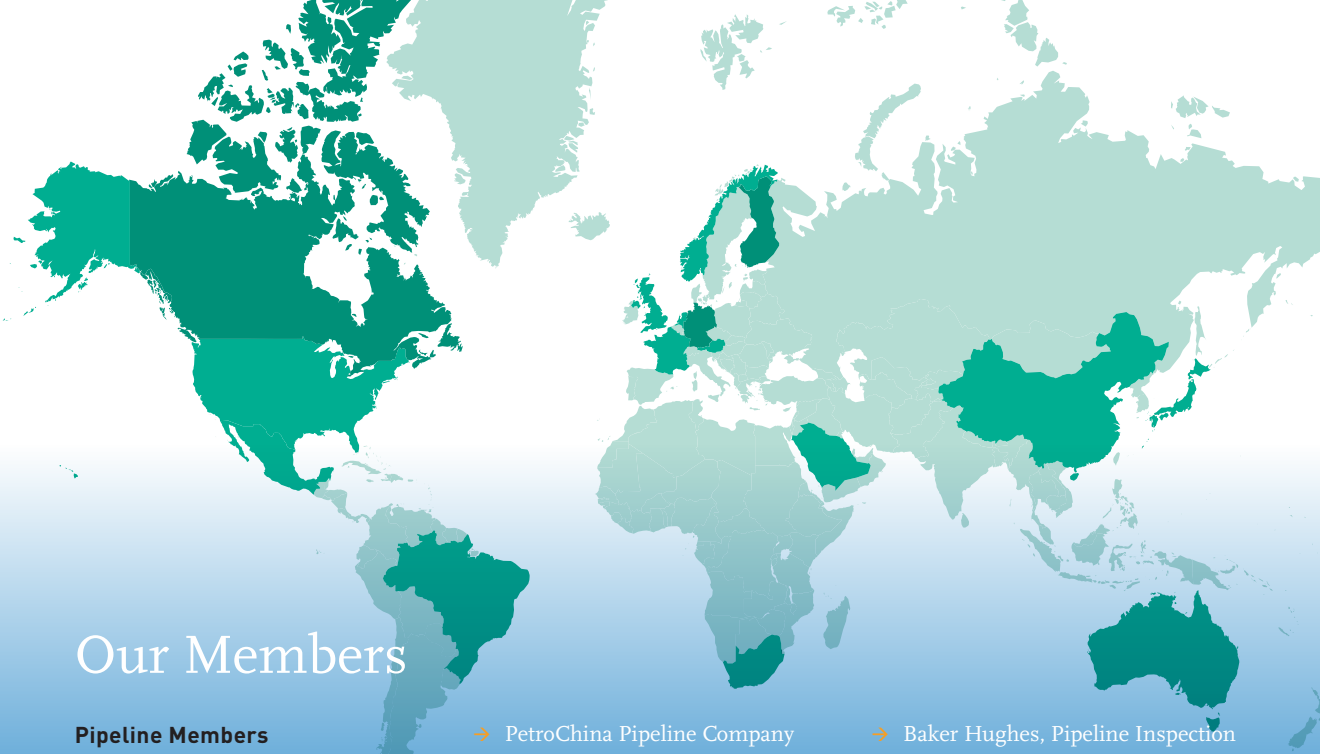
PIPELINE RESEARCH COUNCIL INTERNATIONAL

Year in Review

2014



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
- 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 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

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.

Technical Program Associate Members

- Aegion Corporation
- Australian Pipeline Industry Association, Ltd. (Australia)
- 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)
- Hoerbiger Kompressortechnik Holding GmbH (Austria)
- Innospection Ltd (U.K.)
- JFE Steel Corporation (Japan)
- KROHNE, Inc. (Germany)
- The Lincoln Electric Company
- NDT Global GmbH & Co. KG (Germany)
- 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.
- 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.)

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

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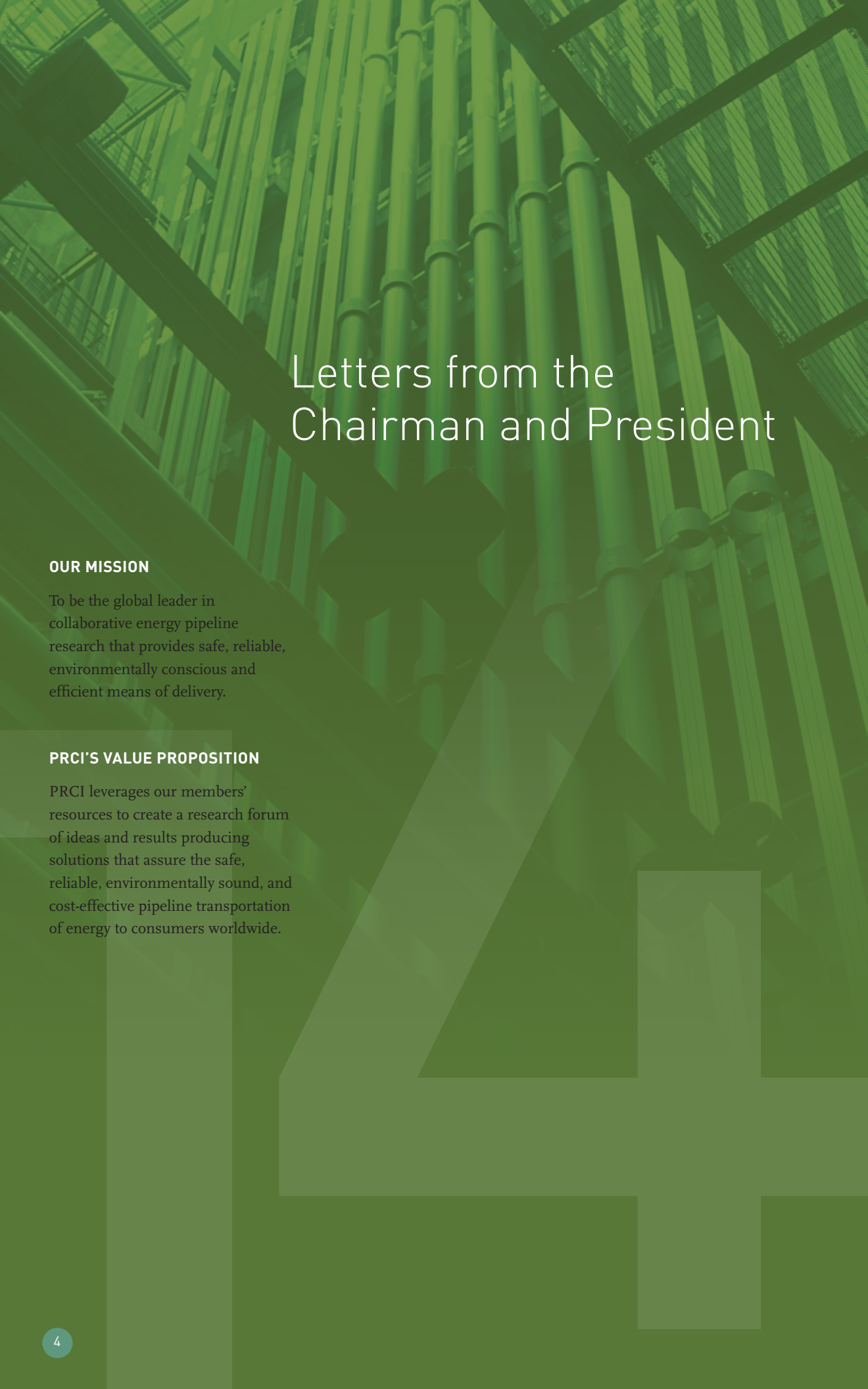


Letters from the Chairman and President

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.

Letter from the Chairman

2014 has been a very active year at PRCI. As mentioned in my message last year, increasing, sharing and disseminating the added value creation of PRCI production is one of the key issue I want to focus on during my Chairmanship. This PRCI production covers its research results, roadmaps, innovative response with new solutions and opportunities to the pipeline industry. To achieve these objectives, we started working on several items including:

1. the need to ensure that our research is addressing the key industry issues;
2. that we are able to deliver in a timely fashion;
3. that we are able to establish a prioritization of needed research; and
4. that PRCI is focused on fewer, larger projects.

This effort is being led by the Executive Committee and the Research Task Force. Significant input to this effort comes from the membership survey completed by PRCI in late 2013, which also highlighted PRCI's importance to its members' research activities.

