Canada Energy Regulator
Régie de l'énergie du Canada

Girth Weld Workshop

Canada Energy Regulator Summary Report

Canada

This page is intentionally blank

Table of Contents

Executive Summary 1
Glossary of Terms 2
Background 3
Presentation Summaries and Recommendations 4
  Session 1: Overview of the issue 4
  Session 2: Failure/Incident Investigation 4
  Session 3: Geotechnical Considerations 5
  Session 4: CSA Pipe Considerations & Pipe Issues 6
  Session 5: Welding Issues 7
  Session 6: Installation and Joining Issues 8
  Session 7: B31.8 Welding 8
Breakout Discussion 10
  Technical Guidance 10
  Strain Monitoring 11
  Pipeline Company Exceeding the Standards 11
  Project pipe 12
  Construction oversight 12
  Industry Group/Knowledge Sharing 13
  Determining Susceptibility 14
  Further Work 15
Proposed Next Steps 15

Executive Summary

In 2019 the Canada Energy Regulator (CER) became aware of a pattern of girth weld area failures in high-strength pipes outside Canada. Although no such failures had been reported in Canada, the CER aimed to avoid similar incidents by raising awareness and continually monitoring industry actions. This led the CER to issue Safety Advisory SA 2020-01 ***Girth Weld Area Strain-Induced Failures: Pipeline Design, Construction, and Operation Considerations.*** To further address the issue, the CER hosted a Technical Workshop on February 15, 2023. The workshop aimed to identify industry knowledge gaps related to the girth weld issue and propose actions to mitigate future risks within Canada.

For the first half of the workshop, the CER brought in various experts to speak on different aspects of the Girth Weld issue. Topics covered included an overview of the issue, current research being conducted, industry incidents, geotechnical management, manufacturing and welding gaps, as well as regulatory shortcomings in Canada. The speakers also offered recommendations for industry improvements in each area.

During the second half of the workshop, the CER organized breakout discussions focused on key questions and topics related to the issue. These sessions fostered meaningful dialogue and idea exchange among participants. The first set of discussions centered on reviewing topics from technical presentations, while the later sessions covered suggestions for further work and recommendations.

This report provides a summary of presentations given at the workshop, recommended actions to address the Girth Weld issue that were made by the participants, the actions that could be implemented by the CER, and opportunities for the CER to work on continual improvement initiatives with industry associations, standards associations, and other regulators.

Glossary of Terms Used

ALA	American Lifelines Alliance
ASME	American Society of Mechanical Engineers
CE	Carbon Equivalent
CEPA	Canadian Energy Pipeline Association
CER	Canada Energy Regulator
COSEA	Corrosion of Steel in Enclosed Areas
CSA	Canadian Standards Association
GW	Girth Weld
HAC	Hydrogen Assisted Cracking
HAS	Heat Affected Zone
ILI	In Line Inspection
IMU	Inertial Measurement Unit
JIP	Joint Industry Project
MTR	Material Test Report
NACE	National Association of Corrosion Engineers
NPS	Nominal Pipe Size
NTSB	National Transportation Safety Board
P_{cm}	Critical Metal Parameter (A chemical composition parameter used to indicate a steel’s hardenability or weldability)
PHMSA	Pipeline and Hazardous Materials Safety Administration
PRCI	Pipeline Research Council International
SA	Safety Advisory
SCC	Stress Corrosion Cracking
SMAW	Shielded Metal Arc Welding
SME	Subject Matter Experts
SMYS	Specified Minimum Yield Strength
TMCP	Thermo-Mechanically Controlled Process
TS	Tensile Strength
WPS	Welding Procedure Specification
Y/T	Yield Strength to Tensile Strength Ratio
YS	Yield Strength

Background

In 2019 the Canada Energy Regulator (CER) became aware of several incidents outside of Canada where failures occurred at the girth weld area (deposited weld area and heat affected zone (HAZ)) on high-strength pipe. These incidents include a 2015 in-service NPS 20 pipe that failed at the weld area less than two years after the pipeline was put in service, as well as a NPS 36 onshore natural gas pipeline that was constructed in 2013 that failed in 2014 and again in 2018.

While no incidents associated with this type of failure have been reported in Canada, the CER is of the view that similar incidents could occur under comparable conditions.

To ensure a broader awareness of girth weld area strain-induced failures the CER issued Safety Advisory SA 2020-01 to all regulated companies. Safety Advisories are issued periodically to inform the oil and gas industry of an identified safety or environmental concern to prevent the occurrence of related incidents. Since issuing SA 2020-01, the CER has continued to monitor industry action on the topic, including discussions with regulated companies and international research organizations.

