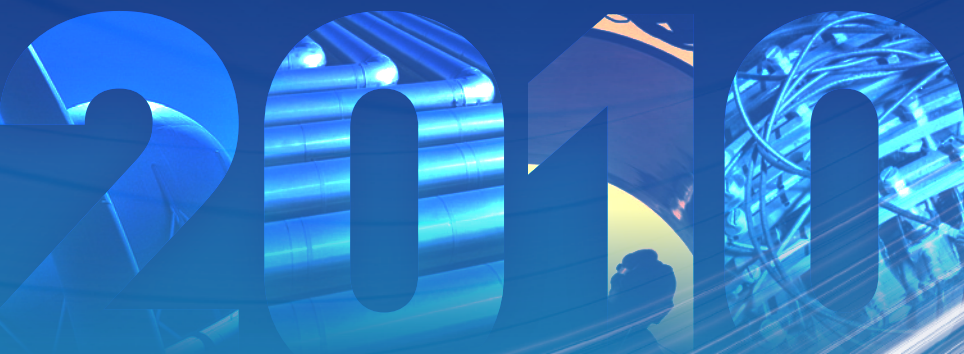




2010 **YEAR IN REVIEW** PIPELINE RESEARCH COUNCIL INTERNATIONAL

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

Our Members

Working to assure the safe, reliable, environmentally-sound, and cost-effective pipeline transportation of energy to consumers worldwide.

Pipeline Members

Alliance Pipeline Limited (Canada)
Boardwalk Pipeline
BP
Buckeye Partners, LP
CenterPoint Energy Gas Transmission
Chevron Pipe Line Company
Colonial Pipeline Company
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Dominion Transmission, Inc.
El Paso Corporation
Enbridge Pipelines Inc. (Canada) & Enbridge Energy Partners, LP
Enterprise Products
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ExxonMobil Pipeline Company
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National Grid (U.K.)
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Shell Pipeline Company LP
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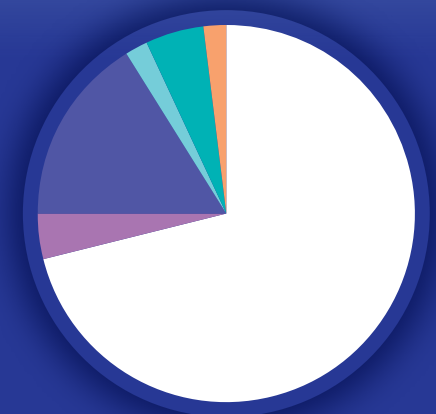
Australian Pipeline Industry Association, Ltd.
Baker Hughes Pipeline Inspection
Berg Steel Pipe Corporation
Cameron Compression
Dresser-Rand Corporation
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Pipeline Industry Organizations

Association of Oil Pipe Lines (AOPL)

Regional Membership Distribution



72% ● North America
2% ● Australia
5% ● Asia
2% ● Middle East
16% ● Europe
3% ● South & Central America



MISSION

To conduct a collaboratively-funded research and development program that enables energy pipeline companies around the world to provide safe, reliable, environmentally compatible, and cost-efficient service to meet customer energy requirements.

VALUE PROPOSITION

PRCI leverages our members' resource contributions to create a research forum of ideas and results producing solutions that provide a spectrum of quantified benefits to the pipeline industry. Formal cost/benefit studies of member participation show a consistently positive ratio ranging from 4:1 to 7:1 from reduced costs of operations and maintenance, inspection, materials, design, construction, and testing.

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Chairman's Statement



This has proven to be a very interesting and exciting time to be the Chairman of PRCI. 2010 has been a year of transition and change within the industry and PRCI. The value of collaborative research and PRCI has never been higher.

As noted in the President's message, this has been a year of transition in PRCI with George Tenley's retirement and the selection of Cliff Johnson as our next President. With this appointment we believe strongly that we are providing PRCI with the leadership it will need as it looks to sustain its success and enhance its service to the energy pipeline industry.

This was also an unmatched year in North America for the pipeline industry. The industry has experienced a number of high consequence failures this year, which highlight and reinforce the need to advance pipeline integrity and public safety.

The members of PRCI have a long history of supporting and participating in a collaborative research program that strives to ensure the safe, efficient, and effective operation of energy pipelines. The goal of pipeline operators is zero leaks or failures and through the research programs at PRCI, companies are addressing some of the most pressing challenges facing the pipeline industry and are moving toward that goal.

Pipelines remain the safest mode of transportation; however, any failure is unacceptable. It is important that the industry work collaboratively to find solutions to issues facing these critical assets. With the ongoing increase in the demand for energy, we will continue to expect more from the pipeline infrastructure, but in meeting that demand, we must assure that pipelines operate in a safe, reliable, and environmentally benign manner.

The strength of PRCI is based in its members. If you are not a member of PRCI, I challenge you to join us in finding the solutions to the problems facing our industry not only in North America, but around the world. This industry will be constrained in meeting the challenges and opportunities it faces unless its commitment to research grows. That growth can occur best through collaboration and the leveraging of ideas, results, and resources it delivers. I know that you will find our 2010 program contributed directly to those outcomes.

As I embark on my final year as Chairman of PRCI, I want to say thank you to the Board, our members, and PRCI staff. I continue to be impressed with dedication of our members and the PRCI employees and have thoroughly enjoyed working with each and every one of you. It is a great pleasure to serve as the Chair and I am looking forward to another exciting and successful year.

Paul F. MacGregor
Chairman

President's Statement



Welcome to the 2010 PRCI Year in Review. 2010 will be seen as a year of transition for PRCI, and I am excited to be a part of it.

This year we say “goodbye” to a great friend and champion of PRCI for over the last 12 years, George Tenley. As President, George was instrumental in establishing PRCI as an independent organization. Under his leadership PRCI grew from 25 members to over 50 members. We have grown from a mainly US natural gas pipelines base to a truly global energy pipeline (gas, liquids, CO₂, and biofuels) membership with companies all around the world. In the last five years he has led staff through a process of refining and improving the research process, communication with our members, and enabling members to vote their dollars to develop a broad collaborative R&D Program. During his tenure we have undertaken and completed a number of key projects that benefit the industry.

George established a close relationship with the Pipeline and Hazardous Materials Safety Administration (PHMSA) of the U.S. Department of Transportation (DOT). Through this relationship, PRCI has developed a conduit for industry to educate the R&D agenda of PHMSA and to participate in a number of R&D projects. Another key effort was the Research Deployment Optimization (RDO) initiative within PRCI. RDO provided new capabilities, procedures, and services to our members and the industry. Key among these is the “PRIME” (Pipeline Research Implementation and Management Engine) system developed for our membership and Program participants. PRIME transformed how we plan, execute, manage, and deliver the essential research that makes up the core of our mission.

Through these efforts, we are well positioned and it is a great time to be involved in the organization. In September, I joined PRCI as President. Since then I have had the pleasure of meeting with many of our members and discussing with them their vision for the future of PRCI. A number of common themes arose: the passion of our members, desire for a strong research effort to support the industry, and agreement that PRCI is a strong model for collaborative research and is vital for the industry. We have great future ahead of us and I look forward to working with each of you to strengthen PRCI. A key activity that we started this year is the development of a Strategic Plan for PRCI. It will be complete in late 2011. We will be seeking as much member input into the plan development as possible over the first half of 2011.

In closing, I would like to thank George for his hard work and dedication to PRCI and wish him all the best in his retirement.

Cliff Johnson
President

Collaborating with the Pipeline & Hazardous Materials Safety Administration



A significant effort by PRCI in 2010 was the coordination with our members companies and research partners to respond to a Broad Agency Announcement (BAA) issued by the Pipeline & Hazardous Materials Safety Administration (PHMSA) of the U.S. Department of Transportation (DOT). The BAA solicited proposals to address the

key research programs and topic areas that were identified during the DOT-sponsored Joint Industry-Government R&D forum held in June 2009. As a key contributor to the R&D Forum, many of the research topic areas identified in the BAA aligned with, and built upon, PRCI's research programs, including extensions and continuations of ongoing, active research projects and several new projects consistent with PRCI's research roadmaps. A number of the projects were included on PRCI's 2011 annual voting ballot.

In September 2010, DOT announced that it would support the development of 17 research projects and provide \$5.9 million in funding to address the challenges of pipeline safety. Projects were selected that address multiple topic areas, including alternative fuels transportation, the detection, prevention, and characterization of threats and leaks, and pipeline construction quality. Of the 12 technical proposals submitted by PRCI, the six listed below were selected by PHMSA for R&D cofunding for a contribution of over \$2 million directly from PHMSA. Each of these projects will be initiated in 2011.