A particular critical decision I am pleased to highlight this year is the Technology Development Center. In order to increase the efficiency and effectiveness of PRCI's research programs, and to provide to the industry a radically new opportunity, the PRCI Board approved the development of the new PRCI Technology Development Center (TDC). With a 30,000 sq. ft. building (office space, workshop and testing space) and a state-of-the-art ILI pull test facility cofunded by the Pipeline and Hazardous Materials Safety Administration (PHMSA) of the U.S. Department of Transportation, the TDC will enable PRCI to accelerate the execution of a number of key projects and programs. The ILI pull test facility will consist of four parallel lines and be able to test pipe samples ranging from six to 42 inches in diameter. It will also house over 600 pipe samples with a unique inventory mixing real world and manufactured defects. This new space will allow the industry to evaluate performance of current ILI tools and provide a space for the development of the next generation of tools. PHMSA's significant involvement in the ILI PRCI – PHMSA project is an important contribution to creating value for the industry, by facilitating its practical application.

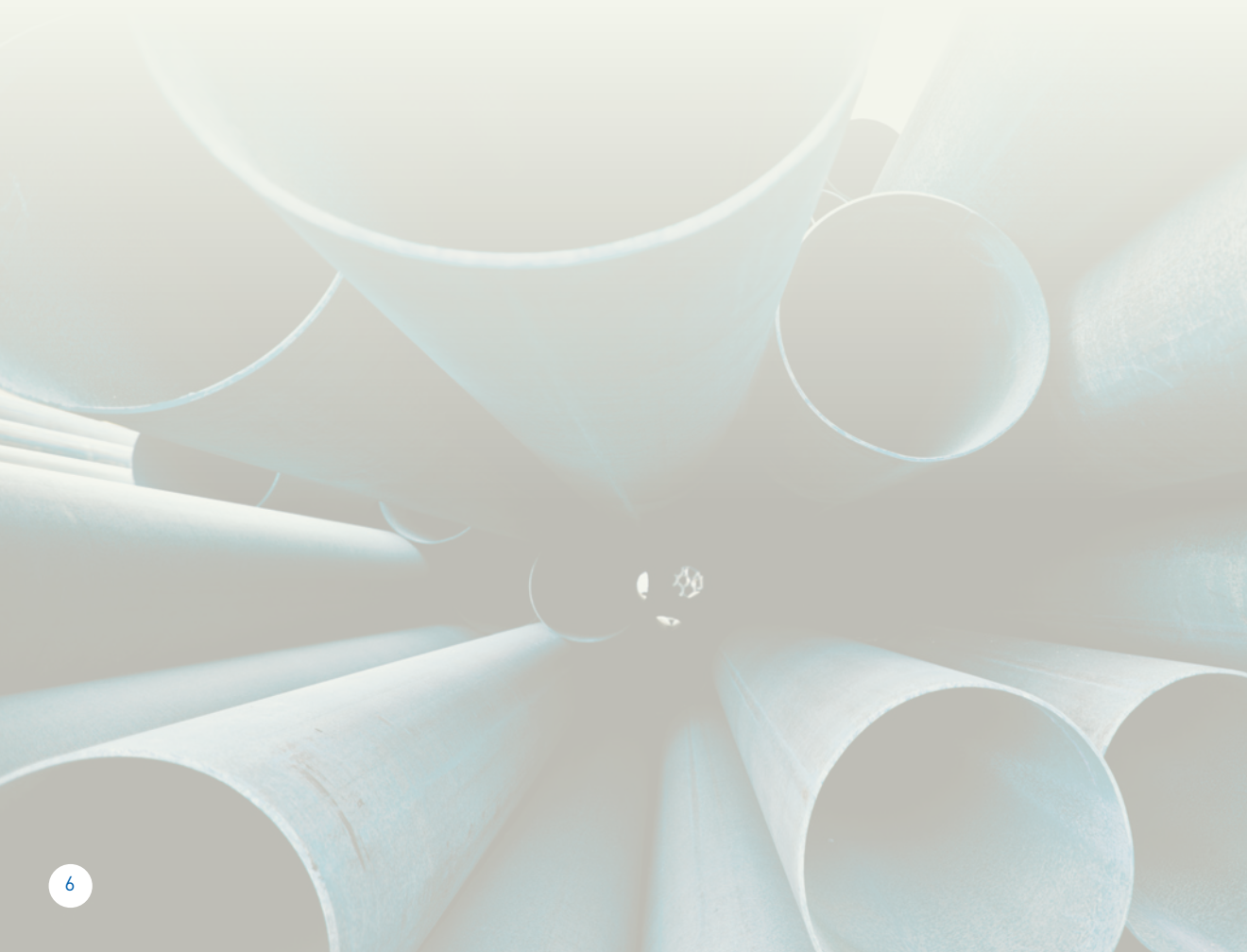
As we wrap up 2014, I am looking forward to:

- The opening of the new TDC in Houston, Texas, which will be an ideal tool to providing value to our members, the industry, and other stakeholders, like standards development organizations, education & training establishments.
- Multiplying the examples of quick cross-over technology transfers, like that of the Seikowave Structured Light 3D scanner, that allows detailed 3D surface scans over defects in tens of seconds, with the accuracy of laser profiling at a significantly lower price. This achievement was enabled by testing the samples at the repository preceding the TDC.

Increasing, sharing and disseminating the added value creation of PRCI production is one of the key issue I want to focus on during my Chairmanship.

Christophe Renier
Chairman

- Several multi-year programs nearing fruition that will provide applicable results, like fatigue resistance criteria for plain dents that provide a technical basis for revising response criteria for mechanical damage defects, completing the technical design for an automated threat detection system for aerial surveillance in order to field test in 2015, and to confirm performance of a methane airborne detector to pursue leak detection field tests in 2015.
- The implementation of the recommendations that the Research and Governance Task Forces will deliver to the Board. These recommendations will be another step in ensuring that PRCI continues to be a focal point for pipeline industry research.



Letter from the President

In closing one the greatest years in our history, PRCI is positioning itself for 2015 and the range of issues, challenges, and opportunities the New Year will inevitably bring. We have grown to almost 80 member companies from around the world and with our partnerships with the European Pipeline Research Group (EPRG) and the Australian Pipeline Industry Association — Research Steering Committee (APIA-RSC), we represent over 60% of the world's pipelines. This provides us with a unique opportunity and responsibility to drive the enhancement of pipeline safety and integrity. PRCI members are dedicated to performing collaborative research that provides safe, reliable, environmentally conscious, and efficient means of delivery.

As you may recall, in 2013 PRCI completed a two year effort to develop a global pipeline R&D roadmap. The roadmap is an amazing tool that has enabled the oil & gas pipeline industry to understand what is currently being done and what is being planned. As we completed this document, the Technical Committees within PRCI began to identify the areas that PRCI needed to address and developed detailed roadmaps for a number key issues including: ILI enhancement, improving leak detection, difficult to inspect pipelines, anomaly assessment, mechanical damage & damage prevention, facility integrity, ERW/Longitudinal seam weld issues, and SCC & cracking issues. These items have led to a number of research programs within PRCI to address these challenges. As you will see in this Year in Review, there are a variety of opportunities to learn about the many projects that we completed in 2014 and how to apply them to your operations.

As was noted in the Chairman's Message, the Board of Directors approved the development of the PRCI Technology Development Center (TDC). I share his excitement about the TDC as it will be a dynamic resource for PRCI and its members as we continue to work with the oil & gas pipeline industry to move toward zero pipeline incidents. The TDC will house a state-of-the-art pipeline pull test facility that will enable PRCI and the ILI tool vendors to further enhance ILI tools. We will also be able to further the testing and development of key NDE tools. Stay tuned for additional information about the TDC and its Grand Opening.

This is an exciting time to be a part of PRCI. There have been a number of projects that PRCI has completed that will assist the industry dramatically. We have a number of projects underway in 2015 and we would appreciate your support. I encourage you to join PRCI and work with us to ensure the safety and integrity of our vital global pipeline system.

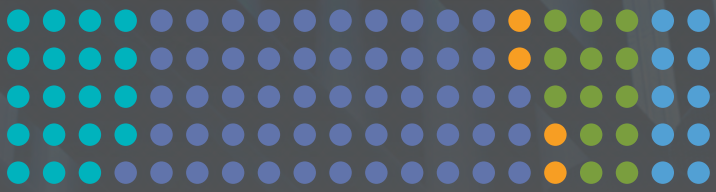
PRCI members have a unique opportunity and responsibility to drive the enhancement of pipeline safety and integrity.

Cliff Johnson
President

Member Survey: You Spoke, We Listened

In late 2013, PRCI developed a survey for its membership to provide feedback on various aspects of the organization including but not limited to value and benefits of membership, operations, communications, general evaluations and opportunities for improvement.

WHO PARTICIPATED IN THE SURVEY?



- **19%** Pipeline Operator: Board Member
- **54%** Pipeline Operator: Technical Committee or Project Team Member
- **4%** Full Associate Member: Board Member
- **13%** Full Associate Member: Technical Committee or Project Team Member
- **10%** Technical Program Associate Member: Technical Committee or Project Team Member

The survey was sent to all members of the organization including individual participants on the Board of Directors, Technical Committees, and Project and Program Teams of both the Pipeline operating and Associate member companies. We would like to sincerely thank the over 180 participants that took the time to complete the survey and provide us with valuable feedback which we will use to improve our operations and offerings to members worldwide.

