



PRCI Technology
Development Center
Houston , Texas



2015 Year in Review



Our Members

Pipeline Members

- Alliance Pipeline Limited (Canada)
- ATCO Pipelines (Canada)
- Boardwalk Pipeline
- BP
- Buckeye Partners, L.P.
- Chevron Pipe Line Company
- Colonial Pipeline Company
- Columbia Pipeline Group
- ConocoPhillips
- Dominion Transmission, Inc.
- Enable Midstream Partners
- Enbridge Pipelines Inc. (Canada) &
- Enbridge Energy Partners LP
- Energy Transfer
- ENGIE (France)
- Eni S.p.A. (Italy)
- Enterprise Products
- ExxonMobil Pipeline Company
- Gassco A.S. (Norway)
- Kinder Morgan
- Koch Pipeline Company, L.P.
- Marathon Pipe Line LLC
- N.V. Nederlandse Gasunie (Netherlands)
- National Fuel Gas Supply Corporation
- National Grid (U.K.)

- Pacific Gas and Electric Company
- Petrobras (Brazil)
- PetroChina Pipeline Company (China)
- Phillips 66 Pipeline LLC
- Plains All American Pipeline, LP
- Sasol Gas Limited (South Africa)
- Saudi Aramco (Saudi Arabia)
- Shell Pipeline Company LP
- Southern California Gas Company
- Spectra Energy
- Total S.A. (France)
- TransCanada PipeLines Limited (Canada)
- TransGas Limited (Canada)
- Williams Companies, Inc.

Pipeline Industry Organizations

- Association of Oil Pipe Lines
- Electric Power Research Institute
- Operations Technology Development

Associate Members

- Applus RTD
- Baoshan Iron & Steel Co., Ltd. (China)
- China Petroleum Pipeline Bureau (China)
- GE Oil & Gas
- RCP Inc.
- Shell Global Solutions (US) Inc.
- Sonomatic Limited (U.K.)

Technical Program Associate Members

- Aegion Corporation
- Australian Pipeline & Gas Association - Research & Standards Committee (Australia)
- Baker Hughes, Pipeline Inspection
- Berg Steel Pipe Corporation
- CNPC Tubular Goods Research Institute (China)
- Dresser-Rand Corporation
- Elster-Instromet N.V. (Belgium)
- Emerson Process Management
- Emerson Therm-O-Disc, Inc.
- Evraz Inc. NA (Canada)
- Hoerbiger Kompressortechnik Holding GmbH (Austria)
- Innospection Ltd (U.K.)

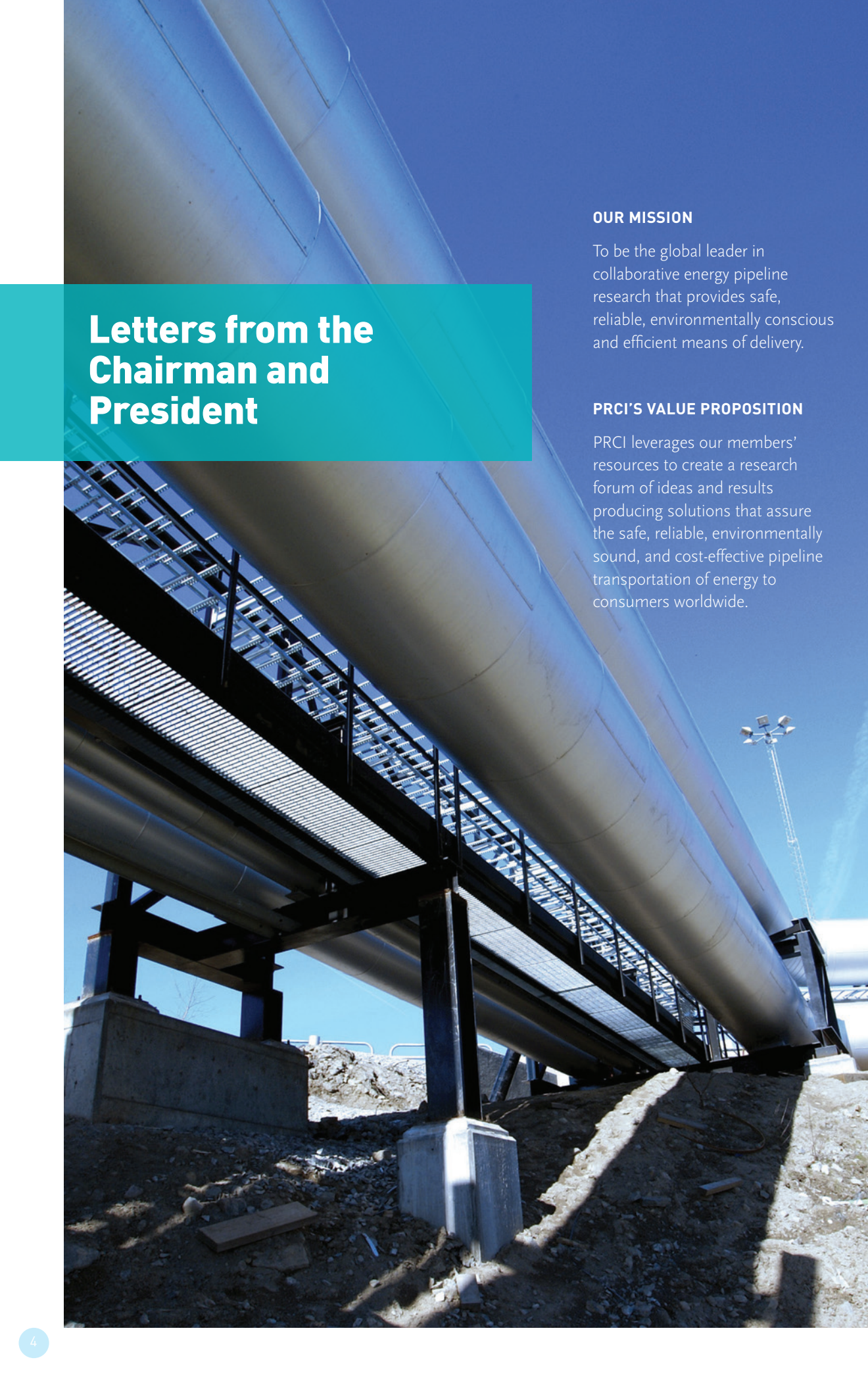


- JFE Steel Corporation (Japan)
- KROHNE, Inc. (Germany)
- The Lincoln Electric Company
- NDT Global (Ireland)
- Nippon Steel & Sumitomo Metal Corporation (Japan)
- Quest Integrity Group, LLC
- Riccardelli Consulting Services
- The ROSEN Group
- SGS Canada (Canada)
- ShawCor Ltd. (Canada)
- SICK Process Automation (Germany)
- Solar Turbines, Inc.
- Subsea Integrity Group (U.K.)
- T.D. Williamson, Inc.
- Tubos de Acero de Mexico, S.A. (Mexico)
- TWI Ltd. (U.K.)
- Welspun Tubular LLC
- WorleyParsons Group Inc. (U.K.)

Pipeline Research Council International is the preeminent global collaborative research development organization of, by, and for the energy pipeline industry.

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Letters from the Chairman and President

OUR MISSION

To be the global leader in collaborative energy pipeline research that provides safe, reliable, environmentally conscious and efficient means of delivery.

PRCI'S VALUE PROPOSITION

PRCI leverages our members' resources to create a research forum of ideas and results producing solutions that assure the safe, reliable, environmentally sound, and cost-effective pipeline transportation of energy to consumers worldwide.



We are in the middle of some rather historic step-change improvements in our capability to deliver value.

Phillip DePriest
Chairman

LETTER FROM THE CHAIRMAN

I am honored to begin serving as the next Chairman of PRCI, and look forward to helping ensure our organization continues to focus on achieving its strategic objectives. We are in the middle of some rather historic step-change improvements in our capability to deliver value. The Technology Development Center (TDC) officially opened its doors on July 15, 2015, and activities continue to ramp up. An improved governance and research structure was developed and approved by the membership at our September meeting, and implementation is underway. Approval was also given to continue development of an information transfer solution that will enhance and replace our existing website and project management database.

The TDC has already proven to be a game changer. We have an inventory of more than 1,500 pipe samples that have been characterized. These samples are keys to moving PRCI research quickly. We have had more than 1,000 visitors from around the world, since the opening. The TDC has hosted a number of PRCI projects, including the first pull tests at the site as part of a U.S. Department of Transportation Pipeline Hazardous Materials Safety Administration project. We have had a number of nonmember groups use the site for training and meetings. We are just beginning to get the facility up and running and we are excitedly looking forward to 2016.

The Board of Directors, in September, approved a number of governance and research changes. We are looking forward to using these recommendations to identify and address the key issues facing our industry in a timely manner. We have moved the Board of Directors to the new Executive Assembly. This body will be responsible for ratifying the new research objectives (RO) and providing key strategic direction to PRCI. The ROs will define the majority of our research portfolio and will ensure that we are addressing the key issues. The Executive Committee has become the new Executive Board and will have clearer focus on the operations of PRCI in conjunction with the staff. The recommendation also created a new Research Steering Committee (RSC). The RSC will be

responsible for ensuring we are on track with the key items identified and that we are delivering in a timely fashion.

What an exciting time!

A common element aiding the advancement of these improvements has been the rather substantial participation and engagement of the membership community, industry researchers, and PRCI staff in helping turn vision into results. These human resource contributions have directly contributed to value creation, which was the focal aspiration of past Chairman Christophe Renier. I intend to continue emphasizing the importance of member participation, not only with strategic initiatives, but also with the execution of the R&D project portfolio. Value creation requires participation.

The R&D projects that are underway and the new ones added from the 2016 ballot are intended to deliver important outcomes to the global energy pipeline industry. I encourage you to take some time to learn more about the work that is occurring within PRCI, and consider how best you and your organization can maximize its participation.

Phillip H. DeLiest



We have a number of exciting projects coming to conclusion in the next year that have a dramatic impact on the industry.