- MWM-Array Characterization of Mechanical Damage and Corrosion
- Development of a Model to Accurately Predict the Conditions of Carrier Pipe within Casings Based on Conditions at the Casing Ends
- Dent Fatigue Life Assessment — Development of Tools for Assessing the Severity and Life of Dent Features
- Integrated Internal Inspection and Cleaning Tool Technology for Pipelines
- Quality Management Systems for Pipelines
- Optimization of Multi-Wire GMAW Welding Procedure for Heavy-Wall Offshore Pipeline Construction



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. PRCI focuses on projects that:

- Assure system safety and environmental performance
- Assure the productivity and reliability of pipeline assets
- Anticipate change and adapt existing systems
- Allow our members to build new pipelines where and when they are needed
- Continue to reduce risks from and to pipelines
- Provide support for public policy positions

PRCI's research projects have produced numerous important findings and technology developments that our members are able to put into practice resulting in cost efficiencies, operational changes, and evaluation programs. Some of the most recent are as follows, a select set of which are described in further detail in the accompanying Appendix:

Corrosion

- Evaluation of the effectiveness of cathodic protection (CP) criteria in globally acceptable CP standards. The evaluation focused on a number of internationally accepted criteria, including on-, off-, and polarized potential criteria and variable CP criteria that account for differing environmental conditions including soil resistivity, temperature, and bacteria levels. The project was directed toward identifying alternative CP criteria for cases where the current and commonly accepted catalog of existing CP criteria and their technical basis may not be appropriate or applicable in certain service conditions or environments. A major outcome of this effort is the contribution of the research results to the NACE committee responsible for revising the SP0169-2007 standard.
- Developed a guidance document for identifying locations where external pipeline stress corrosion cracking (SCC) is most likely to exist and for estimating how frequently re-inspections should be performed. The guidelines are designed to be broadly applicable, for operators with and without prior experience in managing SCC and include discussion of both high-pH and near-neutral pH SCC, gas and (hydrocarbon) liquid pipelines, existing and future pipelines, and to be applied on local and regional scales in North America and internationally.
- Completed the consolidated program on assessing the remaining strength of pipe with external corrosion. The consolidated program consists of six separate projects that all address external corrosion to pipelines including High Strength Steels, Biaxial Loading, Cyclic Loading, Low Toughness Pipe, and an evaluation of the assessment methods used to determine remaining strength of corroded pipe. The culmination of the work is a Guidance Document that compiles the key findings of the individual projects. The Guidance Document represents the final task of the program. Completing the Guidance Document is a significant milestone for PRCI and our research partners, concluding 6+ years of research and a key technical resource for managing corroded pipelines.

- Investigated the effect of cathodic protection (CP) levels on the extent of cathodic disbondment (CD) of coal tar enamel (CTE) coated pipes. The CD extent at under protected CP levels was investigated as well. Additionally, the effect of surface contaminant (chloride) on CD of the CTE coated pipes was evaluated. The results provide operators with a better understanding of the effects and consequences of higher CP potentials in areas where coating damage exists.

Design, Materials & Construction

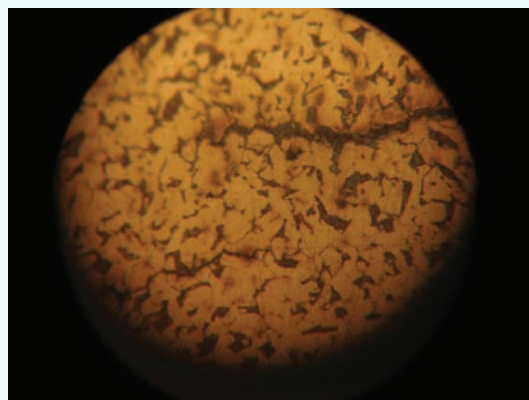
- Completed full-scale testing of mechanical damage defects for modern, higher toughness steels. Testing included plain dents, dents on welds, and dents with metal loss, including focused studies for dent+gouge damage. The testing program consisted of highly instrumented burst and fatigue tests (i.e, cyclic loading) to determine the conditions that lead to immediate and delayed failure of mechanical damage defects. These data are being collected to support the development and validation of improved burst and fatigue strength models for assessing mechanical damage with secondary features. The full-scale testing program will continue in 2011 and will focus on testing of mechanical damage defects in lower toughness materials that are representative of vintage pipeline steels.
- Completed research on the influence of pipe materials including stress-strain curve shape on strain demand. This will enable optimization of pipe material specification to minimize strain demand. Reduction in strain demand can be directly translated into capital and operating cost savings.
- Completed a technology gap study of CO₂ pipeline design and assessment. This study illuminated a critical technology gap that PRCI addressed immediately with a research project. The goal of this project is to determine experimentally the decompression wave speed in CO₂ mixtures with various impurities, from a range of initial pressures and temperatures. Such mixtures are typical of carbon capture streams from industrial sites that must be transported by pipeline to remote sites for sequestration or enhanced oil recovery (EOR) projects. Knowing decompression wave speed is essential for effective fracture control design, which is required for all pipelines transporting hazardous substances. Phase I of this research has been completed and Phase II is now underway.

Operations & Integrity

- Completed several studies to further advance the ongoing multi-year research being conducted as part of the Right-of-Way Automated Monitoring (RAM) Program. The RAM Program consists of developing integrated sensing suites and algorithms for processing data to provide safer, smarter, and more cost-effective aerial surveillance for detecting and providing notification of machinery threats, changed conditions, and leaks. Significant accomplishments in 2010 included 1) the completion of a comprehensive capabilities assessment and gap analysis on the performance of sensor-based technologies for automated surveillance; 2) the development of a detailed Concept of Operations, or CONOPS, document that defines the technical and operational requirements for the RAM technology package; and 3) validating the applicability of hyperspectral sensing technology for detecting leaks from underground pipeline systems based on vegetative stress analysis.
- Validated the use of standardized field inspection protocols for in-ditch measurement of mechanical damage features. In addition, methods were developed for in ditch inspection

of stress corrosion cracking (SCC) features to provide a practical metallographic protocol for differentiation of inter-granular (high pH SCC) and transgranular (near-neutral pH SCC) and distinguishing between the crack propagation modes.

- Completed neutron diffraction testing on mechanical damage test samples containing dent+gouge defects to analyze through wall strain. The neutron diffraction data is being evaluated against full-scale laboratory testing data of similar features to better understand the factors that contribute to failure of mechanically damaged pipe and support the development of improved mechanical damage models.



Photograph showing microscopic view of high pH or intergranular SCC crack propagation.

Hanson, B., McNealy, R. & Fingerhut, M. (2009). *Guidelines for In-Situ Characterization of Cracks*.

Compressor & Pump Station

- An investigation of materials compatibility issues with ethanol for components involved in pump station facilities was conducted. Materials addressed included non-ferrous alloys, stainless steels, and elastomers/plastics. The report provides operators with a cross-reference between materials found in typical pump station and terminal components and their compatibility FGE and FGE-gasoline blends.
- Engine testing of gasoline containing higher concentrations of drag reducing agent was conducted on a typical light duty passenger vehicle engine. The engine testing protocol employed has been widely-used for evaluating the effect of fuel additives on engine deposits. The tests evaluated the incremental effect on inlet valve deposits, combustion chamber deposits, and total deposit mass.
- A compilation of existing greenhouse gas (GHG) emission reduction technologies and work practices for gas pipeline compressor stations and hydrocarbon liquid pipeline pump stations. The report addresses the availability of each approach, not the feasibility, as that is inherently equipment, site, and operator-specific. A section is provided as a case study of the process that could be considered when assessing the technical and economic feasibility of a GHG reduction approach to a specific facility.
- Solar Turbines™ Dry Low NO_x gas turbine engines in regular pipeline compression service were operated at lower gas generator speeds than traditionally recommended to assess the performance of the combustor system at part-load.
- The existing fleet of General Electric Frame 3 and Frame 5 gas turbines compressor engines was evaluated to determine if improved lean-head end-liner concepts could provide cost-effective incremental NO_x reductions for select sub-models.
- A workshop was held to demonstrate the use of the “Engine and Emissions Performance Calculator” software tool that allows operators to estimate the emissions from engines as a

function of trapped equivalence ratio. This is determined in the tool by 1) estimating airflow through an engine based on readily measured parameters and known engine geometry, 2) estimating the relative Scavenging Efficiency under varying engine operating conditions for a given engine make and model, and 3) comparing scavenging efficiencies for various engine types in order to normalize comparative NO_x.

