



2013

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
Eni S.p.A. (Italy)
Enterprise Products
Explorer Pipeline Company
ExxonMobil Pipeline Company
Gassco A.S. (Norway)
GDF Suez (France)
Kinder Morgan
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 Transmission, LLC
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



FULL ASSOCIATE MEMBERS

Applus RTD
Baoshan Iron & Steel Co., Ltd. (China)
China Petroleum Pipeline Bureau (China)
GE Oil & Gas
The Lincoln Electric Company
RCP Inc.
Shell Global Solutions (US) Inc.

TECHNICAL PROGRAM ASSOCIATE MEMBERS

Australian Pipeline Industry Association, Ltd.
Baker Hughes, Pipeline Inspection
Berg Steel Pipe Corporation
Cameron Compression
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)

Innospection Ltd (U.K.)
JFE Steel Corporation (Japan)
KROHNE, Inc. (Germany)
Mears Group, Inc.
NDT Systems & Services LLC
Nippon Steel & Sumitomo Metal Corporation (Japan)
Riccardelli Consulting Services
ROSEN USA, Inc.
ShawCor Ltd. (Canada)
SICK Process Automation (Germany)
Solar Turbines, Inc.
Stupp Corporation
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.)

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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.

A grayscale photograph of a person in a business suit, seen from the chest down, writing with a pen on a white document. The image is partially obscured by a large teal circle containing the number 1.

1

LETTERS FROM THE CHAIRMAN AND PRESIDENT

*2014 will be a year of operational excellence,
value creation and the implementation of
key relationships.*

A Letter from Chairman Christophe Renier

Welcome, and I am happy to share with you my vision for PRCI in the next future. First of all, let me highlight that today PRCI is truly an international organization. From 20 total members and 30% non-North American member companies in 2000, we have grown to 76 total members and 41% non-North American member companies. Having a European chairman for this organization is only one example.

Let me underline the great results achieved under Eric Amundsen's leadership as the previous Chairman of PRCI: under his mandate and with PRCI President Cliff Johnson, PRCI experienced a significant growth in its number of members, worked out its strategic plan, and developed key relationships with important industry organizations and the U.S. Department of Transportation (DOT).

Now it is time to reap the fruit from the organization's multiple R&D projects and programs by focusing on value creation for members and the industry. PRCI still faces great challenges and great opportunities.

PRCI shall increase its creation of value for its member companies in several ways:

- PRCI membership is more and more diverse, so information and expertise sharing as well as mobilizing a wide range of specialists, helps to address an equally wide range of problems: while in some areas the pipeline network is rapidly expanding, in other parts of the world operators optimize and manage pipeline networks that are less than 50 years old, and other areas are concerned by very old pipes. But safety, economics and sustainability remain the common objectives and allow us to build consistent R&D roadmaps for design and integrity, and help cross-fertilize exchanges among the experts of PRCI member companies.
- Continuously improving the R&D deliverables production process will be an area of particular emphasis, ensuring the involvement of the member companies' best experts to design, provide guidance, and verify the completion of the R&D efforts; constant attention is required to align R&D results with the real member company and industry needs.
- The PRCI Technology Development and Deployment Center in Houston is a significant achievement that transitioned in 2013 to a whole new level beyond solely PRCI projects, with significant participation and integration of member company projects around the samples in the repository center. This opportunity will have to be further developed.
- PRCI's ability to federate expertise and produce reference R&D for this industry was acknowledged by the U.S. DOT by requesting PRCI to perform specific R&D actions in the context of investigations of recent accidents. This mission is still underway, and will be monitored closely, as well as other projects funded by the U.S. DOT. They are strong assets for North American operators and the industry in general.
- Finally, as the energy business context is dramatically changing, and as new technologies such as nanotechnologies offer new opportunities or gamechangers, PRCI supports its members' efforts to successfully meet the challenges brought in by these changes by highlighting the new opportunities introduced by innovation and preparing R&D roadmaps that ensure that innovation serves the industry's objectives well.



The unique value of PRCI is to turn research into industrial and safety value with the expertise and innovative vision coming from any and all of its members. This is possible with the involvement and direction of the PRCI staff, the Board members, and the Technical Committee members through sharing and disseminating the results within the member companies.

I look forward to meeting these challenges and I am proud and grateful for your trust to let me serve as PRCI's Chairman.



Christophe Renier

A Letter from President Cliff Johnson



As we look back on 2013, we see another year of membership growth, the renewal of our relationship with the Pipeline and Hazardous Materials Safety Administration (PHMSA) of the U.S. Department of Transportation (DOT), and the progression of our research program.

Over the last year we were pleased to welcome two new Pipeline members, ATCO Pipelines and ConocoPhillips. We have increased the mileage represented by our members by over 8% in 2013 and currently represent over 60% of the world's transmission pipelines. Not only did we add new Pipeline members, we saw significant growth in our associate membership, as both RCP Inc. and Shell Global Solutions (U.S.) Inc. joined as Full Associate members in 2013 and serve on the PRCI Board of Directors. Additionally, we added six Technical Program Associate members: Berg Steel Pipe Corporation (U.S.), Innospection Ltd (U.K.), JFE Steel Corporation (Japan), Riccardelli Consulting Services (U.S.), TWI Ltd. (U.K.), and WorleyParsons Group Inc. (U.K.). These are all great additions to PRCI and we look forward to working with each of them.

This year we were able to reestablish our relationship with PHMSA. A few years ago there was a decision to halt government and industry co-funded research. The impact of the decision crippled a number of projects that were deemed important by industry and government. This was not the desired outcome and it has not increased pipeline safety. Last Spring, Congress passed a law requiring PHMSA to seek at least 30% co-funding for their research program. Once again establishing a Government-Industry partnership for research, PHMSA created three categories for their research program: 1) government and industry co-funded projects; 2) efforts that will be solely funded by government; and 3) a portion that is to be led by universities. Through the recent Research Announcement, PRCI was awarded one of the projects and many others have been jointly funded by industry. The project that we received is part of PRCI's NDE-4 Program and will be looking at enhancing in-line inspection (ILI) technology. The partnership with PHMSA is a great benefit for both the industry and government.