As part of the CER's commitment to monitoring industry progress on this issue, the CER hosted a Technical Workshop on undermatched and low-strength girth welds on 15 February 2023. This workshop was set up to provide an in-person forum for stakeholders to:

- investigate, discuss, and explore the girth weld area strain-induced failure incidents that have occurred internationally, their causes, and contributing factors;
- observe the current state of research and knowledge of the issue;
- examine any progress that has been made internationally and within the Canadian context to prevent and mitigate incidents from occurring in Canada; and
- explore whether any gaps remain and how to address them.

The workshop's goal was to for industry to discuss this issue and identify possible actions to prevent failures from occurring in Canada.

Presentation Summaries and Recommendations

The Girth Weld workshop featured several presentations on a variety of topics related to girth weld area strain-induced failures. These presentations are available on the CER Dialogues website (www.cerdialogue.ca/girth-weld-workshop). Presenters covered issues ranging from broad issue overviews, Geotechnical Considerations, and welding and joint issues. Overall, the key points and recommendations from the presentations are summarized as follows:

Session 1: Overview of the issue

Presenter; Yong-Yi Wang, Ph.D., CRES
Discussion Topic: Current state of Research and Knowledge of Issue, Scope of Issue

This presentation focused on the mismatch in girth welds, risk assessment, and recommended improvements for pipeline design and construction. One of the main points offered was the need for initial screening to determine if further engineering evaluation is required. Yong-Yi emphasized that proper estimation of mismatch and HAZ softening level is necessary for accurate risk assessment.

Yong-Yi stated that having an axial stress tolerance of 90% specified minimum yield strength (SMYS) is inadequate to meet actual field conditions in service. He argued that the stress design at 90% SMYS of buried pipes, except under ideal conditions, is not sufficient as normal ground settlement after construction and construction stresses would likely exert stresses greater than 90% SMYS in certain locations which may not be identifiable beforehand. Therefore, having sufficient intrinsic strain capacity in the pipelines is necessary to accommodate the likely levels of axial stresses in a pipeline.

Furthermore, Yong-Yi suggested the use of a 0.5% offset or 0.75% total strain as a strain value to define yield strength. This can lead to the reduction of scatters in reported yields strength which is beneficial for accurate representation of a pipe's tensile properties. He also recommended establishing a sensible upper limit for the ratio of yield strength to tensile strength (Y/T).

Yong-yi recommended two possible girth weld qualification options. With Option 1, no failure in the weld area (weld metal and HAZ) is permitted. With Option 2, failure in the weld area is permitted with additional performance requirements. Both options would need to be exercised by selecting appropriate pipes for the qualification welds. The use of a wide weld cap and the consideration of a risk-based approach, potentially related to the specifications, were additional points raised in the presentation.

Overall, Yong-Yi's presentation points out the importance of taking a holistic approach in identifying and addressing potential risks in all phases of a pipeline's life, including design, material specifications and construction to ensure the safety and reliability of pipelines.

Session 2: Failure/Incident Investigation

Presenter: Dave Warman, CRES
Discussion Topic: Industry Incident Example

Dave Warman's presentation provided an overview of aspects related to incidents and strain capacity in pipelines. Firstly, low strain capacity is defined as the inability of pipelines to withstand high levels of deformation without failing, and the term "Low-Strain Capacity of Girth Weld Areas" refers to the low level of nominal strains measured in a specific segment of a pipeline remote from the weld region. Secondly, the importance of strain capacity in pipelines is highlighted through examples of girth failure incidents.
During the presentation Dave used a specific incident from 2015 that failed after one and a half years in service. The global strain and cross-weld strain were calculated, showing no flaws in the weld. Examples were provided to demonstrate in-service stress levels greater than 90% of specified minimum yield strength (SMYS), with calculated bending and axial strains below 0.5% in the girth weld.

Dave also mentioned ASME's allowable strain of up to 2% and showcased the difference in settlement between an allowable 0.5% strain and one causing 1.2% strain. It was noted that the pipe would have buckled in compression under the bending load. The evolution of pipeline materials was highlighted, with a note that welding procedures have remained unchanged over time, though pipeline materials have changed. An example of a vintage pipe from 1980-2005 with a significant flaw was given, indicating a tensile strain capacity of 0.43%, and it was noted that a modern flaw-free pipe would have the same strain capacity due to weld strength undermatching and HAZ softening. Dave also mentioned that longitudinal properties were not reported in the material test report (MTR).