Cliff Johnson
President

LETTER FROM THE PRESIDENT

It is important that we as individuals, corporations, and associations take time to reflect on what we have done, to celebrate our successes, and to look forward to the new opportunities that lie ahead. When looking back at 2015 it is amazing to see what we have done to enhance the governance and research models at PRCI. As was noted by Chairman DePriest, we opened the Technology Development Center and this new site will be a game changer for years to come for research and development and for technology transfer. We have completed a number of key projects that will greatly impact the pipeline industry for years to come. These projects will go a long way to support the pipeline industry stated goal of zero failures. This Year In Review (YIR) will provide you with a small sample of the projects that we have completed in 2015. Once you complete reading the YIR, I encourage you to take some time to visit our website to dive into the details of each of these projects.

In September, the Board of Directors (BOD) approved a vital overhaul of the PRCI governance and research model. These changes will enable PRCI to be efficient and effective in executing our research portfolio. The BOD approved the acknowledged need to enable a smaller body to lead the organization. The BOD approved the creation of the Executive Board (EB) which will provide more guidance to PRCI to ensure that we are developing the value needed by the industry. The BOD of will become the new Executive Assembly and will be responsible for providing strategic guidance and ratifying the Research Objectives (RO).

The ROs are a critical piece of the new organization. PRCI will establish key ROs on an annual basis to ensure that we are achieving needed research in a timely fashion and to be able to explain to our key audience what, when, and how we are producing vital results. The ROs will be developed by the Research Steering Committee (RSC), as part of their responsibilities. They will recommend the ROs to the EB and seek ratification from the EA. The ROs will be supported by the roadmaps that are developed, which in turn are supported by the individual projects. These steps will ensure that Research Portfolio is aligned with the desired outputs. The RSC will also be the body to assist in the progress review of the research projects and perform periodic review of the

research being done. All of these steps are providing the underlining tools need to ensure that PRCI is answering the correct issues in a timely fashion.

As we begin to look to 2016, the focus on value creation will continue as a key part of our efforts. We know that we need to do more to allow our members to participate remotely and we will leverage the TDC more because of the meeting technology that has been built into the site. We are looking at increasing the number of webinars for key project results discussions and working with our researchers to identify key conferences or publications to highlight our findings. PRCI is in the process of enhancing the website and database to increase the usability of each. The efforts of 2015 have set us up nicely for an active and productive 2016. We have a number of exciting projects coming to conclusion in the next year that have a dramatic impact on the industry. If you would like to learn more about the next steps for PRCI please feel to contact me (cjohnson@prci.org) or any staffer.

A handwritten signature in black ink, appearing to read "Clifford M. Johnson", followed by a long horizontal line extending to the right.

PRCI OPENS NEW TECHNOLOGY DEVELOPMENT CENTER

In March 2014, PRCI embarked on a major endeavor that would be a game changer for energy pipeline and facilities R&D worldwide when the PRCI Board of Directors approved the establishment of the PRCI Technology Development Center (TDC) in Houston, Texas. On July 15, 2015 PRCI held the TDC Grand Opening, an event attended by over 200 PRCI members and industry stakeholders. The new Center houses



a world class pull test facility to further enable PRCI to partner with the in-line inspection (ILI) industry to enhance the tools that are a key aspect of pipeline integrity management. The site provides additional testing opportunities to develop and characterize new nondestructive evaluation tools and techniques. Another key resource of the TDC is over 1,500 pipe samples with defined & measured defects that enable service companies to work on real world samples to improve their inspection technologies and provide a greater degree of assurance of the integrity of pipeline systems. The TDC contains state of the art meeting and classroom space that will enable PRCI to more effectively transfer these research results to our members and the industry.

The TDC will shape the direction of energy pipeline integrity management technology options for years to come. With this new site,

**PRCI Technology Development Center
Houston, Texas**

PRCI will be able to work closely with pipeline operators and solution providers to continue to enhance the tools that are needed to ensure pipeline integrity and safety, and assist in the development of the next generation of tools. As noted earlier by Phillip DePriest, PRCI Chairman, the TDC is a key part of the value creation story that PRCI has developed in 2015.

The TDC is the result of a major commitment by the energy pipeline industry to address the key issues that it is facing to ensure the safety and integrity of the vital national and international pipeline infrastructure. It is a critical tool for the energy pipeline industry as we continue to strive for zero failures. The TDC will provide the industry with an independent third party site to fully understand the capabilities of current tools and to guide the development of the new technologies needed to push toward that goal.

“The TDC enables efficient and timely access to industry samples in support of technology projects and programs,” TDC Steering Committee member and Past Board Chair, Eric Amundsen stated. “The TDC is a success story in and of itself; there is no other similar or comparable collection in the world and will attract R&D efforts unique to the contained assets and capabilities.”

PRCI would like to acknowledge the members of the TDC Steering Committee for their dedication and support, as well as the PRCI member companies that have and continue to contribute samples and whose financial support help to supplement the TDC’s operations. In its first six months of operation, the TDC has hosted dozens of individual research projects, seminars and workshops. It will house expanded testing capabilities and additional samples in 2016.

State-of-the-art pull test facility with 24, 16, and 12 inch pull test strings.



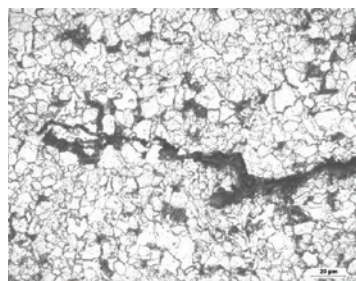
ILI CRACK TOOL RELIABILITY & PERFORMANCE EVALUATION

In the summer of 2015, PRCI completed a landmark study looking at the effectiveness of ILI tools to identify cracks in pipelines. The foundation for this study was the development of an extensive database of crack inspection data collected from pipeline operators through an industry-wide data mining exercise. The database was used to characterize the performance of ILI technologies with respect to detection, identification and sizing of crack features. ILI technologies considered in the study include magnetic and ultrasonic-based technologies.

The study resulted in the collection and analysis of over 50,000 crack features that were identified through crack detection ILI technologies, excavation and field NDE in the ditch, or both. The majority of the features included in the database are cracks detected in stress corrosion cracking (SCC) colonies (approximately 30,000), with a more limited number of features (approximately 6,200) detected in the longitudinal seam of the pipe. These data were analyzed using a number of approaches and techniques to establish the current performance specifications for crack ILI tools and to identify the areas where improvements can be made.

The study represents the first known exercise to establish an industrywide database for ILI technologies and has set a new standard for data mining as a basis for establishing ILI performance metrics. Significant results of this analysis concern crack shape and its influence on detection, burst pressure, and differences between ILI indications and field measurements, and effective crack detection depth.

The results from this study are useful for integrity management programs where the outcomes are sensitive to ILI tool performance. For example, risk modeling and integrity scenario comparisons can both make use of the results from this study. Phase II of this project will start soon and will focus on developing recommended practices based on the work done in Phase I and will aim to extend the analysis to include other similar integrity technologies such as EMAT ILI tools.



Accomplishments and Important Findings in Research



UNDERGROUND STORAGE

The Underground Storage Technical Committee focuses on the integrity of underground storage facilities, both reservoir (porous rock) and cavern, for both natural gas and liquids operators. 2015 results include:

- ▶ Storage well casing can experience downhole mechanical stresses that are quite different than those that affect pipelines. Downhole casing stress has the potential to affect the response of magnetic flux leakage (MFL) inspection tools used to determine the remaining strength of casing. Samples of vintage casing were logged with a conventional MFL tool prior to their removal from service, and tested under tensile stress in a controlled setting, where comparisons of the in-situ and stressed MFL results is conducted. This quantification of mechanical stress effects should reduce uncertainty in downhole inspections.
- ▶ Storage operators benefit from an improved understanding of the accuracy of magnetic flux leakage (MFL) tools used to characterize corrosion defects in the downhole well environment. A full NDE defect characterization of corrosion defects was performed on a number of casing joints that were previously in service and contain external and internal corrosion features. The results were correlated to field ILI measurements to determine the accuracy of the MFL inspection. These results can help operators with determining the inspection uncertainty when evaluating their well integrity risk, and whether or not casing should be taken out of service if the risk is too high.

OPERATIONS & INTEGRITY

The Operations & Integrity Technical Committee focuses on the integrity of the pipeline infrastructure and supports the continuity of service through the development and deployment of technologies to prevent, locate, characterize and assess integrity threats. The Operations & Integrity Committee accomplished several project completions and achieved important milestones for projects in 2015, including:

- ▶ Completed the construction phase of a DOT-PHMSA awarded major cost-shared project that will conduct pull tests of commercial ILI tools through pipe strings built with pipe samples containing well-characterized defect features. Initial tests by ILI vendors have been completed. The pipe samples are being provided by the TDC sample characterization work, which is being

PRCI conducts research to deliver intelligence and technology that address the needs of the worldwide pipeline industry and, by extension, the global energy consumers.



FIGURE 1
Setting the winch in place, April 14, 2015

supplemented by pipe with manufactured defects. The pull testing will include both improvement (full information testing) and evaluation (blind testing) trials to enhance technology performance and demonstrate its capabilities. This project will provide standardized testing protocols, challenging test specimens, opportunities for ILI technology improvement and an understanding of current technology performance. The project supports the response to an NTSB recommendation

to PRCI. The participating ILI vendors have coordinated with the PRCI project team and PHMSA to establish the specific testing technical protocols being used, and live tests (on blinded features) were completed in September, 2015. The pull-rig has 500 foot long 24 inch and 12 inch strings, and a 350 foot long 16 inch string. It is powered by a winch that will allow ILI tools up to 36" in diameter to be pulled up to 5 meters/second, thus simulating typical full speed pipeline inspection conditions. **(Fig. 1)**

- ▶ Completed technical notes on the management of pipe with plain dents, providing guidance to operators for which pipe joints with dents should be cut out vs. which can be safely monitored & maintained.
- ▶ Additional mechanical damage defect samples were created, including dents & gouges and dents with interacting defects, which will be used in subsequent remaining life modeling and ILI testing. **(Fig. 2)**
- ▶ Characterized a number of both emerging and widely-used in-ditch NDE tools that enable operators to better determine the nature, size and dimensions of pipe defects to reduce the uncertainty of critical dimensions and thus improve integrity management decision-making.
- ▶ Conducted a field evaluation of the performance of crack detection ILI tools across a very large number of features, corroborated by actual digs and in-ditch NDE for confirmation.
- ▶ Additional data-mining on an extensive array of vendor ILI data to assess whether ILI data can be used to establish pipe properties where the origin and specific grade of the pipe is not known.
- ▶ Acceptance and publication by the American Petroleum Institute of the PRCI work to update the publication *API 1149: Pipeline Variable Uncertainties and Their Effects on Leak Detection*. This

comprehensive update is a major step to more effectively model and validate the variable uncertainties that operators need to account for within their real-time pipeline leak detection monitoring. The original publication from API was published in 1993. Ongoing work to release a complementary software tool will be completed in early 2016.