Our research program continues to grow by leaps and bounds. In 2013, over half of our budget was focused on Operations and Integrity related projects. In this area we are working to enhance ILI tools, exploring the impact of mechanical damage

and developing tools to address it, finding leaks before they become critical, working to understand the impacts of cracks and interacting threats, and working to ensure that we understand the potential threats on our rights-of-way. This is a large focus area for PRCI, however, we are active in a number of other critical issues for the industry, which are highlighted further in this publication.

We produced over 55 project final reports this past year. These reports range from an evaluation of low-cost gas energy sensors (BTU sensors) as alternatives to gas chromatographs, to the investigation of stress corrosion cracking (SCC) dormancy and re-activation behavior in terms of the effect of low frequency and cyclic stress typical of pressure fluctuation. These and many more are described in greater detail in this Year in Review. We have been able to produce a number of great reports, but we are not done yet and there is a lot of work to be done.

In 2014, we will be increasing our focus on research program execution and the value created by our research. We are looking forward to working with our members, industry, and government to ensure that we are moving forward with key projects and programs. It is important that we understand the value that is derived from our work and how our members are able to apply the solutions and tools that we are developing. In the coming year, we will be reaching out to our members to see how they benefit from participation in PRCI. We are looking forward to another great year in 2014 and we want to thank you for being a part of team!

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

Cliff Johnson



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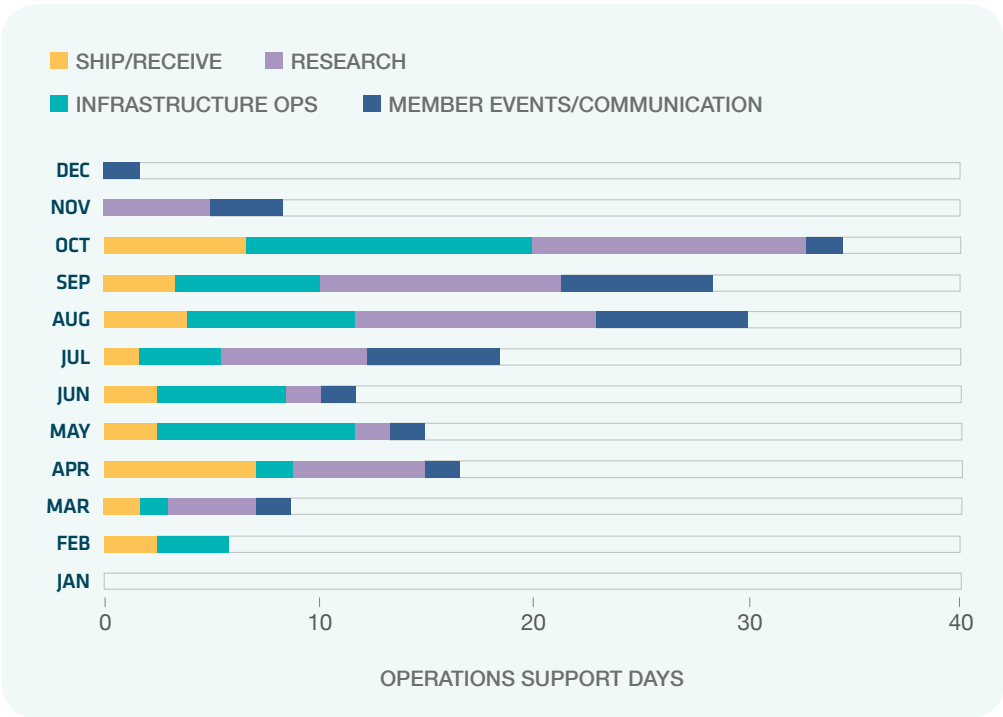
ACCOMPLISHMENTS AND IMPORTANT FINDINGS IN RESEARCH

PRCI members support the research program with technical leadership and expertise, funding and other valued material contributions, and the time and resources required to deliver intelligence and technology that address the needs of the worldwide pipeline industry and, by extension, the global energy consumers.

Operations & Integrity

The Operations & Integrity Committee accomplished important milestones for projects in 2013. The projects include:

- **Mechanical Damage:** Completed processing of recovered pipe containing rock dent anomalies and initiated a research contract under the Mechanical Damage Program to understand the cause for cracks in dents and the performance of ILI technology to detect and discriminate such damage. A total of 3,100 feet of pipe was prepared and screened for mechanical damage features under contracts issued to a construction support contractor attached to the PRCI Technology Development and Deployment Center.
- **Non-destructive Evaluation (NDE):** The infrastructure associated with the Technology Development and Deployment Center (TDC) in Houston was improved with the addition of pipe storage racks and 10-inch and 18-inch pipe test loops. Two Open Houses were held in 2013, one for PRCI Board Members in March and another in conjunction with the Fall Pipeline Technical Committee Meetings in October. A project with an aim of evaluating in-ditch NDE tools using the TDC completed trials of two external metal loss evaluation technologies: 2nd generation laser and structured white light profilometer. The utilization of the TDC is categorized by days supporting operations identified as pipe shipments, infrastructure construction, research conducted at the TDC, and member events and meetings.



