



2008

YEAR *in* REVIEW



Leading Pipeline Research



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

—GEORGE W. TENLEY, JR. • PRESIDENT

2008

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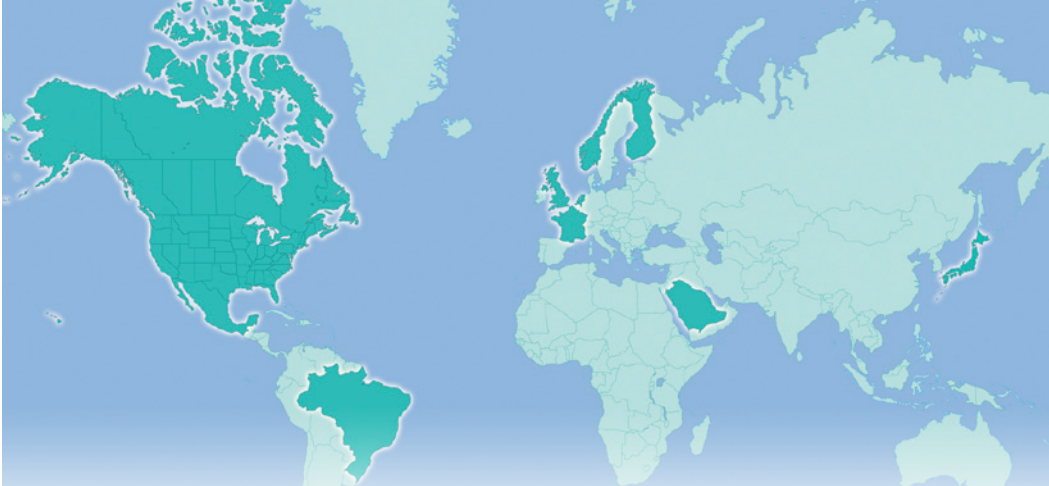
PRCI is a not-for-profit, tax-exempt membership organization of energy pipeline companies and service providers directing research to enhance the safety, reliability, and productivity of the energy pipeline industry. Unique among all pipeline research organizations, PRCI brings together leading pipeline companies from around the world to engage in a collaborative process that is truly “of, by and for” the industry. With the commitment and technical expertise of its members, PRCI develops dynamic research programs devoted to identifying, prioritizing, and implementing the industry’s core research objectives.



2008

YEAR IN REVIEW

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our members

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

PIPELINE OPERATING COMPANY MEMBERS

Alliance Pipeline Ltd (Canada)
Boardwalk Pipelines
BP
Buckeye Partners, LP
CenterPoint Energy Gas Transmission
Chevron Pipe Line Company
Colonial Pipeline Company
Colorado Interstate Gas
Columbia Gas Transmission Corp.
ConocoPhillips Pipe Line Company
Dominion Transmission Corp.
El Paso Natural Gas
Enbridge Pipelines Inc. (Canada) &
Enbridge Energy Partners, LP
EPCO, Inc.
Explorer Pipeline Company
ExxonMobil Pipeline Company
Gassco A.S. (Norway)
Gasum Oy (Finland)
GDF Suez (France)
Marathon Pipe Line LLC
N.V. Nederlandse Gasunie (Netherlands)
National Fuel Gas Supply Corporation
National Grid (U.K.)
ONEOK Partners
Pacific Gas & Electric Co.
Panhandle Energy Company
Petrobras (Brazil)
Saudi Aramco (Saudi Arabia)
Shell Pipeline Company LP
Southern California Gas Co.
Southern Natural Gas

Spectra Energy Transmission, LLC
Tennessee Gas Pipeline
Total S.A. (France)
TransCanada PipeLines, Ltd. (Canada)
TransGas Ltd. (Canada)
Transwestern Pipeline Co.
Williams Companies, Inc.

PIPELINE INDUSTRY ORGANIZATIONS

Association of Oil Pipe Lines (AOPL)

ASSOCIATE MEMBERS

Applus RTD
GE Oil & Gas
Lincoln Electric Company

TECHNICAL PROGRAM ASSOCIATE MEMBERS

Berg Steel Pipe Corp.
BJ Pipeline Inspection Services (Canada)
Cameron
Evraz Inc. NA (Canada)
NDT Systems & Services (America) Inc.
Nippon Steel (Japan)
Rosen
Siemens Energy & Automation, Inc.
Solar Turbines
T.D. Williamson, Inc.
Tuberia Laguna (Mexico)
Tubos de Acero de Mexico (Mexico)

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MISSION

To conduct a collaboratively-funded research 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.