Measurement

- Determined the effect of buildup and wear on the performance of plate-type flow conditioners, specifically in terms of its ability to effectively redistribute disturbed velocity profiles. Exposure of perforated plate flow conditioners to conditions in natural gas pipelines could result in changes to the geometric characteristics of the flow conditioner due to dirt buildup on the flow conditioner face or wear of the edge sharpness. The findings can assist in determining maintenance requirements for flow conditioners to sustain the accuracy of flow measurement.
- Orifice Meter expansion factor data gathered between 2003 and 2005 was reexamined to assess the impact of using the real isentropic expansion factor (k) that is utilized by ISO equations, in place of the ideal gas value of k=1.3. This change results in a very modest shift in the acoustic ratio, but has no effective change to the overall results, and both the original and revised SwRI expansion factors datasets were determined to have negligible differences. Both data sets were also compared to expansion factor curves obtained using the Buckingham equation of the AGA standard and the ISO 5167-2:2003 equation.
- A LNG measurement uncertainty study characterized the uncertainties associated with both static and dynamic methods of determining LNG volumes and energy content delivered to, processed by, and shipped from LNG terminals. This was performed to determine whether dynamic methods are potentially more effective than existing static methods for accurate measurements and LAUF determination at LNG terminals, and to establish which methods offer the most potential for reducing custody transfer measurement uncertainty and LAUF within LNG receipt terminals.
- With increasing deepwater natural gas supplies from sources producing gas in the supercritical state, an extensive literature search was performed to identify sampling methods for natural gas streams in the supercritical region. No sampling methods were identified, however guidelines were found in various references that are useful in tailoring existing sampling methods or designing new sampling methods for supercritical gas service. These include means to avoid phase changes in the samples, methods of regulating pressure while maintaining sample temperatures, avoiding issues with adsorption and desorption on equipment, and recommendations for designing a sampling method for high-pressure service.
- The Meter Station Design Tool (MSDT) software optimizes the design process for a natural gas orifice flow meter station. It creates station designs that incorporate the latest design methodology to produce accurate flow measurement in the most cost-effective way possible and minimizes the likelihood of problems being engineered into the designs from the outset. Measurement experts do not typically design pipeline meter stations, consequently, design flaws can creep into the process or additional capital costs can be incurred. The MSDT makes it possible to estimate the total measurement uncertainty for a given meter station configuration; and allows for tradeoff or “what if” comparisons of various designs.



Underground Storage

- Casings in a gas storage or production well can have large longitudinal loads in addition to the hoop stress resulting from internal pressure. The most commonly used method for corrosion evaluation is based on B31G which does not include longitudinal loads. The RSTRENG software has been adapted to include tensile, and the results have been validated by burst tests of casing with real and machined metal loss under axial loading. These results have been utilized by downhole MFL inspection vendors in order to improve the MFL tool algorithms and performance. Apart from improved MFL inspection, gas storage operators use this software to make repair decisions based on a more accurate assessment of the effect of that loss on the casing's remaining strength.
- Assessed the feasibility and developed a conceptual model of a real-time digital x-ray tool for in-situ compositional identification and quantification of scale in gas storage wells. The tool has the potential to assess and quantify defects, pitting, and penetrations in casings and associated piping. Also included in the final report are results from efforts focused on transmission pipeline NDE as well as the technology's effectiveness in evaluating non-metallic materials such as high density polyethylene and polyamides. Further work is pending the development of a suitable platform to cost-effectively house & transport the inspection device, which is underway with distribution company R&D support.

Research Reports

Corrosion

- Determine the Requirements for Existing Pipeline, Tank, and Terminal Systems to Transport Ethanol Without Cracking
- Guidance for Assessing the Remaining Strength of Corroded Pipelines
- Guidelines for Reliability-Based Pipeline Integrity Methods (Phase II)
- Guidelines for the Identification of Stress Corrosion Cracking Sites and the Estimation of Re-Inspection Intervals for Stress Corrosion Cracking Direct Assessment
- Large-Scale Cathodic Disbondment Testing for Coal Tar Enamel
- Variable Cathodic Protection Criteria

Design, Materials & Construction

- CO₂ Transmission and Storage — Research Plan Development
- Criteria for Determining Seam Failure Susceptibility Due to Crack Defects
- First Major Improvements to the Two-Curve Ductile Fracture Arrest Model
- Guidance for Repair of Pipeline Defects
- Pipe to Soil Interaction Model for Reliability Based Design and Assessment in Permafrost Areas
- Vintage Girth Weld Defect Assessment — Comprehensive Study

Operations & Integrity

- Best Practices and Technology to Reduce the Risk of Directional Drilling and Boring Operations

- Contaminants in Sales Gas Pipelines — Sources, Removal, and Treatment
- Guidelines for In-Situ Characterization of Cracks
- Human Factors Influence on Mechanical Damage — Phase 1 Report
- Pipeline Right of Way Automated Monitoring Technology Package Analysis: Concept of Operations and Conceptual System Architecture
- Right of Way Automated Monitoring Program — Summary of Responses to Request for Information, Technology Capabilities and Gap Assessment for Commercial off-the-Shelf Systems
- SCC Mapping with Flexible Eddy Current Array

Compressor & Pump Station

- Determine Effect of Ethanol on Pump Station Facilities
- Gas Turbine PEMS Model Development
- ERLE Cost Study of the Retrofit Legacy Pipeline Engines
- Extend Solar Turbines DLN Operating Range
- General Electric Frame 3/5 Lean-Head End Liner Evaluation
- Increased Use of Drag Reducing Agents — Effect of Increased DRA on Vehicle Engine Deposits
- Methods to Reduce the Carbon Footprint of Pipeline Compressor Stations
- Test Facility for Pump Performance Characterization in Viscous Fluids
- Trapped Equivalence Ratio Tool — Engine & Emissions Performance Calculator

Measurement

- Assess the Performance of Dirty or Worn Flow Conditioners
- Investigate Active Meter Cleaning Concepts
- Laboratory Confirmation of the Effect of Methanol on Gas Chromatograph Performance
- LNG Measurement Uncertainty Analysis
- Meter Station Design Tool
- Proposed Sampling Methods for Supercritical Natural Gas Streams
- Revised Analysis of Orifice Meter Expansion Factor Data

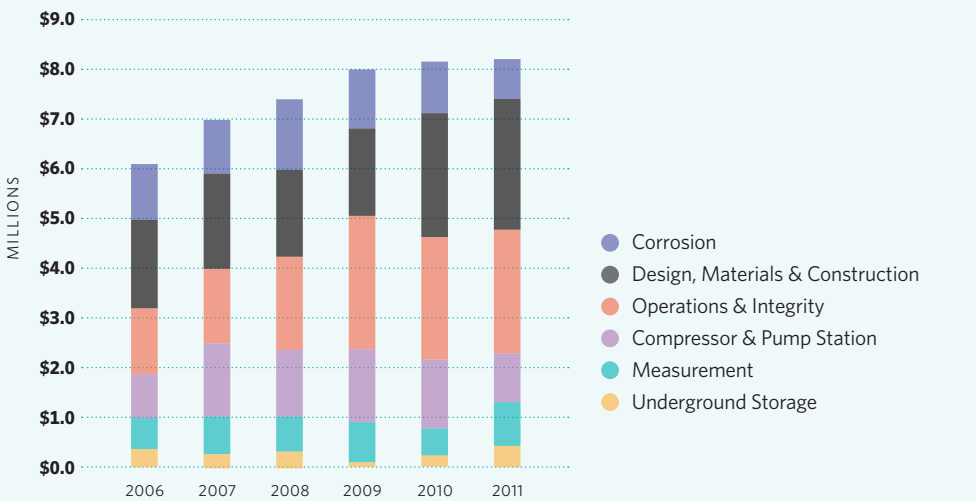
Underground Storage

- Evaluation of Magnetic Pulse Welding (MPW) for Improved Casing Repair
- Extension of a Method to Validate the Remaining Strength of Corroded Casing to Additional Cases
- RGB X-Ray Technology: Wellbore Inspection Feasibility Study
- Temperature Logging as a Cavern Mechanical Integrity Test (Concept Evaluation)
- Testing for the Dilation Strength of Salt

Current Research

Every year, PRCI produces a collaborative research program aligning with the industry’s priorities by means of an annual voting ballot. Members allocate funds directly to programs of importance to their operations and business drivers. The funding for this research is further augmented by member company supplemental contributions and cofunding from non-member companies, including DOT. Following are some highlights of our current program focus, and related projects.

■ 35% Increase in Member Research Spending Since 2006



Program Year	2006	2007	2008	2009	2010	2011	Totals
Corrosion	\$1,108 K	\$1,086 K	\$1,405 K	\$1,193 K	\$1,037 K	\$802 K	\$6.631 M
Design, Materials & Construction	\$1,789 K	\$1,914 K	\$1,771 K	\$1,760 K	\$2,512 K	\$2,634 K	\$12.380 M
Operations & Integrity	\$1,325 K	\$1,500 K	\$1,869 K	\$2,679 K	\$2,462 K	\$2,492 K	\$12.327 M
Compressor & Pump Station	\$890 K	\$1,464 K	\$1,320 K	\$1,462 K	\$1,376 K	\$981 K	\$7.493 M
Measurement	\$626 K	\$757 K	\$718 K	\$816 K	\$566 K	\$875 K	\$4.358 M
Underground Storage	\$384 K	\$300 K	\$348 K	\$118 K	\$236 K	\$454 K	\$1.840 M
Totals	\$6.122 M	\$7.021 M	\$7.431 M	\$8.028 M	\$8.189 M	\$8.238 M	\$45+ M