Design, Materials & Construction

The Design, Materials & Construction Technical Committee completed several key projects in 2013. The projects include:

- **Materials – Seals for CO₂ Service.** With the increasing interest in CO₂ transport, PRCI completed research this year on the prevention of leaks in CO₂ pipeline valves and launchers by the correct seal material selection. The goal of this project

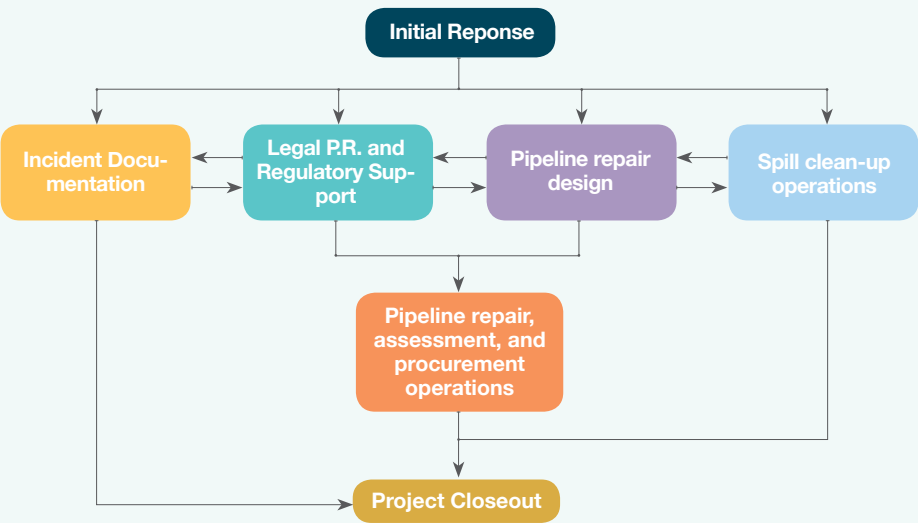
was to help prevent valve stem leaks in CO₂ injection applications, including supercritical services for both enhanced oil recovery (EOR) and carbon sequestration projects. The project examined the effects on non-metallic seals of impurities in supercritical CO₂ and developed guidance for seal-related concerns that arise when an existing pipeline is considered for supercritical CO₂.



The project resulted in guidelines for pipeline valve stem seals in CO₂ rich applications including EOR and carbon capture and storage (CCS). In particular, guidance was needed to ascertain when standard O-rings may be used, when a switch to rapid gas decompression (RGD) resistant O-rings is recommended, and when O-rings should be replaced by more robust energized lip seals and/or by more robust seal materials.

The guidelines interface with existing standards and give specific details on procedures, steps and decisions that have to be taken when attempting to qualify seals for dense phase CO₂ use. In order to develop these guidelines, two well established sealing compounds having proven RGD resistance were selected for study, along with two materials which were not known for their RGD resistance. RGD testing was performed on housed O-rings of each compound using four different gas compositions that cover an appropriate range of field conditions for CO₂ applications.

- **Assessment and Repair Subsea.** Subsea pipelines and flow lines are periodically subjected to damaging events such as anchor impacts that result in massive pipeline movements, dropped object damage, and internal/external corrosion damage. Knowing how to assess these damage events is often challenging, especially considering the potential for product release. The cost of production shut-ins can be significant and avoiding unnecessary shut-ins is desirable. While most pipeline operators have company-level procedures and programs in place for responding to



SUMMARIZED OFFSHORE PIPELINE DAMAGE INCIDENT RESPONSE GUIDELINES DECISION/TASK MATRIX

pipeline emergencies, at present there is no single resource for providing guidance for the pipeline industry. Project SPDA-1-2, Developing Guidelines for Evaluating Damage to Subsea Pipelines, was intended to fill that gap. This work resulted in the development of emergency response guidelines for operators to respond to offshore pipeline damage emergencies in an effective and timely manner.

One unique feature of this project is that the product was developed through a series of facilitated workshops to collectively build the Decision/Task Tree, which is the key feature of this work. Further, a collaborative effort was continued to develop detailed input for the report. This approach drew from a wide range of operator offshore experiences and best practices to develop the industry guideline.

A second unique feature is that this report is formatted as a computer-based entry portal – a “front door” to existing proprietary documents that each company has assembled for use in responding to an offshore pipeline damage incident. Critical company documents that exist in notebooks now can be scanned for incorporation with this front door framework. This guideline document in its final form can provide live links to the proprietary company documents, along with the materials that were developed for the project. This front door is intended for use on a computer that is linked to the internet. A very high level diagram of the approach is shown on the previous page.

Corrosion

The Corrosion Technical Committee completed several key projects in 2013. The projects include:

- A study that identified the most appropriate AC corrosion criteria based on literature data and analyses of established models from around the world. In total, 67 papers were reviewed in order to identify mechanisms of AC induced corrosion on pipelines under cathodic protection and possible stray current interference. It is concluded that AC and DC current density are the most important parameters determining the influence of AC on corrosion rate. Current densities can be measured on coupons or probes with a known surface. An extensive database of ER probe results was used in this study and the field observations were compared with simulation results. Additionally, the AC criteria were refined by combining the independent technologies in the validation process.
- Evaluated the corrosiveness of glycol-water mixtures in dry gas pipelines. The study provides a review of the state-of-the-art knowledge on glycol-water mixtures carried over to dry gas pipelines, including the physical properties, the causes of entry, and the corrosiveness of the mixture. The report also provides a list of recommendations to minimize the amount of glycol-water mixtures carryover and to reduce the corrosion risks associated with the mixture.
- Investigated stress corrosion cracking (SCC) dormancy and re-activation behavior in terms of the effect of low frequency and cyclic stress typical of pressure fluctuation. Additionally, the inhibitive effect of organics on the growth rate of SCC cracks was also considered. The study showed that under typical cyclic loading conditions, SCC growth demonstrates dormancy, indicated by blunting crack tips. High frequencies showed to dramatically increase the crack growth rates, while other parameters only slightly enhanced the crack growth. Based on this research, cracks under typical gas line operating conditions appear dormant.
- Developed criteria for pipelines' susceptibility to circumferential stress corrosion cracking. The report summarizes the capabilities of ILI to detect circumferential stress corrosion cracks or the conditions that promote them. Additionally, a method for calculating the size of circumferential flaws that can cause ruptures is presented and compared with service

experience. The calculation results can provide useful guidance for ILI requirements, and decisions can be made regarding which flaws need to be removed immediately. The benefits and limitations of hydrostatic testing also are described in the report.

