Guidance for Post Construction Acceptance Criteria

Document	Revision	Date
CQ-G-4	0	9/20/2021

1.0. BACKGROUND

1.1. In recent years there has been an apparent increasing trend in construction, installation, or fabrication-related incidents. As a result, construction and fabrication failures have and will continue to be an area of focus in INGAA and the INGAA Foundation, and both organizations will continue to hold 'Lessons Learned' Workshops and Roundtables to address construction-related incidents and work to prevent their recurrence.

1.2. As part of the INGAA Foundation's commitment, a virtual meeting/workshop was held on October 29, 2020. The workshop was aligned with the organization's objectives and explored the current best practices established by leading pipeline operators, case studies highlighting when construction practices may not have resulted in desired outcomes, forward-looking technology showcases from suppliers and research organizations, and the Pipeline and Hazardous Materials Safety Administration (PHMSA) new construction perspectives. The outcome from that workshop resulted in this Consensus Safety & Quality Guideline (CSQG) pertaining to new construction best practices.

2.0. PURPOSE

2.1. These guidelines identify what needs to be considered for the Post Construction Acceptance Criteria (PCAC) for high pressure gas pipelines.

2.2. These guidelines do not address all the detailed activities involved in the entire process of construction to operation, nor do they address all options available for the activities described; however, they do provide guidance on areas of concern that may result in early failure of pipelines entering service.

2.3. These guidelines are not meant to supersede or replace regulatory requirements, nor is it intended to be all-inclusive of the applicable regulatory requirements. Instead, view this data as supportive and complementary to any existing requirements.

3.0. SCOPE

3.1. The scope of this guideline is to provide areas of considerations for identifying PCAC for natural gas transmission pipelines.

3.2. The scope covers the following stages of pipeline construction:

- Line Pipe Specification and Girth Weld Matching
- Construction Quality Program

- Welding Procedures/Welding Processes
- Owner Construction Inspection
- Owner Acceptance
- Commissioning and Start-up
- Material Verification
- Records and Survey Data
- Non-destructive Testing
- In-line Inspection
- Coating and Corrosion Protection
- Civil and Environmental Monitoring
- Additional Considerations

3.3. The scope excludes detailed specifications, method, and workmanship approaches involved in the construction and pre- and post-hand-over stages, and is more focused on experiences and lessons learned.

3.4. The scope of this document is not to provide a singular PCAC solution; this is dependent on a combination of elements that build to a high-quality deliverable.

4.0. NOTATION / ACRONYMS

Term / Acronym	Definition / Usage
ACVG	AC Voltage Gradient Survey
ART	Acoustic Resonance Technology
CIS	Close Interval Survey
DCVG	DC Voltage Gradient Survey
FCAW-G	Flux Cored Arc Welding – Gas Shielded
GMAW	Gas Metal Arc Welding
HAZ	Heat Affected Zone
HDD	Horizontal Directional Drill
ILI	In-line Inspection
IMU	Inertial Mapping Unit

Term / Acronym	Definition / Usage
ITP	Inspection and Test Plan
LIDAR	Light Detection and Ranging
LHVD	Low Hydrogen Vertical Downhill
LHVU	Low Hydrogen Vertical Uphill
MAOP	Maximum Allowable Operating Pressure
MFL	Magnetic Flux Leakage
PCAC	Post Construction Acceptance Criteria
PCM	Carbon Equivalency
PHMSA	Pipeline and Hazardous Materials Safety Administration
PSSR	Pre-Start-up Safety Review
PQP	Project Quality Plan
PQR	Procedure Qualification Record
SMYS	Specified Minimum Yield Stress
SUTS	Specified Ultimate Tensile Strength
TVC	Traceable, Verifiable, and Complete
UTWM	Ultrasonic Wall Measurement

5.0. POST CONSTRUCTION ACCEPTANCE CRITERIA CONSIDERATIONS

5.1. Line Pipe Specification and Girth Weld Matching (PRCI MATH-5-3B, PR-350-174507, 2020)

5.1.1. Some instances of hydrostatic failures and in-service failures on newly constructed pipelines have been reported in the use of higher-grade pipeline material. There have been over 30 incidents – in the US, China, southeast Asia, and South America. The grades susceptible appear to be X52 to X80, and the welding processes have tended to be manual or semi-automatic (API 1104/5L Joint Task Group, 2020).