The Results

We are pleased to report that overall, the results of the survey are highly favorable and a majority of the membership is satisfied by most aspects of PRCI especially in areas such as communications, benefits, understanding roles and responsibilities, and opinions of staff. These findings were consistent among the different types of members as well. That said, there were a few opportunities for improvement that were identified by the membership in the areas of research operations and deployment, and general governance.

The Next Steps

To address these items, PRCI established two Task Forces to review the current processes in detail and make recommendations for improvement. The Task Forces were made up of PRCI Board members and Technical Committee members from both Pipeline operating and Associate member companies, and PRCI staff to ensure we had a broad representation of the membership to develop a plan that would be applicable to all.

- **The Research & Development Task Force** was charged with evaluating and identifying opportunities to improve the research ballot development and execution process, and dissemination and sharing of the results. The goal of the Task Force was to provide a critical assessment of the present approach to program planning and project development, the manner in which projects are managed and results are distributed, and provide recommendations to improve the timeliness and effectiveness of the existing PRCI R&D model to ensure that key industry needs are being addressed and available resources are being properly utilized.

- **The Governance Task Force** was charged with reviewing the current structure of PRCI governance model and identifying any shortfalls, gaps and opportunities for improvement. The goals of the group included identifying the reasons for change, gaps to be filled and specifically identifying the rights, obligations and structure of the Board of Directors, various committees and members of PRCI to improve the methods to achieve the missions of PRCI.

Both Task Forces have been working diligently since mid-year to closely analyze PRCI's current structure, operations and processes and have developed recommendations to be considered by the Board of Directors for approval in the first quarter of 2015. The recommendations will directly address the feedback from the member survey and are expected to identify process improvements efficiencies to enable members to more readily participate in PRCI and better realize the ensuing research program benefits.

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The PRCI Technology Development Center

In July 2014, PRCI broke ground on a new Technology Development Center (TDC) in Houston, Texas. The TDC is a major commitment by the energy pipeline industry to address the key issues that it is facing to ensure the safety of the national and international pipeline system.

Since the creation of the PRCI pipeline repository in 2012, PRCI has been progressively building a unique, world class inventory of pipeline samples to support technology development. The benefits of having such an establishment available to the industry have already been realized, as the current site has already been extensively utilized for the evaluation and development of new and emerging technologies. Having a single location able to accumulate former in-service pipe materials with real-world pipeline features/flaws is invaluable to PRCI's R&D Program and the industry, and provides a central point for hosting industry-sponsored training and workshops. The TDC will open with over 600 test specimens available for advancing pipeline research. It will be a key enabler to understanding and improving current inspection and integrity assessment technologies, and promoting the development of new technologies for pipeline integrity management.

The Technology Development Center is a critical tool for the energy pipeline industry as it continues to strive for zero failures.

The TDC is a critical tool for the energy pipeline industry as it continues 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 towards that goal. This new site will further enhance PRCI as a focal point for the R&D efforts of the energy pipeline industry.

The new TDC will be located on over eight acres and will include a five acre state-of-the-art pull test facility, and an over 20,000 sq. ft. work shop and test facility with an additional 9,000 sq. ft. of office and meeting space. This new site will allow us to continue to grow our pipeline sample inventory and to perform the research needed to ensure the safety and integrity of our vital pipeline infrastructure globally.

The effort to locate the new site has been spearheaded by the PRCI TDC Steering Committee made up of PRCI members and staff who have been heavily involved in TDC planning since its inception and understand

Rendering of the new PRCI Technology Development Center

the incredible opportunities and benefits the pipeline industry can reap from its utilization. PRCI would like to acknowledge the members of the Steering Committee for their dedication and support, as well as the PRCI member companies that have and continue to contribute samples and sponsor the TDC's operations.

Demonstration of JENTEK Sensors, Inc. MWM-array technology for characterizing Mechanical Damage dent+gouge defects.

Former in-service pipeline samples with surface preparation completed and ready for inspection.

Steering Committee Members

- John O'Brien, Chevron ETC
- Eric Amundsen, Energy Transfer
- Mark Piazza, Colonial Pipeline Company
- Scott Collier, Buckeye Partners
- Cliff Johnson, PRCI
- Mike Whelan, PRCI
- Steven Trevino, PRCI

We recognize all PRCI Contributing Companies for their support in this initiative with specific mention of additional support from:

- Chevron
- Colonial Pipeline Company
- Energy Transfer
- GDF Suez
- Marathon Pipe Line LLC
- Petrobras
- Southern California Gas Company

Accomplishments & 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.

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 operation efficiency, and reduced capital expenditures. The Measurement Technical Committee completed several key projects in 2014, including:

- An assessment of how heat transfer effects at low flow rates impact the flow measurement accuracy of ultrasonic meters at low flow rates. (*Fig. 1*)
- An analysis of the presence of liquids on the short and long term performance of transducers on ultrasonic meters. (*Fig. 2*)
- An assessment of low cost MEMS sensors for applicability to detect and quantify the presence of potentially corrosive constituents (H_2S, H_2O, O_2 and CO_2) in natural gas.
- The effect of thermowell designs on the ability to accurately measure the temperature of the flowing gas. (*Fig. 3*)
- The development of design guidelines to minimize flow induced pulsations that can adversely impact flow meter accuracies.
- An evaluation of the next generation of ultrasonic meters in compact piping configurations.
- Developed a tool to estimate the overall measurement uncertainty for liquid measurement facilities.
- Extensive work is being done to evaluate how different piping

Figure 1

An assessment of how heat transfer effects at low flow rates impact the flow measurement accuracy of ultrasonic meters at low flow rates.

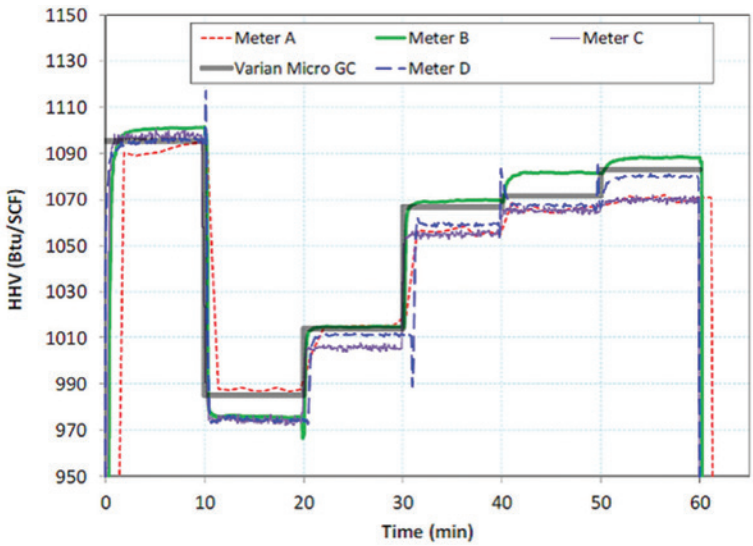

Figure 2

An analysis of the presence of liquids on the short and long term performance of transducers on ultrasonic meters.

configurations impact ultrasonic meter performance, even when the piping configuration conforms to accepted industry standards and practices.

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 2014 results include:

- Completing a field demonstration test of Continental Controls' advanced NSCR control system.
- An evaluation of an in-situ CO sensor for potential NESHAP monitoring.
- An evaluation of a real-time NOx and CO laser sensor for emissions monitoring.
- Developing a spreadsheet tool for efficiently configuring air/fuel ratio controls on legacy pipeline engines.
- An evaluation of gas turbine emissions at cold ambient temperatures.
- Evaluating a fuel additive for its potential to reduce NOx emissions on lean burn engines.
- Publishing methods to reduce the carbon footprint of pipeline stations.
- Evaluating technology challenges for liquid CO_2 pump stations.
- Developing a mechanical seal auxiliary system guideline to help improve pump seal life and reduce leaks.
- Completing an evaluation of reciprocating engine combustion stability for the likelihood of detonation/over fueling and the associated engine damage.
- Assessing the operational impact to operators associated with extending engine exhaust stack height to comply with nitrogen dioxide (NO_2) ambient air quality regulations.
- Additional development of a project to evaluate optimized timing of reciprocating engine power cylinder lubrication to minimize oil

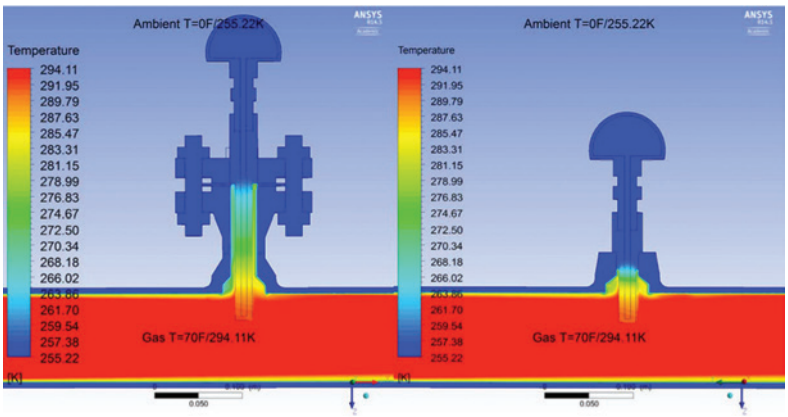

Figure 3

The effect of thermowell designs on the ability to accurately measure the temperature of the flowing gas.

consumption and reduce particulate emissions associated with combustion of carryover lubricating oil.