Measurement

The Measurement Technical Committee completed several key projects in 2013. The projects include:

- An analysis on the impact of calibrating an ultrasonic meter at pressures and temperatures that are different than where the meter operates was completed. The results were significantly different for dry calibration than they were under flowing calibration conditions. Many ultrasonic meters compensate for geometry changes of the meter as operating pressures and temperatures. The study showed that these compensations are not always sufficient.
- A study to assess the ability of an ultrasonic meter to accurately measure in the presence of pulsations was conducted. The ability to accurately measure is dependent on the sample frequency of the meter and the frequency of the pulsation. The results varied by meter manufacturer.
- An evaluation of diagnostic tools for turbine meters was completed. The diagnostics were able to identify common operating issues affecting turbine meter performance including blockage directly upstream of the meter and bent/broken turbine blades.
- An evaluation of cost gas energy sensors (BTU sensors) as alternatives to gas chromatographs was completed. The study evaluated four different pieces of equipment. Some instruments performed much better than others. One instrument was found that is a low cost alternative with a fast response time such that it is suitable for continuous engine control optimization. The analysis determined that off-the-shelf configuration for some of the instruments is not sufficient for the natural gas transportation industry. Follow-on research is being conducted to evaluate alternate configurations and an additional instrument.
- A study was completed to evaluate the next generation of hydrogen sulfide analyzers. These analyzers do not employ lead acetate tape that is commonly used on conventional analyzers and therefore have less environmental disposal issues than most analyzers. Of the three instruments evaluated, all three accurately measured hydrogen sulfide but one of the instruments had a very slow response time.
- Extensive work is being done to evaluate how different piping configurations impact ultrasonic meter performance, even when the piping configuration conforms to accepted industry standards and practices. The header designs that appear to be the worst based on computational fluid dynamic modeling will be physically flow tested.
- Work was completed testing the next generation of gas ultrasonic meters in piping configurations typically used with turbine meters. The analysis concluded that these meters are acceptable for these shorter piping configurations when they are properly flow calibrated and configured.
- A study documented where the commonly used AGA-8 equations of state are reasonably accurate to the GERG 2008 equations of state. The GERG model is generally considered to be the current reference standard model. However, the AGA-8 model is reasonably accurate over most common natural gas compositions and operating pressures. This effort defined the range of gas compositions and operating conditions where the AGA-8 models are acceptable. This will eliminate the need for operators to replace electronic flow measurement equipment in many cases.

Compressor & Pump Station

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

- Evaluating the AERMOD air modeling tool with respect to relatively recent changes in the nitrogen dioxide (NO₂) ambient air quality regulations. The research has identified multiple factors that results in the over prediction of NO₂ by a factor of two to three times.
- A project to evaluate optimized timing of reciprocating engine power cylinder lubrication to minimize oil consumption and reduce particulate emissions associated with combustion of carryover lubricating oil.
- An alternate gas turbine design that significantly improves part load efficiency. The technology also improved engine turndown at lower ambient temperatures.
- Developing and enhancing diagnostic methods to pinpoint reciprocating engine performance deviations. The diagnostic methods will help ensure compliance with emission permit requirements and assist the operators with identifying the specific causes of performance deviations.
- Evaluation of industry related greenhouse gas data to develop more accurate and streamlines reporting methods.
- Developing software tools to assist operators in configuring lean-burn reciprocating engine control systems for optimum air/fuel control.

Underground Storage

The Underground Storage Committee program is primarily directed to ensuring the integrity of underground storage facilities, both reservoir (porous rock) and cavern, for both natural gas and liquids operators. 2013 results include:

- Completion of a study to review the factors that contribute to downhole geo-mechanical stresses and their possible effects on casing inspection methods. An extensive literature review was conducted to catalogue the potential mechanisms for imposing stress, including estimates of the magnitude of stress that might be imposed; an assessment of how in-situ stresses might affect the response of MFL tools; an assessment of how in-situ stresses should be considered in determining the remaining strength of casing; and an evaluation of methods for calibrating or verifying downhole MFL response (where confirmatory digs are not possible as with pipelines).
- Review of factors that affect well cement degradation and degradation mechanisms. Worldwide, leaks through wellbore failures account for about one-third of all product releases from underground storage facilities. The report investigated the conditions that can lead to the failure of the main structural seal in a well, the cement sheath created between the bore hole wall and the outside of the well casing and the casing itself. The report discussed methods that are used to determine the condition of the cement sheath and casing and methods employed that may repair leak pathways that might develop in the original cement sheath.

Completed Research Reports

OPERATIONS & INTEGRITY

- + Field Testing and Verification of Existing Tool Capabilities for Mechanical Damage Detection and Characterization
- + Guidelines for Safe Inspection and Repair of Mechanical Damage Defects
- + Internally Coated CS Risers as Alternative to CRA

DESIGN, MATERIALS, & CONSTRUCTION

- + A Comprehensive Update on the Evaluation of Pipeline Weld Defects
- + Development of Improved Methods for Estimating Remaining Fatigue Life of ERW Pipelines – Phase I
- + Development of Sleeve End Fillet Weld Fitness for Service Assessment Tools – Phase I
- + Field Validation of Surface Loading Stress Calculations for Buried Pipelines
- + Guidelines to Address Pipeline Construction Quality Issues
- + Offshore Pipeline Damage Emergency Response Guidelines
- + Standardization of Weld testing Methods - SE(T) Fracture Toughness Measurements – Phase I
- + Support for Standardization of Weld Testing Methods - Curved Wide Plate Testing

CORROSION

- + Criteria For Susceptibility to Circumferential Stress Corrosion Cracking
- + Determine the Effectiveness of the -850 mV On-Potential Criterion for Cathodic Protection
- + Determine New Design and Construction Techniques for Transportation of Ethanol and Ethanol/Gasoline Blends in New Pipelines
- + Develop a New Unique AC Corrosion Cathodic Protection Mitigation Criterion
- + Effect of Pressure Fluctuations on Growth Rate of Near-Neutral pH Stress Corrosion Cracking – Phase I
- + Evaluation of The Corrosiveness of Glycol-Water Mixtures in Dry Gas Transmission Pipelines
- + Improvements to Consequence Modeling in RBDA: Reliability Targets, Acceptable Risk, Updated Consequence Analysis
- + Investigation on Crack Dormancy of Stress Corrosion Cracking

