



# 2011 YEAR IN REVIEW

PIPELINE RESEARCH COUNCIL INTERNATIONAL





## Our Members



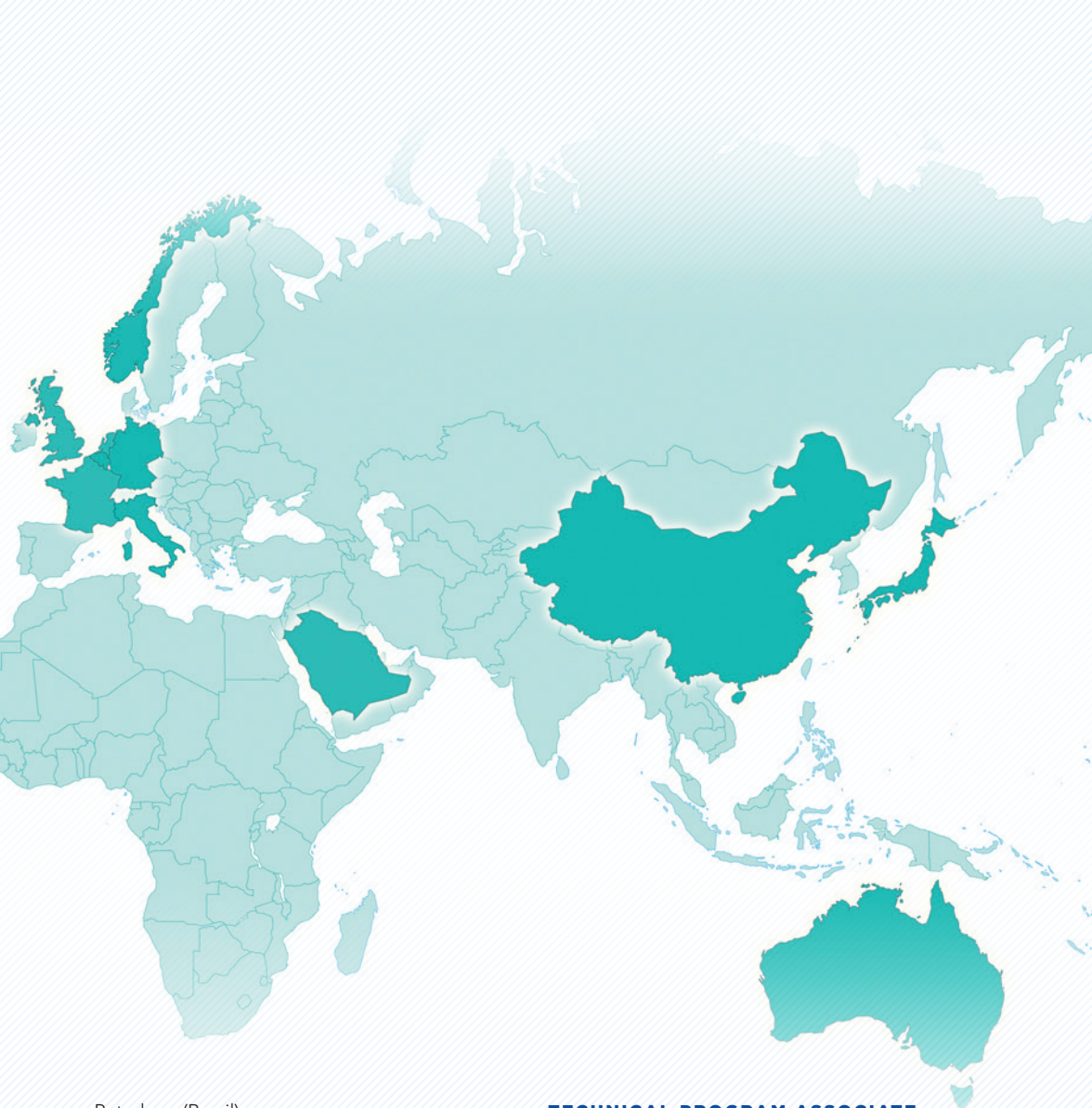
PRCI is proud to include the following organizations and companies as members. Since 1952, PRCI has grown from small group of 15 members based in North America to an international organization spanning five continents and growing.

Unique among all pipeline research organizations, PRCI brings together leading pipeline companies from around the world to engage in a collaborative process that is truly “of, by and for” the industry with one objective: to direct research enhancing the safety, reliability and productivity of the energy pipeline industry.

### PIPELINE MEMBERS

Alliance Pipeline Limited (Canada)  
Boardwalk Pipeline  
BP  
Buckeye Partners, LP  
CenterPoint Energy  
Chevron Pipe Line Company  
Colonial Pipeline Company  
ConocoPhillips Pipeline Company  
Dominion Transmission, Inc.  
El Paso Corporation  
Enbridge Pipelines Inc. (Canada) and  
Enbridge Energy Partners, LP

Eni S.p.A. (Italy)  
Enterprise Products  
Explorer Pipeline Company  
ExxonMobil Pipeline Company  
Gassco A.S. (Norway)  
GDF Suez (France)  
Marathon Pipe Line LLC  
N.V. Nederlandse Gasunie (Netherlands)  
National Fuel Gas Supply Corporation  
National Grid (U.K.)  
NiSource Gas Transmission & Storage  
Pacific Gas & Electric Company  
Panhandle Energy



Petrobras (Brazil)  
PetroChina Pipeline Company (China)  
Plains All American Pipeline, LP  
Saudi Aramco (Saudi Arabia)  
Shell Pipeline Company LP  
Southern California Gas Company  
Spectra Energy Transmission, LLC  
Total S.A. (France)  
TransCanada PipeLines, Ltd. (Canada)  
TransGas Limited (Canada)  
Transwestern Pipeline Company  
Williams Companies, Inc.

**PIPELINE INDUSTRY ORGANIZATIONS**

Association of Oil Pipe Lines (AOPL)  
Operations Technology Development

**ASSOCIATE MEMBERS**

Applus RTD  
China Petroleum Pipeline Bureau (China)  
GE Oil & Gas  
Lincoln Electric Company

**TECHNICAL PROGRAM ASSOCIATE MEMBERS**

Australian Pipeline Industry Association, Ltd.  
Baker Hughes, Pipeline Inspection  
Cameron Compression  
Dresser-Rand Corporation  
Elster-Instromet N.V. (Belgium)  
Emerson Process Management  
Emerson Therm-O-Disc, Inc.  
Evraz Inc. NA (Canada)  
KEMA Nederland B.V. (Netherlands)  
NDT Systems & Services (America) Inc.  
Nippon Steel Corporation (Japan)  
ROSEN USA, Inc.  
ShawCor Ltd. (Canada)  
SICK Process Automation (Germany)  
Solar Turbines, Inc.  
Stupp Corporation  
Subsea Integrity Group (U.K.)  
Sumitomo Metal Industries, Ltd. (Japan)  
T.D. Williamson, Inc.  
Tubos de Acero de Mexico, S.A. (Mexico)  
Welspun Tubular LLC



Pipeline Research Council International is the preeminent global collaborative research development organization **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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### 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.