5.1.2. The contributing factors appear to be **undermatched weld strength**, where the weld strength is lower than the line pipe strength, and **heat affected zone (HAZ) softening**, where the resulting HAZ is weaker than the weld metal and line pipe.

a. These failures occur despite full compliance with the requirements in existing codes and standards.

b. Most of the failures have occurred due to normal construction and settlement stresses.

c. A minority of failures have resulted because of large-scale geological activity such as landslides.

5.1.3. To mitigate this failure threat, it is suggested that:

a. The line pipe maximum longitudinal strength should be specified in accordance with existing linepipe manufacturing codes, and, if possible, the measured values of the yield strength and the ultimate tensile strength should have a range of (-)0 ksi to (+)17 ksi from their specified minimums (SMYS and SMTS).

NOTE: It is noted that pipe mills may not be able – or prepared – to meet these requirements.

b. Alternatively, hoop tensile tests should be conducted to address the actual pipe yield strength uncertainty/variations. This is not a standard test and may not be possible depending on the diameter and wall of the pipe. This is often not a requirement and can be provided as an option for information only.

c. Currently, the Pipeline Research Council International (PRCI) is in the process of publishing test protocols to facilitate the implementation of longitudinal tensile tests, ring expansion tests, short reduced-section tensile tests, and round bar tests. These tests all have the same focus on determining the true tensile properties of the pipe material.

5.1.4. Mitigating measures that can be applied to the girth weld comprise:

a. The use of mechanized gas metal arc welding (GMAW) or a gas shielded flux cored arc welding (FCAW-G) process.

NOTE: This is may not feasible for short pipelines or replacement sections. As of the release date of this CSQG, there are current PRCI projects reviewing the ability to use FCAW-S wires on X-70 pipelines.

b. Additional measures related to manual welding.

c. Considerations for developing welding procedure specifications.

d. Reducing the concern of HAZ softening.

e. The actual pipe yield strength uncertainty / variations.

5.1.5. Additional measures related to manual welding:

a. Consider discontinuing use of E6010/E8010 electrode combination for fill and cap passes for X65 and X70 pipe when destructive testing results in coupons breaking in the weld or HAZ.

b. When best suited, root pass should be E8010 electrodes when possible and use a low heat input as this helps to enhance strength.

NOTE: E8010 may not always be superior to E6010 for the root/hot passes, specifically for higher carbon content or higher carbon equivalent materials like fittings and flanges.

c. When an E8010 electrode is used for root pass, use E8010 electrodes for hot pass deposition with a low heat input and small weld bead size.

d. Consider use of high strength fill and cap passes using LHVD, E9045, E10045 consumables.

e. Consider limiting heat input where possible; it is suggested this be less than 40 kJ/inch.

f. Watch for scenarios that could produce high heat input such as LHVU, E9018, or E10018 consumables.

5.1.6. Considerations for developing welding procedures:

a. Select appropriate pipe (considering mechanical and chemical properties) for qualification tests.

NOTE: Some owners do not require welding on project pipe if test on similar material, dimensions, chemical composition are equivalent. If the test pipe deviates too much to be representative of the desired weld procedure, the strength/properties may not represent the properties achieved in the field. Hence, it is considered best practice to use project pipe to develop welding procedure.

b. Use project pipe for set-in welds.

c. Select PQR test pipe or project test pipe that has low carbon equivalent PCM and has high yield and tensile strength properties.

d. Qualification test and criteria beyond the minimum required standards:

- Option 1: Traditional cross-weld tensile tests without instrumentation – acceptance criterion: no failure in the weld region.

- Option 2: Instrumented cross weld tensile test – PRCI is publishing test protocol and acceptance criteria.

5.1.7. Reducing the concern of HAZ softening:

a. Pipe chemical composition.

b. Consideration should be given to managing the carbon equivalent; a typical value would be PCM ≥ 0.140.

NOTE: Pipe manufacturers may not commit to minimum PCM limits or minimum carbon chemistries.

c. Very lean chemical composition contributes to greater propensity of HAZ softening and other issues.

d. Heat input control.

e. Limit nominal heat input.

f. Heat input should be monitored periodically.

g. Specify minimum travel speeds.

h. Specify number of passes as a function of wall thickness.

i. Small diameter electrodes for root and hot passes, reduce heat input smaller weld size.

NOTE: There needs to be an evaluation of costs of higher tensile/ thinner wall pipe and higher welding/construction costs versus lower tensile, heavier wall pipe and lower construction costs. Some operators have moved away from using thin wall high grade steel to slightly lower grade and slightly thicker wall pipe.