MEASUREMENT

- + Better Defining the Uncertainties for the AGA-8 Equation
- + Effects of Liquid Contamination on Ultrasonic Meter Performance - Final Report
- + Evaluation of Enhanced Diagnostics for Orifice Meters
- + Investigation into High Pressure DP Transmitter Calibration
- + Proposed Sampling Methods for Supercritical Natural Gas Streams
- + Sensitivity of Clamp-On Ultrasonic Meters to Installation Effects & Pipe Condition
- + Testing of Orifice Plate Tolerance Specifications - Effect of Orifice Plate Manufacturing Variations on Orifice Meter Performance

COMPRESSOR & PUMP STATION

- + Determining the Effects of Ethanol on Pump Stations and Terminal Facilities - Guidelines Document
- + Field Demonstration of the Performance of Pre-Production and Production Ion Sense Hardware on Typical Pipeline Engines
- + Field Demonstration Test of Advanced Engine & Compressor Diagnostics for CORE
- + Gas Turbine Rotor Life Method & Procedure for Remaining Life Assessment of the Combustion Turbine Disks
- + Improved Part Load Efficiency of Solar DLE Units
- + Modeling of NSCR Performance with Exhaust Gas Mixtures from Natural Gas Fueled Engines
- + Minimizing Gas Compressor Lubricating Oil Consumption
- + Performance Measurements of Oxidation Catalysts on an Exhaust Slipstream
- + Physics-Based Characterization of Lambda Sensor Output to Control Emissions from Natural Gas Fueled Engines
- + Power Cylinder Timed Lube Oil Injection to Reduce Consumption and Oxidation Catalyst Fouling

UNDERGROUND STORAGE

- + Investigation and Review of Mechanisms that Lead to Well Cement Deterioration and Failure
- + Underground Storage Downhole Factors Affecting MFL Response and Analysis



3

CURRENT RESEARCH

Every year, PRCI produces a collaborative research program aligning with the industry's priorities to which members allocate resources directly to projects and programs of importance to their operations and business drivers.

Operations & Integrity

○ Mechanical Damage

- Continuing projects for evaluating the performance capabilities of ILI tools.
- Full Scale validation of mechanical damage assessment models.
- Improved models for predicting burst pressure of dents with gouges.

○ In-line Inspection

- Continued research concerning the feasibility to determine line pipe properties from ILI data.
- Feasibility of mechanical property measurements for low toughness vintage pipe.
- Evaluation of the reliability of crack detection tools.

○ Non-destructive Evaluation & Difficult to Inspect

- Continued development of the Integrated Cleaning and Inspection tool.
- Continued development of EMIT sensor for difficult to inspect pipelines.
- Development of improved crack depth measurement techniques.
- Evaluation of NDE techniques applied to the assessment of composite wrap repairs.
- Evaluation of magneto tomography method technology (Large Standoff Magnetometry).
- Characterization of anomalies (metal loss cracks and dents) in the TDC inventory.

○ Subsea Pipeline Integrity

- State of the art study for subsea pipeline life extension.
- Review of erosion and corrosion monitoring technologies.

Design, Materials & Construction

- The Design, Materials & Construction (DMC) Technical Committee continues its extensive research program in the use of composite material repair systems for onshore energy pipeline applications with the on-going evaluation of the long term performance of commercially available repair systems.



Composite Repairs



- While composite repair systems have been used extensively for onshore energy pipelines, operator experience with offshore applications is minimal. To examine the applicability of composite repair systems in the subsea environment and their performance under subsea conditions, composite repairs are being installed under conditions that as close as possible simulate that environment, as shown in the photos on the previous page.
- In the welding arena, research continues to achieve greater reliability and consistency in the mechanical performance of X80 and lower grades of pipe line welds. Essential welding variables for pulsed gas metal arc welding (GMAW-P) will be established that optimize consistency in mechanical performance while providing fabricators the ability to produce welds of desired quality. This work leverages the new understanding and methods that were developed for high strength steels during the seminal 21st welding research initiative that was completed last year.
- Pipe double jointing offers operators significant advantages. The objective of this project is to improve the quality and efficiency of this process by developing double jointing SAW welding procedures that will provide consistently acceptable material properties and can be readily applied. Research is considering the effects of advanced welding systems and consumables on the required welding parameters and weld mechanical and metallurgical properties. The sensitivity or range of parameters that can be used in the procedure will be defined. The research will also develop testing guidelines to support the characterization of the properties.
- Code-based weld flaw assessment methods are either silent or provide only minimal treatment of weld high/low misalignment. Misalignment leads to increased likelihood of weld flaws. Repairs on deep flaws are problematic as they have a much higher risk of hydrogen cracking particularly for X70 or higher grades. Therefore, it is important that codes have realistic procedures for assessment of flaws coincident with weld misalignment. With realistic procedures, it will be possible to avoid repair of innocuous flaws and/or allow specification of maximum misalignment. This research is providing the experimental basis to validate methodologies for assessment of weld high/low misalignment.
- DMC structural integrity research also includes improving the methods to estimate the remaining fatigue life of ERW pipelines. The objectives of this work are as follows: to improve the understanding of the most commonly used crack growth models, determine the fundamental differences among those models; evaluate the benefits of various refinements to the analysis process; and to provide information concerning the determination of initial defect sizes to be used in fatigue analyses of ERW pipelines, based on the likelihood of defects going undetected in the steel mill.
- Research is also being accomplished to develop a complete defect assessment procedure for sleeve end fillet welds. This work includes a numerical modeling effort considering a range of fillet weld defect depths and lengths from which parametric solutions will be developed to evaluate the potential for failure by both fracture and plastic collapse. This research will complement existing work on pipeline integrity and repair by providing state of the art methods to assess the integrity of sleeve repairs.