- Continuing effort to develop and enhance 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.

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. 2014 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 prepared for future testing under tensile stress, where comparisons of the in-situ and stressed MFL results will be compared. This quantification of mechanical stress should reduce uncertainty in downhole inspections.
- The stability of brine strings in salt cavern storage operations is a limiting factor for the rate of fluid injection and withdrawal. Brine string failure results in a significant replacement cost, creates a safety hazard and puts the cavern out of service. Increased injection and withdrawal rates would significantly increase the utility and value of cavern storage to better serve market needs. A risk-analysis study was conducted on an operating salt cavern to determine if a planned brine string test would be feasible. The results indicated that a field test to thoroughly evaluate the effect of enhanced stiffeners on brine string stability as a function of injection & withdrawal velocities would create undue risk to an existing cavern in routine commercial operation. As a result, project plans have been modified such that the testing will occur in 2016 on a new cavern that will be solution mined, prior to it entering commercial service.

Approximately 25% of PRCI funding is directed to Programs and Projects conducted under the Facilities Technical Committees.

Operations & Integrity

The Operations & Integrity Technical Committee improves the reliability of the pipeline infrastructure and ensures 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 2014, including:

- Completed leak detection research including identifying alternatives to current leak detection approaches for hydrotesting. The objectives of the project were to identify possible alternate technologies and then to further

Figure 4

Evaluation Parameters.

PARAMETER	DEFINITION
Adaptability	Ability of technology to effectively work over various pipeline types (e.g., new, legacy, lines with elevation changes, different line diameters, etc.).
Cleanup Cost	Cost to (a) remediate any contaminated water and (b) remove equipment from site, relative to baseline costs that are incurred by pipeline operators' current use of SF_6.
Developmental Effort	Effort required to bring technology to commercial market or to adapt existing commercial application specifically for pipeline monitoring.
Environmental Footprint	Environmental footprint resulting from hydrotest activity.
False Positives	Ability to reliably detect leaks without false positives.
Leak Location	Ability to accurately locate the position of the leak.
Reliability	Probability that a leak would be detected.
Resistance to Damage	Determination of whether the test might cause damage to pipeline (e.g., material that would later corrode pipe, accidental contact with line, etc.).
Robustness	Ability of system to work independent of changes in conditions, such as poor weather or operator error. Would also include ability of system to function independent of interference (e.g., electromagnetic wave interference) and performance regardless of radial position of leak.
Safety Impact	Safety considerations during testing. Also includes handling/storage of material during transport and actual testing.
Sensitivity	Smallest leak that can be detected.
Test Cost	Cost to conduct a test, including any hardware cost, relative to the baseline costs that are incurred by pipeline operators' current use of SF_6.
Time to Assess	Amount of time required from beginning of test to make determination of leak location.

explore the tradeoff for each technology against a set of requirements. The final report, which was approved for publication, provides final reporting for objectives and comprehensive evaluation of the alternatives for hydrotesting leak detection. (*Fig. 4*)

- Additionally, completion of a major undertaking to develop a complete update to publication API 1149: Pipeline Variable Uncertainties and Their Effects on Leak Detection was submitted to API for acceptance and publication. 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.

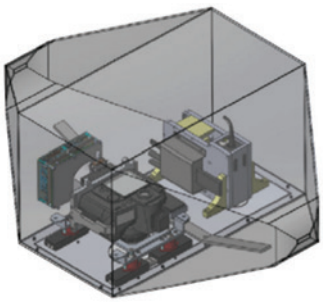

Figure 5

Prototype ATDS technology package specifically tailored to ROW surveillance requirements.

- Significant 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). The unique ATDS technology package incorporates a high resolution imaging camera with a long wave infrared sensor which, in combination, will be validated to provide more accurate detection of ROW encroaching machinery even under overhanging vegetation. In late 2014, the RAM Program deployed the software and hardware integrated prototype ATDS technology and initiated operational testing for continued validation and algorithm training missions that will continue into 2015 in partnership with PRCI members, American Aerospace Advisors Inc. (AAAI) and University of Dayton Vision Lab. (*Fig. 5 and 6*)
- Completed a study of the state-of-the-art for subsea pipeline and equipment life extension (beyond design operational life). This work documented the status of regulations, industry standards, best practices, and experiences relevant for life extension of subsea pipeline systems. The

report covers the following main topics: literature review, industry survey, analysis and critical review and, recommendations for further work.

- Completed a review of technologies for monitoring erosion and corrosion and direct inspection of subsea pipelines and equipment, which screened current and potential techniques that provide a direct measure of loss of pipe wall thickness, rather than indirect measurement (e.g. erosion and corrosion probes, acoustic sand and electric field corrosion monitors). Such techniques should also be capable of being embarked on AUV, snake like robots, mini ROV etc.
- Completed the second phase a project on inspection of composite repairs for pipelines and piping, which evaluated the non-destructive examination of composite repairs as applied to aggressively-cycled pipelines and piping, including repairs that contained interlaminar defects and steel/composite debonding from four composite repair vendors, with one being an underwater repair system.
- Completed a study on internally lined steel risers as an alternative to corrosion resistant alloys, which evaluated the feasibility and current state of development of alternatives to clad steel in steel catenary risers (SCR).
- Completed a project on the application of a mobile sensor to monitor water hold-up and corrosion in pipelines. Pipeline operators will have access to a fully validated, low cost integrity management tool for accurate spatial detection of water hold-ups in piggable and unpiggable gas pipelines subjected to a wide range of pressures under various gas flow velocities and pipe geometries. This low cost inspection method also simplifies repeat measurements to ascertain whether corrosion is ongoing.
- Evaluated internal coatings for energy transmission, which includes a software tool suitable for comparison of the net present value of various coating options.
- Completed a study on flaw characterization using guided waves, which assessed its applicability to a range of pipe and flaw sizes. The report

The Operations & Integrity Technical Committee improves the reliability of the pipeline infrastructure and ensures the continuity of service through the development and deployment of technologies to prevent, locate, characterize and assess integrity threats.

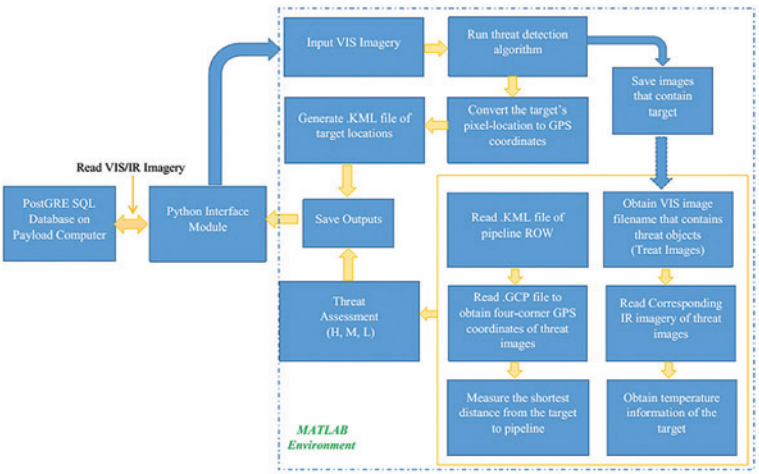

Figure 6

Flow diagram of the prototype automated threat detection software developed by the University of Dayton Vision Laboratory.

summarizes the modeling and analysis of laser mapped real corrosion data and presents the results of the experimental work on the performance of the guided wave technique.