5.2. Construction Quality Program

5.2.1. Quality is important for:

a. **Long-Term Health of Asset**

Assets may be in operation for many years and over the years' threats to the facilities may compound. Therefore, ensuring a quality facility upon placing an asset in-service can help to mitigate the threats of concern in the years to come.

b. **Operational and Public Safety**

Confirmation that regulatory requirements are met, and work is completed within Company and industry standards helps to ensure assets may operate safely and effectively for employees and the public.

c. **Social License to Operate**

Extensive scrutiny and visibility on the industry, which is poised to continue, means it is crucial we maintain our social license.

d. **System Reliability and Efficiency**

Deficiencies that are not remediated during construction may eventually need remedy which may require future outages in operation.

NOTE: An added benefit of a successful quality program is cost efficiency. A successful quality program should prevent deficiencies, as well as identify deficiencies during construction before a facility is placed in service. Prevention and early detection eliminate additional costs incurred during repair and remediation.

5.2.2. The key elements of a construction quality program are highlighted in Table 1 (follows).

Construction Contractor Quality Program	**Owner Construction Inspection Program**	**Owner Commissioning and Operation Integration**
Key Elements: • Contractor expectations • Construction and material specifications • Inspection and test plan requirements • Codes and standards • Quality plan requirements • Training and operator qualification (OQ)	Key Elements: • Inspection standards • Required Inspector Qualifications • Inspector roles and responsibilities • Continuous Inspector development/training • Standard inspection forms • Assurance program • Digital inspection management program	Key Elements: • Commissioning procedures and forms • Commissioning onboarding procedures • Commissioning roles and responsibilities • Assurance Program • Operational integration process

Table 1 - Key Elements of a Construction Quality Program

5.2.3. Construction contractors receive a package of documents from Owner with requirements for the project and begin to create their quality program. This would normally include:

a. Construction standards, specifications, reference to industry codes.

b. Quality management system requirements.

c. Project-specific onboarding materials which may be considered for large projects; in the case of smaller projects, contractors may have a general quality construction guideline to refer to.

5.2.4. The contractor may then produce their own documentation, including:

a. Project quality plan.

b. Inspection and Test Plans (ITPs) – example ITPs can be found in *INGAA Pipeline Construction: Quality Issues and Solutions Action Plans*, 2012).

c. Quality records supporting each ITP activity.

d. Competency and training requirements (including plans for verification).

e. Final turnover package.

5.2.5. The documents may be submitted to the Owner Company for review and comments prior to the commencement of work. In some cases, these may be compared to internal documents.

5.2.6. The expectation is that the contractor manages and confirm these quality requirements (i.e., Owner inspection are separate, and the contractor should ensure that the quality program requirements established by the owner are followed).

5.3. Owner Construction Inspection

5.3.1. The Owner should maintain a program to assemble a competent inspection team capable of inspecting the contractor against the Owner requirements.

5.3.2. In general, the following apply to the Owner inspection process:

a. Standardized inspector onboarding and training.

b. Roles and responsibilities.

c. Standardized inspection forms.

5.3.3. Recommended use of the INGAA Foundation's *Practical Guide to Pipeline Inspection* (CEPA / INGAA, 2016) or API RP 1169 for creating of inspection forms.

Forms should be used throughout the construction process and cover all activities (e.g., Material Receipt, Clearing, Pipe Loading, Stringing, Ditching, Welding, Coating, Hydrostatic Test, Backfill, Environmental).

5.3.4. Inspection staff are required to sign off, witness, review, and provide inspection activities of the contractor quality documents to verify completeness.

NOTE: The Owner Construction Inspection Program is not a substitute for quality activities that should be performed by the contractor. These activities are independent of one another.

5.4. Owner Acceptance

5.4.1. Prior to owner acceptance and turnover for commissioning and operations:

a. Walk through the asset with project stakeholders (e.g., operations, health and safety, commissioning technicians).

b. Ensure punch-list is updated. Ensure outstanding deficiencies are tracked and have an action plan.

c. Complete a review of the as-built drawings and ensure all redlines have been incorporated and are managed.

5.5. Commissioning and Start-up

5.5.1. Owner maintains the appropriate tools, materials, training, and role profiles to assemble a competent commissioning and start-up team.

5.5.2. In general, the following apply to commissioning and integration processes:

a. Commissioning technical procedures and forms.

b. Roles and responsibilities.

c. Pre-Start-up Safety Review (PSSR).

d. Standardized Commissioning and PSSR procedures, along with project-specific Commissioning and PSSR detailed plans, Construction and commissioning turnover procedure.