Corrosion

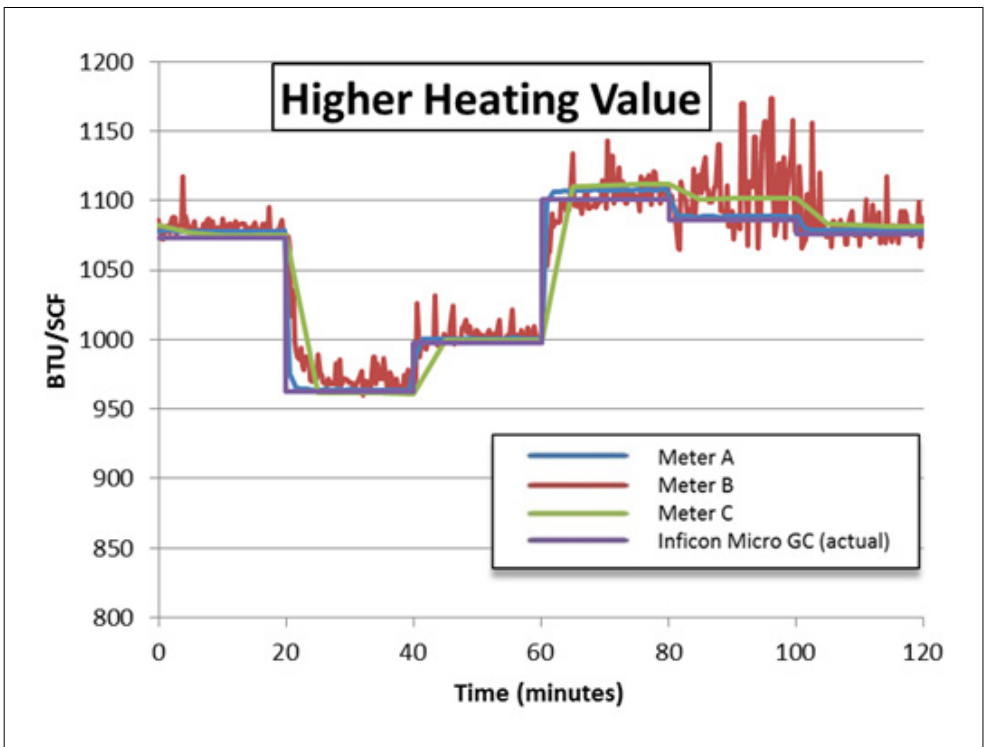
- Evaluation of current practices and equipment used for assessing the integrity of the coating system in trenchless crossings. The deliverable will include a re-evaluation of the various methods of assessing coating quality, a recommendation

for the most reliable and cost effective method(s), and a pass/fail acceptance criterion for coating conditions.

- Development of pipeline coating fault excavation and inspection documentation procedures to increase the accuracy of external pipeline inspection technologies. The outcome will enhance operators' ability to accurately plan and budget pipeline repairs based on the results of indirect inspections as part of ECDA inspections.
- Improving the performance of the External Corrosion Direct Assessment (ECDA) methodology by generating an integrated ECDA "report card" and provide a benchmark for operators to compare individual ECDA metrics.
- Investigation of an alternative method for potential measurement to assess the level of cathodic protection on a buried or submerged metallic pipeline. If successful, this research may provide a new technology that can more accurately determine the effectiveness of cathodic protection on buried pipelines.
- Developing guidelines for an internal corrosion sample collection process. The goal is to help pipeline operators manage internal corrosion threats through better knowledge of the effects of time on the composition of liquid and solid samples.

Measurement

- A tool for calculating the uncertainty of measurement facilities for liquids is under development. This will be a tool similar to one previously completed for gas measurement facilities.
- Work is underway to evaluate the diagnostic capabilities of Coriolis meters.
- Additional study is underway to assess the effects of liquid contamination on ultrasonic meter sensors. Previous work has shown that there was a shift in meter



accuracy when exposed to high concentrations of liquids. This work will test lower concentrations of liquids and assess if the meter performance returns to normal after the liquid loading is removed for a period of time.

- Work on design guidelines to minimize flow induced pulsations at metering facilities is nearing completion.
- A study is being performed to assess 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 computational fluid dynamics study is underway to assess the potential measurement error associated with thermowell designs, especially under low flow conditions.
- Development of low cost sensors to measure hydrogen sulfide, water, and oxygen in gas streams is underway. The goal is to significantly reduce the installation and operating costs to install these sensors that can detect potentially corrosive gases.

Compressor & Pump Station

- Additional work is being performed to develop emission factors for greenhouse gas emissions reporting.
- A field test of continuous equipment performance monitoring is underway.
- An evaluation of controlling pump transients to protect low pressure piping components is being performed.
- A study is being performed to evaluate laser based instruments to measure nitrous oxides and carbon monoxides in engine exhaust.
- A field evaluation of non-selective catalytic reduction control systems is being performed.
- An evaluation of gas turbine emissions at cold ambient temperatures is nearing completion.
- A study is being performed to assess varying gas compositions on engine performance and emissions.
- A field study is being performed to assess the long term performance of oxidation catalysts on lean burn reciprocating engines.
- A paper study is underway to evaluate the feasibility of fuel additives to reduce the formation of nitrous oxides.
- A study is nearing completion to evaluate the hazardous air emissions from gas turbines.
- A study is continuing to assess alternate materials and design to prevent guide vane lockup on gas turbine axial compressors.

Underground Storage

- Storage wells that were scheduled for casing replacement were logged with MFL tools before the pipe was removed from service. This casing is over 60 years old. Samples of the recovered pipe have been sent for conclusive documentation of the exact metal loss (primarily external corrosion) and closer examination of any other defects, in order to better calibrate the MFL algorithm results and to have test articles for the planned MFL stress-effects testing. This enables the MFL results on legacy pipe to be compared three ways: with known stresses applied in a test fixture, with in-situ loadings, and under external stress. These results will be run through the existing RSTRENG calculation for remaining strength, and be validated against burst testing to further refine the use of RSTRENG for casing replacement/repair decisions.