PRCI'S VALUE PROPOSITION

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

chairman's statement

I am sure that you will find this "Year in Review" to provide an informative look back at the many accomplishments of Pipeline Research Council International (PRCI) in 2008. Communication with our stakeholders is a priority and second only to meeting the research objectives of our members in the energy pipeline industry and our partners in business and in government.

Given that 2009 will be my last year as Chair, I will take this opportunity to share my perspectives on PRCI's strengths and value.



First, PRCI is based on a foundation of strong membership. As of 2008, the organization had members on four continents with representation from North and South America, Europe and Asia. Our members transport natural gas and associated liquids, synthetic and crude oil, refined products, biofuels and carbon dioxide. Member company pipelines are operated in every type of terrain from onshore continental to deepwater systems, from urban to rural areas, and from arctic to desert conditions. Collectively the membership brings tremendous resources and experience to collaborative research on pipeline safety, operational reliability, efficiency and design.

Second, PRCI offers significant value to its members. Each year members vote their subscriptions towards projects reflecting their company's interests. Any member can propose a project. The voting ballot will typically include projects addressing corrosion and pipeline integrity, materials, design and construction, operations, compressors and pumps, measurement, and underground storage. Electronic voting over the internet permits members from different companies, sectors or countries to identify common needs and collaborate on projects while significantly leveraging funding.

Third, PRCI has had the benefit of a strong executive and staff. George Tenley has led PRCI as President for 10 years following a career in government where he was head of the U.S. Office of Pipeline Safety. Eric Thomas oversees all research activities as our Chief Operating Officer and joined PRCI following a 30 year career with Southern Natural Gas where he held the position of Chief Engineer. PRCI's Program Directors and Managers have extensive industry, academic and research experience. Our administrative and office staff have proved themselves to be efficient and focused on ensuring that member needs are met.

These strengths explain in part why PRCI is now entering its 57th year as one of the world's leading research organizations for the energy pipeline industry. The organization's endurance and stability over that time frame is a testament to the value that PRCI brings to its members, its partners in business and government, and to its many stakeholders.

A handwritten signature in black ink that reads "Art Meyer".

Art Meyer
Chairman

president's statement

I am pleased to present the membership and PRCI's stakeholders a review of our 2008 program year. This Review will give you a summary of some of our most important research and program achievements, the highlights of which include:

- Completed and produced over 35 research reports in our Pipeline and Facilities programs, adding more value to our comprehensive research library.
- PRCI continued and enhanced its broad-based program on the pipeline transportation of ethanol including, as part of Phase 2, the submission to the U.S. government of a white paper for cofunding entitled "*Determining New Design and Construction Techniques for the Transportation of Ethanol and Ethanol/Gasoline Blends in New Pipelines.*"
- A substantial project began in developing the techniques and tools for Right-of-way Automated Monitoring—the "RAM" program. This effort is funded by 27 of our 54 members in conjunction with the U.S. government, and is being conducted by NASA through PRCI's Operations & Integrity Technical Committee, under the direction of the RAM Steering Committee.
- We are also kicking off projects reflecting important drivers for the industry and its future success; one on the issue of modernizing means and mechanisms of pipeline construction, and one on the pipeline transportation of CO₂ reflecting the growing global need for carbon capture and storage.
- As a reflection of the strong PRCI research partnership with the U.S. Department of Transportation's Pipeline and Hazardous Materials Safety Administration, we are a key part of a multi-party collaborative project team that was awarded a contract for evaluating "*The Structural Significance of Mechanical Damage.*"



In 2008 our initiatives under the Research Deployment Optimization program came to fruition, providing new capabilities, procedures, and service to our members and the industry. Key among these is our new PRIME ("Pipeline Research Implementation and Management Engine") software-based project management tool. PRIME is transforming how we plan, execute, manage, and deliver the essential research that makes up the core of our mission and our value proposition. With this tool we are enabling a global membership to participate fully and in real-time in all of our research and related activities.

To our members and stakeholders, thank you for helping to make 2008 a year in which not only did the benefits of collaborative research continue to grow, but in which the foundations of our future success were strengthened. The value of PRCI research continues to enable our members to deliver energy to their customers throughout the world—safely, reliably, and cost-effectively.