- ▶ A Leak Detection Cable Based System Retrofit analysis study was completed to identify technologies or approaches for retrofitting existing pipelines with cables (e.g., fiber-optic cables, vapor-sensing tubes, etc.) for use in leak detection applications. This project was aimed at identifying any gaps or maintenance requirements that must be considered prior to retrofit installation of an in-the-ditch, cable-based technology to avoid damaging the existing pipe and provide full functionality of the leak detection system.
- ▶ Additional work was completed on the feasibility study of a Petroleum Pipeline Polymer Absorption Sensor Leak Detection Cable. The interim report evaluates the viability of interconnecting multiple underground Polymer Absorption hydrocarbon sensor nodes through a single cable that provides both power and data communication inductively to each node. The premise of this concept is that installing the cable alongside a pipeline would create a continuous underground sensor network that could detect any hydrocarbon migration from a leak and therefore would have sensitivity for underground hydrocarbon releases. A second phase of this project for large scale field testing is being developed for an additional three years starting in 2016.
- ▶ Hydrocarbon vapor plume modeling was completed, aimed at evaluating the proof of concept for two alternative methods for leak detection: 1) Monitoring petroleum hydrocarbon (PHC) vapors at or above ground surface over the released product, and 2) Use of plants as visual sensors to indicate the presence of a leak below. Key outcomes discussed include: mathematical modeling

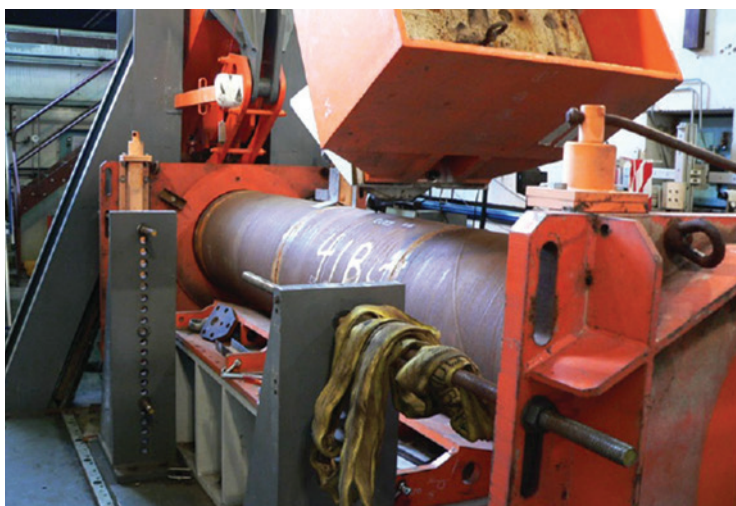


FIGURE 2

Gouges created in 24 inch Grade 70 pipe utilizing an excavator tooth

Members support PRCI research with technical leadership and expertise, time, funding and other valued material contributions.

of subsurface vapor transport and atmospheric dispersion, comparison of the model simulations to empirical data, a review of available portable sensing technologies to detect PHC vapors, and a review of mechanisms and species of plants that could be used as pipeline leak sensors.

- ▶ Field testing and demonstration of a prototype of a handheld gas leak detection tool that uses technology adapted from NASA's Mars Rover was completed in order to provide more reliable detection of methane releases. The final report describes Phase 1 of the project, the prototyping and initial testing of a hand-held, open path laser spectrometer (OPLS) capable of measuring natural gas based on tunable laser spectroscopy at 3.3 μm lasers. The prototype optical head and electronics together weigh < 150 g making it suitable for many airborne platforms. In Phase 2, this will be deployed on a small unmanned aerial system with testing to be completed in 2016.
- ▶ Completion of a Comparison of Radar Satellite Methods for Observation of Pipeline Infrastructure Stability. This final report discusses the use of Synthetic Aperture Radar (SAR) satellites for monitoring above ground pipelines and buried pipeline Rights-Of-Way (ROWs) using Interferometric Synthetic Aperture Radar (InSAR) techniques. The research evaluated the technique of utilizing the pipeline support members of above-ground pipelines as InSAR measurement points, and to adapt existing techniques to allow for precise monitoring of jacking and subsidence of the ground caused by permafrost dynamics.

DESIGN, MATERIALS & CONSTRUCTION

- ▶ **Guidelines for the Determination of Pipeline Lowering-in Stresses and Mitigative Strategies for Construction.** During construction of a cross-country pipeline, bending stresses are produced when the pipeline is lifted and lowered into the ditch. However there is little in the way of formal guidance in current codes and standards for controlling stresses during this construction phase. At present, two dimensional analysis and methodologies are generally employed to assure that the lifting and lowering-in stresses are maintained within allowable limits, typically by conducting a static analysis on level ground with the pipe shape as defined by an S-curve with all side booms equally spaced, taking up their portion of the load. There has been a very limited amount of three dimensional analyses conducted to simulate the actual pipe lowering operations with varying terrain and distances between side booms. While individual operator internal guidelines exist, there is not a comprehensive industry guidance document for this phase of construction that can be used by both owners and contractors. This project will bridge that gap, and is approaching its final phase with the following objectives:

extend the analysis to all pipe diameters, cover depths, and side boom spacing within given ranges; extend the applicable pipe diameter range; and develop a standard application tool suitable for both operators and contractors. An easy-to-use application tool will enable the ready selection of operational parameters to control stress levels during the lifting and lowering-in processes. All stakeholders will benefit by having access to construction best practices for enhanced integrity of new pipeline systems. This PRCI project is jointly supported by International Pipe Line & Offshore Contractors Association (IPLOCA) and the Interstate Natural Gas Association of America (INGAA) Foundation.



- ▶ **Guidance Document for Onshore Pipeline Route Selection and Associated Data Gathering.** Route selection for onshore pipelines has become progressively more complex over the past several decades due to ongoing land development and expansion of public and private infrastructure, coupled with increased population and environmental permitting constraints. Addressing these challenges, a PRCI project updated current route selection methodologies. This guidelines document is expected to reduce costs resulting from failure to anticipate various conditions that could impact construction. Pipeline construction contractors should benefit from more confident route definition allowing the reduction of contingency items in their cost estimates. This PRCI project was jointly supported by IPLOCA and the INGAA Foundation.

- ▶ **Development of Improved Methods for Estimating Remaining Fatigue Life of ERW Pipelines.** While the general fracture mechanics methodology for calculating fatigue life is well documented and validated, its application to define pipeline system fatigue lives has differed from field experience. Several elements were reviewed for sources of uncertainty that could be investigated to produce life estimates with known levels of conservatism. The project considered: 1) Ovality and misalignment stress concentration factors, 2) Fatigue crack growth rate (da/dN) material performance, and, 3) Bulging correction factor. Both experimental and numerical simulation techniques evaluated

FIGURE 3



the impact of these factors on the rate of fatigue crack growth of pipeline axially-oriented defects. The project results were compared to existing codified treatments to quantify the level of conservatism inherent in current practice for more precise ERW pipe integrity management.

- ▶ **Refined Methodology for Assessment of Weld High-Low Misalignment (Phase 1).** The impact of high-low misalignment on the load capacity of nominally defect-free girth welds was studied. Two girth welds, one mechanized Gas Metal Arc Weld (GMAW) and the other, a manual Shielded Metal Arc Weld (SMAW) with intentional high-low misalignment, were used in this study. One of these is shown in the photograph and sketch in **Figure 3**.
 - Shown in **Figure 4** are the measured high low misalignments around the circumference of two pipes represented by the offsets between the solid and dashed lines for both pipe specimens. For ease of visualization these variances are shown with X20 magnification.
 - Samples were tested to determine material properties; e.g. tensile strengths, hardness levels, and toughness. Tensile tests were conducted to assess the effects of high-low misalignment on the load capacity of the girth welds. Finite element models were constructed for simulating the cross weld tensile tests, and the tests and modeling was validated against each other. Follow-on work is underway to assist in code implementation.
- ▶ **Criteria for Determining Seam Failure Susceptibility Due to Crack Defects.** This research effort was aimed at developing a state-of-the-art fracture model to predict burst pressure of pipes with longitudinal seam weld flaws. Approximately 200 finite

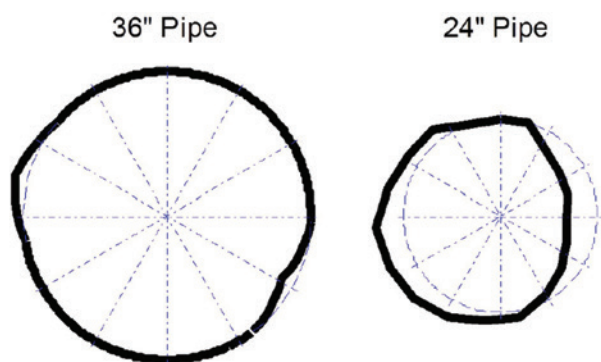


FIGURE 4

element simulations were performed, and the results were fit to a parametric equation. The report contains the theoretical framework of the model, a description of the finite element study, and a set of tables that contain fitting constants for the model. A rigorous fracture assessment entails comparing the crack driving force (the applied J-integral in this case) with the material resistance (a.k.a. the fracture toughness). The present work addresses only estimating driving force. A companion report, which is a critical review of crack assessment methods, considers both driving force and toughness, and is expected to be released later in 2016.