### MISSION

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

# Chairman's Statement

■ Eric J. Amundsen



Welcome and thank you for your interest in this 2011 PRCI Year in Review. Whether you are a member of PRCI, a prospective member, or an interested stakeholder, I believe you will find this look-back informative as we highlight the major accomplishments of 2011 and also offer a glimpse into the future. Through the collaborative research model that PRCI employs we have delivered significant and relevant technology solutions during 2011. That same model was used to develop a research agenda for 2012 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.

This is an exciting time to be the Chairman of PRCI. Knowledge base, technologically superior tools, and sound process are keys to success for any company engaged in the transportation of energy via pipelines. PRCI has always been focused on advancing the underlying technology that impacts all three of these components. As mentioned in the 2010 Year in Review, recent high profile incidents have catalyzed the energy pipeline industry to systematically step improve its safety performance. The industry is looking to PRCI to provide timely research and technology to enable that change. PRCI is committed to meeting this challenge in the pipeline integrity arena while at the same time continuing to deliver technology advancement in the areas of design, materials and construction, compressor and pump, measurement, and underground storage for all of our members around the world.

The 2011 Year in Review marks the end of the first full year of Cliff Johnson's leadership and I would be remiss if I did not acknowledge his considerable energy and commitment to moving the organization forward in all respects. Cliff has been relentless in his pursuit of advancing PRCI worldwide as evidenced by new member recruitment in 2011. I would also like to take this opportunity to thank former Chairman Paul MacGregor for the leadership he provided to the PRCI staff and Board of Directors and only hope that I can match his significant contributions over the past two years.

The true strength and overall value of PRCI is sourced in its members. If you are reading this and are not a current member of PRCI, I encourage you to reach out to Cliff, myself, or any of our Board members to learn more about what might compel your company or organization to join us. The value we realize is multifaceted and is returned as a function of input and effort. So if you are a current member, we challenge you to participate at a higher level and realize the enhanced benefits of that effort. I look forward to the challenges, excitement, and rewards that I know 2012 will bring and am honored to be entrusted with the position of Chairman.

**Eric J. Amundsen**  
Chairman

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# President's Statement

■ Cliff Johnson



2011 has been an amazing year for PRCI and the energy pipeline industry. It has been a year of focus.

In March 2011, the PRCI Board of Directors approved a new Strategic Plan for 2012–2017 to ensure that PRCI continues to be the focal point for the industry's R&D needs. At the core of the Plan are five goals summarized below along with commentary on the significance and interdependence of each component:

1. Execute the R&D program – timely, relevant, and effective R&D results and technology solutions continue to build credibility for PRCI.
2. Communicate results and implement technology – assure the value proposition is realized by stakeholders.
3. Engage and grow the stakeholder community – realized value compels participation and grows the financial and intellectual capability of PRCI and fosters enhanced intrinsic value such as networking, professional development, and industry leadership.
4. Establish the worldwide R&D roadmap – attainment of critical mass leads to a stature and position to collaborate to a greater extent and on a worldwide scale for the industry leading to:
5. Delivery of step change technology – the ultimate goal and achievement; possible through execution of the entire Strategic Plan.

It has been a year of growth. Over the last year we have also added a number of new members to the PRCI as noted in the *Growing & Collaborating* article later in the Year in Review. For the first time in our history we have exceeded 60 members in PRCI – 36 Pipeline-operating Company Members, four Associate Members, 21 Technical Associate Members, and two Pipeline Industry Organizations. The growth has been truly international with members joining from China, Italy, Germany, the Netherlands, and the US. The importance in developing and executing a truly collaborative research program is as significant as ever and PRCI continues to be at the center of the activity.

It has been a year of change. As a result of further deliberation from significant North American pipeline safety incidents in 2010, the Pipeline and Hazardous Materials Safety Administration (PHMSA) has rescinded its commitment to industry co-funded research. While this policy change will have some short-term impacts, PRCI leadership is committed to collaborative R&D in a more tactical manner such that the industry continues to derive value from PHMSA-sponsored R&D and vice versa by consideration of and complementing the work done by each organization.

I am looking forward to an amazing 2012! I invite you to join us.

**Cliff Johnson**  
President

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# A Fond Farewell



## Eric Thomas Retires

It is with bittersweet emotion that PRCI says farewell to Chief Operating & Financial Officer Eric Thomas who retired at the end of 2011. Mr. Thomas has been involved in pipeline industry research for over 30 years, which includes participating in organizations such as the Gas Technology Institute (GTI), the Institute of Gas Technology (IGT), and the Interstate Natural Gas Association of America (INGAA) Foundation. He also served as Chairman of the Board for both

PRCI and the Gas Machinery Research Council (GMRC). For ten years, he served as the industry appointee to the Technical Pipeline Safety Standard Committee (TPSSC), the federal advisory committee that provides peer reviews of all proposed pipeline safety rules to assure technical feasibility, reasonableness, cost-effectiveness and practicability. He has been the COO at PRCI since 2007.

Since joining PRCI, Mr. Thomas has achieved a number of accomplishments. Most notably, he led an initiative for research deployment optimization where we examined the organization's program execution capabilities relative to our growing portfolio of projects and membership to further strengthen PRCI as a leader in research for the pipeline industry. While he will no longer be serving full-time in the position of COO, he will continue working with PRCI in a part-time controller role beginning in January 2012.

We are also pleased to announce that Mr. Thomas was presented with the Edward N. Henderson Award for distinguished service to the industry and to GMRC. The award was presented at the closing awards ceremony of the Gas Machinery Conference in October 2011 in Nashville, Tennessee.

Mr. Thomas has been a key player in shaping the future of PRCI and the industry. On behalf of our members and staff, we thank him for his many contributions to PRCI and would like to congratulate him on this momentous period of his life. In his retirement, Mr. Thomas plans to spend time with his lovely wife Rhonda and enjoy the countryside on his motorcycle.

# Growing & Collaborating at PRCI

This year marks an incredible period of growth across the entire PRCI membership with new members from around the globe including pipeline members, associate members, and a pipeline industry organization member. The international breadth of our membership is an excellent illustration of just how important the collaboration within the pipeline industry is worldwide. There truly is need for research to solve pipeline issues all around the world, and PRCI is recognized as the unique forum where companies can engage, work together, and develop the solutions. In 2011, we were pleased to welcome three new pipeline members: Eni S.p.A., Plains All American Pipeline LP, and PetroChina Pipeline Company.