A handwritten signature in black ink that reads "George W. Tenley, Jr." with a stylized flourish at the end.

George W. Tenley, Jr.
President

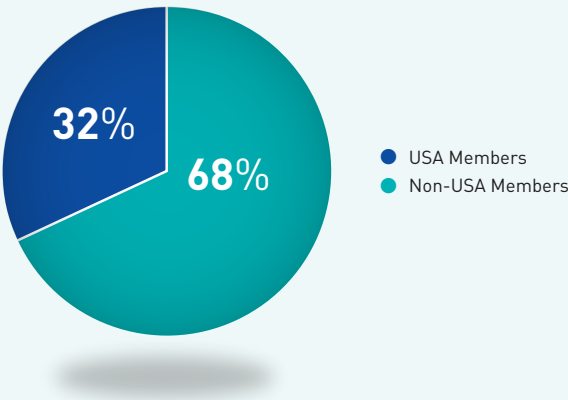
the “I” in PRCI

Our research planning, development, management, and communication in 2008 provided an excellent illustration of just how important the international aspect of the PRCI collaboration is.

In addition to our fall Executive Committee and Board of Directors meetings hosted by Pipeline Member Gasum Oy in Helsinki, Finland in September, our Technical Committees held two European meetings. The Pipeline program’s three Technical Committees held a consolidated spring ballot-development meeting hosted by Associate Member Applus RTD in May in Berlin, Germany. The Compressor and Pump Station Technical Committee meeting was hosted by Associate Member GE Oil & Gas in May in Florence, Italy.

In addition, President George Tenley was a featured speaker at the 41st Annual Meeting of the International Pipe Line and Offshore Contractors Association (IPLOCA) in Athens, Greece in October, and chaired a panel on integrity at the 2008 International Gas Research Conference in Paris, also in October. He also attended the Annual General Meeting of the ITF (Industry Technology Facilitator) in Aberdeen, Scotland in November and gave a presentation on building a formal, collaborative relationship between that organization and PRCI for shared research planning, execution and, where appropriate, project funding. Finally, George wrote an article for *Next Generation Oil and Gas*, a magazine covering the global oil and gas industry.

These interactions are critical to maintaining our reputation as the preeminent collaborative research development organization worldwide, as well as widening the global awareness of our important work.



the RDO initiative

The Research Deployment Optimization (RDO) initiative, which had the unanimous support of the Board of Directors in 2007, came to full fruition in 2008.

This effort, which involved teams comprised of PRCI staff, Board members, member company technical representatives, and consultants, established new and revised processes, structures, tools, and roles for substantially all of PRCI and affected every aspect of the organization. In addition to the direct results of the RDO program, we also completely revised the look, operation, and capabilities of the PRCI website.

The key results of the RDO initiative have enabled us to increase the cost-effectiveness of our operating model while generating new benefits for our members. These results include:

- A realignment of our Technical Committees under our Pipeline Program to better reflect the focus of our research as well as the capabilities and availability of our members' technical representatives. The new committees are: Corrosion; Design, Materials & Construction; and, Operations & Integrity. The reexamination of our Technical Committees also led to the codification of their core governance under committee-specific charters (for all committees, including the three under our Facilities Program).



- The development of an off-the-shelf software application affecting and enabling all phases of our research planning, implementation, and management. The PRIME System, as implemented and operated through our new website, also has the added benefit of capturing and reporting important program performance metrics (for the committees, staff, and the Board), and serves as an essential element of our overall communications strategy.
- Based on our consideration of supply chain management issues, we have developed a master contract applicable to all of our projects when appropriate as well as other standard contract forms for specific applications. By using PRIME as an element of our ongoing relationship with our research providers, we are better able to deploy task orders in lieu of initiating contracts for each engagement thereby improving the timeliness and efficiency of our contracting process.