Dave also detailed the causes and consequences of girth failure and explored the lessons learned from past incidents and the implications for pipeline design and operation. Inertial Measurement Unit (IMU) bend strain is mentioned as a potential tool for monitoring and assessing strain levels in pipelines. Finally, Dave provided a qualitative ranking of pipeline materials based on their strain capacity, highlighting the importance of selecting materials with sufficient strain capacity to ensure safe and reliable pipeline operation.

Session 3: Geotechnical Considerations

Presenter: Jim Oswell, Ph.D., P.Eng., NAVIQ
Discussion Topic: Geotechnical Strain Management

Jim Oswell gave a personal perspective on some recent improvements in pipeline-soil interaction and specifically addressed pipe-soil interaction rather than pure geotechnical issues or strain considerations. The presentation provided a critique of the American Lifelines Alliance (ALA) guidelines, highlighting their limitations in addressing muskeg (peat) and the combined frictional and skin friction components. The presentation identified the following specific limitations of the ALA guidelines:

- They only address mineral soils (i.e., do not include muskeg)
- They imply pipe-soil interaction has simultaneously frictional (drained) and skin friction (undrained total strain) components

Jim also mentioned that the undrained model for soil resistance and stiffness was thought to provide a better representation of actual pipeline performance. However, it was noted that geotechnical engineers, drawing on pile performance, tend to assign low values for stiffness and ultimate strength, suggesting that the undrained model may not necessarily be more accurate. The varying resistance of peat to vertical and horizontal loading was illustrated, with different friction angles observed.

Furthermore, Jim highlighted that pipe stress analysis software, such as CAESAR II, lacks a default option for muskeg, leaving users to select soft clay as an approximation. This approximation results in a much softer soil spring component than would be the case with muskeg, potentially impacting the accuracy of the analysis.

Presenter: Doug Dewar, M.Sc., P.Eng., Pembina
Discussion Topic: Geotechnical Strain Management

Doug Dewar provided an overview of landslides, with a specific focus on the unique characteristics of the Western Sedimentary Basin in Canada compared to other regions in North America. The importance of ground/pipe monitoring for landslide prevention and mitigation was emphasized. Doug discussed different types of landslide failures, emphasizing the need for early detection through monitoring systems along with discussing the use of the IMU as a potential tool for monitoring axial strain in pipelines.

In examples given, the majority of failures were observed at the toe of the slope in plain pipe due to buckling. The understanding of tension loading was highlighted to lag behind the comprehension of compression loading. The recommended route selection strategy was the selection of routes through slower landslide areas, typically with a movement rate of zero to 25 mm/year and a strong case was made for avoiding landslides rather than accommodating them.

Tension failure was described as "sudden death" and deemed difficult to predict through in-line inspection (ILI). The potential for axial strain has to be deduced from topographical data and could be confirmed using strain gauge measurements or cut-outs. The future was envisioned as the continued evolution of axial strain tools, enabling a comparison of ILI results between runs.

Doug concluded with the discussion of the future of landslide monitoring and prevention, stressing the significance of developing more advanced monitoring systems to enhance safety and prevent landslide-induced damages.

Session 4: CSA Pipe Considerations & Pipe Issues

Presenter: Alex Afaganis, EVRAZ
Discussion Topic: Gaps in Manufacturing

Alex Afaganis focused on various factors influencing the strain capacity of the girth weld region in pipeline design, specifically highlighting the longitudinal pipe strength and Heat-Affected Zone (HAZ) softening. It was noted that there is limited information available concerning the longitudinal strength capabilities of larger-diameter pipes. To address this issue, improvements in testing methods and the consideration of mandatory testing are being explored. Additionally, guidance on welding design considerations and supplemental Welding Procedure Specification (WPS) requirements for jointer welds are being considered.

To gain a better understanding of the steel response to welding processes and establish correlations between chemical composition and softening susceptibility, an assessment process is being developed. This would contribute to enhancing the knowledge regarding specific steel behavior during welding.

Furthermore, the impact of flattening specimens for tensile testing on the definition of yield was emphasized as having a significant effect. The limitations of using the P_{cm} (Critical Metal Parameter) to detect HAZ softening were acknowledged, with no established correlations available. Heat input was identified as a major influencing factor in HAZ softening.

Other important points made by Alex included a warning against excessively reducing alloy content (specifically alloys 4, 5, and 7), the need for longitudinal tensile limits, and the consideration of a CSA supplement to Z245.1 for jointer welds. Additionally, it was suggested that if flattened strap specimens are underpredicted, alternative options such as ring expansion or round bar tests should be considered.

Session 5: Welding Issues

Presenter: Bill Bruce, Kenneth Lee, P.E., DNV
Discussion Topic: Gaps in Welding and Consumables

Kenneth (Ken) Lee highlighted manual girth welding using cellulosic electrodes as a common practice but acknowledges the potential issues, such as hydrogen-assisted cracking. The question of weld strength was discussed, emphasizing the difficulty in determining this factor accurately and underscoring the importance of careful selection of welding methods and consumables.