**Eni S.p.A.** operates in the oil and gas, electricity generation and sale, petrochemicals, oilfield services construction and engineering industries. In these businesses it has a strong edge and leading international market position. Eni is active in 79 countries with a staff of about 80,000 employees. They are a major integrated energy company, committed to growth in the activities of finding, producing, transporting, transforming and marketing oil and gas.



**Plains All American Pipeline, L.P.** is engaged in the transportation, storage, terminalling and marketing of crude oil, refined products and liquefied petroleum gas and other natural gas related petroleum products (together "LPG"). Through their general partner interest and majority equity ownership position in PAA Natural Gas Storage, L.P., they are also engaged in the development and operation of natural gas storage facilities. Plains owns and operates a diversified portfolio of strategically located assets that play a vital role in the movement of U.S. and Canadian energy supplies.

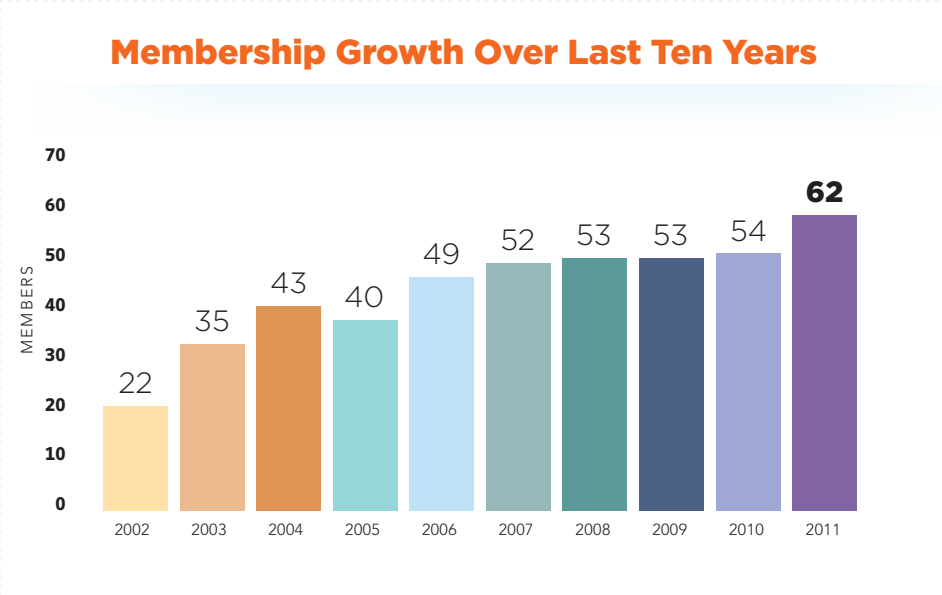


**PetroChina Pipeline Company** is the largest pipeline operating company within PetroChina Company Limited. PetroChina is the largest oil and gas producer and distributor, playing a dominant role in the oil and gas industry in China. It is not only one of the companies with the biggest sales revenue in China, but also one of the largest oil companies in the world. It is engaged in wide range of activities related to oil and natural gas, including: exploration, development, production and marketing of crude oil and natural gas, transportation of natural gas, crude oil and refined oil pipelines.

In addition to our new pipeline members, we were also fortunate to expand our Pipeline Industry Organization membership by welcoming Operations Technology Development (OTD). OTD's membership provides PRCI with an excellent opportunity to collaborate and also to explore the research OTD has conducted in the distribution systems of the pipeline industry rather than solely the transmission and see how it can apply to our current work.

Operations Technology Development (OTD) was established in May 2003 as an Illinois not-for-profit company to facilitate voluntarily funded, collaborative research on issues related to gas operations and infrastructure, with a focus on reducing operating costs, enhancing safety, and increasing the operating efficiency of natural gas distribution systems. OTD's membership has grown to 20 members, representing utilities throughout North America.

Further augmenting PRCI's membership in 2011 is the addition of six Technical Program Associate Members, which are members of one or more of the six technical committees through which PRCI conducts its research. Associate Members are the industry service providers, vendors, and manufacturers of equipment whose capabilities enable PRCI research to be deployed in the industry and the marketplace. We are pleased to welcome KEMA Nederland B.V., SICK Process Automation, Emerson Process Management, Shaw-Cor Ltd., Emerson Therm-O-Disc, Inc., and Baker Hughes, Pipeline Inspection to PRCI.



# 2011



## Accomplishments & Important Findings in Research

## 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:

### COMPRESSOR & PUMP STATION

- Developed preliminary designs and accurate cost estimates of a pump test facility capable of performing tests on pipeline size pumps with crude oil. Current pump design techniques extrapolate the potential effects of viscosity on pump performance from empirical formulas derived from tests on much smaller pumps running lower viscosity fluid. If the pump test facility is to be built, full-scale testing can increase the confidence in the correction factors and enable more efficient viscous oil centrifugal pump designs. The study surveys several institutions and government agencies to determine the interest in pursuing the development of such facility.
- Tested oxidation catalysts on a full-scale laboratory engine to extend the knowledge base for application of these catalysts to pipeline reciprocating engines in three areas: 1) Species-specific removal efficiencies over a wide range of operating conditions; 2) Temperature dependence on removal efficiency and overall performance, which are very non-linear and related to species-specific light-off temperatures, and help to inform decisions on catalyst location; and, 3) Removal efficiency as a function of space velocity, which determines catalyst sizing and long-term performance. This work is important to develop a body of knowledge in advance of the 2013 MACT deadlines, as well as to support the industry's compliance with the expected requirement that all large lean burn engines be outfitted with oxidation catalyst mid-decade.
- Excessive power cylinder (engine) lubrication in large bore two-stroke cycle natural gas engines can lead to increased operating costs due to high lubricating oil consumption, poisoning of catalyst elements, and potentially increased pollutant emissions of the oxidized oil base and additive package. Catalyst poisoning and increased pollutant emissions can occur when lubricating oil, either fully, partially or un-combusted, passes through the cylinder and into the exhaust system, where it may react to form other compounds. Testing quantified the mass of oil carryover into the exhaust system by

its physical form – either as free oil, particulate matter (combusted oil) or incremental volatile organic compounds (combusted oil). The relationship between lubrication rates and particulate and VOC emissions was established, as was the chemistry of the lube oil combustion residue. A follow-on project in 2012 will develop a timed lube oil injection system for slow-speed integral two-stroke engines that will provide improved control lubrication rates to minimize oil carryover.

- A variety of Non-Selective Catalytic Reduction (NSCR) systems are in use on rich-burn engines for NO<sub>x</sub>, CO and VOC control. These will also be installed on many engines for 2013 MACT compliance. Long-term, stable NSCR operation can be challenging due to oxygen sensor performance variability, integration with the three-way catalyst, and the capabilities of the engine control algorithm. Significant progress has been made in each of these sub-systems, with improved and/or novel sensors, more robust control algorithms, and improved packaging. A set of field tests have either been completed or are underway that validate the improved performance of NSCR systems.