4

INITIATIVES FOR THE 2014 RESEARCH PORTFOLIO

Through the collaborative research model that PRCI employs, we have developed a research program for 2014 that will continue to deliver on the organization's core mission of technology development in support of safer and more environmentally friendly approaches to operating and maintaining the energy pipeline infrastructure around the world.

Operations & Integrity

- **Mechanical Damage.** There are two mechanical damage programs; the first is mechanical damage inspection and characterization, the second is full scale experimental validation of mechanical damage assessment models. These programs were funded to 75% of that requested on the 2014 ballot. Due to the underfunding an alternate execution plan was developed at the Technical Committee meeting to prioritize desired work and defer as appropriate unfunded research work to subsequent years
- **In-line Inspection.** In September 2013, the Pipeline and Hazardous Materials Safety Administration of the U.S. Department of Transportation awarded to PRCI a contract to develop an industry test facility and qualification processes for in-line inspection technology evaluation and enhancements. The total value of the work is \$5.2 million with \$1.4 million dollar cost share from the government. The PRCI cost share is \$3.8 million which is made up of in-kind value represented by the TDC sample inventory and characterization and PRCI member research funding. Due to timing and historical experience associated with PHMSA research awards this project was not placed on the 2014 ballot. A proposition was placed before the project teams for the ILI program (NDE-4) and to manage this research from the ILI program and reprogram funds from the seam weld integrity management project (IM-3) based on like objectives related to measurement and reestablish the seam weld integrity funding on a subsequent ballot.
- **Non-destructive Evaluation.** Research was funded in 2014 to evaluate the capabilities for pipeline girth weld assessment using MFL based ILI by comparing to UT-based ILI. This project was proposed by PetroChina and will be executed by PetroChina research group under the co-leadership of Kinder Morgan and PetroChina.

Design, Materials & Construction

- A project has been started this year to develop an industry guideline for pipeline operators to use for evaluating existing and future composite repair systems. The absence of such a document presents challenges for operators to evaluate the competing composite repair technologies, objectively. Because not all composite repair systems perform equally, and field failures have occurred, it is essential that minimum acceptance criteria be established. This includes design validation for the repair system itself, but will also include establishing quality control measures focused on manufacturing, handling, and installation.
- Updates to the PRCI On-bottom Pipeline Stability Program to account for additional subsea conditions, not currently in the software program but being encountered by operators. In addition, this program is being improved to include improved solution approaches and to provide a better user interface.
- Operators have reported concerns with the use of launcher and receiver facilities and procedures for cleaning and inspection pigs in subsea energy pipelines. In response, the Committee is pursuing research with the objective of identifying best practices and developing an industry guideline for the design and operation of these facilities.
- Hydrogen cracking has and continues to be observed in both heat affected zones and weld metals. High carbon equivalent weld heat-affected zones (HAZ) combined with rapid cooling produce susceptible microstructures. Weld metal cracking is observed in both high and low strength welds. It is a particular concern for root passes due to parent metal dilution, applied load, and weld fault stress riser effects

which promote cracking. Therefore, the DMC Committee has initiated research to develop a new weld hydrogen cracking susceptibility-prevention, design approach.

- In the non-metallic pipe area, the DMC Committee is initiating a research project to examine commercially available non-metallic pipe materials that are suitable for transmission and gathering lines. The goal of the research is to develop a tool that permits pipeline engineers to efficiently consider alternatives to steel pipe conveyance either to solve corrosion issues or to allow cost reductions through the efficient selection of alternative pipeline material solutions.
- Structural integrity assessment remains a DMC Committee priority. To assess the strength of vintage girth welds, the needed material properties are frequently not available so the values used in assessments are typically 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 in a searchable database that can be used to improve vintage girth weld structural integrity assessments.
- Cracks, like SCC, often appear in clusters. The structural integrity impact of such clusters depend on the size of individual cracks, spacing among the crack, material properties, etc. Flaw interaction rules are often used to determine the impact of multiple cracks. This project will develop a methodology to allow accurate assessment of the structural integrity of pipes with clusters of cracks, like SCC. This is a critical need because, with ongoing improvement in the resolution and accuracy of ILI tools, it is likely that more and finer cracks will be found. Accurate representation of the impact of clusters of cracks can reduce unnecessary remediation actions while also assuring the pipeline integrity.

Corrosion

- Monitor the effectiveness of cathodic protection systems at Horizontal Directional Drill (HDD) crossings. This project will support and supplement the current research effort on the evaluation of coating quality at HDD crossings.
- Determine the corrosion risk of fluctuations in AC interference on pipelines buried along high voltage AC transmission corridors. This study will likely involve a laboratory test program in a soil box to predict the AC corrosion occurrence risk at various operating conditions.
- Minimize model driven uncertainties in current internal and external corrosion assessment criteria. This project will examine the relationship between the shape factor and the bulging factor of corrosion defects through a numerical analysis for historical data.
- Examine the effect of pressure fluctuations on the growth rate of near-neutral pH stress corrosion cracking. The effort will build on recently completed research to better understand this phenomenon.
- Determine the drying time of residual hydrotest water in pipe crevices, side branches and dead-legs based on operating conditions. This research effort will allow operators to determine if the trapped/stagnant water poses any internal corrosion threat.



- Validate the existing models and guidelines for internal corrosion threat evaluation in dry gas transmission pipelines. Field and operational data will be used for the validation process.

Measurement

The Measurement Technical Committee has identified emerging issues that they will focus on in the upcoming research efforts. Specifically the increased production of shale gas has resulted in several technical issues:

- Gas compositions vary widely, even on an hourly basis.
- Gas compositions contain higher concentrations of ethane and propane.
- Gas sampling is often performed at or to the left of the phase curve line where both gas and liquid phases exist.