As we move into 2009, we will continue to refine and deploy these initiatives with the goal of creating complete transparency of our operations and thereby enable our members to engage with PRCI faster and more thoroughly to meet their specific needs.

recent accomplishments

The projects members support with their input, funding, time, and resources result in knowledge and technology addressing the needs of the worldwide pipeline industry and, by extension, 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
- Build new pipelines where and when they are needed
- Continue to reduce risks from and to pipelines
- Provide support for public policy positions

Research Reports

Pipeline

- A Review of Methods for Assessing the Remaining Strength of Corroded Pipeline
- Acceptance Criteria for Mild Ripples in Pipeline Field Bends
- Application of RBDA to Onshore Natural Gas Pipelines—Phase 2
- Automated Weld Deposition for Repair of In-Service Pipelines
- Characterization of SCC Using Laser Ultrasonics
- Cooling Rate Simulation for Welding In-service Pipelines
- Corrosion Assessment Guidance for High Strength Steels
- Determine the Requirements Necessary to Allow Existing Pipeline Systems to Transport Ethanol without Cracking
- Development of a Pipeline Encroachment Prediction Model/Right of Way Structure Management
- Drop Weight Tear Test as ISO Standard
- Effects of Yield/Tensile Ratio on Mechanical Damage Tolerance
- Guidelines to Prevent Internal SCC in Liquid Pipelines Carrying Ethanol
- Human Factors Analysis of Pipeline Monitoring and Control Operations
- Incorporation of Enhancements to PRCI Thermal Analysis Model for Hot Tap Welding—Version 5.0
- Inventory of Types of Mechanical Damage Experienced by Gas and Oil Pipelines
- Investigate Fundamentals and Performance Improvements of Current In-Line Inspection Technologies for Mechanical Damage Detection
- Limit State Function Development for the Application of Reliability Based Design and Assessment to Onshore Natural Gas Pipelines
- Local Buckling and Collapse of Corroded Pipes
- Pipeline Facility Incident Data Review and Statistical Analysis
- Pipeline Integrity Management for Ground Movement Hazards
- Pipe-Soil Interaction Model for Reliability Based Design and Assessment in Permafrost Areas
- Pre-Construction Drillability Assessment for Horizontal Directional Drilling in Rock
- Static and Dynamic Analysis of Highly Tensioned Suspended Pipeline Span

recent accomplishments

- Technologies for In-Service Measurement of Seal Gaps in Internal Floating Roof Tanks
- Understanding Magnetic Flux Leakage (MFL) Signals From Mechanical Damage In Pipelines
- Upheaval Buckling Limit State Function for Onshore Gas Pipelines
- User Manual for Electrical Isolation Devices
- Utilization of Ground Positioning Satellite Device in Conjunctions with Current One-Call System—Virginia One Call Project

Compressor & Pump Station

- Predictive Control System
- State-Of-The-Art Pipeline Pump Technology
- Turbocharger Booster System Development

Measurement

- Clamp-On Ultrasonic Meter to Confirm Conditioned Flow at Primary Meter
- Evaluate Existing Hydrocarbon Dew Point Measurement Methods & Equipment
- Liquid Ultrasonic Meters in Heavy Oil Service
- Meter Station Measurement Uncertainty Analysis Tool
- Quick Response Measurement Standards Support

Underground Storage

- Remaining Strength of Corroded Pipe under Tensile Loads Software
- Temperature Effects on Threaded Couplings in Caverns

important findings

PRCI's research projects have produced numerous important findings 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

- The results of a comprehensive study of the methods for assessing the remaining strength of corroded pipe demonstrate that the standard methods used by the pipeline industry give conservative predictions for the failure pressures of corroded pipelines in most cases, even very conservative predictions in some cases. The study also indicates that additional research is needed to improve the understanding of the effects of corrosion on the integrity of higher strength steels (X70 and above), particularly for deep defects.
- Development of a practical solution for measurement and evaluation of identified SCC in pipelines is particularly challenging due to the complexity of crack shapes and their inter-relationship and distribution within a crack colony. A laser ultrasonic inspection system that is based on the Time of Flight Diffraction (TOFD) technique was developed and validated to reliably and accurately measure the depth of SCC in pipeline systems.

Design, Materials & Construction

- A first generation "Liquid Pipeline Operator's Control Room Human Factors Risk Assessment and Management Guide" was developed incorporating a comprehensive review of human factors in pipeline monitoring and control operations resulting in a methodology that could be applied by operators to assess and manage human factors risks in their operations. The process can be conducted by an operator to identify and assess the human factors risks in their control room, develop a plan for mitigating the highest-priority risks, and then develop and implement the selected mitigations.
- Present regulations and industry standards differ in their treatment of mild ripples, ranging from silence to prohibition, depending upon interpretation. Recommendations were made for ASME Code criteria specifically permitting mild ripples within stated limits.
- Developed the "Engineering Design Guide for the Installation of Pipelines by HDD." This is an update of a prior design guide developed by PRCI in 1995. The new guide expands the capabilities of the pulling load calculation and installation stress analysis and provides new updated software (MS Excel).