Note: Member funding only. Does not include outside funding

Corrosion

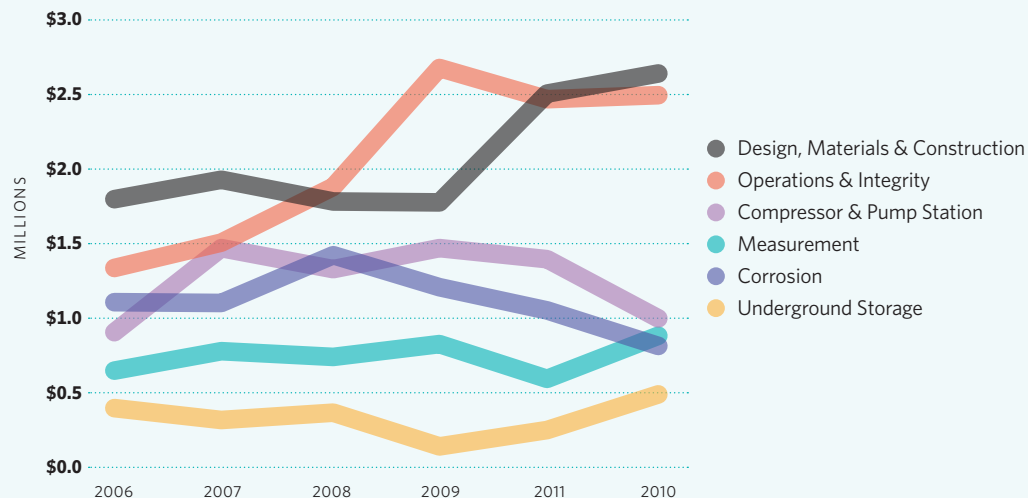
- Assessing the advantages and limitations of reliability-based integrity management approaches for external corrosion features in real-world operating scenarios. This will be accomplished by evaluating reliability-based corrosion management approaches in comparison to conventional deterministic methods using actual pipeline inspection data with the focus on natural gas transmission pipelines.
- Analyzing ECDA data and evaluating the range of probability of detection for various pipe characteristics and combination of survey methods. Additionally, the effort takes advantage of PRCI member direct-assessment activities to carry out additional field case studies where required. Several coating types, geographic locations/soil conditions and combinations of survey methods are considered.
- Developing accurate and reliable cathodic protection monitoring criteria for corrosion control of pipelines subjected to stray current interferences through improved methods to measure and predict where AC and/or AC+DC induced corrosion may occur and establishing innovative approaches for monitoring. In addition, determine whether and when these monitoring methods are needed and most effective.
- Defining the mechanisms and behaviors of dormant SCC cracks to maintain the dormancy or eliminate the conditions for reactivating the dormant cracks. This is accomplished by investigating the effect of low frequency and low amplitude cyclic stress typical of pressure fluctuations in gas pipelines, and the inhibitive effects of organics to the SCC cracks growth rate.
- Continuing research on developing the best approach to manage the potential for internal stress corrosion cracking (SCC) to occur while transporting fuel grade ethanol. The PRCI SCC-4 program “Ethanol Transportation in Pipelines” began in 2007 and projects SCC-4-1 and SCC-4-4 are complete and SCC-4-3 research is complete and the final report under review by the project team. The program will conclude in 2012 with the completion of SCC-4-5. The research has indicated that a 10% mixture of ethanol in gasoline (E10) can be transported without any modification to the existing transportation system.

Design, Materials and Construction

- Continuing program to develop a safe and viable alternative to the pre-service hydrotest of natural gas pipelines. This could result in significant time and cost savings, especially for pipelines in Arctic areas.
- Research initiated to develop guidelines and criteria for the evaluation and protection of buried pipelines subjected to the effects of close-in blasting on an undamaged pipeline in rock. This work relates to protection of existing pipelines from external loads and improving construction efficiency and safety.
- Research continues to develop an enhanced model to predict the start of a pipe fracture event and the maximum failure pressure of an axial crack in a high-strength line pipe. This model will improve design and assessment capabilities.
- Joint PRCI & DOT funded research is nearing completion on the validation & documentation of pipeline tensile strain limit design models. The primary objective of this project is to provide a set of tensile strain design models for the strain-based design of pipelines. The implementation of the tensile strain design models involves pipe specifications, welding procedure qualification, field girth weld flaw acceptance criteria, and field construction practice.



■ Over \$45 Million in Member Funding Since 2006



- Research and development in welding high strength steel pipelines remains a high priority. This ongoing effort, jointly funded by PRCI and DOT, is developing a fundamental understanding of factors that affect the mechanical properties of these welds as influenced by welding parameters and to develop optimized solutions.
- Evaluating the structural significance of mechanical damage to pipelines is another high priority. As part of a comprehensive multi-year program addressing mechanical damage, work continues to validate improved burst and fatigue strength models using data generated through a comprehensive full-scale testing program.

Operations & Integrity

- Evaluating and qualifying the performance of NDE technologies for in-ditch inspection of corrosion, cracking/SCC, and mechanical damage to establish a benchmark for current technology and reduce the uncertainty associated with the measurement systems for pipeline inspection. Work has also included the development of technology for inspecting SCC crack colonies and determining fitness for service of the affected pipeline by filtering and identifying the significant cracks in the colony.
- Research to address subsea pipeline integrity management challenges, including a comprehensive subsea integrity management program, including a performance capabilities study and test trial program for current and emerging inspection technologies for detecting fatigue cracks in heavy wall Steel Catenary Risers (SCRs) and piping used in offshore applications.
- Further validation of the use of Magnetic Flux Leakage (MFL) technology for improving the detection and characterization of mechanical damage features, including substantial progress on validating the dual-field MFL ILI technology and expanding the MFL signal response database and library to include dent+gouge features from test samples developed to replicate the types of mechanical damage experienced in the field.

- Detailed assessment of the performance of current and emerging technologies for detecting small leaks in pipeline systems through comprehensive field testing programs. Methods being evaluated include ground-based sensing technologies and use of sensors from airborne platforms.
- Developing a technique for sizing external corrosion features using guided wave ultrasonic technology and validating the model through a series of test trials. The technique builds on prior research performed primarily on small diameter pipelines, and extends the approach to a greater range of pipe diameters. Continued research is being performed in 2011 and will include additional testing in a controlled setting and validation of the technique using field sites where real corrosion features will be excavated and inspected.
- The pipeline industry continues to be challenged by damage incidents caused by work on the pipeline infrastructure by first, second, and third parties operating in the common right-of-way. This effort is aimed at identifying the human factor elements associated with first, second, and third parties that contribute to the damage statistics, and identifying practical methods to manage their adverse effects on the effectiveness of damage prevention measures. Phase 2 of the project will be completed in 2011.

Compressor & Pump Station

- Developing the methodology and procedures to determine the remaining life of combustion turbine disks, thus avoiding overly-conservative fired-hour based replacements. This effort focuses on analytic procedures based upon the history of the engines' operation to characterize component integrity and successfully extend the life of turbine disks beyond the OEM's original specification without unacceptable integrity risk.
- A continuing effort to develop alternatives to gas turbine expansion starters. This involves examining the advantages and disadvantages of multiple hardware configurations for each concept, and developing detailed cost and performance estimates and rough design layouts for a number of potential devices and approaches.
- Developing a "best practices" guideline for designing small diameter branch connections that are susceptible to failure due to vibration fatigue. The guideline discusses the major types of branch connections and provides an allowable mass for components and length of connection.
- Compiling publicly available literature and actual installation and maintenance practices to produce a guideline for assembly and maintenance of bolt joints in high vibration environments. A summary presentation for training at the station operator level will be developed for operating personnel.
- Work is being completed on the multiple technical dimensions required for NO_x reductions in a cost-effective manner. The Emissions Control for Legacy Reciprocating Engines program will be completed in 2011, culminating with field tests of two two-cycle field test engines that have been outfitted with a variety of the NO_x reduction technologies developed in the PRCI program. The seemingly continual tightening of NO_x regulations has continued into 2010, with indications that widespread engine retrofits will be required from 2014 through 2017. The emphasis is now shifting to rich-burn engines, where troublesome NSCR systems are the prescriptive rich-burn control technology. Evaluation of these systems and their individual components such as the air/fuel ratio sensor, the controller, and the catalyst elements, are attempting to isolate which components need additional development effort for the unique



natural gas exhaust chemistry of natural gas. Formaldehyde compliance will also drive many of the NSCR initiatives.

- While waste heat can be recovered at some compressor stations via large heat recovery boilers that generate electricity for sale back to the grid, there may be smaller scale heat recovery options that provide useable energy within the compressor station itself. The second phase of an engineering design study is underway to detail potential concepts that would enhance various station unit operations and provide an overall reduced energy consumption profile.
- New greenhouse gas (GHG) reporting regulations will place a significant burden on operators to estimate their fugitive emissions from a variety of specified locations at compressor stations. Per the GHG reporting rule, emission sources to be reported include pneumatic devices, compressor venting, storage tank venting (from dump valve leakage), and centrifugal compressor seals. Emission estimation methods include vent measurement, engineering calculations, and emission factor approaches based on component counts and identification of leaking components. These methods will be evaluated and organized for immediate operator use. A separate project will develop new factors for estimating fugitive emissions from various components within the station.
- Projects to determine emissions factors for fugitive emissions and to re-examine standard emissions factors for compressor station fugitive emissions and to develop improved fugitives measurement methods and reporting procedures.