- Completed a report on contaminants in sales gas pipelines (sources, removal and treatment), which investigated "black powder" – the various forms of iron sulfides that can foul pipelines and equipment. Guidelines for removal, handling, and disposal of the material, root cause treatments, and the corporate culture necessary to manage the problem, as well as recently developed technologies for cleaning, treatment and management of the problem are described.
- Developed a technical note 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 maintained.
- A significant set of mechanical damage samples were created, including dents and gouges, and dents with interacting defects, which will be used in subsequent remaining life modeling and potentially ILI testing.
- Characterized of a number of 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.
- Confirmed that an in-ditch hardness testing method could determine the lower-bound yield strength of pipe, for application where materials records are not available.
- Detailed NDE characterization of the defects found in vintage pipe samples housed at the PRCI Technology Development Center. Over 100 segments have been fully examined, enabling the inventory of pipe samples for future ILI testing in conjunction with the Pipeline and Hazardous Materials Safety Administration (PHMSA) of the U.S. Department of Transportation to be further refined to enable a ILI testing strategies to be developed.
- Data-mined 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.

Design, Materials & Construction

The Design, Materials & Construction Technical Committee completed several key projects in 2014, including:

- Research was completed to develop guidelines for pipeline valve stem seals in CO_2 rich applications such as for enhanced oil recovery (EOR) and carbon capture and storage (CCS). The guidelines will interface with both NORSOK M 710 Rev. 3 and ISO 23936-2, and give specific details on

procedures, steps and decisions that have to be taken when attempting to qualify seals for dense phase CO_2 use. In order to develop these guidelines, well established sealing compounds having proven rapid gas decompression (RGD) resistance were selected for study, along with materials which were not known for their RGD resistance. RGD testing was performed on housed O-rings of each compound using CO_2 rich applications.

- Completed a project to consider composite materials as an alternative method for the determination of MAOP. The objective of this project was to evaluate reinforcing technologies, specifically, the use of composite materials for the MAOP determination of high-pressure gas or liquid transmission pipeline systems. Reinforcing a pipeline using composite materials is not for the purpose of providing strength to a damaged section. Rather, the intent is to use composite materials to establish a Maximum Allowable Operating Pressure (MAOP) with an improved safety factor as required by DOT 192 for pipelines that have been subjected to encroachment involving the construction of facilities on or near the pipelines. Emphasis is placed on the increased safety factor that is most often accomplished with line replacement using thicker-wall pipes or higher grade steel. This research evaluated reinforcing technologies, specifically, the use of composite materials for the MAOP determination of high-pressure gas or liquid transmission pipeline systems. The report provides a state-of-the-art assessment of composite materials in their current usage in reinforcing and repairing damaged pipelines. A discussion is also included the technical aspects for properly designing a composite system for reinforcing non-damaged pipelines, as well as limits that should be imposed on the proposed methods.

- Review of Compressive Strain Capacity Assessment Methods. Buried pipelines subjected to non-continuous ground movement such as frost heave, thaw settlement, slope instability and seismic movement experience high compressive strains that can cause local buckling (or wrinkling), in which the pipe wall buckles like a thin cylindrical shell in axial compression. In a strain-based design and assessment framework, excessive local buckling deformation that may cause loss of serviceability, or even pressure containment in some cases, is managed by limiting the strain demand below the strain limit.

  The determination of compressive strain limit is typically performed by full-scale structural testing or nonlinear finite element analysis that takes into account material and geometric non-linearity associated with the inelastic buckling of cylindrical shells. Before performing testing and numerical analysis (or when such options do not exist), empirical equations are used to estimate the strain limit.

  This research evaluated a number of representative equations by comparing strain limit predictions to full-scale test results. Work prior to this study has identified the importance of key variables that have the greatest impact on the local buckling behavior. This evaluation focused on how existing equations address these key variables, and their performance with respect to key variables and in different ranges.

Figure 7

Wrinklebend sample having severe pitting.

→ Wrinklebend Evaluation Study and Tool Development. The goal of this research was to develop a practical approach for helping operators select from among candidate wrinklebends those that pose the greatest threat to pipeline integrity. Prior to this study, the traditional assessment method focused on the geometry of the wrinklebend itself, in particular, the height and length of individual wrinkles. If an operator has thousands of wrinklebends in their pipeline system, those deemed as having the most severe geometries were identified as posing the greater threat. This research identified knowledge gaps from previous efforts and included a survey of pipeline operators to identify the state-of-the-art assessment techniques currently employed in evaluating wrinklebends. The insights provided by studying prior failures, along with interaction with several pipeline operators, closed some of the knowledge gaps and permitted a greater focus on identifying the critical issues and factors that have contributed to wrinklebend failures.

Through the process of studying 40 years of data, this research concluded that was that there was no direct correlation between wrinklebend geometry and likelihood of failure in gas pipelines where cyclic pressure was not a primary operational concern. Additionally, currently-available in-line inspection (ILI) caliper tools are constrained in their ability to accurately capture wrinklebend geometry, so the current ability to integrate geometry into any assessment method is limited. Therefore, an alternative approach was developed.

This approach was essential because the traditional method could not discriminate between benign wrinkles and those that posed a threat to the system. This led to the development of an analysis tool referred to as the Threat Prioritization Tool (TPT). The TPT identifies threats associated with a given wrinkle based on common factors identified in previous failures that are generally detectable with current ILI technology. These factors include bend orientation, seam weld interaction, distance between overbends, proximity to nearby water sources, and presence of corrosion. It should be noted that the TPT does not replace previous approaches; instead, it provides operators with another tool that can be used whenever prior approaches cannot identify high-threat wrinklebends.

The greatest value for the pipeline industry in utilizing the TPT is the ability to prioritize the more severe wrinklebends from among larger data sets. While exact figures are not available, the number of wrinklebends in the U.S. is on the order of several hundred thousand or greater. Since its impractical to consider removing or reinforcing all wrinklebends, the need to prioritize wrinklebends is essential for those operators with numerous wrinklebends within their systems.

In addition to the development of the TPT, this research included full-scale testing in an effort to replicate failure conditions, including fracture surfaces, observed in the field.

The goals for the full-scale testing effort were three-fold:

1. Produce a high-strain, low-cycle failure
2. Produce a fracture surface similar to actual failures
3. Demonstrate the effectiveness of composite reinforcement

Failures commensurate with low-cycle, high-strain conditions were observed in field failures; testing sought to replicate those loading conditions. A bend test fixture was used to replicate common fractures, demonstrating that both bending and low-cycle, high-strain conditions may be contributing to wrinklebend failures. Pipe/soil interaction is also a likely contributor in that bending loads are imparted to pipelines.

For operators with a large number of wrinklebends in their systems, the TPT can now be used to rank the severity of the identified wrinkles. This helps guide remediation activities to focus on evaluating, and addressing those wrinkles that pose the greatest threat to the pipeline system. In the future, as the industry learns more about wrinklebends and how they fail, the Threat Prioritization Tool can be further refined to incorporate new information and insights. The ultimate goal is to provide operators with a resource to efficiently and more accurately estimate the threats associated with wrinklebends. This research moves industry closer to that ultimate goal. (*Fig. 7 and 8*)

→ Pipe Response to Buried Explosive Detonations. The primary hazards associated with blasting near pipelines include permanent rock mass displacement owing to delayed gas pressures and ground strains from wave propagation. Current pipeline standards do not address criteria and limitations for blasting in proximity to buried pipelines. Existing methodology is often applied quite conservatively in the form of permissible ground particle velocity thereby limiting ground strain, which leads to increased costs for the party conducting the blasting and/or the pipeline owner who must provide pipeline protection.

The research, recently completed, resulted in the development of strain and displacement-based methodology, guidelines and criteria for the evaluation and protection of buried pipelines subjected to the effects of close-in blasting on an undamaged (clean) pipeline in rock. This work relates to protection of existing pipelines from external loads and improving construction efficiency and safety.

The research report contains a state of the art review of current methods for evaluating the effects of close in blasting on pipelines. The report also includes a comparison of current methods for determining the stress resulting from blasting with available experimental results. It also covers the subject of block movement as a result of delayed gas pressure, methods to determine the likelihood of ground movement and procedures for evaluating if movement has occurred. More accurate methods to determine blasting stresses are also investigated and a procedure to be followed to evaluate the effects of blasting is proposed. Finally, it includes a review of recent developments in blasting technology that are relevant to blasting near pipelines.

Figure 8

Axial tension wrinklebend testing with composite reinforcement.

- Guidelines for Interpretation and Application of API 1104 - Twenty-first Edition. The application of requirements contained in many industry codes and standards requires some interpretation by the user and by the regulator who is called upon to enforce their use. The objective of this research project was to update the PRCI guidance document for API Standard 1104 - Welding of Pipelines and Related Facilities - for the recently published Twenty-first Edition of the standard and to further develop and enhance the document. The use of this document will allow operators and regulators to better understand the intent regarding interpretation of some requirements in API 1104, the rationale behind the requirements, and the applicability of the requirements to both conventional and modern high-strength pipelines.