Operations & Integrity

- Magnetic finite element analysis (FEA) modeling of Magnetic Flux Leakage (MFL) signals for dents and comparison with experimental results obtained both from laboratory-dented samples and dented pipe sections was conducted to improve the understanding of MFL signals for characterizing mechanical damage to pipelines. A comprehensive dent/gouge MFL signal library was developed for use in interpreting MFL signals from mechanical damage defects.
- A comprehensive and in-depth review of the current status of in-line inspection technologies was completed for a number of inspection methods, including but not lim-

important findings

ited to, Magnetic (Axial MFL, Circumferential MFL), Ultrasonic (UT), and Geometrical (Caliper). The technologies were evaluated in terms of their capabilities, limitations and potentials in detection, discrimination and characterization of various forms of pipeline mechanical damage, such as dents, dents with corrosion, and dents with cracks, and dents with gouges.

Compressor & Pump Station

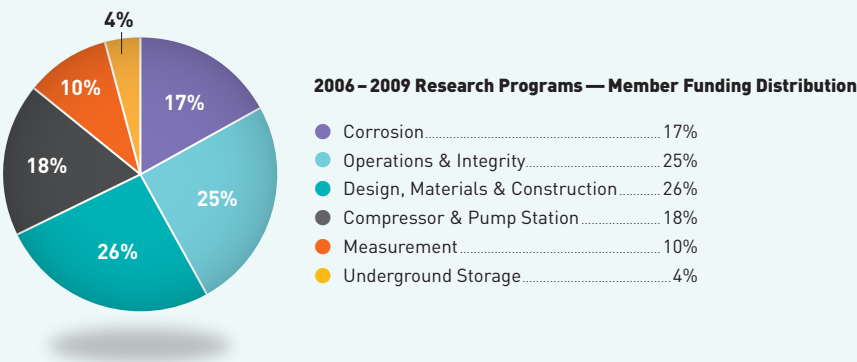
- A prototype turbocharger booster system was developed for engines that face high ambient operating temperatures and thus can lose the required combustion air flow on hot days as inlet air density is decreased. The system employs a small packaged burner firing into the engine exhaust manifold upstream of the turbocharger turbine, and successfully passed lab testing and initial field testing on a two-cycle field engine. This will enable some engines to maintain emissions performance across the full operating envelope without extensive turbocharger retrofits.
- Extensive screening tests of a variety of low-NOx precombustion chamber designs for two-cycle engines identified a candidate unit that will be fully evaluated on a full scale engine. Optimized ignition performance is essential to combustion stability and low engine-out emissions. This work uncovered some fundamental relationships between combustion conditions in the prechamber and main chamber that are important for low-NOx operation.
- Evaluation of commercial non-selective catalytic reduction (NSCR) exhaust aftertreatment technologies as they are presently applied in the field indicates a significant trade-off of NOx reduction and ammonia emissions, a phenomenon well known in the literature, but generally ignored to date by Federal and State agencies. This “disbenefits” argument can provide some flexibility in discussions over air permits.

Measurement

- A meter station uncertainty analysis tool was developed for use by measurement engineers during the meter station design and equipment selection stage of a new meter station, to minimize/manage measurement uncertainty. The tool is capable of calculating multi-run meter station uncertainties for orifice, turbine and/or ultrasonic meters.
- Characterized the current global application of ultrasonic meters in the fiscal measurement of heavy, viscous, crude oil. The study consisted of a review of existing publications, surveying operators of existing installations, and interviewing qualified ultrasonic meter vendors.
- Confirmed the performance of commercially available automated hydrocarbon dew point analyzers is functionally equivalent to the Bureau of Mines (BOM) chilled mirror procedure, thus offering cost savings over the manual BOM method. Both pipeline quality and high-BTU rich production gases were evaluated.
- In support of the AGA-3 orifice meter revised gas expansion factor standards revision, prior gas expansion factor assumptions were reviewed for possible conflict with the AGA-3 revision presently being balloted. It was determined there were no concerns with the isentropic constants being used in the AGA-3 revision.

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.