## MEASUREMENT

- Methanol is commonly used in deep, high-pressure gas wells to avoid hydrate formation, and can be found in varying concentrations in the gas stream at large ultrasonic custody transfer meters. The accuracy of these meters relies on knowledge of various gas physical properties, including the super-compressibility factor, the speed of sound and the heating value. A detailed review of the impact of different methanol concentrations on these bulk gas parameters indicated that heating value was the item that methanol could potentially distort, and this depends on how the particular station chromatograph processes methanol. A follow-on project characterized how widely-used GC's processed methanol, and how this may affect the ultimate performance of the meter.
- Natural gas meters are often used to measure flows below their minimum design flow rate. This can occur because of inaccurate flow projections, widely varying flow rates in the line or sporadic production rates. The project examined temperature and hydraulic parameters that contribute to measurement error at flow rates below 10% of a meter's capacity, determine the expected range of error at these flow rates, and established methods to reduce measurement error in this range. Three meter types were utilized – orifice, turbine and ultrasonic meters. Several possible ways to improve temperature measurements in low flows were identified for further study, and threshold values below 10% were established for each meter type up to which the meters maintained acceptable accuracy.

## UNDERGROUND STORAGE

- A multi-year project to improve the integrity of brine strings has developed a novel sensor package that enables the operator to determine the precise location of the brine string within the cavern. This enables monitoring of the movement of the string as fluids are injected/withdrawn, which is critical information for ensuring that the cavern is being operated in a safe manner and the brine string is not in danger of failure.

## CORROSION

- Evaluated existing and new external corrosion direct assessment (ECDA) procedures for techniques that can detect the presence and type of casing-carrier pipe contacts, with emphasis on unpiggable casings with or without test leads. Additionally, completed a technical evaluation of the tools' criteria for their effectiveness in predicting the type of contact between a casing and the carrier pipe. This study provides a comprehensive and consistent guidance to address casing situations to ensure shorts are located and mitigated. It also assists pipeline operators in using the tools to comply with ECDA Standard NACE SP 0502-2010 for cased pipe segments.
- Completed a comprehensive assessment of current needs and opportunities to improve the identification and management of external microbially influenced corrosion (MIC) on pipelines. The findings are grouped into key components common to all Integrity Management Plans, and the gaps are organized under goals that represent the anticipated benefit that can be achieved. This effort provides an improved understanding of the factors and influences that contribute to MIC and potential methods for control and mitigation.
- Co-funded a major research effort, led by GTI, to establish an unbiased, third-party basis for operators to select girth weld coatings which are appropriate for their particular application requirements, and to provide the long coating life demanded by the industry. This multi-phase test program included all major coating types and accounted for a wide verity of operating conditions. The final deliverable includes comprehensive guidelines, specifications, and test data regarding the preparation, installation, and actual field performance of the coating systems.

## DESIGN, MATERIALS & CONSTRUCTION

- Completed the full-scale testing program to evaluate the effects of mechanical damage on pipelines for higher strength, modern steels. This work included the completion of full-scale tests on plain dents, dents on welds, and dents with metal loss and with gouges. The full-scale testing program included complete metallurgical and material characterization of the test pipes, creation of a range of mechanical damage features in the test pipes, and highly instrumented full-scale burst and fatigue (pressure cycling) tests on the features created. The full-scale testing data are being used to improve the current mechanical damage models used by the pipeline industry, and better understand the behavior of pipeline to mechanical damage as a function of defect characteristics, operating conditions, and material properties of the pipes impacted. Continued full-scale testing will occur in 2012, with testing being performed on lower strength, vintage pipe materials that are representative of most of the materials in use for energy transportation systems.
- Completed PRCI Guidelines for Interpretation and Application of API 1104 – Welding of Pipelines and Related Facilities. The application of requirements contained in many industry codes and standards requires some interpretation by users. There are often differences in the way requirements are interpreted because of unclear rationale behind the requirements of novel or non-traditional applications. Some codes and standards contain guidance in the form of commentary sections or companion

documents. This is not the case for API Standard 1104 which is written in the form of a specification without the background information. This project developed reliable interpretation and guidance material for API 1104 that help clarify the important areas of uncertainty for operators and regulators.

- Welding of High Strength Steel Pipelines was the focus of a collaboratively funded, multi-year research effort that was completed this year. The project involved expert researchers from several public and private organizations to achieve a fundamental understanding of the full range of factors that affect the mechanical properties of welds, as influenced by welding parameters. The problems addressed are exacerbated in high strength steels, but are common for all pipe grades. The project had two primary focus areas:

- **Update of Weld Design, Testing, and Assessment Procedures for High Strength Pipelines.** Knowledge gaps were identified and guidelines provided for the effective use of high strength line pipe from design and testing to weld integrity assessment procedures.

- **Development of Optimized Welding Solutions for X100 Line Pipe Steel.** The range of viable welding options for X100 line pipe was established. Performance was validated through small and large scale tests. Full implementation is expected to be achieved through changes to applicable codes and standards.

This project was designed to address the most critical gaps and bring the necessary technology together for the practical use of high strength steel pipelines. The baseline information on X100 steel compositions and supply is essential to material selection.



- PRCI completed a project to develop the on-shore construction modernization research plan. This work considered the entire on-shore pipeline construction process with the goal of identifying new technologies, or new applications of existing technologies, with the potential to reduce significantly the time and/or cost of construction, while maintaining or enhancing construction quality. The project established linkages with several top-tier pipeline contractors, owner-builders, and relevant industry associations including IPLOCA (the International Pipeline & Offshore Contractors Association) and the INGAA Foundation. In addition to questionnaires, workshops and interviews with key pipeline construction specialists, the project drew from the requirements identified by the IPLOCA-led Novel Construction initiative through the development of its *Road to Success* document.