Ken suggests various options for girth welding, including higher-strength root and fill-pass welding alternatives. It is noted that with cellulosic SMAW manual welds, the typical failure occurs in the line pipe away from the heat-affected zone (HAZ) and weld. Welding with TMCP (Thermo-Mechanically Controlled Process) pipes presents challenges in making the welds stronger than the line pipe itself. To prevent cracking, using E8010 is recommended as the highest option available. The importance of transitioning from an E6010 root to low hydrogen or gas metal arc weld, or an E8010 root, is also highlighted.

Ken discussed the need for the use of low hydrogen electrodes and mentioned the use of round tensile specimens in thin-wall pipe, which may not be representative of the overall weld. The classification of pipes by specified minimum yield strength (SMYS) and welding electrodes by tensile strength adds to the complexity of matching strengths. A study involving 22 welders found that they were equally comfortable using E8010 or E6010 roots, with all meeting industry heat test requirements.

The importance of utilizing low alloy pipe for increased crack resistance and considering flux-cored alternatives, whether gas- or self-shielded, was highlighted. It is emphasized that if the weld is not strong enough, it overwhelms all other considerations. The need to move away from cellulosic electrodes and the increasing use of mechanized welding in Canada were mentioned as trends in the industry.

In conclusion, the Ken emphasizes the significance of ensuring strong and reliable girth welds in pipeline design and operation. The use of E8010 is recommended as part of an effective solution to address pipeline girth weld strength undermatching.

Session 6: Installation and Joining Issues

Presenter: Eric Willett, M.Sc., P.Eng., TCEnergy
Discussion Topic: Current State of Installation and Welding in Canada

Eric Willett focused on the upcoming changes to the CSA Z662:23 pipeline welding requirements, specifically for pipe grades greater than 386 MPa (greater than X56). Eric highlighted the inclusion of new informative notes and commentary in the updated requirements. Strategies for avoiding unexpected girth weld failures due to strain localization were discussed, including considerations of actual pipe strength when designing and qualifying a welding procedure specification (WPS) or reusing a previously qualified WPS. The use of lower heat input welding processes and higher strength low-hydrogen filler materials was recommended. Additionally, Eric emphasized the importance of implementing additional WPS qualification testing to gain a better understanding of the properties of the weld region.

The importance of oversight and control of production welding and the implementation of proper construction practices were also emphasized. Eric underscored the need for careful consideration of welding procedures and practices to ensure strong and reliable girth welds in pipelines.

The current state of installation and welding in Canada was by Eric and some key points included the testing with weld reinforcement intact and the absence of a standard for cross-weld tensile testing. Failures in the heat-affected zone (HAZ) were discussed, stressing the importance of meeting the minimum tensile strength (TS) of the pipe material and ensuring it is not less than the flow stress (average of TS and yield strength).

Eric suggested the need for strength testing of procured pipe and accounting for different yield strengths in supposedly "identical" filler metals. In assessing the potential for weld mismatch, Eric recommended to start with transverse strengths since longitudinal strengths may not be available. If a cross-weld tensile test failure is reported, verification through a photo is recommended to confirm that the failure occurred outside the HAZ.

Eric concluded by emphasizing the importance of tightening construction specifications, possibly concerning compaction.

Session 7: B31.8 Welding

Presenter: Mike Rosenfeld, P.E., RSI Pipeline Solutions

Discussion Topic: Gaps in Regulations and Standards

Mike Rosenfeld addresses issues such as hydrogen-assisted cracking, heat-affected zone (HAZ) softening, and girth weld strength undermatching, which can impact the quality and reliability of pipeline welds. Mike also provided an overview of the current regulations and standards in the US that aim to address these concerns and the planned revision to the ASME B31.8 standard, which sets forth requirements for gas transmission and distribution pipelines.

Mike highlighted that the purchaser has the option to request longitudinal testing and mentions that the outside weld at 95% specified minimum yield strength (SMYS) is acceptable, although the specific context of this statement is unclear. The presenter emphasizes the need to work with the way pipes are manufactured today, alluding to the challenges associated with the use of Thermo-Mechanical Controlled Process (TMCP) pipe.

Several clauses in the ASME B31.8 standard are described during the presentation. Clause 828.1 addresses hydrogen-assisted cracking (HAC) risks and recommends taking appropriate actions if HAC is suspected or present. The delayed nature of HAC is mentioned, highlighting the importance of conducting inspections within 12 to 24 hours for better detection. Clause 828.2 discusses HAZ softening, noting that it is generally not a problem for internal pressure loading but requires precautionary measures if high longitudinal stress is present. Clause 828.3 addresses the undermatching of welds and emphasizes the need to take measures, referring to the guidelines outlined in ASME BPVC IX.