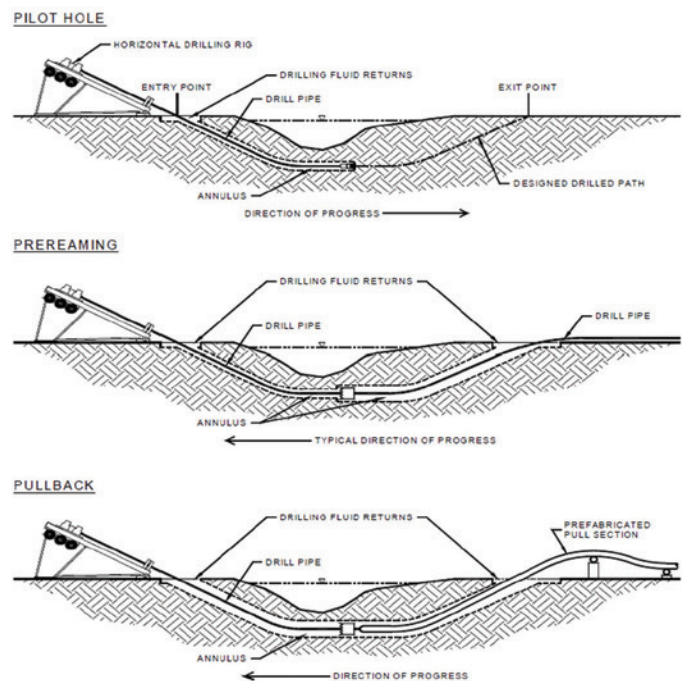
► **Corrosion Resistant Alloy Weld Overlay Pipes for Subsea**

Application. Research has been completed to examine the key issues in the manufacture and testing of full length weld overlay pipe. The work included pipe fatigue performance with different surface conditions through full scale resonance fatigue testing. The objectives were to determine the effect of pipe length on manufacturability, consider NDE alternatives for CRA pipe and evaluate fatigue performance. Follow-on work is underway to develop the NDE approach.

► **Guidance on Subsea Launchers and Receivers.** This state-of-the-art review of subsea launchers & receivers identified the issues that are currently limiting their use. These include their design & commissioning, and ongoing pipeline operations, maintenance and inspection. In addition, the effects of water depth and other relevant factors were studied. A subsequent phase of the research, underway now, will expand on these results and lead to a comprehensive industry guidance document.

► **Installation of Pipelines by Horizontal Directional Drilling, an Engineering Design Guide.** This report is a consolidated version of the original engineering design guide published first in 1995 and updated in 2009. It includes subsequent studies in a single comprehensive document for ready use by operators and consultants. As with the original document, it is intended to serve as a step by step guide for engineers engaged in the evaluation, design, and management of natural gas pipeline construction

FIGURE 5



by horizontal directional drilling (HDD). Topics covered include a description of the HDD process, technical feasibility and cost considerations, surface and subsurface site investigations, drilled path design, steel pipe installation and operating stress analysis, environmental impact, construction contracts, and construction monitoring. The design guide includes two Microsoft Excel workbooks for use in analyzing HDD installation loads and stresses on steel pipe. (Fig. 5)

CORROSION

The Corrosion Technical Committee completed several key projects in 2015. These projects include work that:

- ▶ Developed models and methods to determine appropriate corrosion growth rates (CGR) suitable for use with both reliability-based and deterministic integrity management methodologies. This work was accomplished by applying a stochastic CGR models that account for spatial and time dependence of external corrosion features. The established model accounts for basic temporal and model uncertainty, for the specific spatial context of corrosion growth, and for the fact that mass data produced by in-line inspection (ILI) tools/runs are themselves subject to sizing uncertainties. The result is detailed procedures for the estimation of suitable CGRs based on matched ILI data that accounts for sizing uncertainty. This can be implemented using an Excel-based analysis tool.
- ▶ Evaluated current practices and equipment used for assessing the

integrity of coating systems on pipelines installed in trenchless crossings. This study provides a review of the most reliable and cost effective methods for evaluating coating condition after a horizontal directional drilling (HDD) installation, and establishes a set of acceptable pass/fail criteria, in concert with HDD contractors, that can be embedded into standards or specifications. This approach can ensure operators that a pipeline segment will remain fully protected, both before and after the energizing of a permanent cathodic protection system.

- ▶ Evaluated the drying time of residual hydro-test water in challenging areas such as crevices and dead legs and its relative risk to internal corrosion. A “time to dry” calculation for both scenarios was conducted based on common pipeline operating conditions. The research took into account various operational factors such as temperature and pressure, as well as other factors such as crevice geometry, water content, and water type. The geometry considered for water drying in a dead leg included the entire dead leg, a section of the main line, and a section of the lateral line in a horizontal orientation. The result allows operators to determine if the trapped stagnant water poses any internal corrosion threat.
- ▶ Established a statistically-defensible process for estimating the degree of confidence that can be assigned to the effectiveness of a stress-corrosion cracking direct assessment (SCC-DA) program for maintaining the safety of a pipeline. This study builds on the currently accepted SCC-DA process by providing a usable and practical method for determining the number of excavations necessary or to limit the excavation program based on observed results. A Bayesian statistical methodology is used as a basis for the model which updates the likelihood of finding SCC on a pipeline segment based on the results of excavations and a predetermined confidence level.



FIGURE 6

One of several piping configurations evaluated. This assembly has a 4.3 nominal diameter inlet section and a 5 nominal diameter outlet section with 90° long-radius elbows and 5 nominal diameter risers on the inlet and the outlet.

MEASUREMENT

The Measurement Technical Committee's research provides measurement technologies that result in increased customer satisfaction and achieve cost savings through more accurate metering, better management of data, improved operating efficiency, and reduced capital expenditures. The Measurement Technical Committee completed several key projects in the past year, including:

- ▶ An evaluation of new generation ultrasonic meters installed in compact installations. This work focused on the potential to install multi-path wetted ultrasonic meters to measure natural gas in piping configurations commonly used by turbine meters. **(Fig. 6)**
- ▶ A performance assessment of gas ultrasonic meters in the presence of liquid transients. The research identified that the

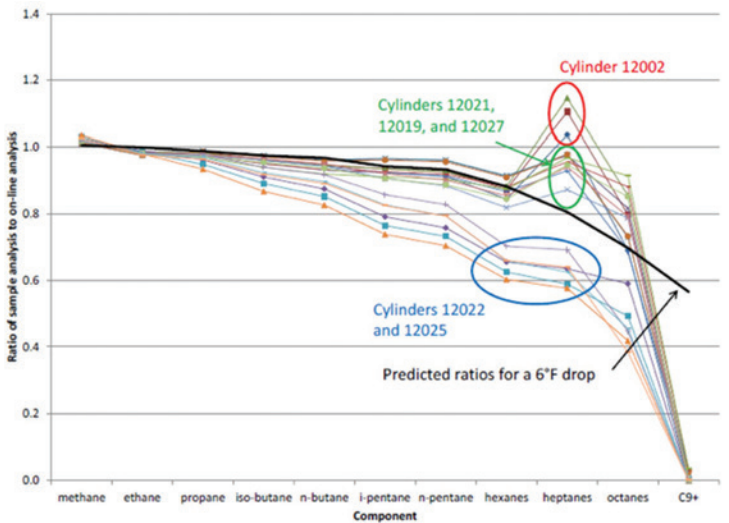
FIGURE 7
Test setup of ultrasonic meters in liquid transients. Meters from four different manufacturers were evaluated.



accuracy of ultrasonic meters shifts when liquids are present in the gas stream and that the shift did not return to baseline levels on all of the meters when the liquids were no longer present. (Fig. 7)

- ▶ Evaluating gas sampling techniques for shale gas. Shale gas often has small amounts of free liquids in the gas stream but the energy content used for custody transfer is only based on the gas portion. There are currently no established standards to address this situation. This project evaluated different sampling techniques to assess the range of energy differences that can be expected from shale gas. (Fig. 8)
- ▶ Determining when an ultrasonic flow meter should be removed from service for recalibration. Extending the interval between meter recalibrations can significantly reduce the cost of operation and reduce the disruption to service. (Fig. 9)
- ▶ Extensive work is being done to evaluate how different upstream piping configurations impact ultrasonic meter performance, even when the piping configuration conforms to accepted industry standards and practices.

FIGURE 8
Ratios of hydrocarbons retained in the shale gas samples.



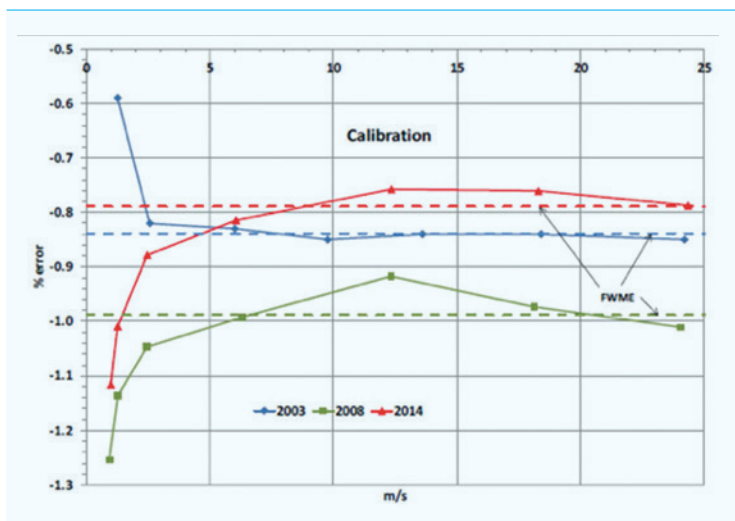


FIGURE 9
Meter baseline and recalibration data – multi-year comparisons.