## OPERATIONS & INTEGRITY

- ➔ Completed several important studies to advance inspection technologies for the detection and characterization of flaws/features related to pipeline transportation systems. These studies included evaluation and development of new sensors and platforms for in-line inspection (ILI) technologies and tools and other non-destructive evaluation (NDE) technologies and methods that are used for direct inspection and measurement of features from the pipe exterior, i.e. "in the ditch." Work performed in 2011 ranged from preliminary assessments and laboratory-scale analysis of emerging technologies and sensor systems for inspection of cracks and other flaws (e.g., MWM-array and Electromagnetic Impedance Technology, or EMIT) to full-scale field studies where technologies were tested through deployment in operating pipeline systems. This work included the completion of several multi-year research projects related to Magnetic Flux Leakage (MFL) ILI technology, including the Dual-field MFL ILI technology field validation and the final phases of work on understanding MFL signals for mechanical damage in pipelines, which expanded in 2011 to include magnetic modeling and neutron diffraction analysis of dent+gouge features. In addition, studies were also completed that focused on quantifying the performance of the inspection technologies and the effects of measurement uncertainty on methods and models used to analyze inspection data.
- ➔ Advanced and completed a research project that resulted in the development of an integrated tool for and mapping, sizing, and evaluating Stress Corrosion Cracking (SCC) on pipelines remaining strength prediction. The integrated NDE tool was developed to screen and filter significant cracks within an SCC colony (i.e., those that may lead to failure) and provide a prediction of safe operating pressures for pipelines affected by SCC. The project provides a process for characterizing the effect of SCC on pipelines, and addresses known difficulties relating to accuracy of crack measurements within SCC crack fields using current technologies. This research integrated data from promising technologies identified by prior research, including depth screening and crack mapping technology (MWM-Array), data analysis for identifying the most significant SCC crack fields and features on pipe, and Laser Time of Flight Diffraction (LToFD) for ultrasonic depth sizing. The technology was verified through comparison of predictions of crack sizing and burst pressure with full-scale hydrostatic burst tests.
- ➔ Continued to advance research to identify and evaluate technologies for pipeline leak detection. Work completed in 2011 included the continuation of a multi-year study on technologies for detecting small leaks in pipelines. Accomplishments in 2011 included the completion of a laboratory-scale study for technologies focused on detecting very small leaks from pipelines that transport petroleum products, including Distributed Temperature Sensing (DTS) and Acoustic Emission technologies. The laboratory-scale study has provided the basis for expanding the research to a full-scale field study on operating pipeline systems, which will be performed in 2012. A separate test was also performed in 2011 for gas leak detection as part of the PRCI Right of Way Automated Monitoring (RAM) Program, which includes automated methods for monitoring leaks along pipeline ROW corridors from fixed wing aircrafts used for pipeline surveillance and patrol. Under the RAM Program, two separate field tests were performed to

evaluate Cavity Ring-Down Spectroscopy (CRDS) technology for detecting leaks from natural gas pipelines. The field test confirmed that leaks can be detected using CRDS in a fixed wing platform. Additional detailed studies will be performed in 2012.

## RESEARCH REPORTS

### Compressor & Pump Station

- Advanced Controls for Non-Selective Catalytic Reduction Systems
- Characterization of Lubricating Oil Carry Over in a 2-Stroke LB NG Engine
- Characterization of Oxidation Catalyst Performance: VOCs and Temperature Variation
- Design Guideline for Small Diameter Branch Connections
- Long-term Test of In-Situ NOx Sensors
- Lubricating Oil Carryover from 2-Stroke Engines
- NOx Retrofit Projects – Lessons Learned from NOx RACT and SIP Call
- Small Scale Waste Heat Recovery (Phase II)
- Test Facility for Pump Performance Characterization in Viscous Fluids, phase II
- Variable Geometry Turbocharger

### Measurement

- Effect of Upstream Piping Configurations on USM Bias, Phase I
- Evaluation and Full Utilization of Auto-Adjust and Auto-Checking Capabilities of Dual Rotor Turbine Meters
- Extended Low Flow Range Metering
- Investigation of the Jetting Behavior of Perforated Plate Flow Conditioners

### Corrosion

- ECDA Techniques for Shorted and Non-shorter Cased Crossings
- Evaluation of the Current Understanding of External MIC and Gap Analysis
- Field Applied Coatings: Short- and Long-Term Performance, Phase IV
- Identify Environmental and Stress Factors that Produce SCC in Existing Ethanol Pipelines and Terminals

### Design, Materials & Construction

- Addition of Graphical Model Presentation within Existing HDD Pulling Load Program
- Criteria for Determining Seam Failure Susceptibility Due to Crack Defects
- Interpretation and Guidelines for Application of API 1104
- Modernizing On-Shore Pipeline Construction - Research Plan Development
- State of the Art Assessment Of Composite Repair Systems
- Validation and Documentation of Tensile Strain Limit Design Models for Pipelines
- Vintage Girth Weld Defect Assessment - Comprehensive Study

## Operations & Integrity

- Development and Demonstration of an Integrated Tool for Mapping, Sizing and Evaluation of SCC for Remaining Strength Prediction
- Evaluation of External Leak Detection Systems –Laboratory Work
- Gap Analysis of NTSB Report PAR 09-01 & ERW Pipe/Long Seam Anomaly Identification, Characterization, and Assessment
- Guidelines for Preventing Underground Facility Damage as a Result of Horizontal Directional Drilling
- Internal Coatings Evaluation for Energy Transmission Pipelines
- Subsea Pipeline Damage Inspection and Protocol - Guideline Development
- Understanding Magnetic Flux Leakage Signals from Mechanical Damage in Pipelines - Phase III

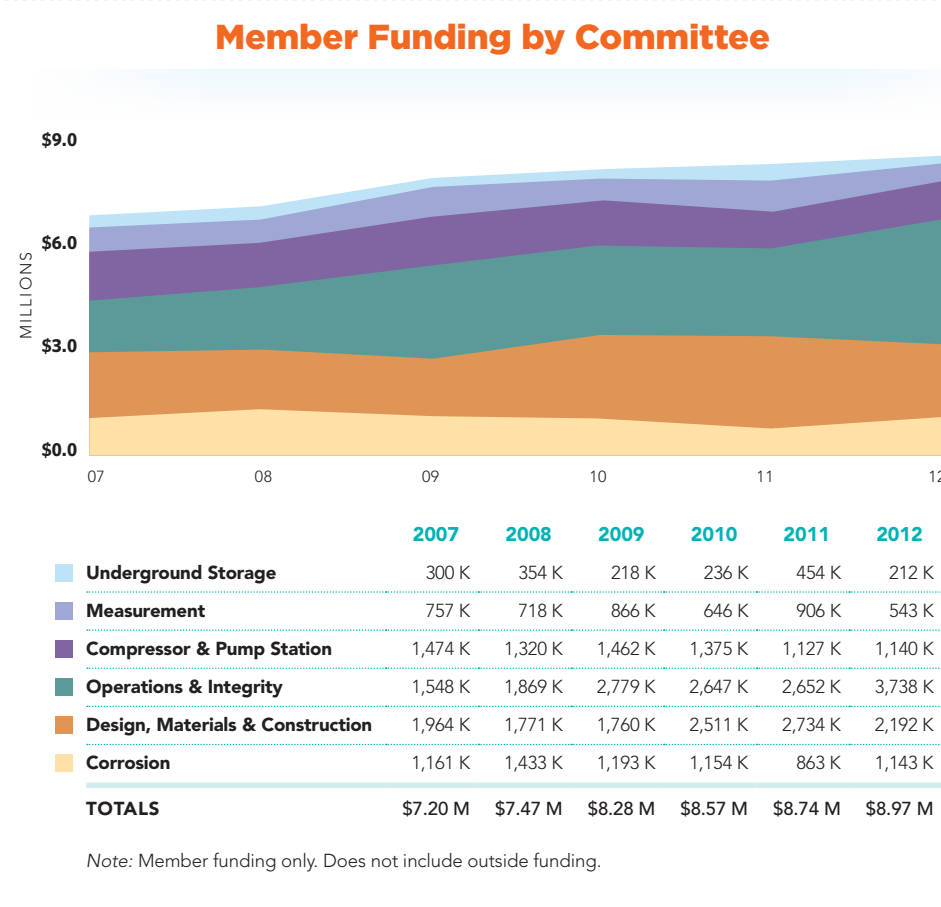
# 2011



## Current Research

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. Following are some highlights of our current program focus, and related projects.