Mike also mentions that relatively high bending stresses are not uncommon in pipeline construction, indicating the significance of considering such stresses during the design and construction phases.

In conclusion, Mike emphasizes the importance of addressing welding concerns to ensure safe and reliable pipeline construction in the US. It highlights the need to comply with relevant regulations and standards, including the forthcoming revision to the ASME B31.8 standard, and underscores the significance of proactive measures to mitigate welding-related challenges and ensure the integrity of pipeline welds.

Breakout Discussion

In addition to the presentations the CER organized breakout discussions for workshop participants to discuss key questions and topics related to the undermatch girth weld issue. These breakout sessions provided an opportunity for participants to engage in meaningful dialogue, and exchange ideas, to obtain effective solutions to the issue.

Groups were led by discussion leaders from the CER, and notes were also taken by CER staff. By facilitating these discussions, and providing key questions, the CER was able to leverage the expertise of workshop participants and promote collaboration. Discussion leaders had a series of prepared questions that they could use to initiate or prompt discussion, however, they were instructed to allow free-flowing conversation on the topic areas of the SME presentations and the general girth weld area strain-induced failures issue.

For the initial breakout sessions, participants were instructed to focus on reviewing topics raised in the technical presentations. For later breakout sessions, participants were instructed to focus on suggestions for further work and recommendations for addressing the girth weld issue.

During the course of discussions, the following key themes emerged:

- Technical Guidance
- Strain Monitoring
- Pipeline Company Exceeding the Standards
- Project pipe
- Construction oversight
- Industry Group/Knowledge Sharing
- Determining Susceptibility
- Further Work

The following sections detail the discussions that occurred during the breakout sessions in each of the discussion groups, sorted by key theme. Please note that these are records of the discussions by the workshop participants and do not reflect the CER's views and position on the topics that were discussed.

Technical Guidance

Attendees discussed the need for technical guidance, or welding design guidance related to the issue, and proposed that the CER should consider providing guidance that covers what the CER expects from regulated companies in terms of compliance and mitigation of the issue. Additionally, they suggested more CSA workshops and that the focus should be on pipes with elevated stress conditions rather than facility piping.

Furthermore, they suggested that the CSA commentary should be expanded to help people with this issue throughout its lifecycle, as well as that welding design guidance would be appreciated. It was also proposed that something needs to be done to address the disconnect between those conducting the work in the field and those in the office or project design. Participants noted that although PRCI has done a lot of work in this field, one must pay to be a member of the organization.

Strain Monitoring

In the field of strain monitoring, it was stated that several companies are actively engaged in monitoring strains using a method called In Line Inspection (ILI), which focuses on analyzing bending strains. One company has even developed a specialized program for conducting tensile testing. This program allows the company to assess the tensile strength of new assets during their construction phase. Initially, the staff performs front-end threat assessments for these assets, followed by secondary assessments as the construction progresses, specifically focusing on strains that may arise.

To mitigate potential geohazard risks, companies stated that they employ the use of Geohazard data to identify and avoid such risks right from the start. During the construction process, an IMU is utilized to capture the shape of the pipeline. However, when dealing with older pipelines, determining axial strains remains a challenge, and there are limitations associated with IMU data.

Participants discussed the analysis of data provided by the Pipeline and Hazardous Materials Safety Administration (PHMSA) which reveals that in a majority of pipeline failures in the United States, operators were already monitoring the pipeline, but unfortunately, these failures occurred before any appropriate action could be taken. This highlights the need for a comprehensive and efficient system that can integrate all available data and deliver it promptly to the relevant individuals.

Participants stated that there is a desire for the evolution of geotechnical threat management to follow a similar path as Stress Corrosion Cracking (SCC) management. Companies desire a comprehensive framework that guides them through the steps of threat management, ensuring consistency and adherence to accepted practices. While many companies excel in monitoring the pipeline's condition, the challenge lies in determining the appropriate actions to take based on the gathered data. It is difficult to justify the need for funding to address potential failures with uncertain outcomes. The industry seeks a consistent and accepted approach that others would agree with, facilitating effective decision-making.

In terms of measuring bending strain, it was identified that relying on enhanced bending strain requirements from vendors is not a common practice. Instead, strains are typically measured by analyzing curvatures and bending effects. This approach provides valuable insights into the strain levels experienced by the pipeline, enabling companies to assess its structural integrity effectively.