Measurement

- Assessing the latest in-line meter techniques to decrease safety risks associated with field disassembly and reduce the operation & maintenance cost of periodically cleaning metering and control equipment internals. This study will provide a cost-effective option for cleaning large equipment, or equipment with poor field disassembly design provisions.
- Characterizing ultrasonic meters' responses to liquid contaminants produced by pipeline operations, particularly compressor oil and glycol. This will determine whether ultrasonic meter diagnostics can identify contaminant types, whether the diagnostic ability of the meter depends upon the meter and transducer designs, and how various contaminants affect measurement accuracy.
- Investigating alternatives to the Periodic Calibration Verification procedure for turbine gas meters to improve methods of conducting diagnostic tests or periodic recalibrations. Controlled Lab flow testing will be performed to validate and determine the sensitivity of these techniques.
- Develop a station measurement uncertainty estimation tool for metering of atmospherically stable liquids.

Underground Storage

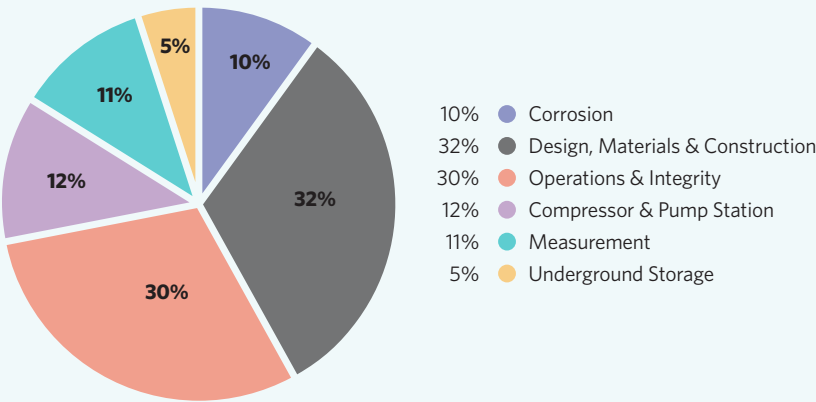
- The stability of brine strings in underground salt caverns is a limiting factor for integrity and deliverability, as these tubular components can move violently and fail if fluid injection or withdrawal velocities are not closely monitored. The current project phase is identifying technologies that can detect the magnitude of brine string displacement and velocity. This pipe location capability will be a key element of a 2011 field test of an improved brine string stiffener.

Looking Forward...

The 2011 Research Program

Direct member funding of over \$8 million will be directed toward PRCI's 2011 Research Program comprised of more than 60 projects and programs addressing the core topics: pipeline corrosion, integrity, operations, design, materials, construction, and facilities. Additional cofunding committed by our partners and other organizations, contributes to an active program exceeding \$35 million.

\$8+ Million Direct Member Funding to 2011 Research Program



The following highlights a number of specific initiatives in 2011 that will advance the energy pipeline industry through research:

Corrosion

- A state-of-the-art review of the available R&D and field information on the performance of FBE coating in service and of methods to monitor the coating condition and to predict future performance.
- Further evaluation and improvement of the Internal Corrosion Threat Guidelines developed by PRCI through field data collection and statistical analysis to increase the confidence level in field applications.
- Development of grinding limits guidelines for repair of SCC on operating pipelines.

Design, Materials & Construction

- The capabilities of PRCI's On-bottom Pipeline Stability Analysis tools are being expanded and updated. This computer program, a key resource for subsea pipeline engineers, was reviewed in detail last year leading to the improvements selected for implementation in the coming year.
- The results of PRCI - DOT research on the welding of high strength pipelines will be applied to take the tools being developed to a mature stage for field applications. Experimental and



analytical investigations will be conducted on the relationship between welding procedure/parameters and the mechanical properties of the girth welds. The focus will be on multi-wire GMAW processes, especially for thick walled pipe in offshore applications.

- Weld overlay pipes will be evaluated for increased subsea applications in critical segments such as flow lines and tower risers. Main issues to be addressed are NDT inspection, impact of installation methods, including reeling and J-lay, on pipe characteristics, and subsequent fatigue performance in subsea applications.

Operations & Integrity

- Continued focus on NDE inspection technologies. New approaches being added to the program in 2011 include evaluating the capabilities of current methods for inspecting composite materials used in pipeline integrity and repair applications. In addition, the 2011 NDE program will include the development of new inspection technologies for operating pipelines, including an internal integrated pipeline cleaning and inspection tool and evaluation and performance testing of Electromagnetic Impedance Testing (EMIT) technology. Work will also continue on improving the understanding of current technologies for corrosion, mechanical damage and SCC/cracking, including continuing the assessment of EMAT technology as a viable tool for integrity management for SCC and cracking and performing a series of projects that are focused on quantifying the stress and strains induced in pipe steel from mechanical damage deformation and linking the inspection technology capabilities to the data from the full-scale testing of mechanical damage defects (see Design, Materials, and Construction section).
- Performing field tests to evaluate and quantify the performance of leak detection technologies. Testing will be performed to expand on the laboratory trials of in-ground sensing technologies completed in 2010 and to develop specifications for field deployable systems and define the system capabilities and limitations.
- Substantial efforts to address pipeline Damage Prevention through multiple projects and programs. Work will include the continuation of the RAM Program, with emphasis on comprehensive flight testing of selected sensor technology packages for machinery threat and leak detection, refining the detection algorithms, and engineering and testing a prototype operational system. In addition, PRCI will implement an evaluation of the use of satellite-based technologies for detecting encroachment/unauthorized access to pipeline ROW corridors, building on and updating prior PRCI research to confirm the improvements in satellite capabilities for damage prevention. Work is also continuing on evaluating Human Factors associated with pipeline Damage Prevention, and a separate project will evaluate the effectiveness of Damage Prevention techniques and the efficiency of Data Collection Tools and Procedures and their influence on Damage Prevention.

Compressor & Pump Station

- Develop and test monitoring methods capable of predicting the condition of liquid pumps mechanical seals and alerting the operator before a failure occurs.
- Leverage results that were accomplished under the CPS-1 (Emissions Reduction from Legacy Engines) program to exploit the non-emissions benefits of those NO_x retrofit technologies. Establish common performance specification standards and installation guidelines to ensure that equipment options can meet user needs the first time while avoiding expensive field iterations.

- Characterize the performance of catalyst-based after-treatment technologies for formaldehyde compliance, and assess catalyst performance at low loads, under difficult excess oiling conditions, and at various locations on the engine.
- Minimize gas compressor cylinder lubricating oil consumption.
- Evaluate whether crude oil treated with an electric field undergoes a durable viscosity reduction such that flow friction losses are meaningfully reduced.
- Complete an evaluation of a gas turbine field maintenance package that eliminates inlet guide vane lockup on units in intermittent service.

Measurement

- Assessment of the Auto-Adjust and Self-Checking capabilities of dual rotor turbine meters in providing diagnostics and maintenance capabilities.
- Quantify the ultrasonic meter accuracy shifts of varying grime thicknesses on the meter body and acoustic transducers only, and correlate the accuracy shifts with thickness and type of grime and diagnostic indicators.
- Identify and recommend candidate technologies for development into practical, cost-effective orifice meter performance diagnostic tools.
- Examine whether the use of thermowells for temperature measurement introduces bias into gas measurement, and assess if ultrasonic meters are a functional substitute when thermowells are affected by diurnal temperature swings and/or dynamic startups.
- Assess whether Micro Motion's "Structural Integrity Meter Verification" capability can be used to verify meter accuracy without removing the meter to a calibration lab.
- Extend the Meter Station Design Tool capability to include ultrasonic meter stations, turbine meter stations and possibly coriolis meter stations.
- Develop low cost, distributed gas quality sensors using crossover technologies from other industries.
- Determine the proper maintenance and test intervals for primary and secondary measurement equipment.