COMPRESSOR & PUMP STATION

The Compressor and Pump Station Technical Committee's research is focused on controlling emissions of hazardous pollutants, enhancing engine reliability and emission compliance. Key 2015 results include:

- Field evaluation of oxidation catalyst degradation on a 2-stroke lean-burn natural gas engine. The work included an evaluation of the catalyst reduction efficiency over an extended time period. The presence of poisons on the catalyst surface reduces the conversion efficiency. **(Fig. 10)**

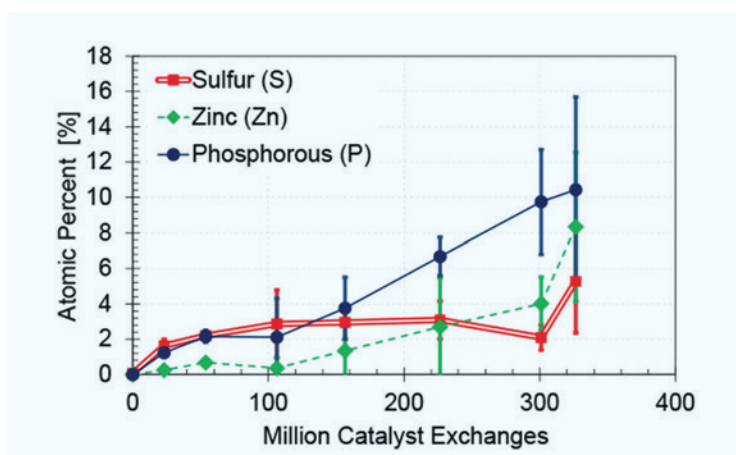
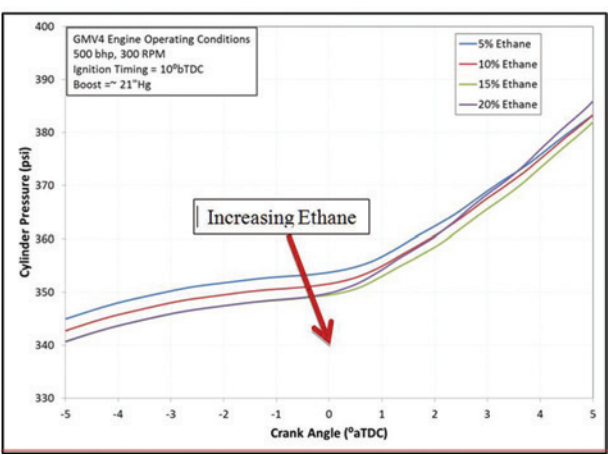


FIGURE 10

- Optimizing reciprocating engine controls to accommodate widely varying gas fuel compositions. **(Fig. 11)**

FIGURE 11
Effect of ethane content in fuel gas on location of peak pressure angle of combustion.



- Evaluation of speed stability as a measure of combustion stability for Continuous Engine Performance Monitoring (CEPM). The research confirmed that the detection of speed instabilities can identify underlying issues that are likely to cause misfire or damaging detonation. (Fig. 12)

FIGURE 12
A time domain trend of the speed stability factor.

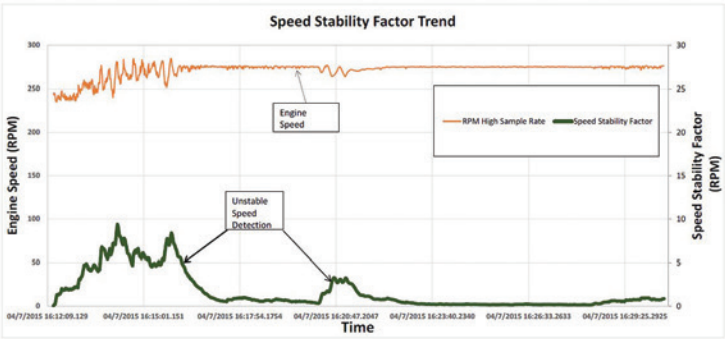
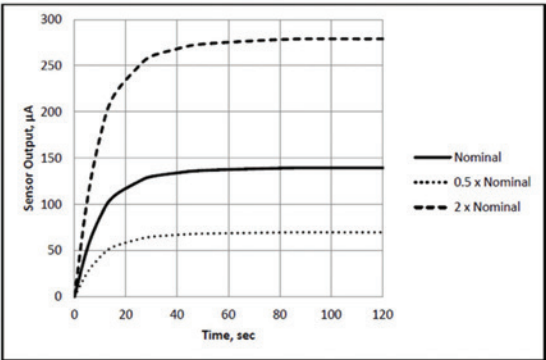


FIGURE 13
Emissions sensor output response time for three different concentration levels.



- An assessment of a portable emissions analyzer test method revision, and evaluation of minimum detection levels for common analyzers. This could lead to reduced air emission verification test requirements and less testing expense without any compromise in the accuracy of results. (Fig. 13)

Completed Research Reports

OPERATIONS & INTEGRITY

- ▶ Characterization of Detection and Measurement Uncertainties Associated with In-line Inspection Crack Detection Tools: Phases 1 and 2
- ▶ Internal Mobile Sensor to Detect Water and Corrosion in Pipelines – Phase 1
- ▶ Performance Evaluation of Current ILI Technologies for Detection and Discrimination of Mechanical Damage using Improved In-Ditch Tools
- ▶ Automated Floating Roof Seal Integrity Reporting Technology for In-Service Tanks
- ▶ Facilities Integrity Management Plan Guidelines Document
- ▶ Mitigating the Hazards Produced by Ruptured Pipelines: Phase 1 Evaluation
- ▶ Subsea Pipeline Damage Inspection Guideline Development
- ▶ State of the Art for Subsea Pipeline and Equipment Life Extension
- ▶ Vapor Plume Detection: Report Compilation & Summary
- ▶ Satellite-Based Pipeline Encroachment Monitoring
- ▶ Quantification and Extension of Lateral Ground Movement Detection Capabilities Derived from Synthetic Aperture Radar-Based Sensors
- ▶ Alternatives to Current Leak Detection Approaches for Hydrotesting
- ▶ Advanced Development of Proactive Infrasonic Gas Pipeline Evaluation Network (PIGPEN) Final Report

PRCI completed and approved over 40 final research reports in 2015.

DESIGN, MATERIALS & CONSTRUCTION

- ▶ Guidance Document for Onshore Pipeline Route Selection and Associated Data Gathering
- ▶ Development of Improved Methods for Estimating Remaining Fatigue Life of ERW Pipelines
- ▶ Refined Methodology for Assessment of Weld High-Low Misalignment - Phase 1 Report

- ▶ Criteria for Determining Seam Failure Susceptibility Due to Crack Defects.
- ▶ Evaluation of Composite Systems for Subsea Pipeline Repairs
- ▶ Development of Guidance on Subsea Launchers and Receivers – Phase 1 Report
- ▶ CRA Weld Overlay Pipes for Subsea Application Report on Phase 2 - Part 1 Investigation
- ▶ Installation of Pipelines by Horizontal Directional Drilling, An Engineering Design Guide
- ▶ Validation and Documentation of Tensile Strain Limit Design Models for Pipelines - Appendix 6A
- ▶ Database of Mechanical and Metallurgical Tests from X100 Welding
- ▶ Development of a Modern Assessment Method for Longitudinal Seam Weld Cracks

CORROSION

- ▶ Develop Corrosion Growth Models and ILI-Based Estimation Procedures for Reliability-Based and Deterministic Pipeline Integrity Assessments
- ▶ Investigate the Feasibility of Developing a Self-Healing Coating for the Prevention of External Corrosion Damage
- ▶ Evaluate Current Practices and Equipment Used for Assessing the Integrity of Coating Systems on Pipelines Installed in Trenchless Crossings
- ▶ Enhance and Validate Internal Corrosion Threat Models for Dry Natural Gas Pipelines (Phase II: Validation)
- ▶ Assess Drying Time of Residual Hydro-test Water in Challenging Areas (Crevice and Dead Legs)
- ▶ Establish a Procedure for Determining the Number of Excavations to Validate Stress-Corrosion Cracking Direct Assessment

COMPRESSOR & PUMP STATION

- ▶ An Alternative to PID Control for Critical Control Functions
- ▶ Reciprocating Engine Speed Stability as a Measure of Combustion Stability
- ▶ Pressure Spike Protection for Booster Pumps with ANSI 150 Flange Ratings
- ▶ Collecting Cold Ambient Emissions Field Data on Solar's Titan 130

SoLoNOx Gas Turbine

- ▶ Field Demonstration of the Benefits of Continuous Engine Performance Monitoring for CORE
- ▶ SCR Application to Typical Two-Stroke Cycle Pipeline Engines
- ▶ Technical Considerations for Developing a New Electrochemical Cell Portable Analyzer Test Method
- ▶ Variable NG Composition Effects in LB 2S Compressor Engines Phase I — Engine Response
- ▶ A Review of Variable Natural Gas - Composition Effects and Control Methods for Reliable Combustion in Lean Burn Two-Stroke Engines

MEASUREMENT

- ▶ Effect of Upstream Piping Configuration on Ultrasonic Meter Bias - Flow Validation
- ▶ Evaluation of Selected Sampling Techniques on Hydrocarbon-Wet Gas Streams
- ▶ Performance Evaluation of New Generation Ultrasonic Meters in Compact Installations without Flow Conditioners
- ▶ Smart USM Diagnostics - Phase 3
- ▶ Miniaturized Gas Chromatography and Gas Quality Sensor

Current Research

UNDERGROUND STORAGE

- ▶ It is argued that the top 3 or 4 joints of a storage well cannot be thoroughly characterized by magnetic flux leakage (MFL) tools because the extensive metal in the wellhead components and concentric casing distort magnetic flux fields and impede MFL use. In addition, the cement can settle back near the surface thus exposing the casing to air. A project is underway to investigate this concern by vertically suspending tubing specimens with known defects into a test well to simulate field conditions. Testing on the casing and tubing string assembly will be conducted using various downhole tools which utilize a spectrum of physical principles, including MFL, Ultrasonic, and Electromagnetic Eddy Current. The results will allow operators to determine the best tool application for their needs.
- ▶ PRCI is cofunding an ongoing multi-year study with the Solution Mining Research Institute aiming to extend the understanding of dynamics and flow-induced instabilities of brine and production strings used in salt-cavern applications. The work is divided into a theoretical and an experimental portion, and will feed into the brine string vibration field testing that is planned by PRCI in 2016. The findings from this will provide operators with added confidence for increasing the maximum allowable product flow velocity while maintaining brine string integrity, which is a primary feature limiting cavern storage productivity.

Every year, PRCI produces a collaborative Research Portfolio aligning with the industry's priorities.