Pipeline Company Practices vs. Standards Requirements

Participants stated that a common practice is to utilize Safety Advisories as a guiding reference during the front-end engineering phase of projects. These advisories are carefully incorporated into the design process, ensuring that safety considerations are adequately addressed. However, one of the challenges faced by this group is in rapidly qualifying new weld procedures. It is often difficult to quickly qualify these procedures, hindering the progress of the engineering work.

In some cases, axial tensile testing is performed for informational purposes. This testing provides valuable data regarding the tensile strength of the materials used. It helps in understanding the capabilities and limitations of the pipeline construction. However, it is important to note that this practice may not be universally adopted by all companies.

Interestingly, some participants expressed their opinion that midstream companies tend to adhere to the minimum requirements and standards. This suggests that they may prioritize meeting the basic safety criteria without necessarily going beyond them. On the other hand, there is a belief that the upstream industry often imposes its standards on the downstream pipelines that interconnect with their infrastructure. This dynamic highlights the influence and interplay between different sectors within the industry.

There was a discussion about axial tensile testing being primarily conducted for greater-grade pipes such as X65 or higher. This implies that for lower-grade pipes, the emphasis on tensile testing might be relatively lower. However, there is a concern across the board regarding the Heat-Affected Zone (HAZ) issue. This problem is recognized as a common challenge that needs to be addressed regardless of the specific pipe grade.

One speaker mentioned that the numeric reference to "386" indicates that decisions are being made based on finding a balance between rectifying existing issues and designing pipelines to meet specific requirements. It signifies the need to strike a balance between solving immediate concerns and constructing pipelines that are designed to perform optimally in the long run.

Project pipe

Regarding pipe procedures, the group emphasized the importance of checking the availability of pipes and conducting procedures on them if they are available. They acknowledge that as projects and pipes change, there is a continuous need to develop more techniques.

The welder qualification process was discussed, highlighting the use of tensile tests. Welders usually pre-qualify by using project pipes and can potentially qualify with a .45 CE (Carbon Equivalent). The concern of heat-affected zone (HAZ) softening was raised as another issue to be considered.

The extent of the material validation project was mentioned, indicating the possibility of qualifying an entire mill run for another qualification. This suggests a comprehensive evaluation process to ensure the suitability and quality of materials used.

The importance of including tensile strain testing in the standard was highlighted by participants. Without data on the tensile properties, it is difficult to predict potential problems that may arise years later, particularly in areas experiencing longitudinal strain.

For large mechanized projects, the group acknowledged the consideration of lifting stresses. This suggests that stress analysis and planning are taken into account to ensure the safe and efficient execution of such projects.

Construction oversight

Participants stated that in the realm of construction oversight, companies often question whether contractors diligently adhere to the specified construction standards and whether those standards are effectively enforced during inspections. It is crucial to have confidence in the development of procedures that can be easily followed. Responsible oversight is necessary to ensure that all elements come together seamlessly.

Participants stated that developing welding procedures that are practical and yield satisfactory results is a priority. This involves creating procedures that ensure proper melting, absence of slag, ease of cleaning, and other desirable characteristics. When procedures are well-designed, people are more likely to follow them, resulting in improved overall execution.

One challenge raised by participants in the construction industry is contractor resistance to changing welding procedures. It is not uncommon for individuals to have specialized tasks, such as a worker solely responsible for moving ladders in a specific manner. When attempting to introduce modifications, such as incorporating low hydrogen practices or emphasizing the importance of proper bead formation and machine selection, resistance can arise due to perceived additional costs. Striking a balance between specifying essential requirements and managing costs becomes crucial in such situations.

There is a notable emphasis on design and welding procedures, but the real concern lies in the field implementation. The question arises: How can we ensure that what happens in the field aligns with the intended design? Mechanized processes offer the advantage of enhanced consistency and control. By employing mechanized techniques, the likelihood of achieving consistent results in the field is increased, providing greater confidence in the overall construction process.

Industry Group/Knowledge Sharing

It was discussed that with the dissolution of CEPA (Canadian Energy Pipeline Association), the industry still could come together and collaborate. Some CEPA subcommittees continue to exist even in the absence of the association. The idea of forming "competency clubs" for enhanced collaboration has been proposed, where industry stakeholders can collectively determine areas that could drive research and development opportunities. This reflects a recognition of the need to bridge knowledge gaps within the industry.

In the context of weld design, there was a suggestion to study the effect of the "aging" process on pipes as they run through the heater, without the coating being applied. By understanding how the steel strengthens during this aging process, a better understanding of how to overmatch welds could be achieved. However, it was determined that implementing this approach at the pipe manufacturing level on a large scale may not be feasible.