Corrosion

The Corrosion Technical Committee completed several key projects in 2014. The projects include:

- Assessed the severity of corrosion metal-loss in high-strength steels relative to vintage pipe through an approach that combined analyses and trending of a corrosion defects database with numerical modeling and full-scale testing. This project was directed at isolating the effects of the metal-loss geometry and the properties of the steels to make corrosion management seamless across grades. Discriminating full-scale tests were performed to assess the role of shape factor and bulging, and demonstrate the shoulder effects relative to leak versus rupture failure. Research has shown that shape factor and bulging of corrosion defects have a first-order influence on failure pressure. While these two parameters are coupled via mechanics, they are considered as independent variables in the empirical calibration of both B31G and Modified B31G. Follow-on research is currently ongoing to examine the interactions between shape factor, bulging, and the shoulder effect on corrosion features.
- Developed guidelines for internal corrosion sample collection process. A set of experiments performed in this study were able to demonstrate some effects of sample holding time, sample holding temperature, and sample container headspace on certain constituents (pH, dissolved CO_2, dissolved H_2S, alkalinity, culturable bacteria) typically measured during internal corrosion evaluations. The project also identified general considerations for establishing and implementing internal corrosion sampling programs, since other factors in addition to changes that occur during handling can affect the accuracy, quality, and utility of test results. The deliverables of this project can be applied directly by operators to assess their sampling programs and also provide a foundation from which a comprehensive best practice for sampling programs can be developed.
- Defined operating conditions in which no stress corrosion cracking (SCC) can be found on a pipeline segment. A survey was conducted of gas and liquid

pipeline operators to determine if there were any kinds of coating, surface preparation, design pressure, or years of construction that could be identified with conditions under which no SCC has occurred. The study demonstrated a low probability of high-pH SCC at distances greater than 20 miles downstream of compressor stations, under asphalt coatings, and in liquid pipelines and at stresses below 60% of specified minimum yield strength (SMYS). Additionally, the results showed a low probability of near-neutral pH SCC under coal tar coatings and at stresses below 60% SMYS. Trends for liquid pipelines differed from those for gas pipelines, possibly because corrosion fatigue cannot be differentiated from SCC, and corrosion fatigue is much less likely to occur on gas pipelines than on liquid pipelines. (*Fig. 9*)

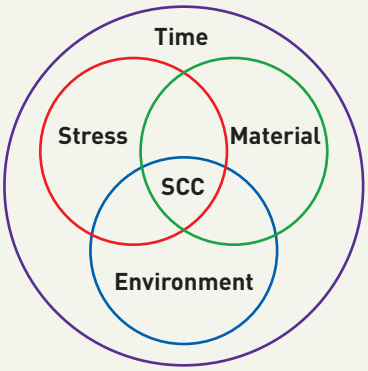

Figure 9

→ Investigated of an alternative method for potential measurement to assess the level of cathodic protection on a buried or submerged metallic pipeline. This study conducted an extensive literature review of the techniques and approaches for determining buried pipeline external corrosion rates that are currently in use, have been used in the past, and have been studied but not implemented. Based on the review, the most promising new approach was determined to be one that focuses on determining the anodic current density using a combined experimental and computational methodology. A 3-D resistive model was developed and was able to predict within 5% of the actual corrosion current measured in a simple water bath corrosion cell. This study is the first phase of a multi-year program, and future research will focus enhancing the model and conducting a fusibility study to ensure its applicability on a larger scale model and in the field.

Completed Research Reports

Measurement

- Ultrasonic Meter Performance in Liquid Transients
- Energy Meter Performance Assessment: Phase 1 - Amendment (blinded and unblinded versions)
- Sensors for Gas Quality Monitoring
- Liquid Measurement Uncertainty Tool
- Performance Evaluation of New Generation Ultrasonic Meters in Compact Installations
- Meter Station Design Procedures to Minimize Pipe Flow-Induced Pulsation Error
- CFD Analysis of the Heat Transfer Characteristics and the Effect of Thermowells Used in Natural Gas Measurement Facilities
- Thermal Irradiance Effects on Ultrasonic Meter Performance at Low Flow Rates

Compressor & Pump Station

- Evaluation of Cylinder Wall Lubrication for Power Cylinder Timed Lube Oil Injection System
- CO Sensor Experimental Evaluation for Catalyst Health Monitoring
- Real Time Laser Sensor for Nitrogen Oxides and Carbon Monoxide for Engine Feedback
- Methods to Reduce the Greenhouse Gas Footprint from Pipeline Compressor and Pump Stations
- Field Evaluation of a Continental Controls Corp. NSCR NOx Sensor Control System
- Emissions Control for Legacy Engines - Cylinder and Cycle Level Control
- Technical Limitations, Constraints and Costs Associated with Raising Existing RICE Stack Heights
- Characterization of Natural Gas Pneumatic Device Types and Review of EPA Default Pneumatic Device Controller Vent Rates
- Mechanical Seal Auxiliary Systems Best Practices Summary
- Role of Fuel Borne Metallic Catalysts in the Inhibition of NOx Formation During the Combustion of Hydrocarbons
- Technology Challenges for Liquid CO_2 Pump Stations
- Mechanical Seal Auxiliary Systems Guideline
- Engine Emissions and Performance Calculator Tool - TER Calculation Wizard

Underground Storage

- Factors Affecting Underground Storage Downhole MFL Response and Analysis - Phase 1

PRCI completed and approved over 40 final research reports in 2014.

Operations & Integrity

- Contaminants in Sales Gas Pipelines – Sources, Removal & Treatment (Black Powder)
- Internal Coatings Evaluation for Energy Transmission
- Flaw Characterization using Guided Waves
- Advancement in the Development and Application of a Mobile Sensor to Monitor Water Hold-up and Corrosion in Pipelines.
- Internally lined Steer Risers as an Alternative to CRAs
- Review of Technologies for Monitoring Erosion and Corrosion and Direct Inspection of Subsea pipelines and equipment.
- ILI Tool Characterization based on In-Ditch Measurement with Related Uncertainty
- Inspection of Composite Repairs – Phase 2, NDE Trials

Design, Materials & Construction

- Leak Prevention in CO_2 Pipeline Valves and Launches by Correct Seal Material Selection
- Evaluation of Application Tool (EPDECOM) for Determination of the Decompression Wave Speed of Mixtures of CO_2 with Impurities
- Guidelines for Interpretation and Application of API 1104 - Twenty-first Edition
- Procedure for Evaluating the Effects of Blasting on Pipelines - Phase 1 Report
- Quality of ERW-HFI Pipe
- Wrinklebend Evaluation Study and Tool Development
- Review of Compressive Strain Capacity Assessment Methods
- Integration of Multi-Scale Mechanics and Welding Process Simulation in Weld Integrity Assessment
- Consideration of Composite Material Reinforcement as an Alternative Method for Determination of MAOP

Corrosion

- Assessing Corrosion Severity for High-Strength Steels
- Internal Corrosion Sample Collection Guidelines
- Define Operating Conditions in Which No SCC Exists
- Development of an Alternative Method to Potential Measurement to Assess the Level of Cathodic Protection to a Buried or Submerged Pipeline
- Pipeline Coating Fault Excavation and Inspection Documentation

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.

Measurement

- Work is underway to evaluate the diagnostic capabilities of Coriolis meters associated with debris buildup and tube erosion.
- 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 guideline for operators on how to interpret ultrasonic meter diagnostics is nearing completion.
- Evaluating sampling methods to accurately quantify the chemical energy content of the gas only phase of a gas that is operating under API Type 1 two-phase flow conditions is nearing completion.
- A study to assess the minimum necessary insertion length for gas sample probes is being evaluated.
- A study to assess the impact of revisions to ASME standards on thermowells is being performed to assess if the improvements in mechanical integrity offset the tradeoffs in measurement performance.
- A study to assess the impact of composite sample mixing methodology and centrifugal forces on the determination of density, sediment, and water.
- A study to assess the ability of using ultrasonic meter diagnostics to determine when meter recalibrations are necessary.
- Further analysis to assess the performance next generation ultrasonic meters in compact installations.
- Assessing turbine and Coriolis meter diagnostics in flows with entrained liquids.
- Further analysis of effect of upstream piping configurations on ultrasonic meter bias.
- Assessing the potential of new and emerging technologies to assess gas compositions.

Figure 10

Field testing of timed power cylinder lubrication optimization.

There are over 200 active programs and projects in PRCI's current Research Portfolio.

Compressor & Pump Station

- Additional work is being performed to develop emission factors for greenhouse gas emissions reporting.
- Additional field tests of continuous equipment performance monitoring are underway.
- An evaluation of controlling pump transients to protect low pressure piping components is nearing completion.
- Several studies are 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 installed on lean burn reciprocating engines.
- 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.
- A final field demonstration test of integrated ERLE / CORE technologies is scheduled the first quarter of 2015.
- Developing and providing training on producing air specification to achieve a given NOx level on lean burn engines.
- 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.
- Developing field pump performance testing procedures.
- Gathering data for ambient NO_2 modeling improvements.
- Evaluating portable analyzer test methods and minimum detection levels for common analyzers as a possible alternative to using full reference testing.
- Continued work on modeling NSCR performance with exhaust mixtures from natural gas-fueled engines.
- Further develop greenhouse gas measurement methods, procedures, and reporting systems.