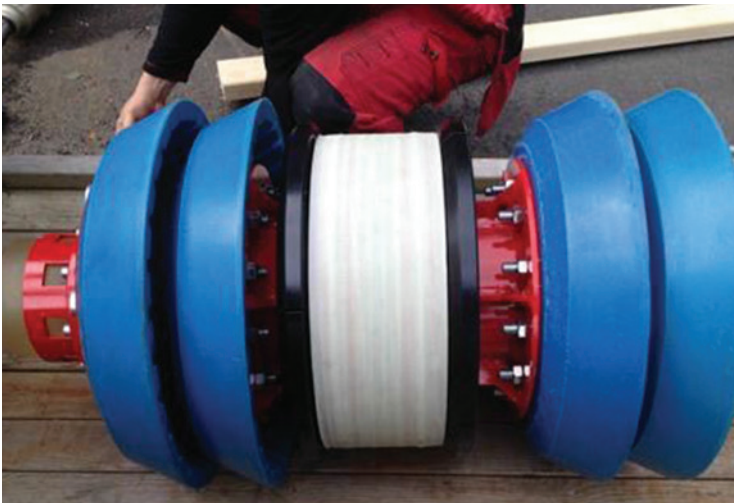
OPERATIONS & INTEGRITY

- ▶ The DOT-PHMSA ILI tool performance project is continuing with initial “blind” tests completed in September, 2015. The results will be compared to the “truth” data obtained through NDE measurements and a second round of pull tests labeled “improvement trials” will be conducted in early 2016 to provide an opportunity for the vendors to incorporate the findings of the initial runs to modify their analysis algorithms if needed. This second round of tests will be on a different feature set.
- ▶ Continuation of the extensive work to develop a crack management database by comparing additional ILI data to in-ditch NDE measurements. This will enable operators to continue to improve their crack detection and management practice, and further confirm the utility of available tools.
- ▶ Quantify the performance of several different magnetometry survey tools that provide a means to conduct standoff pipeline surveys to detect defects and any anomalies causing stress concentration. These

tools are particularly applicable to difficult to inspect pipeline segments. To facilitate this, a testbed was developed that simulates limited pipe access and extensive cover, for a realistic assessment of the performance of these external NDE alternatives.

- Multiple thrusts are underway to better characterize the structural significance of mechanical damage such that it can be managed optimally, including projects on: 1) Advanced Material Characterization for Dent & Gouge Samples, 2) Improved Strain Evaluation & Implementation of Damage Mechanics Modeling for dents interacting with welds and metal loss in vintage pipe, 3) Instantaneous Failure Model for Assessing Mechanical Damage in Vintage Pipe, 4) Improved Model for Predicting the Time/Cycle Dependent Behavior of Dent & Gouge Damage in both modern and vintage Steels, and 5) Fatigue Life Assessment of Dents & Dents Interacting with Welds to develop a severity ranking criteria for dents interacting with metal loss.
- NDE using inside-the-pipe technologies remains a mainstay of pipeline integrity management programs, and PRCI is attempting to broaden its application while evaluating novel equipment configurations and application approaches. Key projects include: Integrated Pipeline Monitoring and Cleaning Tool (ICIP), In-line Inspection and Assessment for Pipeline Girth Weld Defects, Magnetic Stress Gauge Capability Demonstration for the Characterization of Stresses Due to Land Movement using an ILI Tool, and Integration of Inspection Technologies onto a Tethered 10-inch Pipe Crawler Technology for the Inspection of Difficult to Inspect Pipelines. **(Fig. 1)**
- Existing ILI technology holds the promise to be able to detect conditions symptomatic of pipeline stress or bending strain, and other pipe properties such as wall thickness and pipe strength. The key enabling technology utilizes novel spatial pattern recognition methods, or neural models, which are data mining techniques

FIGURE 1
ICIP installed onto a Rosen 16" cleaning
pig in Norway



that allow specific signatures to be isolated from the general background noise. For ILI MFL data, the background noise will be specified as those signals expected from pipes within acceptable operating environments, thus enabling anomalous signatures to stand out. The promise for pipeline O&I applications is the in-line detection of pipeline stress and strain prior to metal deformation and ablation - signals that cannot be found using existing state-of-practice analysis techniques.

- ▶ Hydrostatic testing guidelines. PRCI's work will provide pipeline operators with guidelines for implementing hydrostatic pressure testing as a post-construction/pre-commissioning tool and for integrity management assessments and re-inspections. The project will quantify the effects of hydrostatic pressure testing on a range of test samples through operator data collection and analysis, small-scale testing in a highly controlled procedure, and full-scale validation testing of selected samples.
- ▶ The PHMSA proposed Integrity Verification Process (IVP) makes reference to an Engineering Critical Assessment process as a method that could be used to establish MAOP in lieu of a hydrostatic test or other records. The PHMSA proposal states the ECA process is yet to be defined by PHMSA. PRCI has completed a number of steps that could be used to determine MAOP, and this project will leverage prior PRCI and industry research to produce a guideline document for implementing an Engineering Critical Assessment for compliance with the IVP requirements.
- ▶ Continued progress was made by the Right-of-Way Automated Monitoring (RAM) Program in the development and operational deployment of a prototype automated threat detection system (ATDS) for fixed wing airborne surveillance of a pipeline right-of-way (ROW). In late 2015, the RAM Program will deploy the final automated threat detection algorithm and hardware integrated prototype ATDS technology developed in partnership with PRCI members, American Aerospace Advisors Inc. (AAAI) and the University of Dayton Vision Lab. Final results will be published in a report to be released in 2016.
- ▶ Several initiatives for Unmanned Air System (UAS) platform research were continued in 2015. As part of the ongoing work associated with the Right-of-Way (ROW) Automated Monitoring Program (RAM) researchers, associated with the Mid-Atlantic Aviation Partnership at Virginia Tech, tested new unmanned aircraft sensor technology in June under its approved Federal Aviation Administration Certificate of Authority. This work advances efforts to develop UAS technology for industry applications for safe ROW surveillance and operational uses. Continued flights and utilization of the RAM Program ATDS will be developed for data collection and validation for a fixed-wing UAS platform. Additionally, there are plans to fly the ATDS on a

PRCI members allocate resources directly to projects and programs of importance to their operations and business drivers.

UAS in partnership with NASA's Jet Propulsion Laboratory in 2016, in conjunction with Phase 2 of the Mars Rover-derived methane detection system project.

- ▶ Satellite work in 2015 was continued with the joint project with CalPoly and the Department of Transportation (DOT) Office of the Assistant Secretary for Research and Technology (OASRT), (formerly DOT Research in Innovation and Technology Association (RITA)). As part of a team with California Polytechnic (CalPoly) State University, PRCI is supporting a two-year program to advance satellite use in encroachment and threat detection monitoring along pipeline rights-of-way. The project includes use of satellite remote sensing, geospatial data information, and readily available web-based datasets to enhance existing pipeline operator Decision Support Systems (DSS) for response to observed system threats. The final results and release of the web-based DSS is expected at the end of the second quarter of 2016.
- ▶ A consortium project is underway to evaluate the ability to utilize satellite based InSAR data for measuring the ground subsidence related to longwall coal mining. This ground movement is typically rapid and aggressive. Final results are expected in the first half of 2016.

DESIGN, MATERIALS & CONSTRUCTION

- ▶ An evaluation of the long term performance of composite material repair systems for on-shore pipeline is now in its 7th year. This project is monitoring the condition of repairs on pipe joints under simulated in-service conditions. The long term evaluation program and parallel efforts examining specific applications and issues provide key inputs to the on-going development of a guideline for proper installation of composite repairs.
- ▶ The PRCI On-bottom Pipeline Stability Software Program is being updated to account for additional subsea conditions encountered by operators, with improved solution approaches and a better user interface. The beta version of the update has been issued for project team evaluation, with full release planned for 2016.
- ▶ As a follow-on to prior research, a guidelines document is currently being developed for the design and operation of subsea pipeline launcher and receiver facilities for cleaning & inspection pigs.
- ▶ Corrosion Resistant Alloy weld overlay pipes are being evaluated for subsea application with particular emphasis on inspection of the weld overlay layer and fatigue performance. In 2015, the focus shifted to inspection and the use of in-mill NDE inspection methods to assure the consistent pipe product quality for needed for such critical applications such as flowlines or tower risers.
- ▶ Continuing research in Geohazard Management includes a

project to develop guidance for predicting pipeline strains induced by slope movement. Local slope failure, slip plane definition, evaluation of slope failure severity, and definition of pipe strain limits are being investigated. These will be used to develop a classification for localized slope failures (i.e. insignificant, non-injurious, or significant) and thus enable design, monitoring and remediation decisions to be made based upon a better understanding of the likely significance of the geotechnical fault.

- ▶ Welding research is supporting greater reliability and consistency in the mechanical performance of linepipe welds. Essential welding variables for pulsed gas metal arc welding (GMAW-P) are being established that optimize consistency in mechanical performance while providing fabricators the ability to produce welds of desired quality.



- ▶ Research continues to provide additional guidance on methods to avoid hydrogen cracking which can affect both heat affected zones and weld metals. This is a particular concern for root passes due to parent metal dilution, applied load, and weld fault stress riser effects which all promote cracking. The Phase I report of this work is anticipated in the first quarter of 2016. The final phase of this research will occur in the coming year.
- ▶ Pipe double jointing offers operators significant opportunities for cost reduction. A project is underway to improve the quality and efficiency of this process by developing double jointing SAW welding procedures that factor in the effects of advanced welding systems and consumables on the required welding parameters and weld mechanical and metallurgical properties.
- ▶ Non-metallic pipe is an area of increasing interest to operators because it can provide a lower cost alternative for select transmission and gathering line applications. This project will develop a tool that permits pipeline engineers to efficiently

consider alternatives to steel pipe either to mitigate corrosion concerns or to enable installed cost reductions.

- ▶ Research continues to better understand the implications for operators of the widespread use of modern microalloyed steels, which can exhibit different performance characteristics than older steels. This will develop useful insights over the complete pipeline lifecycle including implications for design, construction, and maintenance activities.
- ▶ Structural integrity assessment methods are used to assess the strength of vintage girth welds; however, the required material properties are frequently not available so the values used in assessments are often taken from experience-based estimates. Such estimates can be overly conservative which may lead to unnecessary remedial actions. The objective of this research is to obtain basic properties of vintage girth welds and organize them into a searchable database that can be used to improve vintage girth weld structural integrity assessments. Important milestones in this research were achieved in 2015 and research will continue in 2016.