The sharing of information within the industry is often a time-consuming process. An example was given when PHMSA (Pipeline and Hazardous Materials Safety Administration) and API (American Petroleum Institute) released information, and within six weeks, PHMSA and NTSB (National Transportation Safety Board) set up a platform for sharing. Marathon managed to successfully share relevant information. The upstream sector has COSEA (Corrosion of Steel in Enclosed Areas), which serves as a platform for sharing knowledge and openly discussing threats. The sharing of information on stress corrosion cracking (SCC) was also highlighted as being previously facilitated by CEPA.

Encouraging companies to actively participate in knowledge-sharing research groups was suggested as an additional step. Previously, CEPA played a significant role in this regard, but with its absence, the question of leadership arises. The suggestion was made for CSA (Canadian Standards Association) to take the lead in formulating and facilitating such initiatives. It was also proposed to consider parallel mechanisms through organizations like the CER (Canada Energy Regulator) or the Banff Pipeline Workshop. The importance of involving not only CSA members but also gathering ideas from across the industry to inform current standards was emphasized. CSA was seen as offering opportunities for workshops and webinars, with the potential for funding support.

PRCI (Pipeline Research Council International) and joint industry projects (JIP) were mentioned as examples of collaborative processes that have proven effective. The idea of creating avenues for companies to engage in these collaborative initiatives was raised, emphasizing the importance of working together to drive industry advancements.

Determining Susceptibility

Determining susceptibility in pipeline systems is a complex task that requires consideration of various factors. One aspect that was suggested is the differences between vintage and modern steels. According to participants, modern steels have a higher propensity for heat-affected zone (HAZ) softening, and undermatching is more prevalent, particularly affecting higher-grade pipelines. While Z662 provides guidance on determining the acceptability of dents, there is a need to address HAZ softening in girth welds as well.

To address this issue, the industry has seen the emergence of recommendations and JIP focused on HAZ softening. However, there is a concern that some individuals without a materials or manufacturing background are blindly following these recommendations, such as those related to P_{cm} requirements. There is a need for a guide that can be easily understood and interpreted by industry professionals.

Monitoring land movement is crucial in assessing pipeline integrity. Some methods employed include yearly strain monitoring, engineering and statistical analysis of land movement data, and tracking weather conditions through databases and weather advisories. The goal is to have an algorithmic approach that categorizes the risks associated with land movement and enables timely response and mitigation efforts.

From an integrity perspective, some companies have implemented programs using In-Line Inspection (ILI) and Inertial Measurement Unit (IMU) technology to identify local strains on pipelines. Stress management programs, also play a role in addressing concerns related to integrity. Stress modeling during the design stage, considering geohazard sampling, operating conditions, and construction stresses, is another crucial aspect of ensuring the integrity of pipeline systems.

The conversation surrounding pipeline design and welding has evolved in recent years. However, there is still a need for a holistic approach that considers material and weld design principles. It is advised not to solely design to meet the standards but to base the design on fundamental engineering principles. This approach should incorporate stress analysis, longitudinal street limitation, and the consideration of potential welding flaws and undermatching issues.

Knowledge sharing and collaboration within the industry are essential for addressing these challenges. Competency clubs and collaborative research groups can facilitate the exchange of knowledge and drive research and development opportunities. The role of industry associations like CSA and PRCI, as well as forums like CEPA, can be instrumental in coordinating such efforts and providing guidance and workshops to enhance industry-wide understanding and practices.

In conclusion, determining susceptibility in pipelines requires a comprehensive understanding of factors such as steel properties, weld design, land movement, and stress analysis. It is important to bridge knowledge gaps, promote collaboration, and ensure a holistic approach to pipeline design and integrity management. By leveraging industry expertise, incorporating research findings, and sharing best practices, the industry can strive toward safer and more reliable pipeline systems.

Further Work

Changes to standards, while often prescribing minimum requirements, do not always result in the adoption of best practices. These changes can present challenges for smaller companies that may struggle to adhere to the updated standards. Additionally, there are knowledge gaps in the industry, particularly related to metallurgy and welding compositions. For instance, specific engineering programs focused on these disciplines, such as P.Eng. programs in Canada, are scarce or diminishing at the undergraduate level in the United States. To address this, there is a growing desire to expand industry-level discussions and research and development (R&D) forums, similar to the collaborative model employed by NACE.

The concept of a curve-wide plate test was also discussed, with some participants confirming that it is not a production test but rather a tool that could validate certain philosophies or serve as a research tool. Another topic of debate revolves around stress-based design versus strain-based design. The question arises as to whether additional requirements should be imposed on top of stress-based design, potentially involving factors like global weld overmatching. Interestingly, many clients do not actively work on welding procedures themselves, instead leaving it to smaller operating companies to handle. The changes to the Z662 standard were generally well-received as they are expected to support these smaller companies.