Underground Storage

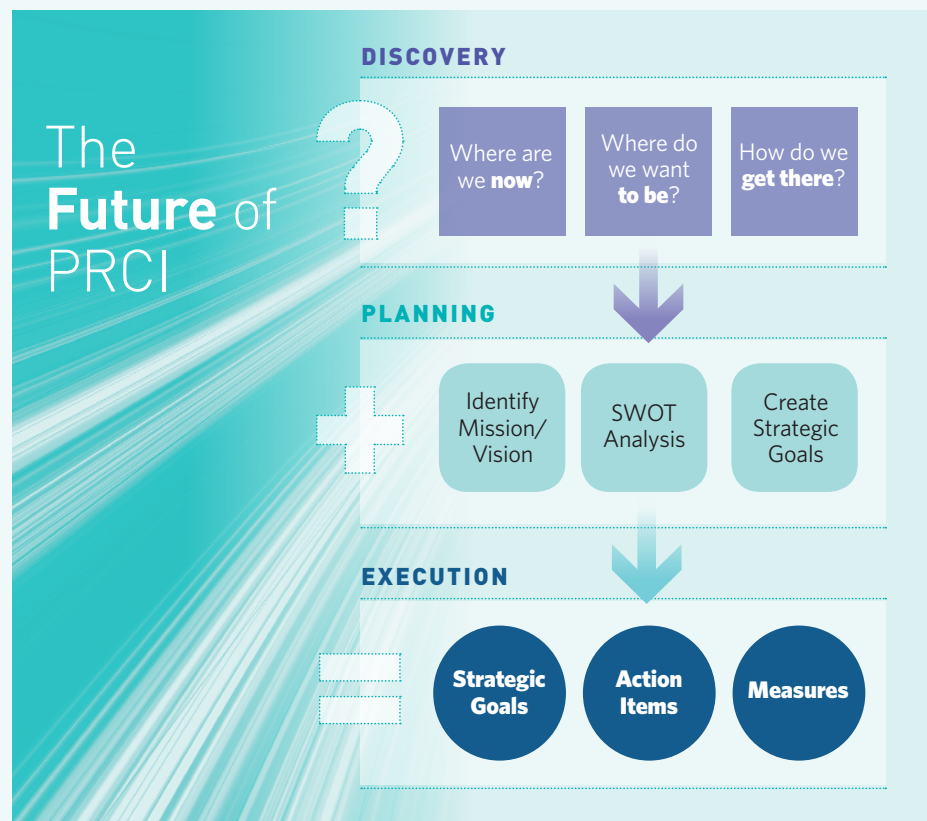
- Conduct a field test of an improved brine string stiffener in a salt cavern, with the objective of increasing the fluid injection/withdrawal velocity by 66%.
- Evaluate the performance of new cement bond log inspection tools.
- Model the temperature anomalies of casing leaks in salt caverns as part of the further development of a possible mechanical integrity test based on gas expansion cooling.

The 2011 Research Program will see PRCI develop research solutions that are responsive to business and regulatory drivers as well as public expectations. By taking on new projects in a number of areas, PRCI is positioning itself for the future and demonstrating the merit and benefits of broad and diverse collaboration.

» Planning the Strategic Direction of PRCI

As we wrap-up 2010 and begin looking to the future, PRCI has begun the process of developing a five-year Strategic Plan. The initial meetings were held in November and December of 2010 to develop a draft plan that will be discussed at the Board meeting in Atlanta in March 2011.

As was pointed out in the Chairman's and President's Statements, this has been a year of change and transition for PRCI and the industry and it is great time to develop a Strategic Plan for PRCI. This plan will be establish a five-year vision for PRCI that will enable us to continue build on the remarkable success of the last 58 years and position us to strengthen our leadership role in Energy Pipeline Research and Development. Many of our member companies have been involved in the first meetings and we are continuing the look for additional inputs. Once the Board has discussed and approved the draft plan will begin talking with key industry and government partners.

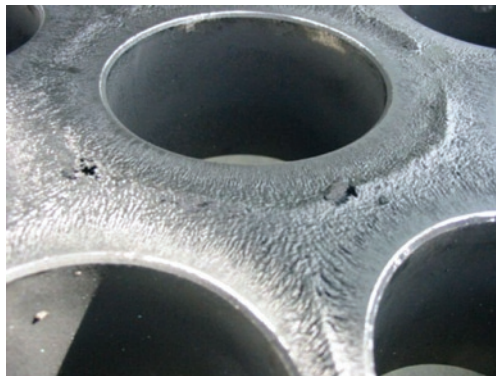


Appendix

- Assess the Performance of Dirty or Worn Flow Conditioners
- Determine Effect of Ethanol on Pump Station Facilities
- Determine the Requirements for Existing Pipeline, Tank, and Terminal Systems to Transport Ethanol Without Cracking
- Development of a Variable Cathodic Protection Criteria
- Development of Guidelines for Identification of SCC Sites and Estimation of Re-inspection Intervals for SCC Direct Assessment
- Engine and Emissions Performance Calculator
- Equations of State Relevance for Supercritical CO₂ with Impurities
- Guidelines for In-Situ Characterization of Cracks
- Research on Composite Repair Systems
- Right-of-way Automated Monitoring (RAM) System Architecture and Concept of Operations

» Assess the Performance of Dirty or Worn Flow Conditioners

A large portion of current natural gas metering technology requires a fully-developed velocity profile for accurate flow measurement results. Two methods can be used to obtain a fully-developed velocity profile in natural gas pipelines: long lengths of straight pipe, or shorter pipe lengths in combination with a flow conditioner. Due to size limitations, long lengths of straight pipe are not always practical and flow conditioners may be the only viable option.



Dirty Flow Conditioner Example. The powder buildup on the surface of the perforated plate flow conditioner is evident. ■ Grimley, T.A. & Hawley, A.G. (2010). *Performance of Dirty or Worn Flow Conditioners*.

Flow conditioners that are based on a distributed pattern of holes through a plate are commonly used in the natural gas industry and are referred to as “perforated plate” flow conditioners. The ability of a perforated plate flow conditioner to redistribute a disturbed velocity profile is based on multiple geometric characteristics of the plate (e.g., hole pattern, porosity, and plate thickness) and on the hole details (e.g., edge sharpness). Exposure of perforated plate flow conditioners to conditions in natural gas pipelines could result in changes to the geometric characteristics of the flow conditioner due to dirt buildup on the flow conditioner face or

wear of the edge sharpness. The ability of dirty or worn plate flow conditioners to effectively redistribute a disturbed velocity profile is unknown.

KEY PROJECT RESULTS

This project specifically addressed the ability of dirty or worn perforated plate flow conditioners to redistribute disturbed velocity profiles. Four flow conditioners were modified to exhibit two levels of buildup and wear that were representative of typical field examples of effected flow conditioners. An orifice meter and two ultrasonic meters were used to assess the effect of the changes in the flow conditioner geometry. Through the individual path measurement data, the ultrasonic meters provided information on the shape of the velocity profile, as well as information on the overall shift in meter error as a result of changes to the flow conditioner. In addition, the pressure drop across the flow conditioner was measured to determine if there was a significant change in pressure drop as a function of the wear or material buildup.

» Determine Effect of Ethanol on Pump Station Facilities

Ethanol is widely used as both an oxygenate additive and as a fuel substitute for gasoline. Legislation mandates a significant increase in ethanol usage as fuel over the next twenty years. The widespread use of ethanol will require efficient and reliable transportation from widely dispersed ethanol producers to distribution terminals. Pipelines are by far the most cost-effective means of transporting large quantities of liquid hydrocarbons over long distances. For transporting ethanol, both existing pipeline infrastructure and new pipeline construction are being contemplated.

In companion PRCI projects, the stress corrosion cracking (SCC) of pipeline steels and the performance of elastomer seals/gaskets are being studied. The SCC study not only includes piping grade steel, but also a cast steel that could be used in pumps. Many of the issues related to corrosion are being resolved in these projects. However, to completely address the effect of ethanol and ethanol-gasoline blends in pipeline systems, investigation of the effects of ethanol on other components, such as pumps, valves, screens, springs, and metering devices need further investigation. These components may have different materials (e.g., non-ferrous alloys), different types of loading, and different exposure conditions.

KEY PROJECT RESULTS

This effort focused on investigating materials compatibility issues with ethanol for components involved in pump station facilities. A number of different materials were found to be present in the components in pump stations. Metals included carbon and low alloy steels, stainless steels, pure nickel, bronzes, and aluminum alloys. There was a variety of stainless steels in pump station components including 300 series (austenitic, high nickel), 400 series (ferritic/martensitic, low nickel), and precipitation hardened alloys. Zinc and titanium were included in the literature search results; although they were not identified in pump station equipment. Nonmetallic materials in pump station components include ceramics, fiberglass, Buna N and butadiene rubbers, polyurethane, Teflon, PEEK, Viton®, and nylon. The materials compatibility data were divided into four different categorizations: not compatible, probably not compatible, probably compatible, and compatible.

» Determine the Requirements for Existing Pipeline, Tank, and Terminal Systems to Transport Ethanol Without Cracking

Pipeline companies have a keen interest in assessing the feasibility of transporting fuel grade ethanol (FGE) and ethanol blends in existing pipelines. Previous field experience and laboratory research, funded by PRCI and API, has shown that steel can suffer stress corrosion cracking (SCC) when exposed to FGE in the presence of oxygen. Though cracking was prevalent under some conditions, variability in cracking susceptibility of steel was noted with different ethanol chemistries. Additionally, the effects of residence time of FGE or its blends on SCC (i.e. crack initiation time and growth rate) had not yet been determined. Finally, the effects of ethanol on other materials used in the pipelines, such as elastomeric seals and internal coatings, needed to be evaluated. Thus, the major objectives of the program are to: 1) Develop data necessary to make engineering assessments of the feasibility of transporting FGE and FGE blends in existing pipelines. The transportation may be in a dedicated pipeline or in a batching mode, 2) Identify ethanol blends that can be transported in existing pipelines without significant modification of the system and operations (Case 1), blends that require significant modifications (Case 2), and blends that cannot be transported in existing pipelines, but could be moved in specially designed systems (Case 3); and, 3) characterize the time to initiation of SCC in a range of potent ethanol environments and identify safe operating and or batching practices that prevent the initiation and growth of SCC.

