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**Pacific Gas and
Electric Company®**

Work Procedure: WP 357 MT-03

Effective Date: 05/23/2019 Rev. 1

Applied Technology Services (ATS)

Failure Analysis Procedure

☒ Yes ☐ No **Approved for Nuclear Quality-Related Work** ■■■ ☐ Periodic Use ☒ Reference Use

Scope

- 1.1 This document establishes general procedures, techniques, and precautions to be adopted during investigation of material / metallurgical failures that occur at PG&E.
- 1.2 As a guideline, failure analyses at PG&E generally follow the methodology described in EPRI report #1016712 "Welding and Repair Technology Center: Nuclear Power Plant Components Failure Analysis Guideline".

2. Target Audience

- 2.1 The procedure described here applies to qualified ATS Materials Engineers performing failure investigation projects.

3. Safety

- 3.1 Wear appropriate personal protective equipment (PPE), including, but not limited to eye protection, gloves, close toed shoes and hard hats.
- 3.2 A job safety analysis (JSA) should be conducted on non-routine tasks. The 2- minute rule safety check should be conducted prior to each routine task.

4. Discussion

A failure investigation is performed in order to determine the mechanism of a failure and the primary cause. Based on the investigation, corrective action or recommendations can be proposed that will prevent a similar failure.

In certain situations, it may be impossible for the materials engineer to visit the failure site. Under such circumstances, data and samples are generally collected by PG&E field engineers, such as PG&E gas engineers or gas construction crew members, Electric Transmission Field Specialists, Line Supervisors or Superintendents. A field failure report sheet and any available field test records generated by other groups at PG&E can be used to ensure that all important information regarding a failure is recorded.

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5. Definitions

- 5.1 Chain of Custody (CoC): a document used to track an item's location. Gas operations has implemented a CoC process for all cut for cause gas transmission pipe. CoCs are also used with evidence items associated with an investigation of a serious incident.
- 5.2 Non-Destructive Examination (NDE) can also be referred to as Non-Destructive Testing (NDT).
- 5.3 Non-Destructive Methods include (but are not limited to):
 - 5.3.1 Radiographic testing (RT)
 - 5.3.2 Magnetic Particle Testing (MT)
 - 5.3.3 Fluorescent Penetrant Testing (PT)
 - 5.3.4 Ultrasonic Testing (UT)
 - 5.3.5 Automated UT (AUT)
- 5.4 Direct Cause Analysis (DCA): This is an analysis that is focused on the recording of factual elements associated with a failed component, such as the direct cause of a leak or fracture.



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6. Responsibilities

6.1 See Table 1

Table 1

PERSONNEL	ROLES AND RESPONSIBILITIES
ATS Materials and Bathymetry Supervisor	<ul style="list-style-type: none"> Ensures general compliance with this procedure. Train and qualify ATS Personnel to Task qualification MTQ-03, in accordance with AP QPR-05 "Personnel Training and Qualifications". Designates the ATS Materials Engineer and subject matter experts.
ATS Materials Engineer	<ul style="list-style-type: none"> ATS Materials Engineers with a strong technical background in the field of materials science and metallurgical engineering can perform failure analysis investigations on all PG&E related projects. Applies the methods or techniques described in this document to perform a failure analysis, determine the direct cause of the failure, and provide recommendations if needed.

7. Instructions

The following are typical steps for material/metallurgical failure analysis of a component delivered to ATS. However, certain constraints may prevent each and every step from being performed. Thus, these are provided as a guideline, and it is not required to follow every step listed below for every investigation.

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- 7.1 A Failure Analysis project generally follows the guidelines of the EPRI report #1016712, see reference section for other references that can be used when conducting a failure analysis.
- 7.2 There are ten common steps to a failure analysis investigation.
1. Logging of the item and as-received photographic documentation
 2. Sample identification and preservation of essential features of the failure (e.g. fracture surface, corrosion deposits)
 3. Collect background data on failure
 4. Preliminary examination of failure
 5. Utilization of NDE methods (Visual, MT, PT, UT, RT, others)
 6. Metallurgical examination
 7. Chemical analysis
 8. Mechanical testing
 9. Identification of failure mechanism based on collected information
 10. Writing a report, including the organized presentation of evidence, formulated conclusion and any recommendation to avoid future occurrences of the failure.
- 7.3 Log-in and tag items per WP 357 MT-06. Include photographs of as-received components for identification purposes and preserve the essential features of the failure.
- 7.3.1 The log-in SharePoint is to be used as a status update for the failure analysis job as it is conducted. The expectation is that on a weekly bases the lead materials engineer will provide a status update to the project on the associated SharePoint site.