Backfill practices were also discussed, with observations of excessive backfill and over-excavation at bell holes, leading to issues such as pipe ovality. It was recommended to address these problems during construction and avoid unnecessary digging beyond what is required. Mechanized techniques were generally favored by larger companies, while stick welding remains prevalent for smaller-diameter pipes in Canada.

Regarding the materials used, there have been instances where pipes labeled as X52 specification actually exhibited properties equivalent to X60 pipes. An initial step towards improvement was acknowledged in the Session 6 presentation, but it was suggested that further enhancements could be explored over the next four years, taking into account any challenges that may arise.

Concerns were expressed about the potential mandating of P_{cm} when its effectiveness as a solution is not universally agreed upon. This is particularly relevant when considering the acceptance of factors like heat input as major contributors to quality outcomes.

Proposed Next Steps

Recommended actions were discussed and proposed by the workshop attendees and presenters. Participants suggested several actions that can be taken by different stakeholders across industry to improve the quality of girth welds used on transmission pipelines.

After further review of the discussions and suggestions that are outlined in this summary report, the CER will determine the actions it will take to address the issue. Meanwhile, the CER will continue its work with various stakeholders including participation in CSA standards development committees.

Below, in Table 1 and Table 2, are the recommendations made in the presentations and breakout sessions, respectively.

Table 1: Presentation Recommendations

Session	No.	Recommendation
Session 1: Overview of Issue	1.1	Conduct initial screening to determine if further engineering evaluation is required.
	1.2	Consider intrinsic strain capacity in pipes to accommodate ground movement.
	1.3	Use 0.5% offset or 0.75% total strain as the strain value to define yield strength.
	1.4	Establish an upper limit for the yield strength to tensile strength ratio (Y/T) for longitudinal tests.
Session 2: Failure/Incident Investigation	2.1	Use IMU bend strain as a tool for monitoring and assessing strain levels in pipelines.
	2.2	Consider the impact on strain capacity when selecting pipeline materials.
Session 3: Geotechnical Considerations	3.1	Address the limitations of current geotechnical guidelines, especially in relation to muskeg.
	3.2	Enhance the pipe-soil interaction models in software like CAESAR II.
	3.3	Opt for early detection systems for landslides and utilize IMU for axial strain monitoring.
	3.4	Choose pipeline routes through slower landslide areas and avoid high-risk landslide zones.
Session 4: CSA Pipe Considerations & Pipe Issues	4.1	Explore improvements in testing methods and consider mandatory testing for longitudinal strength capabilities.
	4.2	Develop an assessment process to better understand steel behavior during welding.
	4.3	Provide longitudinal properties instead of just transverse properties.
	4.4	Form an HAZ task force to focus on heat input and its effects on HAZ softening.
Session 5: Welding Issues	5.1	Consider using E8010 as a high-strength alternative to traditional E6010.
	5.2	Move away from cellulosic electrodes to mitigate hydrogen assisted cracking.
	5.3	Transition from an E6010 root to low hydrogen or gas metal arc welds.
Session 6: Installation and Joining Issues	6.1	Consider actual pipe strength when designing and qualifying a Welding Procedure Specification (WPS).
	6.2	Utilize lower heat input welding processes.
	6.3	Implement additional WPS qualification tests.
	6.4	Ensure production welding oversight and consider strength testing of procured pipe.
Session 7: B31.8 Welding	7.1	Comply with relevant ASME standards, especially the forthcoming B31.8 revision.
	7.2	Take measures to mitigate Hydrogen-Assisted Cracking (HAC) and Heat-Affected Zone (HAZ) softening.
	7.3	Use precautionary measures if high longitudinal stress is present in pipelines.

Table 2: Breakout Discussion Recommendations

Recommendation No.	Recommendation
8.1	Develop lifecycle guidance focusing on girth weld strain accumulation identification, avoidance, threat analysis, baseline surveys and surveillance.
8.2	Continue to raise awareness on the girth weld strain capacity issue by facilitating more dialogue.
8.3	Develop guidance on Design, Construction, Maintenance, and Materials.
8.4	Develop girth weld strain accumulation assessment methodology.
8.5	Research the effects of imperfections on tensile strain capacity (TSC) as it relates to girth weld strain accumulation
8.6	Identify possible improvements to CSA Z662 and Z245 series standards.
8.7	Identify additional unknowns through R&D
8.8	Develop a competency program where individuals can be trained to assess and manage the girth weld strain accumulation issues.