A program consisting of two phases was performed to address these objectives.

- Phase 1: In the first phase, screening tests were conducted to identify ethanol blends that are unlikely to cause internal SCC. A literature survey and laboratory testing also was performed to evaluate static and dynamic elastomeric seals.
- Phase 2: In the second phase, crack growth tests under static and cyclic loads were conducted in ethanols/blends that caused cracking in SSR tests to identify safe operating and or batching practices that prevent the initiation and growth of SCC.

KEY PROJECT RESULTS

Pipelines made of common line pipe steels (e.g., Grade B and X-42 to X-60) are likely to be susceptible to ethanol SCC and any differences in susceptibility are probably not significant from an integrity perspective. While differences in susceptibility were noted for some weld types, in general, the base metal, heat affected zone, and weld metal were all susceptible to SCC in Synthetic Fuel Grade Ethanol (SFGE). For sharp cracks, SCC initiation times are short once the line pipe steel is exposed to FGE or FGE blends capable of promoting SCC. The only blends that can be safely transported in existing pipelines without significant modification of the system or operations (Case 1) are those containing less than 15% (by volume) ethanol. All other blends require significant modifications of the system or operations (Case 2), or specially designed systems being studied in the SCC-4-5 project. Batching does not appear to be a viable method for SCC mitigation.

» Development of a Variable Cathodic Protection Criteria

The CP criteria for buried piping systems are not consistent in different global CP standards. For instance, the standard of the International Standard Organization (ISO) and the European standard (EN) offer more specific CP criteria with respect to environmental conditions such as soil resistivity, aeration, presence of bacteria, pipe temperature and overprotection. However, they do not have the -850 mV on-potential criterion contained in the NACE Standard SP 0169-2007. The Australian National Standard (SAA) recommends the use of coupons or an electrical resistance (ER) probe in conjunction with the -850 mV off-potential or the 100 mV polarization criterion, which was not included in the above standards.

Based on operators’ experience, the current CP criteria in the NACE Standard SP 169-2007 may not always assure that pipes are effectively protected and some pipe/soil environments may require alternative criteria such as those in other global standards. This effort aimed to collect and analyze available global CP criteria and data to better understand why and when the NACE Standard SP0169 criteria are effective.

Table 2.2. Comparison of Historical CP Criteria in NACE RP/SP 0169

RP/SP version	1969	1972	1976	1983	1992	1996	2002	2007
Criteria								
(a) -850 mV “ON”	x(+)	x(+)	x(+)	x(+)	x(+)	x(+)	x(+)	x(+)
(b) -850 mV Polarized					x(o)	x(o)	x(o)	x(o)
(c) 100 mV Polarization	x(o)	x(o)	x(o)	x(o)	x(o#)	x(o#)	x(o#)	x(o#)
(d) 300 mV Polarization Shift	x(+)	x(+)	x(+)	x(+)				
(e) Tafel Segment	x(o)	x(o)	x(o)	x(o)				
(f) Net Protective Current	x(-)	x(-)	x(-)	x(-)				

Note: +, - and o refer respectively to consider, not consider and eliminate voltage drops other than those across the structure-electrolyte boundary. In (c), # refers to the method of measuring formation polarization to be included.

Song, F. &Yu, H. (2010). Variable CP Criteria.

KEY PROJECT RESULTS

By compiling and reviewing global CP criteria along with field and laboratory data, the report provides recommendations on evaluation of the -850 mV on-potential criterion, the -850 mV off-potential criterion, the potential criteria in high resistivity soils, the 100 mV polarization criterion, and CP criteria with elevated temperatures and bacteria. It also discusses how the joint use of monitoring and inspection devices with the effective use of CP criteria may affect how appreciate the significance of CP criteria in pipeline external corrosion control and the overall pipeline integrity management.

Significant research is still needed to understand the effectiveness of CP criteria from a fundamental perspective. Mathematical modeling of a pipeline CP system with consideration of both the temporal and spatial variations of the pipe potential and corrosion rate and solution chemistry near the pipe surface should be performed. This would provide a broad understanding of the effectiveness of CP criteria from both macro and micro scales.

» Development of Guidelines for Identification of SCC Sites and Estimation of Re-inspection Intervals for SCC Direct Assessment

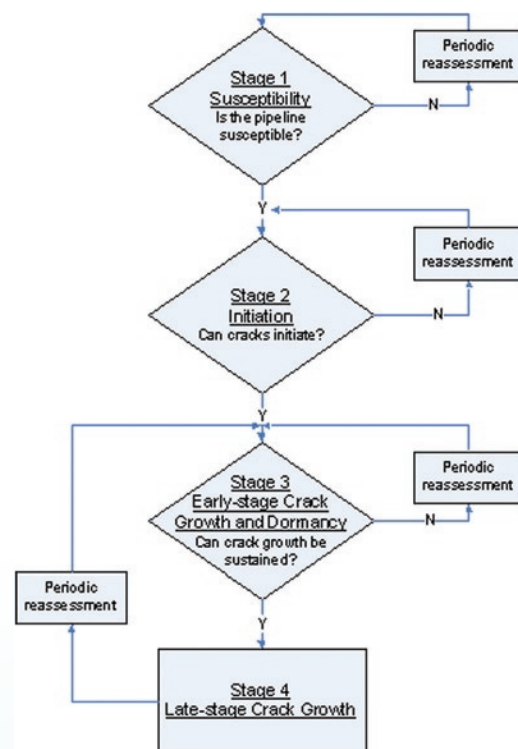
PRCI has completed a multi-year, comprehensive research project

that has established guidelines for identifying locations where external pipeline stress corrosion cracking (SCC) is most likely to exist and for estimating how frequently re-inspections should be performed. The project is largely based on a review, analysis, and synthesis of scientific data developed using sound corrosion science and engineering principles and published in peer-reviewed articles. The guidelines are mechanistically-based and are designed to complement those developed on the basis of field experience. The major route for implementing these guidelines is through improvement of site selection as part of the SCC Direct Assessment (SCC DA) process. The basis for the guidelines is a critical review of over 200 original R&D papers, articles, and reports available in the public domain. These SCC Guidelines have been validated where possible against field data and observations. The SCC

Guidelines have been structured to reflect the various stages of the stress corrosion mechanism. The research conducted under this project was performed in partnership with the DOT PHMSA, which supported the project with R&D funding and technical support and review.

KEY PROJECT RESULTS

The project provides a set of fundamental principles for each form of cracking, and the SCC Guidelines have been developed to determine the susceptibility of a pipeline segment to external SCC, to assess the possibility of crack initiation, of early-stage crack growth and dormancy, and of late-stage crack growth. The results represent a compilation of a vast body of prior work that has not yet been consolidated into a systematic, comprehensive approach for assessing where SCC is likely to be present (or not present) and provide a basis for establishing re-inspection intervals. The guidelines developed in this work are being delivered to NACE and may be included in any future revision of the NACE SCC Direct Assessment Standard Practice (NACE SP0204). The guidelines developed in this project should enhance current operator practices through improved targeting and scheduling or preventative maintenance activities.



General Structure of the SCC Guidelines. King, F. (2010). *Development of Guidelines for Identification of SCC Sites and Estimation of Re-inspection Intervals for SCC Direct Assessment.*

» Engine and Emissions Performance Calculator

Engine Parameter Monitoring System Guidelines developed in prior PRCI work has confirmed that five engine parameters govern engine emissions: 1) Speed, 2) Torque (fuel flow per stroke), 3) Air Manifold Pressure (AMP), 4) Air Manifold Temperature (AMT); and, 5) Ignition Timing.

Conventional methods of engine emissions mapping and modeling required the development of complex multi-dimensional thumbprints to characterize the effects of all five of these parameters. Calculation of the trapped equivalence ratio normalizes the effects of both AMP and torque, significantly reducing the degrees of freedom and resulting in a single parameter that primarily governs emissions. However, important secondary effects remain, particularly for NO_x emissions including speed, AMT, and ignition timing.

The speed effects are particularly important for highly turbocharged engines operating over a wide range of AMP's and airflows. The Guidelines recommended utilizing a multi-parameter linear combination of equivalence ratio, speed, AMT and IT (as required) when mapping or modeling emissions. While somewhat cumbersome, the approach was effective and is in use in engine control and PEMS applications.

Though certainly an improvement over previous approaches, the PRCI-GRI method still requires significant testing, most notably of, combustion airflows. In addition, the results still tend to be engine "make and model" if not unit specific, necessitating the comprehensive mapping of multiple units to develop the required database.