5.5.3. Owner maintains a detailed list of requirements through operations integration processes, which should show all the requirements for the project to proceed to in-service and handoff to operations.

5.5.4. Once all parties have met and agreed that all requirements and punch list items have been successfully completed, project can proceed to in-service.

NOTE: Officially, the commissioning program is not a construction quality tool; however, it assists with facilitating detailed requirements and stakeholder needs.

5.6. Material Verification

5.6.1. Materials records must be traceable (PHMSA CFR, Title 49, Part 192, 2019), verifiable, and complete (TVC).

5.6.2. Traceable

a. Records that can be clearly linked to original information about a particular pipeline segment or facility.

b. Traceable records may include pipe mill records, which include mechanical and chemical properties, purchase requisition, or as-built documentation indicating minimum pipe yield strength, seam type, wall thickness, and diameter.

5.6.3. Verifiable

a. Records are those in which information is confirmed by other complementary, but separate documentation.

b. May include contract specifications for a pressure test of a segment complemented by pressure charts or field logs. May include a purchase order to a pipe mill with pipe specifications verified by a metallurgical test of a coupon pulled from the same pipeline segment.

5.6.4. Complete

a. Records finalized as evidenced by a signature, date, or other appropriate marking such as a corporate stamp or seal.

b. A record that cannot be specifically linked to an individual pipeline segment is not a complete record for that segment.

5.7. Records and Survey Data

5.7.1. Records that document the physical characteristics of the pipeline – including diameter, yield strength, ultimate tensile strength, wall thickness, seam type, and chemical composition – should be collected and retained for the life of the pipeline as per 49 CFR § 192.67 Records: Material properties.

5.7.2. Records that document the pipe is designed to withstand anticipated external pressures and loads – in accordance with 49 CFR § 192.103 – must be collected and retained for the life of the pipeline. Records that document the determination of design pressure – in accordance with 49 CFR § 192.105 – must also be collected and retained for the life of the pipeline.

5.7.3. Records that document the manufacturing standard and pressure rating – to which valves were manufactured and tested – must be collected and retained for the life of the pipeline as per CFR 49 § 192.205 Records: Pipeline components.

5.7.4. For flanges, fittings, branch connections, extruded outlets, anchor flanges, and other components with material yield strength of 42,000 psi or greater and with nominal diameter greater than 2-inches – records that document yield strength, ultimate tensile strength, and chemical composition must be collected and retained for the life of the pipeline as per CFR 49 § 192.205 Records: Pipeline components.

5.7.5. Records demonstrating each individual welder qualification at the time of construction must be retained for 5 years after construction is completed as per CFR 49 § 192.227: Qualification of welders and welding operators.

5.7.6. It is highly recommended to collect as-built survey data in geographical information system (GIS) geodatabase during construction, including:

a. Surveyed features and their attributes based upon data collection standards agreed on by Stakeholders prior to survey kickoff. Examples of Standards may include:

- Data Dictionary
- Geodetics
- Data Model (if relevant)

b. Surveyed alignment at every weld

c. Final deliverable(s) agree upon by Stakeholders. This may include pre-construction survey, a.k.a. Civil Survey.

5.7.7. All regulatory and operational records should be assessed on an ongoing basis throughout construction for accuracy and completeness.

5.7.8. A system should be implemented where all records can be accessed, maintained, updated, and backed up for the life of the pipeline.

5.8. Non-destructive Testing

5.8.1. NDT inspection is critical for proving welds and should be completed on 100% of welds.

5.8.2. Technical evaluation of NDT providers is crucial to ensure competency.

5.8.3. Owner/operator involvement and oversight of NDT results is needed to ensure accuracy.

5.8.4. Auditing techniques should be used where possible.

5.8.5. Best practice: Independent hiring of NDT contractors on all field pipe welding.

5.9. In-line Inspection

5.9.1. For new construction, in-line inspection (ILI) has historically focused on geometry checks using simple calipers. The focus was on detecting post construction defects such as ovality, dents, and other geometric features. The caliper was run *prior* to operations and was part of the commissioning of the pipeline. It was also used a sign-off between the construction contractor and owner/operator.

5.9.2. Caliper pig runs should be completed following hydrostatic testing for defect detection. Key criteria are dents, buckles, ripples, and ovalities. Any findings meeting applicable operator criteria should be investigated and repaired as necessary.