COMPRESSOR & PUMP STATION

- A review of project management experiences with NOx retrofit projects to determine critical lessons learned and best practices that will help to streamline future project timelines, reduce project risk, and optimize project costs and equipment performance.
- Evaluation of alternative oxidation catalysts that appear promising for processing ethane/propane/butane at lower operating temperatures, and catalysts that can be mounted in the exhaust manifold to exploit the higher operating temperature there.

- Greenhouse gas reporting rules require that methane emissions from pneumatic control devices be properly characterized. Work is underway (co-funded with the Gas Machinery Research Council) to identify and classify the population of these components to simplify their reporting by operators. Acoustic leak detection devices for vent measurement will be evaluated for accuracy, and the initial year of Subpart W data submittals by pipelines will be examined to determine if simple emissions factors can be developed for future use in lieu of actual measurements.
- Field demonstrations of advanced NSCR systems continue to assess advanced control algorithms and novel sensor integration.
- Field demonstration of advanced reciprocating engine diagnostics will determine the potential that current technology holds for self-reporting incipient maintenance events, reducing the burden on plant personnel to closely monitor engines, and to possibly enable enhanced remote management of compressor fleets.

## MEASUREMENT

- A meter station design tool currently capable of designing orifice meter stations is being expanded to handle ultrasonic, turbine and coriolis meter station designs.
- An examination of whether the use of thermowells for temperature measurement introduces biases into flow measurement, and characterization of the critical ambient and flow factors that may create unacceptable performance.
- Ultrasonic meter accuracy shifts due to the buildup of grime on the meter body and acoustic transducers will be characterized.
- Primary and secondary measurement equipment maintenance is critical for the stable performance of meters, and a great deal of investment in advanced equipment has been made. However, in some cases maintenance, calibration, and verification practices and frequencies are the same as those practiced when measurement was completed using circular charts and gauges. A study determining the proper maintenance and recalibration frequencies for a variety of components will establish a scientific and statistical basis for improved maintenance practice.
- Orifice meters still process the majority of gas flow, however orifice meter diagnostics are not in widespread use. A review is being conducted of existing technologies that can monitor conditions affecting orifice meter accuracy and reliability, with preliminary evaluation of approaches that hold promise to be developed into field-ready, cost-effective diagnostic tools.

## UNDERGROUND STORAGE

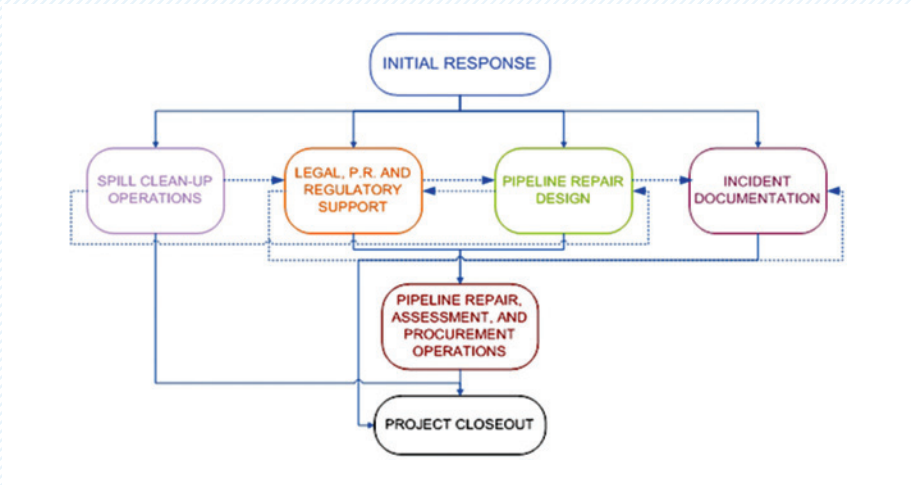
- A full scale salt cavern field test of an improved brine string stiffener is scheduled for 2012, which will determine the extent to which fluid velocity for cavern injection and withdrawal can be safely increased while keeping the brine string motion within a controlled and safe range.

CORROSION

- ➔ Develop a “best practices” document for FBE-coated pipelines that describes how FBE coatings behave under field conditions. Two specific test programs will be performed to investigate the effects of operating at elevated temperature and to determine the maximum cathodic potential for various environments and coating types.
- ➔ Further enhance and validate the tools and guidelines developed in prior PRCI projects to predict the likelihood of internal corrosion threat based on pipeline operating conditions. The effect of hydrotest water leftover and gas quality upsets on internal corrosion threat will be further investigated.
- ➔ Examine records of cases where circumferential stress-corrosion cracking (CSCC) was discovered, in an attempt to learn more about the causes and to consider possible ways to manage the problem.
- ➔ Refine and extend the technical bases for responding to corrosion anomalies identified in in-line inspection by comparing the degree of safety of the alternative response criteria from the standpoint of probabilities of failure associated with each alternative.

DESIGN, MATERIALS & CONSTRUCTION

- ➔ Comprehensive off-shore emergency response guidelines are being developed to assist operators in responding to pipeline damage incidents. This project drew from a series of facilitated workshops attended by PRCI offshore experts to collectively and collaboratively build an incident response Decision/Task Tree. The collaborative effort continued to flesh out and develop detailed input for the response guidelines reflecting industry best practices. The product being developed is a computer based overview, with subordinate and supporting decision paths, that permit operators to drill-down efficiently through any branch of the response guidelines. The very high level screen is shown below. The major elements in the screen open into more detailed screens with the links to the relevant information needed by operators.



Also, the supporting guidelines, when tailored for a specific operator's requirements, are expected to have value as a training support vehicle for operating company personnel.

- ➔ PRCI's Strain Based Design research continues to develop a reliable methodology to meet the needs for design and assessment of pipelines in unstable soil and geological conditions as well as in arctic and deep-water offshore areas. This year a project was completed to develop tensile strain design models which address a key component of the strain-based design of pipelines. Although a preliminary validation of the models was accomplished, additional validation and research is required. Strain-based design includes at least two limit states, tensile rupture, and compressive buckling. Work is also ongoing to assess the available compressive strain capacity assessment methodologies with the objective of identifying best practices and knowledge gaps.
- ➔ PRCI continues research to evaluate composite repair systems. The work began in 2008 with an ongoing long-term assessment of the performance of several commercially-available composite systems to repair corrosion in buried pipelines for up to ten years (photos below). In subsequent years the program was expanded with separate projects to evaluate composite repair systems for the reinforcement of mechanically damaged pipelines and more recently for the repair of subsea pipelines and for the reinforcement of vintage girth welds. This demonstrates the industry's increasing interest in seeking more cost effective energy pipeline repair and reinforcement alternatives.