Corrosion

- Developing methods and protocols for determining corrosion growth rates and status (active/inactive), including the use of field methods and data from successive ILI tool runs to quantify corrosion growth.
- Continuing research on the consolidated program to assess the remaining strength of corroded pipelines, with the focus on analysis of high strength steels and low toughness pipe. These results, in conjunction with work completed to date, will provide the basis for updating existing guidance documents on methods for evaluating corrosion metal loss.
- Analysis of Cathodic Protection (CP) criteria and developing the basis for variable CP criteria for environment-specific monitoring criteria.
- A comprehensive program on developing a methodology and guidelines for assessing pipeline integrity with respect to corrosion over time using reliability-based methods.
- A multi-year ethanol research program with emphasis on identifying environmental and stress factors that produce SCC in existing ethanol pipelines and terminals, developing requirements for existing pipeline, tank and terminal systems to transport ethanol without cracking, and identifying the requirements and develop design criteria/ guidelines for new pipeline systems to transport ethanol without cracking.

Design Materials & Construction

- A comprehensive and consolidated program to evaluate the structural significance of mechanical damage, consisting of establishing a detailed experimental database to support the development and validation of improved burst and fatigue strength models to assess mechanical damage interacting with secondary features, including gouges, corrosion, and welds.
- Continuing program to develop a safe and viable alternative to the pre-service hydrotest of natural gas pipelines. This could result in a significant time and cost savings for pipelines in Arctic areas.

current research

- Work continues to review the state-of-the-art, assess the availability, variety and long term performance of composite pipeline repair systems.
- New program approved to identify technical challenges in the pipeline transport and storage of CO₂.
- New program approved to consider improvements to the pipeline construction process to reduce time and increase efficiency while maintaining or improving quality.
- Consolidated program for research and development for welding high strength steel pipelines jointly funded with DOT continues in 2009 with an estimated completion date in 2010.

Operations & Integrity

- Continuing research on the development and evaluation of new technologies and systems for damage prevention and surveillance along pipeline right-of-way corridors for machinery threats, encroachment and changed conditions, and leaks including the comprehensive Right-of-way Automated Monitoring program.
- Several programs focusing on the performance characteristics of ILI systems and technologies for various types of damage and defects, including mechanical damage, corrosion/metal loss, and environmental and fatigue cracking.
- Developing new tools and analytical methods for Non-Destructive Evaluation of pipeline systems, including the development of new systems, sensors, and analytical methods for characterizing defects and identifying, evaluating, and interpreting the data obtained from those systems.
- Work continues to solve the difficult problem of rapid, external small leak detection from liquid pipelines with the development of criteria, parameters, and a scoring methodology against which currently available technologies can be measured for suitability and effectiveness.
- A focused effort to mine data and determine the susceptibility of operating pipeline systems to Stress Corrosion Cracking (SCC) and fatigue cracking and to develop guidance for SCC Direct Assessment and re-inspection intervals.
- A program to develop an industry Recommended Practice for managing pipeline facility integrity.

Compressor & Pump Station

- A project to increase the efficient operating range of centrifugal pumps is near completion after a series of tests on a physical pump with a modified impeller design. The pump was located earlier this year, which allowed for the testing to proceed. If the underlying design model is validated through this testing, this will have very wide applicability across many pump designs.
- Work continues on a multi-technical dimension and multi-year R&D program to develop cost-effective options for reciprocating engine operators to meet very aggressive and expected NO_x reduction requirements. New regulations issued by the EPA in 2008 to further tighten air quality standards confirm the underlying regulatory trend, and provide clarity that new compliance deadlines have been established for 2013. Various state-level anticipatory actions and intersecting control programs will accelerate the pressure on engine emissions reduction in the meantime. The work includes improved controls, improved ignition, reduced cost of turbocharger operation and maintenance, evaluation

of after-treatment emissions control options, and new concepts for managing the air flow within reciprocating engines.

- An extensive review of facility reportable incidents was conducted as the first step of a facility integrity program. A preliminary R&D roadmap with specific projects was developed that will identify technical approaches to resolve systematic root causes, and will identify items that may be more intractable and differentiate between operating practice, engineering design, and component performance. A parallel project currently underway in the Pipeline Program will incorporate these findings into a risk management framework.
- Compressor station operations are being examined to determine what opportunities exist for reducing fuel consumption and fugitive (methane) emissions.
- Some methods that are used to start gas turbines are very costly in terms of fuel and overall cost. New turbine starting concepts are being examined that will mitigate these effects.
- Engine testing is being initiated to determine if increased levels of drag reducing agent in gasoline has an adverse impact on automobile engines, with the objective of allowing greater use of DRA in product pipelines to increase capacity and/or reduce pump energy requirements.