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- 7.4 Collect as much information as possible concerning the part, including engineering drawings, specifications, product literature, life history of part including servicing, etc.
1. The source of any data collected and used in the determination of the failure or quoted from (e.g. Event reports, CAP items, e-mails) should be clearly identified in the final report.
 2. Items referenced in the report, where ever possible, shall be attached to the final report.
- 7.5 Perform preliminary examination of failed item. Develop preliminary list of potential failure modes. Note part numbers, serial numbers, supplier or manufacturer's markings and document them photographically. Photograph part with special attention paid to anomalies (fractures, scratches, wear, unusual marks, etc.). Preliminary examination may include selecting samples, noting location of pieces separated from the failed item, questioning witnesses, etc.
- 7.5.1 Develop a test plan based on the preliminary evaluation include (but not limited to):
- NDE methods
 - Destructive testing methods
- 7.6 Collect samples of residue or corrosion product for chemical analysis
- 7.7 Perform appropriate NDE on the failed part.
- 7.7.1 Check for cracks and internal flaws. Potential NDE methods to be considered are:
- RT
 - MT
 - PT
 - UT or AUT

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7.7.2 Perform dimensional inspection using one or more of the following tools:

- micrometer, Vernier, plug gauges, thread gauges, radius gauges
- surface finish
- optical comparator
- coordinate measuring machine
- laser scanning

7.7.3 Check coating thicknesses:

- magnetic induction
- eddy current

7.7.4 Leak testing:

- Bubble leak test (345.TEST-23) and Hydrostatic leak test (345.TEST-22)

7.8 Clean and preserve fractures or other surfaces of interest. Perform examination (visual and binocular microscopic) and document same. If required, prepare samples for SEM, X-ray analysis, etc.

7.9 Prepare samples for determination of mechanical properties, chemistry (alloy identification), macrostructure, hardness, etc. Compare measured values with required/specified values (if applicable) or typical values.

7.10 Prepare samples for metallographic examination and review microstructure, finishes, etc. Document same.

7.11 Perform supplemental testing on identical or similar parts if required. Such testing can include corrosion testing, fatigue testing, vibration testing, dimensional studies, etc.

7.12 Determine actual failure mechanism.

7.13 Analyze all evidence, formulate conclusions, and prepare report with recommendations.

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- 7.14 Send the report out for internal peer review. Author should incorporate the reviewer's changes and suggestions. If the Author of the report chooses not to include the Reviews comments/suggestions.
- The Author and Reviewer must discuss and come to an agreement to include or not to include comment/suggestion.
 - If Author and Reviewer cannot come to an agreement. The Materials Supervisor will determine the appropriate course of action.
 - Final signatures of the author and reviewer for reports should be a digital signature in the final PDF formatted report.
- 7.15 Gas operations COC pipe: This section provides additional guidelines specific to the DCA process for CoC gas pipe.
- 7.15.1 The ATS metallurgist will work with the lead gas engineer to develop a scope of work and if applicable, prepare a Traveler form. In general, there are several items that are required, these may include:
- Measure the diameter and wall thickness of each pipe segment
 - 3D scan of corrosion areas or dents and gouges
 - Determination of the seam type (e.g. ERW, lap weld, seamless)
 - Chemical and mechanical properties evaluation
 - Tensile test (include the curve)
 - Yield Strength (API 5L)
 - Elongation
 - Impact toughness (CVN) at 32 and 50deg.F
 - Chemistry

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7.15.1 (continued)

- e. All reports should include a corrosion evaluation section. Corrosion evaluations include but are not limited to visual examinations of both the internal and external surfaces. Where appropriate photographic documentation should be collected.
- f. In general, all girth welds should be radiographed and evaluated to the appropriate API codes. These would be attached NDE reports.

7.15.2 ATS reports for Gas operations COC items shall include:

- a. A title block showing:
 - Reason for cut out (ECDA, ILI, Hydrotest, In-service leak)
 - Line or DFM number
 - Mile Point
 - Location (closes city to cut out site)
 - Actual measurements for Diameter and Wall thickness
 - Seam weld type
- b. Identity of the Gas Lead(s) for whom the report was prepared.
- c. An area for the final signatures of the author and reviewer for reports. The signatures should be a digital signature in the final PDF formatted report.
- d. An executive summary.
- e. A corrosion assessment section.
- f. Chemical and Mechanical properties assessment section (if requested).

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7.15.2 (continued)

g. Attachments

- Other ATS reports (e.g. NDE or welding)
- H form (corrosion failures) or A- form (in-service leaks)
- CPUC Failure/Leak Report (Hydrotests)
- COC forms
- 3rd party test reports

8. Governing Documents

8.1 ATS Quality Manual

9. Records

9.1 Completed failure analysis reports shall be submitted to ATS records.

9.2 Copies of software generated data summaries, micrographs, photographs may be stored separately.

10. Compliance Requirement/Regulatory Commitment

N/A

11. References

- 11.1 D.A. Ryder et al., "General Practice in Failure Analysis," in ASM Metals Handbook Volume 11 "Failure Analysis and Prevention", Ed. Kathleen Mill (Ohio: [ASM International](#), 1986).
- 11.2 Welding and Repair Technology Center: Nuclear Power Plant Components Failure Analysis Guideline. EPRI, Palo Alto, CA: 2008. Report #1016712.



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14.1 WP 357 MT-03 Rev. 0, "Failure Analysis Procedure"

Document Contact [REDACTED], LPMC, Sr. Advising Materials Engineer

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Revision Notes

Revision Number	What Changed?
1	<p>CAP# 115103674 Action item 1: Added that qualifications are to meet the requirements of AP QPR-05 "Personnel Training and Qualifications"</p> <p>CAP# 116594422: Added Section 7.14.C and 7.15.2 C final author and reviewer signatures should be made in PDF digitally</p>