel as needed. Ensure appropriate labels are in place. Clean the sectioned piece(s) with an ultrasonic cleaner in acetone.
   b) Examine selected areas of the fracture surface by SEM.
   c) Remove rust from the fracture surface using plastic replicas, and previously noted cleaning methods as appropriate, and repeat SEM examination as needed. If this is not found to be sufficient, then limited application of inhibited acid solution may be used as a last resort.

   d) Examine any samples gathered from exterior or interior surfaces by EDS.

22) Metallography – Prepare metallurgical cross-sections through the fracture at/near an origin area, suspect DSAW seams, other relevant features such as manufacturing marks, and girth welds as appropriate and complete a metallographic evaluation. If required, cross-sections will be taken from mating sides of the fracture surface.

23) Measure hardness at appropriate locations including base metal and microhardness across welds as appropriate.

<u>Additional Work to be Completed:</u>

24) Mechanical Testing. The extent of mechanical testing will be discussed by the group. Initial proposed testing protocol is as follows:

a) For each pipe segment (each pup and each end piece), select areas for mechanical test specimens. Samples needed include one transverse tensile specimen in base metal, one transverse tensile specimen through intact longitudinal seams, one longitudinal test specimen across girth welds, all weld metal tensile specimen, and weld metal Charpy v-notch test specimens tested at +50 F and +32 F, 2/3-size samples or larger. Three CVN bars shall be tested at each temperature, orientation T-L. The report shall include absorbed energy, percentage shear, and mils lateral expansion. CTOD testing is planned, with details based on group consensus.

b) Cut selected pieces of pipe using suitable means such as plasma torch, band saw, etc. Mechanical cutting shall be preferred.

c) Clean exterior surface by abrasive blasting, solvent cleaning, etc.

d) Measure wall thickness of test specimens by ultrasound or mechanical means.

e) Send samples out for mechanical testing in accordance with API specifications, ASTM A370, "Standard Methods and Definitions for Mechanical Testing of Steel Products", and ASTM E 1820: "Standard Test Method for Measurement of Fracture Toughness".

f) Where there is a conflict between specs, API shall be followed.

25) Complete chemical analysis of base metals for each pipe segment (i.e. each pup segment and adjoining pipe) using optical emission spectrometer or similar analysis technique. Carbon and sulfur be analyzed by combustion method.

26) Send sample out for TGA and DSC of the asphalt coating if deemed necessary.

27) The need for additional testing, if necessary, will be determined during and at the close of the examination.