5.9.3. It is recommended to use a gauge plate prior to caliper tool.

5.9.4. It is recommended to use a gauge plate or caliper tool to inspect piping immediately following a horizontal directional drill (HDD) and prior to tie-in. HDDs are subject to increased risk of pipe defects due to the nature of the construction technique.

5.9.5. Prior to, or soon after, placing the pipeline in operation, a baseline can be run on pipeline installations as designated by owner/operator – based on pipe operating conditions and threats of concerns. The owner/operator may need to develop set of criteria for determining when this level of inspection would be required immediately following new installation. The baseline is used to detect all mill, fabrication, and construction anomalies that may be an integrity threat during operation of the pipeline. Also, it can be used to recognize all non-injurious anomalies for future inspections. Technology that is usual for a baseline would be a high-resolution caliper and a metal loss detection tool such as a magnetic flux leakage (MFL) or ultrasonic wall measurement (UTWM).

5.9.6. Consider running a high-resolution mapping run using an inertial mapping unit (IMU); such data can be extremely useful for areas where the pipeline is subjected to land movement. Combining this with high resolution geometry and survey grade above-ground markers provides accurate centerline generation which can:

a. Generate a centerline of the as-built pipeline route.

b. Evaluate pipeline displacement based on bending strain data when subsequently inspected in the future.

c. Be used to evaluate any extraneous bending strains.

d. Be used to perform a bend compliance check.

e. Provide a depth of cover when combined with ground elevation data for example using traditional land survey data or using aerial borne light detection and ranging (LIDAR) technology.

f. Assess any out-of-straightness as a compliance check.

5.9.7. Technology is now available that can detect, size, and characterize many more anomalies which could be extremely useful as a new pipeline enters service. These technologies include:

a. Eddy current and low field MFL for the detection of material properties.

b. Circumferential and helical MFL for the detection of long narrow axial features, long seam, seam anomalies etc.

c. Conventional ultrasonic crack detection (UTCD), electromagnetic acoustic transducer (EMAT), and phased array ultrasonic (PUAT) for detection of cracks.

d. Other technologies – such as acoustic resonance technology (ART), axial strain, and cathodic protection measurement tools – are also coming into the markets.

e. The anomalies each technology can detect are highlighted below in

Figure 1 – ILI Capabilities – Anomalies (see following page).