## OPERATIONS & INTEGRITY

- ➔ Substantial effort is being committed to address pipeline damage prevention. This includes the continuing work on the RAM Program, a multi-year, multi-phased research program to apply sensing technologies and advanced data processing systems and algorithms to automate pipeline ROW monitoring. Other projects are being conducted to establish industry-wide performance metrics for confirming the effectiveness of standard industry Damage Prevention methods being used and the analysis of Human Factors and its influence on preventing damage. PRCI is also supplementing prior research on the use of satellite technology for preventing damage both from the perspective of encroachment monitoring and third-party damage and damage related to ground movement and other naturally-occurring events that could induce strain on pipelines in geologically active areas.
- ➔ Implementing a substantial program on developing qualification protocols for the use of Long-Range Guided Wave Ultrasonics as an integrity management tool. The objective of the work is to provide an objective analysis of the technology performance capabilities in a variety of settings and conditions, qualifying its use based on environmental, coatings, and flaw characteristics. The work is directed to

produce a tool that operators can utilize to determine pre survey the applicability of LRUT, the potential coverage that can be obtained given coating, process, and burial conditions, and finally a definitive methodology of how reliable any sizing of flaws detected might be. Work has been completed in 2011 on controlled laboratory tests and development of models for flaw sizing based on the guided wave signals and field testing using fabricated test loops with embedded features to simulate external corrosion on pipelines.

- Continuing research to support the development new ILI tools for pipeline inspection, including several sensing solutions for an integrated cleaning and inspection tool for pipeline systems that use cleaning pigs for maintenance purposes; application of the EMIT sensor for deployment in pipelines with challenges for use of inspection tools ("unpiggable"); and development of an ILI sensing technology for improved detection of cracks in dents.

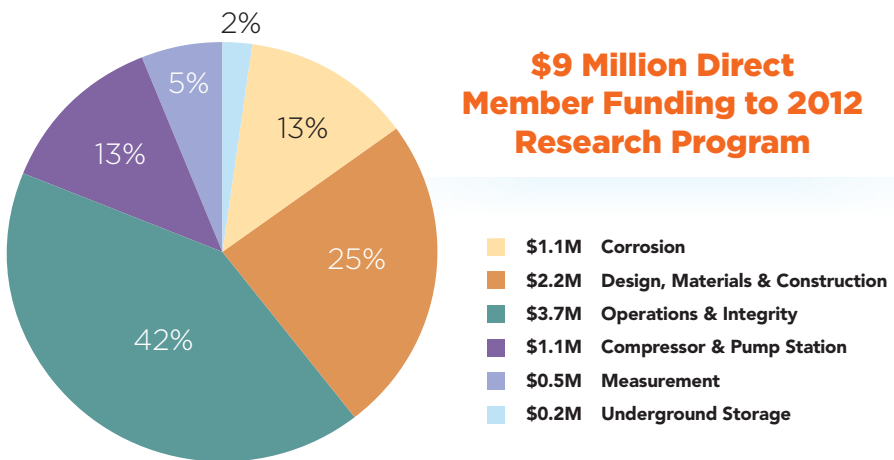
# 2011



What's Next  
for PRCI...

# The 2012 Research Program

Through the collaborative research model that PRCI employs we have developed a research agenda for 2012 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. Each of our members is committed to the long term reliability, safety and integrity of their systems. Through the collaborative process and commitment of financial and intellectual resources we are able to clearly agree on the needs of the industry and advance a technology development program that addresses those needs. Direct member funding of nearly \$9 million will be directed toward PRCI's 2012 research program comprised of more than 50 projects and programs.



PRCI's 2012 Program will address a spectrum of research needs and opportunities covering nearly every aspect of pipeline and facilities operations. The following highlights a number of specific initiatives in 2012 that will advance the energy pipeline industry:

## COMPRESSOR & PUMP STATION

- Document inadequacies in the NO<sub>2</sub> model (AERMOD) that EPA requires for compressor station NO<sub>2</sub> permitting, and identify required algorithm refinements and validation study needs. This will support the industry's technical discussions with EPA to either initiate a program to improve the AERMOD performance or relieve the industry of this modeling requirement.
- To support air toxics (NESHAP/MACT) compliance efforts, develop and/or characterize engine and catalyst controls that maintain a high level of compliance assurance and enable compliance monitoring. Provide an improved technical understanding

of catalyst performance to optimize their procurement, installation, operation and monitoring. Results will apply to both rich-burn and lean-burn engines.

- Leverage prior results from the Emissions Reduction from Legacy Engines program to exploit the operational benefits of those NO<sub>x</sub> retrofit technologies. Establish common performance specification standards and project protocols to ensure that retrofit projects can meet user needs and avoid expensive field iterations. Proper application of these technologies will improve unit reliability, operating range and fuel efficiency, and results will support HP replacement analysis efforts. Onboard diagnostic concepts will be evaluated for large-bore integral pipeline engines.
- Field test retrofit low NO<sub>x</sub> combustor liners for GE Frame 3 (Models F & G) gas turbines, and characterize the low-ambient temperature (to -20F) emissions performance of Solar Turbines Titan 130 units.
- Evaluate the effect of long-term exposures (three and six months) to Fuel Grade Ethanol (FGE) on common metals and elastomers found in pump station and storage terminal components, to continue to refine the matrix of component compatibility to FGE.
- Summarize the technology challenges associated with the transport of CO<sub>2</sub> in liquid phases, and identify typical designs and major equipment options used in CO<sub>2</sub> pump stations.
- Develop a best practices guideline for mechanical seal auxiliary systems in liquids pipelines for the operation and maintenance of these systems, and outline the optimal designs for auxiliary systems.

## MEASUREMENT

- Examine the relationship between ultrasonic meter signal repetition rate and duration, and the frequency and amplitude of reciprocating compressor generated pulsation in order to document the effect of that relationship on meter accuracy.
- Investigate ultrasonic meter accuracy shifts and potential measurement bias resulting from operation at pressures and temperatures that are substantially different than those used for calibration.
- Further investigate various piping configurations that are typically installed upstream of the AGA-9 recommended default meter run to determine if the configurations can cause significant installation bias, and determine if any of the tested configurations cause sufficiently little bias to become acceptable design practice.
- Identify potential approaches to extending the minimum flow capacity of ultrasonic meters as a general class of meters, and determine whether the turndown capability of ultrasonic meters enables them to be installed in fewer numbers to accurately measure low flow rates.