Underground Storage

- Work to characterize the effect of downhole mechanical stresses on MFL performance will continue, and the general question of which casing inspection methods provide the best solution for given storage well circumstances will be evaluated – initially via analytic studies and in future years by coordinated field testing.

Operations & Integrity

- Prior studies and gap analyses have shown that technology improvements for leak detection measures are needed in the areas of computational and control room systems, in-field sensing, and monitoring technologies that achieve limits of detection that confirm releases from pipeline systems at very low volumetric loss percentages. Several studies were started and will continue into next year to look at the means for application of current leak detection technologies to existing pipelines.
- Several initiatives for Unmanned Air System (UAS) platform research were started in 2014 and will continue to be worked in 2015. As part of on-going work within the Right-of-Way Automated Monitoring (RAM) Program, PRCI in cooperation with American Aerospace Advisors Incorporated (AAAI) will conduct research for automated threat and leak detection along the pipeline right-of-way (ROW) utilizing a mid-range Unmanned Aircraft System (UAS), as a result of an approved Federal Aviation Administration (FAA) Certificate of Authority (COA) issued to Virginia Polytechnic Institute and State University (Virginia Tech). Working with Virginia Tech, PRCI and AAAI will be conducting test flights over the next two years under the COA, which was issued to Virginia Tech as one of six test sites selected by FAA to perform research and testing related to an evaluation on integration of UAS into the national airspace. The primary focus of the flight campaigns is to establish a protocol to fly UASs beyond line of sight for mid- to long-range monitoring/surveillance of pipeline ROW corridors and other similar infrastructure are expected to start in the first quarter of 2015. (*Fig. 11*)

Figure 11

Figure 12

PG&E testing a prototype of a handheld gas leak detection tool.

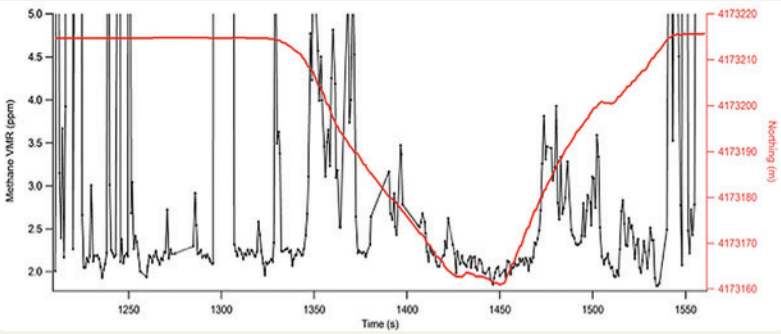

Figure 13

Max amplitude of methane spikes fall exponentially with distance from leak. Diffuse methane gradients can be more easily observed 50+ meters away.

- Additionally, in partnership with NASA's Jet Propulsion Laboratory, PG&E tested a prototype of a handheld gas leak detection tool in a field demonstration which uses technology adapted from NASA's Mars Land Rovers developed in order to use state-of-the-art technology to provide safer, more reliable and affordable energy for consumers. This laser-based technology is lightweight and has superior sensitivity to methane, a major component of natural gas. The current hand-held device would guide an operator's crew using a tablet interface to possible leak locations, fast-tracking their ability to find leaks. The second phase of this project aims at integrating the methane detection system on an Unmanned Air System (UAS) and testing will continue into next year. (*Fig. 11 and 12*)
- Satellite work in 2014 was centered on a new partnership endeavor 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 was granted a contract and research fund for the development of a two-year program for the advancement of satellites in encroachment and threat detection monitoring along pipeline right-of-ways. This US DOT OASRT – CalPoly/PRCI cooperative research program will draw upon the expertise of PRCI's member company subject matter experts (SMEs), including PRCI member company representatives that are currently utilizing satellite service, to provide a comprehensive technical oversight of the program. The project will include use of satellite remote sensing, geospatial data information, and readily available web-based datasets to enhance existing pipeline operator Decision Support Systems (DSS) for pipeline integrity management to support pipeline safety and reliability. The unique opportunity that this program partnership brings is an integrated method for which operators can identify risk areas along the ROW.
- Current in-line Inspection technology development and performance characterization is focused on the PRCI Technology Development Center (TDC), where over 600 vintage pipe samples containing a variety of defects have been gathered. Extensive work is underway to fully characterize all defects and anomalies in these pipe joints, their type, size, geometry, orientation and location in the pipe, along with the pipe vintage and materials characteristics, so that permanent test artifacts are created that can be used as references for ILI and NDE (in-ditch) technology characterization.

These samples contain a wide range of defects – including external and internal corrosion, mechanical damage (dents, gouges and interacting features), stress corrosion cracking, and other cracks. A variety of in-ditch and in-laboratory NDE inspection technologies are being utilized to both characterize the defects in the samples, and also to evaluate the performance of this equipment and methods as practical, in-ditch inspection methods and/or as analytic methods more suitable for controlled environments.

- DOT-PHMSA has awarded to PRCI a major cost-shared project that will create at the TDC the capability to conduct pull tests of commercial ILI tools through a set of pipe samples containing well-characterized defect features, and initially conduct a specified number of tests, per the PHMSA contract requirements. The pipe samples will be provided by the TDC sample development activity described above, which will be 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. The results of this project will be standardized testing protocols, challenging test specimens, opportunities for ILI technology improvement and an understanding of current technology performance. The project is in response to a NTSB recommendation to PRCI. Coordination with the ILI vendors and identification of testing technical protocols is underway, with live tests planned for mid-2015. The pull-rig will have parallel runs 700' in length, 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 pipeline conditions at full speed for up to 500' of that length.
- Investigations into the feasibility of using in-line inspection tools, as well as in-ditch methods, to determine pipe materials properties particularly for low-toughness, vintage pipe.
- Quantify the performance of several different magnetometry survey tools (MTM, SCT, MMM and AQUA MTM) which 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 has been developed that simulates limited pipe access and extensive cover to enable a credible assessment of equipment performance.
- Multiple thrusts are underway to better characterize the structural significance of mechanical damage such that it can be managed optimally, including: 1) Advanced Material Characterization for Dent and Gouge Samples, 2) Improved Strain Evaluation & Implementing Damage Mechanics Modeling, 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 - Modern and Vintage Steels, and 5) Fatigue Life Assessment of Dents, and Dents Interacting with Welds - Development of Severity Ranking Criteria For Dents Interacting with Metal Loss

DOT-PHMSA has awarded to PRCI a major cost-shared project that will create at the TDC the capability to conduct pull tests of commercial ILI tools through a set of pipe samples containing well-characterized defect features, and initially conduct a specified number of tests.

- NDE using inside-the-pipe technologies remains a mainstay of pipeline integrity management programs, and PRCI is attempting to broader its applications while seeking novel equipment configurations and application approaches. Key projects include: Integrated Pipeline Monitoring and Cleaning Tool, Mobile Sensor to Detect Water Hold-up in Pipelines, In-line Inspection and Assessment for Pipeline Girth Weld Defects, Magnetic Stress Gage (MSG) 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.

Design, Materials & Construction

- The Design, Materials & Construction (DMC) Technical Committee (TC) continues its extensive research program in the use of composite material repair systems for on-shore energy pipeline applications with the on-going evaluation of the long term performance of commercially available repair systems.
- Research continues this year to develop an industry guideline for pipeline operators to use for objectively evaluating existing and future composite repair systems. 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.
- Research has been initiated to better understand load transfer in a composite repair scenario. For composite repair systems to work properly, it is essential that load be effectively transferred from the carrier pipe to the reinforcing composite material. For this to take place, composite repair systems must be properly designed and installed so that they provide adequate reinforcement for the full range of operating conditions. This research will draw upon insights gained from prior PRCI research, as well as additional studies to quantify the issues related to load transfer. The work will include a review of prior testing, finite element modeling, as well as full-scale testing to further clarify issues related to load transfer.

  The DMC TC's Subsea research program includes the following continuing work:

- Updates to the PRCI On-bottom Pipeline Stability Program to account for additional subsea conditions being encountered by operators, and improved solution approaches and a better user interface.
- Operators have reported concerns with the use of launcher and receiver facilities and procedures for cleaning inspection pigs in subsea energy pipelines. Ongoing research seeks to identify best practices with the longer term goal of developing an industry guideline for the design and operation of these facilities.
- While composite repair systems have been used extensively for on-shore

energy pipelines, operator experience with off-shore applications is minimal. This gap is being filled by a project that should be completed in early 2015.