Many years of engine testing data and experience allowed standardized methods to document the methodology for modeling, calculating and validating engine and emissions. The performance data is based on the trapped equivalence ratio (Φ), or TER. As each major parameter contributes to the TER in some fashion, this makes the TER a possible output parameter of a theory-derived, empirically-confirmed computer-based calculation tool. This tool normalizes engine inputs for a given engine type, and processes enough independent operating parameters that a TER for the engine can be calculated. With the TER in hand for a given air and fuel flow configuration, engineers can determine how much additional air flow is needed to attain NO_x targets, and specify a turbocharger upgrade or replacement accordingly. This tool has proven robust for both conventionally-fueled engines and enhanced mixing engines, and can save substantial amounts of time and money by avoiding incorrect turbochargers. It is available to PRCI members on the PRIME website for download and use.

» Equations of State Relevance for Supercritical CO₂ with Impurities

This research project addresses the highest priority research gap that was identified through the PRCI assessment of CO₂ pipeline technology that was completed this year. At the request of several of our members, PRCI initiated a quick response JIP in June 2010 to address this specific critical research need for CO₂ transmission pipeline design and analysis. The objective of this project is to determine experimentally the decompression wave speed in predominantly CO₂ mixtures with N₂, O₂, CO and H₂ impurities, from a range of initial pressures and temperatures. Such impurities are typical of carbon capture streams from industrial sites that must be transported by pipeline for sequestration or enhanced oil recovery (EOR) projects.

Decompression wave speed is an essential element for achieving effective fracture control design, which is required for all pipelines transporting hazardous substances. The final goal is to provide essential information to allow CO₂ pipelines to be designed with appropriate material toughness to prevent long running ductile fractures, thus removing a potentially serious obstacle to their efficient design for high-consequence areas. Another technical objective is to compare the test results with various equations of state and determine which ones best represent the properties of both pure CO₂ and CO₂ with impurities, particularly in the dense or supercritical state.

The initial round of testing planned under the JIP has been completed with excellent results. Follow-on testing continues under a PRCI project approved and funded this fall. The ongoing testing addresses a wider range of CO₂ mixtures of interest to our member companies, representing the range of global environments for CO₂ pipelines that are being encountered by operating companies.

This project is also funded by the Australian Pipeline Industry Association (APIA) and the European Pipeline Research Group (EPRG), and is the first tripartite research conducted by these three organizations together.



Shock Tube Facility.

Source: TransCanada/NOVA Chemicals. (2010).

» Guidelines for In-Situ Characterization of Cracks

Stress Corrosion Cracking (SCC) theory postulates two mechanisms for crack growth and initiation; intergranular crack propagation associated with classical or high pH SCC and transgranular crack propagation associated with near-neutral pH SCC. Metallography is a method for distinguishing between the two forms of SCC by observing the mode of crack propagation.

The purpose of this project was to establish a practical metallographic protocol to distinguish between high pH SCC and near-neutral pH SCC in the ditch. The protocol addresses how to distinguish the crack propagation modes. In addition, the protocol addresses procedures for preparation of sample location areas for analysis through the use of mechanical, electrical, and chemical means considering the quality of results, ease of use, portability, and reliability.

KEY PROJECT RESULTS

An “in-the-ditch” SCC identification and characterization protocol was developed that included identification of surface breaking cracks with magnetic particle inspection and metallography. A conventional grind-polish and etch surface preparation procedure coupled with in-situ microscopy and a crack mode assessment methodology was established for in-the ditch use.

» Research on Composite Repair Systems

PRCI has considerable research underway to evaluate the capability of composite repair systems to meet the needs of the pipeline industry. The work began in 2008 with two projects that addressed initial member interests. One developed a survey of the state of the art in commercially available composite repair techniques. The other began a long-term assessment of the performance of several commercially-available composite systems to repair corrosion in buried pipelines for up to ten years. This test program is being conducted at the Stress Engineering Services, Inc. field testing facility near Houston, Texas on joints of buried line pipe subjected to simulated operating environments covering a range of actual field conditions including worst case pressure and defect scenarios. Currently 13 systems are participating in this program that includes the repair of pipe samples with corrosion depths up to 75% of the pipe's nominal wall thickness. Burst testing of select pipe joints is conducted on an annual basis to provide a measure of the composite systems performance at interim times during the extended test period. Additionally, last year PRCI began a project to examine the usefulness of composite repair systems to reinforce mechanical damage; this work is now nearing completion and has evaluated nine different composite systems. This year, PRCI member companies approved two additional projects to evaluate commercially-available composite systems for subsea repairs and for reinforcing vintage girth welds.

These series of projects demonstrate industry's increasing interest in expanding the number of cost effective repair and reinforcement alternatives, along with the broader application of composite repair systems to address pipeline integrity management requirements.



Long-term Repair Study.

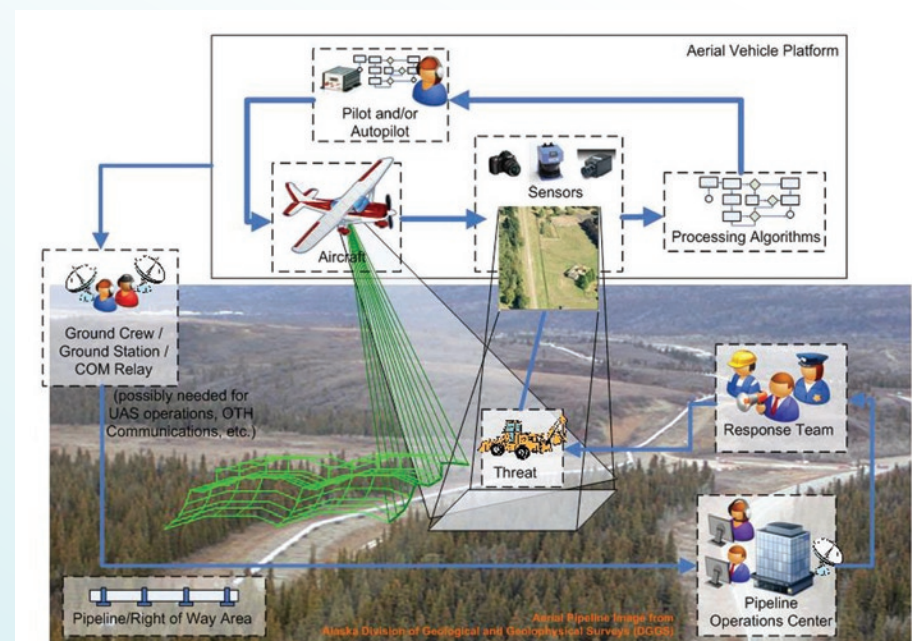


Photos from PRCI Project MATR-3-4. Assuring the Permanency of Composite Systems for the Repair of Corrosion and Mechanical Damage

» Right-of-way Automated Monitoring (RAM) System Architecture and Concept of Operations

PRCI completed a comprehensive document that describes the Right-of-way Automated Monitoring (RAM) system architecture and concept of operations, or CONOPS. It is intended to be a living document and will be updated and revised as the RAM program progresses. Under the RAM program, technologies for detecting heavy machinery threats, leaks, and physical changes are being evaluated, developed, and integrated into a system suitable for deployment on light aircraft. While these technologies and systems are being developed to support the energy pipeline transportation industry, they may be extended to other industries as appropriate. In this report, the system requirements, performance parameters, and assumptions used to develop the system architecture are listed, and the methodology and rationale for the system architecture are explained. Extension of the system architecture to include unmanned aircraft systems (UAS) and satellites, as well as development of operational concepts that include those observation platforms, is anticipated as a future effort.

In developing the RAM system architecture and operational concept, a variety of technology trade-offs were studied and cost/benefit comparisons made. Examples include camera requirements for threat detection (still vs. video; resolution; shutter speed; commercial availability; gimbal-mounted vs. fixed to aircraft), locus of data processing (on-board vs. ground-based), response latency (real-time vs. post-flight), and communications requirements. Details of these analyses are included in the body of the report.



General Operating Concept for Pipeline Monitoring.

Ippolito, C., Frost, C. & Berthold, R. (2010). Pipeline Right of Way Automated Monitoring Technology Package Analysis (RTP): Concept of Operations and Conceptual System Architecture.

KEY PROJECT RESULTS

A key finding of this analysis is that the response time requirement is a major driver of system cost and complexity. Requiring “near real time” capability dictates on-board processing and more sophisticated airborne communications links, whereas post-flight processing of the sensor data mitigates the complexity of the on-aircraft system. The response time requirements for threat, leak and change detection may not be equal, but interrelationships arising from the system architecture (e.g. if change detection is used as a pre-filter to threat or leak detection) can strongly influence the implementation requirements. Thus, the requirements, performance parameters, and cost impacts/trade-offs associated with the system’s response time should be reviewed and validated with the RAM Stakeholders.

An additional finding is that a fleet-wide operations analysis, for both piloted and unmanned systems, should be conducted to determine the implications for the system architecture, operational concepts, and operational costs; within the United States, stringent Federal Aviation Administration requirements on unmanned aircraft operations in the U.S. National Airspace System are a significant issue. These analyses should also include operations outside the United States, as differences in infrastructure and regulations are likely to have significant impact on the RAM system.



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, and support for influencing public policy affecting the industry.



Pipeline Research Council International, Inc.

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