## UNDERGROUND STORAGE

- A multi-faceted program addressing a variety of storage field integrity concerns, including: remaining service life of tubulars, cement integrity, and brine string integrity

and related cavern operating practices. The objective is to provide additional tools to storage field operators (both reservoir and caverns) to meet emerging storage facility integrity management requirements.

## CORROSION

- Investigate the consequence model for the four population density classes of gas pipelines to properly address both mechanical damage and corrosion risk factors, and update both societal and individual risk targets as necessary.
- Development of a practical corrosion growth rate model for reliability-based assessment which accounts for time and location dependencies as well as sizing and classification errors.
- Development of a self-healing coating for pipelines to prevent external corrosion damage at equal to or improved performance level compared to current practices.
- Assess the effectiveness of cathodic protection criteria for a variety of soil and coating combinations through the evaluation of active corrosion features in in-line inspection data.
- Investigate how glycol and water enter dry gas pipelines and determine the corrosive potential of glycol-water mixture as they react with varying degrees of contaminants in the gas stream.
- Establish correlations between stress-corrosion cracking severity and operational and geotechnical characteristics of a gas pipeline through the examination of in-line inspection data.
- Development of a set of guidelines to define an effective electromagnetic acoustic transducer (EMAT) program to optimize digs and re-inspection intervals for stress-corrosion cracking based on reliability principles developed in prior PRCI work.
- Further validate the grinding limits for repair of stress-corrosion cracking on operating pipelines to provide confidence for those who perform the repair through full-scale experimental work.

## DESIGN, MATERIALS & CONSTRUCTION

- Alternate gas products research continues with projects to improve members' design capabilities for new pipelines to transport CO<sub>2</sub> with the types of impurities that are expected, the CO<sub>2</sub> produced by electric power plants and other sources. These design tools more accurately depict the dynamics of these CO<sub>2</sub> mixtures so that resulting pipelines will provide the required transmission capacity at lower cost. In addition to new design tools, work continues on assessment of valves and seals both for new pipelines and for the retrofit of existing facilities for CO<sub>2</sub> service.
- PRCI research seeks to improve transmission pipeline construction efficiency while maintaining required quality standards. This effort is being conducted with the support and valuable input of the International Pipeline and Offshore Contractors Association

(IPLOCA) and the Interstate Natural Gas Association Foundation (INGAA Foundation). This approach draws from the insights and experience of owners and operators of gas and liquid transmission pipelines world-wide, and the contractors who construct these lines.

- ➔ Materials, welding and non-destructive testing (NDT) remain critical concerns of the pipeline industry. The 2012 program continues research in these areas with the evaluation of composite pipeline repair systems for offshore pipeline repair challenges and reinforcement of onshore lines to permit continued rated service. The composite repair systems offer substantial cost avoidance and reduction of transmission line outage time. This program area will also develop a guideline for Automatic Ultrasound Testing of on-shore transmission pipeline girth welds. Current guidelines are inadequate to fully leverage the substantial benefits of this weld inspection technology for on-shore applications. Research also includes projects to advance the state of the art in transmission pipeline weld quality and efficiency.
- ➔ Programs focusing on structural integrity assessment especially fitness for service of vintage pipelines and structural significance of mechanical damage.

## OPERATIONS & INTEGRITY

- ➔ Analysis of suitable remote or robotic techniques to inspect liquid petroleum tanks while remaining in service that will comply with the requirements of API 653.
- ➔ Several comprehensive programs to address high priority issues: understanding failures modes and inspection technologies related to longitudinal seams for ERW and other long seam pipes; developing solutions for detecting and mitigating small leaks from liquid pipeline systems; and developing and validating technologies and tools to detect and discriminate mechanical damage to pipelines.
- ➔ Quantifying sizing uncertainties for pipeline in-line inspection technologies for external corrosion features and developing a more specific framework for specification of tool tolerances in conjunction with ILI vendors.
- ➔ Quantify Corrosion Using Long Range Ultrasonic Guided Wave and Associated Numerical Tools and developing guidance for pipeline operators on guided wave technologies.
- ➔ Developing and testing of an internal mobile sensor that detects water/moisture in pipelines for improving corrosion control.
- ➔ Establish baseline work load conditions for pipeline control room operations.
- ➔ Advancing the multi-year Right of Way Automated Monitoring (RAM Program), a comprehensive research program focused on enhancing the monitoring and surveillance of energy transportation pipelines for damage prevention, leak detection, and other threats to pipeline integrity.
- ➔ Evaluating internally-coated Carbon Steel Risers as an Alternative to Corrosion Resistant Alloys (CRA) for girth welds and coated mechanical connectors for subsea pipelines under sour service.
- ➔ Establish the baseline for the current State of the Art for Subsea Pipeline and develop a technical basis to support an equipment life extension beyond design operational life.

# Shaping the Future of Research

## WITH THE PIPELINE INDUSTRY R&D ROADMAP



The energy pipeline industry is facing significant challenges – the series of high profile pipeline incidents over the past several years has heightened the awareness of regulators, pipeline operators, and the public to the significance of the pipeline infrastructure and has led to a renewed emphasis and focused attention on pipeline safety. The industry has responded to meet these challenges by establishing pipeline safety

initiatives, including the INGAA Integrity Management Continuous Improvement (IMCI) initiative and the AOPL/API Pipeline Safety Improvement Areas (PSIAs) program. Other organizations have also established similar initiatives and made a commitment to further improving pipeline safety, with the goal of zero incidents. Regardless of the party or organization that has established a program or made a commitment, pipeline research has been identified as a core component of meeting the challenges confronting the industry.

In support of the current initiatives and high level of interest in the pipeline community on R&D, PRCI is taking the lead to unify and promote convergence of the pipeline industry R&D agenda. Through a series of summits started in December 2011, PRCI has been bringing together the leaders in the pipeline R&D community to establish a consensus on a new paradigm for pipeline R&D, with emphasis on a unified definition of the top priorities and developing a process by which the top priorities can be addressed in a more efficient and more collaborative manner. While the pipeline industry has established the fundamental elements of an effective R&D structure, there is a need to better define and coordinate the pipeline industry R&D program across the various organizations and key stakeholders. The summits address the processes and procedures for establishing the priorities, defining the resource requirements to address those priorities, and distributing the R&D work. This work will serve as the basis for developing the industry-wide pipeline R&D roadmap. The next year will focus on onshore pipelines and it will take about a year to complete the roadmap. PRCI will also work to develop the subsea/offshore and the facilities roadmaps over the next 24 months.

This research agenda demonstrates willingness by the industry to continue looking for ways to ensure a safer and more efficient pipeline network. As we look for the next opportunities, PRCI is honored to take the lead to establish an overarching agenda for all of the industry. These collaborative efforts continue to move the industry forward.





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