- ▶ Cracks often appear in clusters. The structural integrity impact of such clusters depends on the size of individual cracks, spacing among the cracks and material properties, etc. Flaw interaction rules are used to assess the significance of multiple cracks. Research in this area will improve the current methodology to enable more accurate assessment of the structural integrity of pipe with crack clusters. This is a critical need because with ongoing improvement in the resolution of ILI tools, increased detection of fine, dormant cracks is likely, thus triggering unnecessary remediation actions that have little benefit to pipeline integrity.
- ▶ A defect assessment procedure for sleeve end fillet welds is nearing completion. This work includes a numerical modeling

effort that considers a range of fillet weld defect depths and lengths from which parametric solutions have been developed to evaluate the potential for failure by both fracture and plastic collapse. This research complements existing work on pipeline repairs by providing state of the art methods to assess the integrity of sleeve repairs.

CORROSION

Ongoing research in the corrosion area focuses on the technical and operational challenges related to external corrosion assessment and mitigation. The current collection of research projects aims to provide operators with practical results that can be applied directly on-site and therefore have an immediate impact on managing the corrosion threat. These initiatives include:

- ▶ Validating newly established AC-induced corrosion criteria using real-world measurements of pipeline survey data along with pipeline characteristics. These criteria were developed under a previous PRCI effort aimed at refining the existing AC Corrosion criteria and guidelines for better control and mitigation of AC corrosion.
- ▶ Assessing the effectiveness of vapor corrosion inhibitors (VCIs) for corrosion control in casing annuli and aboveground storage tank foundations. This study will provide operators with a solid foundation on when to deploy VCIs as a corrosion control strategy, and how to gauge/monitor its effectiveness over the life-cycle of the assets involved.
- ▶ Developing an improved methodology for identifying coating faults and their severity through electrolyte resistivity measurements. This project is a continuation of last year's study on enhancing the classification of coating anomalies by measuring soil resistivity as close as possible to the pipeline to electrolyte boundary.
- ▶ Determining the effects of foam trench breakers and foam ditch pads on the cathodic protection of pipelines. This study will supplement a former PRCI research project to either dispel or confirm claims of cathodic protection shielding by these products through rigorous field and laboratory testing.
- ▶ Minimizing model driven uncertainties in current internal and external corrosion assessment criteria. This continuation project will examine the relationship between the shape factor and the bulging factor of corrosion defects through a numerical analysis for historical data. Full-scale burst testing will be conducted to validate the updated models and prove the utility of criteria in applications to higher-strength steels that supplements prior PRCI research.

MEASUREMENT

- ▶ Evaluation of the diagnostic capabilities of Coriolis meters to detect debris buildup and tube erosion.
- ▶ An assessment of the suitability of Coriolis meters in supercritical ethylene applications. The study will also evaluate the potential interaction of Coriolis meters installed in series for both gas and liquid applications.
- ▶ A study to assess the minimum necessary insertion length for gas sample probes
- ▶ An assessment of the capabilities of several static mixers to extract a representative liquid sample.
- ▶ Evaluation of the effects of gas stream pulsations on ultrasonic meter performance.
- ▶ Assessment of the impact of composite sample mixing methodology and centrifugal forces on the determination of density, sediment, and water.
- ▶ Assessing turbine and Coriolis meter diagnostics in flows with entrained liquids
- ▶ Using ultrasonic meter diagnostic parameters to estimate the measurement uncertainty.
- ▶ The effect of filters on ultrasonic meter performance.
- ▶ Assessing the performance of online instruments used to determine liquid density.
- ▶ Further analysis of the effect of upstream piping configurations on ultrasonic meter bias.

COMPRESSOR & PUMP STATION

- ▶ Further development of emission factors for greenhouse gas emissions reporting.
- ▶ Improvements to greenhouse gas measurement methods, procedures, and reporting systems.



- ▶ Additional field tests of continuous equipment performance monitoring for increased instrument reliability.
- ▶ Several ongoing and follow-on studies to assess varying gas compositions on engine performance and emissions.
- ▶ Field assessments of alternate materials and designs to prevent guide vane lockup on gas turbine axial compressors.
- ▶ Demonstration of improved control algorithms to reduce part load emissions for less restrictive load following on gas turbine engines.
- ▶ Field testing of timed power cylinder lubrication optimization.
- ▶ Development of field pump performance testing procedures.
- ▶ Gathering extensive data sets to support a modification of EPA-mandated NO₂ modeling.
- ▶ Continued work on modeling NSCR performance with exhaust mixtures from natural gas-fueled engines.



A low-angle, upward-looking photograph of a complex industrial facility. The image is dominated by a network of large, bright yellow pipes that curve and run horizontally across the frame. These pipes are supported by a grey metal framework of beams and brackets. In the background, more industrial structures, including a tall yellow tower and various valves and smaller pipes, are visible against a clear blue sky with a few wispy clouds. The lighting is bright, suggesting a sunny day, and the overall composition conveys a sense of scale and industrial complexity.

Initiatives for the 2016 Research Portfolio

UNDERGROUND STORAGE

Storage Field Integrity remains the primary focus of the Underground Storage Committee, with work generally directed at asset Integrity and risk assessment. Field testing of brine string integrity to assess whether fluid injection/withdrawal velocities can be increased is now planned for 2016 at a specific cavern site. Additional projects for the 2016 program include:

- ▶ Field Evaluation of a Cement Bond Log Tool in Gas Filled Storage Wells
- ▶ Assess the accuracy of MFL tools by comparing field-gathered data to controlled laboratory test results
- ▶ Review and Demonstration of Methane Emission Quantification Techniques for Storage Facilities

OPERATIONS & INTEGRITY

The Operations and Integrity Committee is being segmented into two Committees starting with the 2016 R&D program: the Integrity & Inspection Committee, and the Surveillance, Monitoring & Operations Committee. Together, they will address a number of critical issues facing pipeline operators as they strive towards the industry goal of zero incidents, minimal environmental footprint and cost-effective operations. Six new projects in the Integrity & Inspection Committee that will start in 2016 to address key needs in non-destructive evaluation and integrity management are outlined below. These augment a number of active projects in the 2015 portfolio that will continue into 2016.

- ▶ Metal in Close Proximity (MCP) indications extracted from MFL in-line inspection runs do not distinguish whether an object is another pipeline or a separate metallic article. However, MCP data can be used to detail the location of known pipeline crossings and identify sites that may be of concern due to CP interference issues or potential ground movement. This would facilitate additional focused monitoring.
- ▶ A liquid flow loop will be constructed in 2016 at the TDC. ILI tool flow test loops in North America are restricted to private operating company projects or individual ILI vendors. The availability of a flow loop facility to PRCI members will enable independent research identified by the PRCI R&D roadmap on ILI tools using liquid-coupled sensor technology.
- ▶ Unsupported branch connections or branch connections under loads due to unstable support conditions could lead to failures. No industry

The 2016 Research Portfolio will continue to address the key challenges facing the pipeline industry and deliver on the organization's core mission.

accepted method exists that could assist operators in identifying suspect locations in a measurably reliable way. PRCI will determine the ability of existing ILI technologies to differentiate the stress/strain in these connections. Results from this project would enable the development of an ILI-based service that could be utilized by operators to identify suspect locations and mitigate this threat.

(Fig. 1)

- ▶ Real-world features verses machined features. The real-world corrosion features (in pipe retrieved from service) with a wide range of conditions will provide a basis for assessing the difference between real world defects and machined representations of the real-world features as ILI test articles, when used in a controlled pull test setting. The project will provide input data for further improving ILI MFL technology for assessment of corrosion anomalies.
- ▶ In-line detection of long seams. This project will determine the performance of ILI technologies in identifying and characterizing anomalies in the longitudinal seam of ERW Pipe. Other long seam pipe manufacturing methods will be considered and included as appropriate. Recent results from the PHMSA ERW Pipe Program and the PRCI ILI Crack Tool Reliability Work have provided initial data on the performance of several ILI tools/technologies, with further analysis needed to supplement the existing data sets and further define ILI tool performance for seam anomaly management. Testing will be performed on a set of well characterized test samples for an objective basis for assessing ILI technologies and defining areas for improvements for detecting and sizing ERW seam anomalies.
- ▶ Analyzing ERW pipe crack growth rates. This project will supplement three prior phases of completed research through a full-scale testing and validation program to determine the rate of fatigue damage accumulation for fitness-for-service assessment of anomalies in ERW Pipe. The project results will support severity

FIGURE 1
**Branch connection test rig will be utilized
from a previous project**



ranking and/or inspection scheduling in liquid and gas pipeline systems by better understanding pipeline crack growth rates and stress analysis. This will result in an industry reference document and improve confidence and reduce conservatism inherent in present fatigue damage accumulation assessments and correctly define required inspection or pressure test intervals. The 2016 work is a final validation study using former in-service pipeline materials for the testing program.

The new Surveillance, Monitoring & Operations Committee will include the following 2016 research initiatives:

- ▶ **Petroleum Pipeline Leak Detection Cable - Polymer Absorption Hydrocarbon Sensor Node.** This research project is follow-on work to demonstrate the feasibility of an external leak detection system targeting the detection of very small releases from underground liquids pipelines. The technology combines polymer absorption hydrocarbon sensor nodes and inductive coupling for power and communication in a cable package suitable for deployment along the pipeline right of way. As part of the 2016 and future phases for this project, the objectives include: construction of a fully-contained test bed suitable for hydrocarbon release experiments, evaluating the system's effectiveness in realistic environments, understanding the limitations of the solution and developing deployment techniques for field service protocols.
- ▶ **Miniature Ethane & Methane Sniffer.** This project will extend the current miniature PRCI methane hand-held and UAS based sniffer system developed in 2014 & 2015 to include ethane. This instrument will help identify the source of natural gas leaks by differentiating them from bio-methane sources, such as sewers, plant waste decay, etc. The instrument will offer higher sensitivity than existing tools, allowing an earlier and faster identification of the methane source.
- ▶ **Ground Based Radar Monitoring of Slope Stability along Pipeline**

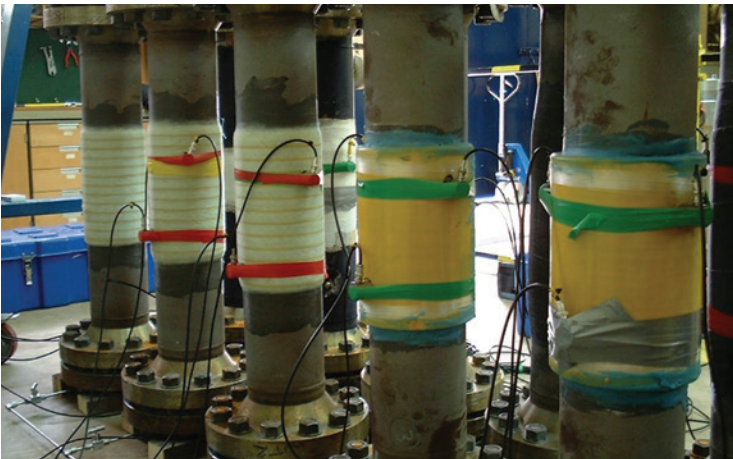


Rights of Way. This project is follow-on work to apply what was learned with the earlier compressor station monitoring to the application of slope stability monitoring. The objective is to demonstrate the ability of the Ground Based Synthetic Aperture Radar to measure small deformations on unstable (or moving) slopes along a pipeline ROW. It is intended to show that the technology can be used effectively on vegetated slopes using very small corner reflectors and that the technology can be used to derive precise lateral movement of ROW slopes. The project attempts to demonstrate if this approach can fill a gap in north to south monitoring that traditional satellite monitoring tends to be less effective at observing.