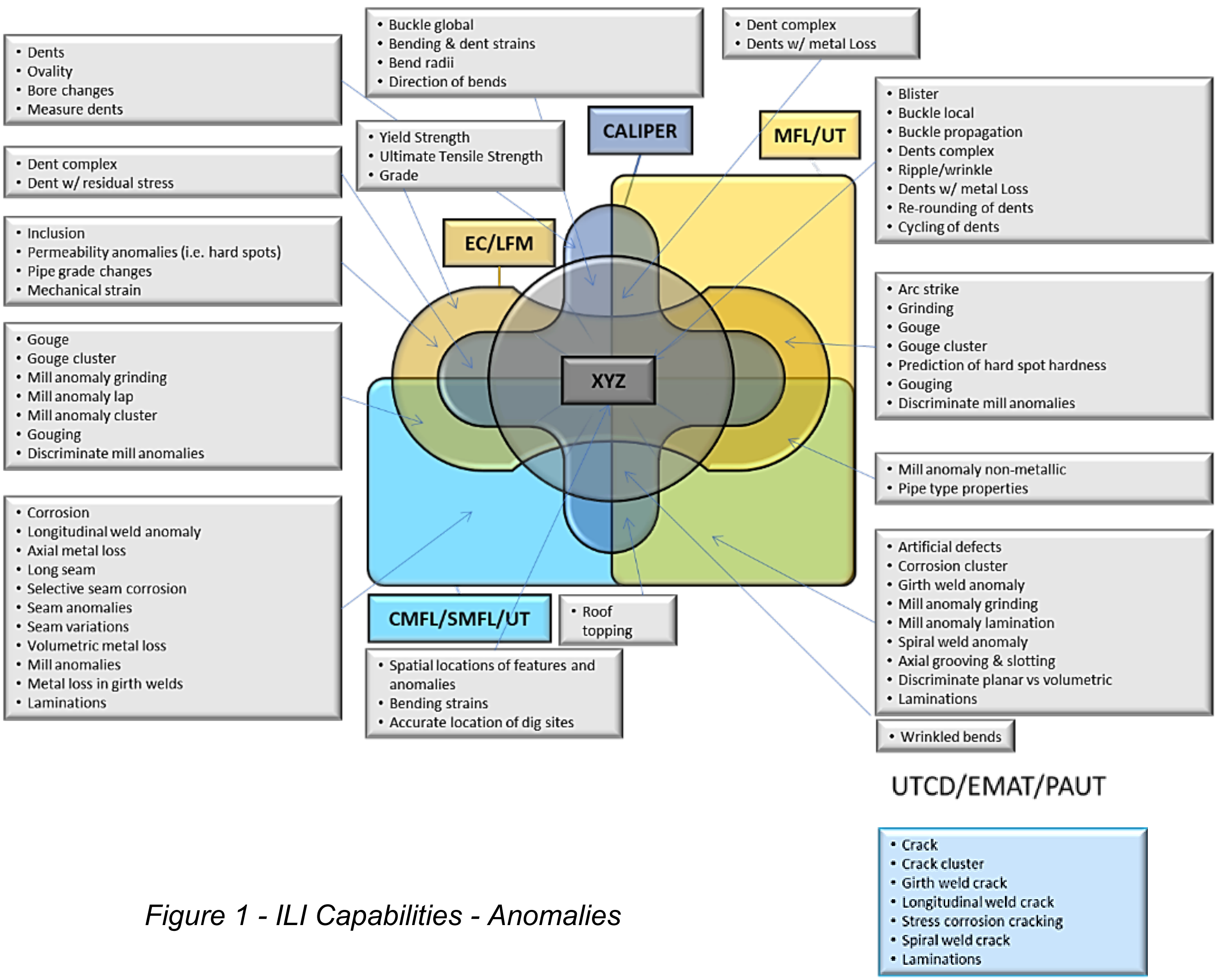

Figure 1 - ILI Capabilities - Anomalies

5.10. Coating and Corrosion Protection

5.10.1. Coating verification should be completed following pipe installation as designated by owner/operator and should include:

a. Completion of Voltage Gradient Surveys (ACVG or DCVG as appropriate).

b. Analyze results and determine areas requiring excavation and coating repair.

NOTE: This may not be feasible for smaller projects.

5.10.2. Close Interval Survey (CIS) should be used for post construction verification as designated by owner/operator:

a. Prior to energization of the CP system, consider performing a test station survey and CIS.

b. Perform a second on/off CIS once the system has been energized.

c. Interference Testing is performed (as-needed basis).

NOTE: This may not be feasible for smaller projects.

5.10.3. For pipelines near high voltage power lines, AC potential and current density testing should be completed to assess potential of risk of AC interference and/or verification of AC mitigation systems.

5.11. Civil and Environmental Monitoring

5.11.1. Periodic investigation of the right of way should be performed after construction to identify any erosion issues and the success of erosion control measures.

5.11.2. Also, verification of vegetation requirements (e.g., seeding has taken, no intrusive vegetation such as saplings, etc.) should be completed post re-instatement of the environment.

5.12. Additional Considerations

5.12.1. When pipe is stored outside for long periods of time, for more than one year, prior to construction, proper consideration should be given to security (for example, to prevent malicious damage), weather protection, and other environmental damage to both the pipe and coating. Also, a quality assurance/quality control program may be required that inspects for such damage and remediates before installation.

5.12.2. Rockshield, padding, etc. are an effective measure used to help to prevent potential anomalies that could occur on buried facilities. Often when anomalies are identified on buried facilities, they are located where no Rockshield or padding were specified or installed. Consider standardizing the parameters used to determine where these measures should be implemented on a project to most effectively prevent future anomalies.

5.12.3. Pipelines are commonly designed to have sags at creek crossings or ditches that may experience added stress once backfilled. This additional stress can contribute to the development of dents or ovality in the pipeline – which may only become evident upon completion of a caliper tool run.

5.12.4. Consider developing detailed and standardized plans or processes for each of the phases of construction. This would help to facilitate consistent and favorable levels of quality from all contractors which would ultimately improve PCAC results.

6.0. KEY TAKEWAYS

6.1. Careful selection and testing of materials are key to mitigating common issues related to girth weld quality.

6.2. Construction Contractor and Owner programs are separate. Although complementary, separation is necessary to fully own quality.

6.3. A successful Quality Management System combines key elements from a broad range of owner/operator construction processes and procedures.

6.4. Establishment of best practices across industry reduces issues for all pipeline operators and constructors.

6.5. The best way contractors can contribute to successful PCAC is to have detailed plans and procedures before the project begins and to execute the project with quality workmanship and quality control.

7.0. SOURCES

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9.0. HISTORY OF REVISIONS

Revision	Date	Description
0	9/20/2021	Initial Issue