- Weld overlay pipes are being evaluated for subsea application considering issues related to inspection of the weld overlay layer and fatigue performance. Weld overlay pipes have been used in hard pipes or top risers in platforms, but could also be considered in more critical applications (as flowlines or tower risers).
- 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.
- Research begun last year continues to develop better guidance to avoid hydrogen cracking. This phenomenon 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.
- 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 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 hi/low misalignment.
- In the non-metallic pipe area, research continues 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 TC 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 pipeline integrity.
- DMC TC 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 nearing completion 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

Ongoing research projects related to external corrosion monitoring and mitigation include: (*Fig. 14*)

- Monitoring the effectiveness of cathodic protection systems at trenchless crossings. This project will support and supplement another PRCI research effort on the evaluation of coating quality at trenchless crossings.
- Determining the corrosion risk of fluctuations in AC interference on pipelines buried along high voltage AC transmission corridors. This study involves a laboratory test program to predict the AC corrosion occurrence risk at various operating conditions.

Continuing research aimed at quantifying the threat of stress corrosion cracking (SCC) on pipelines examines the effect of pressure fluctuations on the growth rate of near-neutral pH SCC. This effort builds on recently completed PRCI research to better understan d this phenomenon and provide a model for ease of implementation of research results. Studies focused on pipeline operational practices to prevent and minimize internal corrosion include:

- Determining the drying time of residual hydrostatic test water in pipe crevices, side branches and dead-legs based on operating conditions. The results will allow operators to determine if the trapped/stagnant water poses any internal corrosion threat.
- Validation of recently developed models and guidelines for internal corrosion threat evaluation in dry gas transmission pipelines. Field and operational data are used for this validation process.

Figure 14

External corrosion control.

Initiatives for the 2015 Research Portfolio

Through the collaborative research model that PRCI employs, we have developed a research program for 2015 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.

Measurement

Additional work will be performed to assess 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. It is expected that the outcome of this research will result in modifications to measurement standards.

Other work to be performed includes:

- An evaluation of the performance of total sulfur concentration measurement instruments.
- Evaluating in-situ proving techniques for gas ultrasonic meters.
- An evaluation of the effects of scrubbers/filters located directly upstream of ultrasonic meters.
- Further evaluation of pulsation effects on ultrasonic meter performance.
- Using diagnostic data to estimate the installation uncertainty of ultrasonic meters
- Additional flow assessment of ultrasonic meters with various upstream piping configurations.
- Issues associated with emerging gas supplies including:
  - Sampling techniques for shale gas,
  - LNG sampling and measurement refinements, and
  - Equation of state assessment and improvement for supercritical gas mixtures.
- Liquid density master meter field testing protocols and instrument assessments.

Compressor & Pump Station

The largest effort of the committee is gathering data to be used to improve the accuracy of EPA's AERMOD 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 identified and efforts are underway to site the instruments necessary to gather the necessary data.

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

Other work to be performed includes:

- Continued field evaluation of optimized power cylinder lubrication injection.
- Validating field pump performance testing procedures.
- Continued efforts on alternate gas turbine lean premixed combustion control to reduce emissions on startup and shutdown.
- A white paper study on selective catalytic reduction on lean burn engines.
- A field test of selective catalytic reduction on lean burn engines.
- Assessing the effect of suction and discharge piping layout on the performance, reliability and integrity of pipeline pumps.

Underground Storage

Storage Field Integrity remains the primary focus of the Underground Storage Committee, with work generally directed at characterizing casing integrity and comparison of casing inspection methods in both reservoir and cavern applications. Field testing of brine string integrity to assess whether fluid injection/withdrawal velocities can be increased is now planned for 2016.

Key projects for the 2015 program include:

- Downhole ILI Technology comparative evaluation.
- Assessing the accuracy of MFL tools, including top joint inspection performance.
- Defect characterization of well casing pipe to confirm MFL tool accuracy.

Operations & Integrity

The construction of the new Technology Development Center and its use by many O&I projects will be a primary aspect of the 2015 program as PRCI continues to advance technology to improve pipeline inspection and integrity verification capabilities. Key programs and projects include:

- Engineering Critical Assessment for establishing MOP/MAOP for vintage pipe.
- An ERW Integrity Management Program, which includes projects to: Thoroughly characterize and examine ERW and long seam pipe for its failure susceptibility, Evaluate the ability to inspect ERW pipe with conventional ILI tools, Quantify in-ditch NDE methods to evaluate ERW pipe still in the ditch, Evaluate the effects of hydrostatic testing on ERW seam weld anomalies and Evaluate ERW fatigue life integrity management improvement opportunities.
- Continuation of the Program to assess the Structural Significance of Mechanical Damage.
- Development and assessment of (in-ditch) tools to detect and discriminate Mechanical Damage.
- Assess the accuracy and repeatability of light-based NDE systems for large/interacting metal loss areas.
- Field validation of EMIT fatigue crack inspection technology.

- In-line Inspection of Pipeline Girth Weld Defects.
- Assessment of in-ditch NDE tools and techniques.
- NDE & Inspection methods for composite wrap repairs.
- Aboveground methods to inspect pipelines using high resolution NDE (Magnetometry).

  ILI Technology Improvements – Development of an Industry Test Facility and Qualification processes for ILI Technology Evaluation and Enhancements – including site preparation and facility commissioning.
- Pipeline industry database Data gathering and refinement.
- Benchmarking of human and organizational factors used by transmission operators for control room operation.
- Right of Way automated monitoring to detect threats and leaks along the pipeline right-of-way.
- Right of Way Monitoring & Surveillance by Satellite, to protect against ground movement threats.
- Map and Test Fatigue Cracks on Heavy Wall Risers and Pipelines (SubSea).

Design, Materials & Construction

In 2015, the Design Materials & Construction (DMC) Technical Committee continues ongoing research focused on technical issues identified in its research roadmaps for each of the seven key Emphasis Areas: Assessment & Repair, Design, Construction, Fracture, Materials, Strain Based Design and Assessment and Welding. In addition to the continuing research funded by the PRCI Board of Directors supporting these emphasis areas are the following new initiatives.

- Research will occur to better understand the implications for operators of the widespread use of modern microalloyed steels which typically can exhibit different performance characteristics than older steels. The research will take a comprehensive look to develop useful insights for the complete lifecycle of energy pipelines including effects on design, construction, and maintenance activities.
- DMC has managed extensive research on the performance of commercially available composite repair systems. The new initiative beginning this year focuses on load transfer. In order for composite repair systems to work properly, it is essential that load be transferred from the carrier pipe to the reinforcing composite material. For this to take place, composite repair systems must be properly designed and installed so that adequate reinforcement is provided for the full range of operating conditions. This research will draw upon insights gained from prior PRCI research, as well as additional studies to quantify issues related to load transfer. The work will include a review of prior testing, finite element modeling, as well as full-scale testing to further clarify issues and fill any knowledge gaps related to load transfer.
- Evaluation of Girth Weld Flaws in Vintage Pipelines is an area requiring

Figure 15

additional research. This new project will develop assessment models for vintage pipelines to reduce uncertainties in performing assessments compared to the range currently achievable employing traditional stress-based design and analysis methods. The research will seek complimentary tools for operators to make the full use of the results of prior PRCI research through which mechanical properties of vintage welds were generated. This will permit the better integration and use of in-line inspection and other inspection results.

Corrosion

In 2015, The Corrosion Technical Committee continues its focus on industry challenges related to AC- induced corrosion, coatings effectiveness and cathodic protection. These newly funded projects are directly linked to the roadmaps developed by the technical committee which ensures seamless integration of research results to other initiatives in PRCI and the broader pipeline industry.

- Validate 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.
- Assess the effectiveness of vapor corrosion inhibitors 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. (*Fig. 15*)
- Develop 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.
- Determine the effects of foam trench breakers and foam ditch pads on the cathodic protection of pipelines. This study will supplement former PRCI research project to either dispel or confirm claims of cathodic protection shielding by these products through rigorous field and laboratory testing.
- Minimize 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 in support of prior PRCI research. (*Fig. 16*)

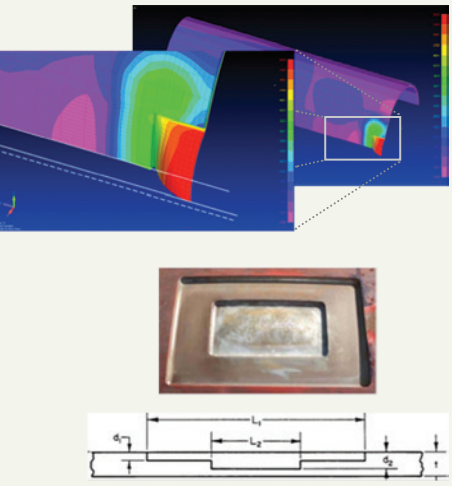

Figure 16

Of, by, and for the energy pipeline industry.

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' funding and resource/expertise contributions 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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