DESIGN, MATERIALS & CONSTRUCTION

The Design Materials & Construction (DMC) Technical Committee focuses on the technical issues identified in its research roadmaps for its seven key Emphasis Areas: Assessment & Repair, Design, Construction, Fracture, Materials, Geohazard Management and Welding. In addition to numerous continuing research projects supporting these emphasis areas, the following are new initiatives for 2016.

- In the Assessment and Repair Emphasis Area, DMC has managed extensive research on the performance of commercially available composite repair systems. The new initiative for 2016 focuses on quality assurance. This research will integrate lessons learned regarding inspection technologies from a parallel PRCI assessment of NDE technologies completed in 2014. This work will integrate full-scale testing using composite repair systems having known defects used to reinforce corrosion and dent anomalies. Inspections of the repairs will be made before and after testing to determine the effectiveness of the inspection technologies in identifying the composite defects and also determine how they might have changed through the course of static and



cyclic pressure loading. Finally, by pressurizing the samples and measuring strain in the reinforced sections of the pipe, an evaluation can be made as to whether or not the defects in the composite material impact the performance of the repair.

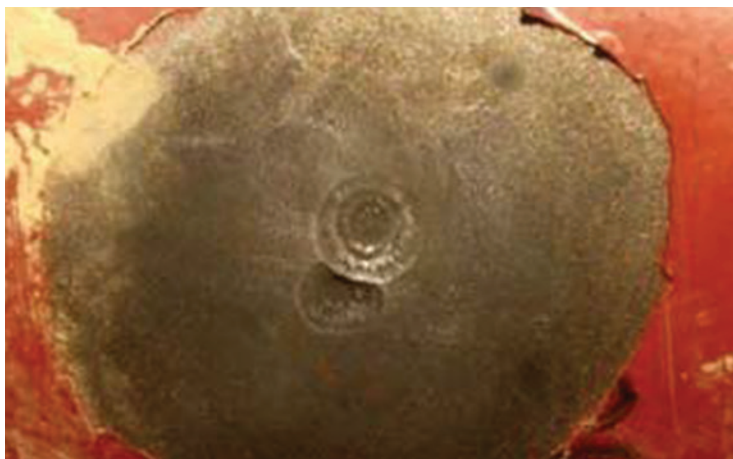
- ▶ Welding research begins a new initiative “Improved Reliability in the Semi-Automatic Welding of Pipelines.” This will expand the PRCI essential welding variables methodology as the first step in improving manual welding integrity and reliability. The results will provide practical recommendations for operators. In addition to improved awareness of the influence of individual operator technique on weld integrity, PRCI members will gain a quantitative knowledge of property variation of pipeline welds made with Flex-cored semiautomatic arc welding (FCAW-S) welds, and the correlation between weld property variation and welding parameter variation. The project will develop guidance for welding process and weld quality control to assure consistent weld properties and reduced repair rates.
- ▶ A new initiative in the Geohazard Management area reviews the effect of wall loss on pipeline strain capacity. Currently no systematic methods exist for Fitness for Service (FFS) assessment of strain-based pipelines with wall loss damage. By developing sound engineering methodologies for assessment, operators can avoid cost and time through reduced analysis and intervention effort. Finite element models will be validated by full scale tests and will be used to develop tools for quick assessment by operators. Tests will establish how much wall loss affects strain capacity, what aspects of wall loss have the largest impact, and validate finite element results that will be expanded to develop FFS methodologies.

CORROSION

In 2016, The Corrosion Technical Committee continues its focus on industry challenges related to external corrosion prevention and mitigation, as well as stress-corrosion susceptibility evaluation and repair. These initiatives are driven by a set of roadmaps developed by the Technical Committee which support the efficient integration of research results with other initiatives in PRCI and the broader pipeline industry.

- ▶ Assess high voltage direct current (HVDC) interference risks on buried pipelines by understanding the influence of HVDC system configuration and operational conditions, as well as pipeline and soil properties. This study will provide operators with a comprehensive field test protocol for on-site threat assessment, and a guidance document for predicting, assessing, and selecting counter-measures for mitigating HVDC interference.
- ▶ Evaluate AC corrosion coupons used for corrosion monitoring

applications. This project will identify and confirm the most significant factors impacting the sensitivity and reliability of various AC corrosion coupon assemblies. The resulting document will guide operators in selecting suitable monitoring hardware for accurate measurement and acquisition of AC corrosion related pipeline data, and specify proper installation and monitoring procedures for pipelines susceptible to AC corrosion.

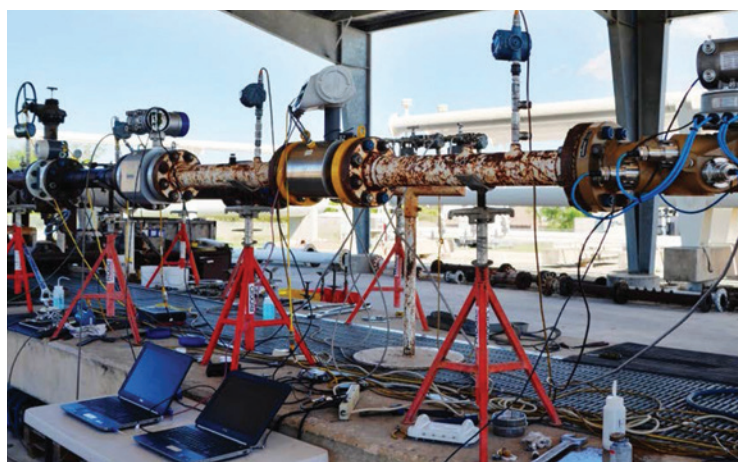


- ▶ Establish the potential severity of various cathodic protection (CP) shielding parameters. The aim of this work is to develop a list of pipeline operational variables and categorize their implications on CP shielding based on literature and incident reports. This effort will be in collaboration with NACE TG 523 “Consequences of Coating Failures as Related to Interaction with Cathodic Protection.”
- ▶ Characterize internal corrosion conditions under the deposits in the pipe wall and the effectiveness of corrosion inhibitors in controlling under-deposit corrosion.
- ▶ Assess the feasibility of a polarization shift-based cathodic protection (CP) criteria for mitigating stress-corrosion cracking. This study will develop a technical basis for the use of a polarization shift based CP criteria for mitigating High-pH SCC, in addition to the -850 mV polarized potential criterion presently used by operators.
- ▶ Improve the technical effectiveness of the stress-corrosion cracking direct assessment (SCC-DA) process as applied to near-neutral pH SCC. This study will investigate on-site measurement of key parameters which are well connected to the crack growth mechanism to determine the SCC risk level.
- ▶ Assess the sizing of crack anomalies using in-line inspection (ILI) data to that is confirmed by in-ditch NDE measurements to refine practical responses to ILI-based crack detection. This study will feed into a database for continuous improvement and application of lessons learned.

MEASUREMENT

New work to be performed in 2016 by the Measurement Technical Committee includes:

- ▶ Additional work using meter-generated diagnostic data to estimate the installation uncertainty of ultrasonic meters.
- ▶ Investigation of the effect of orifice geometry variations on the meter discharge coefficient.
- ▶ Full scale flow testing of ultrasonic meter upstream piping configurations on meter performance.



- ▶ Determining the effect of calibration gas blend on chromatograph accuracy and the evaluation of new gas chromatograph technologies.
- ▶ Estimating hydrocarbon dewpoint temperatures using inferred measurements.

COMPRESSOR & PUMP STATION

The largest effort of the committee is gathering extensive datasets to improve the accuracy of EPA's AERMOD NO₂ emissions modeling program to more accurately model NO₂ ground level concentrations. This is large undertaking that involves several other industry organizations. To date, a host site has been selected, monitoring equipment purchased and installed, and engines have been emissions mapped. The official data gathering period will begin near year-end 2015. The current EPA model was developed for power plants.

New projects for the Compressor & Pump Station Technical Committee include:

- ▶ A review of previous emissions data on a large bore, two stroke

cycle engine to assess which technologies have the smallest greenhouse footprint.

- ▶ Assessing technologies to use fugitive emissions from compressor rod packing and engine crankcase vents as engine fuel.
- ▶ Additional analysis of operator-reported greenhouse emissions data.
- ▶ Follow-on work to utilize portable emissions analyzers for emissions verification.
- ▶ Additional assessment of station piping layout on liquid pump efficiency and performance.
- ▶ Additional work on verifying liquid pump performance in field installations.
- ▶ Assessing alternate control techniques to reduce start-up and part load emissions from a Solar Turbines Taurus 60S.
- ▶ Developing best practices and design guidelines for vertical pumps used in liquid pipeline applications.
- ▶ Additional development of control methods to accommodate variable fuel compositions for both reciprocating engines and gas turbines.
- ▶ Additional evaluation and design refinement of a timed lube oil system for reciprocating engine power cylinders.



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PIPELINE RESEARCH COUNCIL INTERNATIONAL

Main Office

3141 Fairview Park Drive, Suite 525
Falls Church, VA 22042 • USA
Main +1-703-205-1600
Fax +1-703-205-1607
www.prci.org

Technology Development Center

6410 Langfield Road, Building J
Houston, TX 77092 • USA
Main +1-281-846-7570