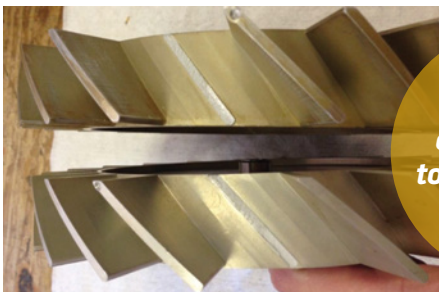
The accuracy of quantifying the sediment and water content in liquid products is a new focus area for the committee. While there are existing standards for this type of testing, a wide range of results can be produced depending on the specific testing methods. This research is especially important on heavy crude oils.

Other work to be performed includes:

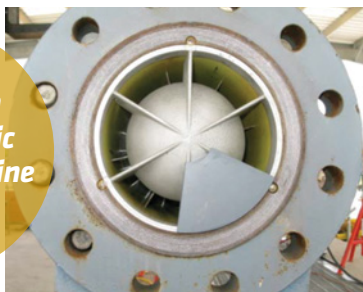
- Additional flow assessment of ultrasonic meters with various upstream piping configurations.
- Additional evaluation of the next generation ultrasonic meters in compact piping configurations.
- Evaluating turbine and Coriolis meter diagnostics on gas streams with entrained liquids.
- Additional evaluation of ultrasonic meter diagnostics.
- Assessing sample probe and thermowell designs for mechanical integrity and measurement accuracy.
- Additional analysis on determining the recommend recalibration frequency of ultrasonic meters.

Compressor Pump Station

The widespread production of shale gas is having an impact on the reliable operation of engines. As such an area of focus for the new research is to optimize engine controls for dynamic changes in gas composition. The goal is to maintain air emission



*Evaluation
of diagnostic
tools for turbine
meters*



permitted limits while avoiding unnecessary power reduction to avoid engine damaging detonation and pre-ignition.

Also of importance is developing a plan to modify AERMOD to more accurately model the real world. This will be a large undertaking that will require coordination with other industry organizations.

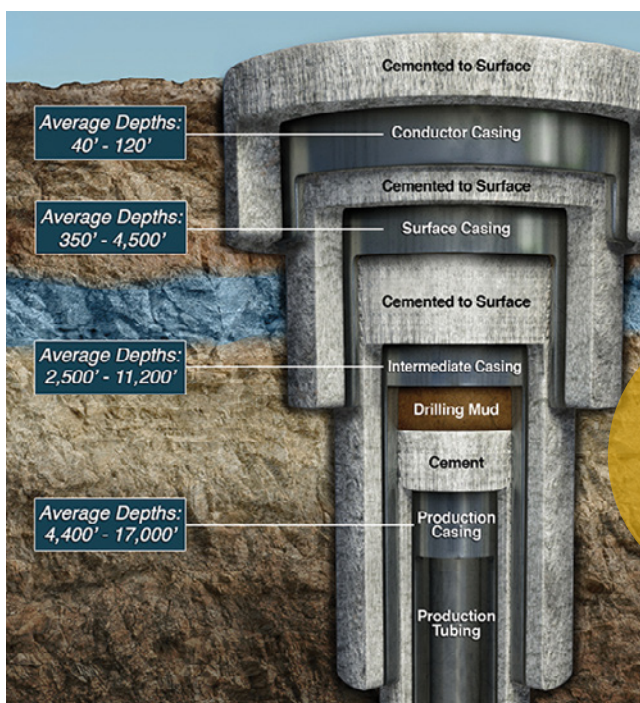
Other work to be preformed includes:

- A field evaluation of optimized power cylinder lubrication injection.
- Developing field pump performance testing procedures.
- Alternate gas turbine lean premixed combustion control to reduce emissions on startup and shutdown.
- Updating test method protocols to include the use of portable emission analyzers.

Underground Storage

The Underground Storage Committee program is primarily directed to ensuring the integrity of underground storage facilities, both reservoir (porous rock) and cavern, for both natural gas and liquids operators. Key 2014 projects include:

- Evaluation of the effects of downhole geo-mechanical stresses on the accuracy of magnetic flux leakage (MFL) inspection tools. MFL tools are commonly used to assess the condition of downhole casing, however this pipe is subject to significantly different loading forces than are surface pipelines. Confirming that MFL accuracy is not impaired by tensile or lateral loads will further refine the evaluation of casing condition and determination of remaining safe life.
- The “top joint” of a storage well, a generic term for the ~150 feet of casing nearest the wellhead and surface, is difficult to inspect with MFL tools due to interference



**Top Joint
Example -
How MFL is
Confounded**

with surface, intermediate and/or production casing that was required to drill the well. In addition, the large mass of metal at the wellhead and surface piping itself creates discontinuities in the MFL magnetic field, making detailed interpretation of the MFL signals more challenging. In 2014, PRCI will assess alternatives to MFL for top joint inspection, and will identify protocols for MFL use that may alleviate some interference effects.

- A critical aspect of cavern storage productivity and reliability involves the integrity of the brine string (the main pipe leading from the surface into the cavern). Typically a flow velocity limit is established to ensure safe, stable operation, as otherwise the brine string could whip around in the cavern like a garden hose if flow exceeded a threshold level. Testing in 2014 will be conducted on operating caverns to determine the relationship between wellhead vibration and the extent of brine string displacement. These findings will support refinements to existing cavern operating practices to either confirm current flow limitations or illustrate that higher velocities are possible with acceptable brine string movement. This would both enhance the integrity of brine strings and possibly lead to productivity increases at existing facilities if cavern injection or withdrawal velocities can be safely increased.



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OF *worldwide pipeline industry organizations:*

Since 1952, PRCI has been recognized around the world as a unique forum within the energy pipeline industry delivering great value to its members and the industry — both quantitative and qualitative — through the development and deployment of research solutions to the operational, maintenance, and regulatory challenges that face it.

BY *members working together through PRCI:*

The collaboration achieved through members' resource/ expertise contributions and funding results in the development of pipeline industry research and technological advances that benefit member organizations and all energy users.

FOR *the global pipeline industry and those who have an interest in it:*

Members vote for research projects most relevant to their organizations, so projects truly reflect the industry's priorities. The results provide intelligence allowing the industry to continue reducing risks from and to pipelines.



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