Measurement

- Characterization of the uncertainties and errors associated with operating orifice meters at low differential pressures and low beta ratios, as is increasingly common as gas fields deplete.
- Assessment of dirty vs. clean meter performance by determining the magnitude of measurement error caused by incremental levels of dirt build-up.
- Determine the feasibility of using micro-electronic mechanical sensors (MEMS)-based sensors to determine the chemical composition of natural gas and liquids in situ, and at or near real-time.
- Investigate the latest in-line meter cleaning techniques to decrease safety risks associated with field disassembly and reduce the O&M cost of periodically cleaning metering and control equipment internals.
- Develop a R&D compendium containing all work done that is relevant to the all of the primary meter types. This will become the starting point when assessing new projects, will ensure no duplication of effort with prior work, and will be a ready resource for Measurement Engineers.
- Evaluate the effects of temperature on gas sampling in the field at near hydrocarbon dew point conditions.

Underground Storage

- Field tests of a laboratory developed method to improve gas deliverability of gas storage wells through the injection of surfactants to increase the wettability of the core, which should reduce the tendency of water to occupy pore volume.
- Work to validate downhole magnetic flux inspection tools, by calibrating these inspection results with updated RSTRENG for downhole tubulars software.
- Investigation of whether novel X-Ray backscattering methods in common use in other applications can be adapted to the downhole environment to determine scale composition, as well as to provide improved images of pipe and cement condition.

new research initiatives

Member contributions of approximately US \$8 million were voted towards 2009 projects addressing pipeline corrosion, integrity, operations, design, materials, construction, and facilities.

US \$4 million will be directed specifically towards research that will enhance pipeline safety. These amounts will be incremental to PRCI's total research program, which exceeds US \$20 million.

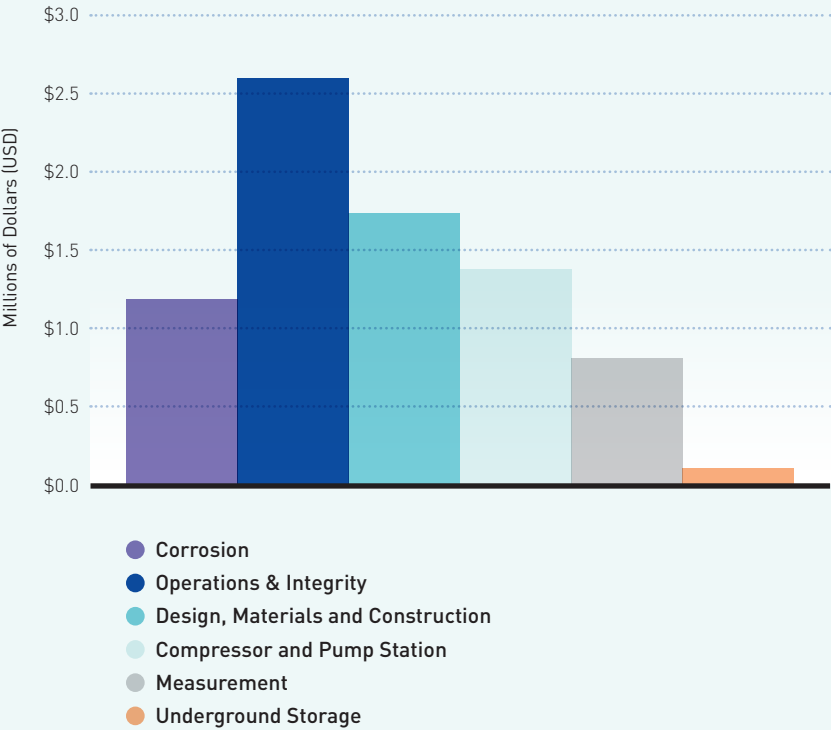
The projects selected by our members reflect their commitment to the safe, efficient, and reliable operation of energy pipelines worldwide. Our continued growth in funding and membership speaks clearly to the value of collaborative research to the pipeline industry, our partners, and stakeholders.

In addition to core programs, the following highlights a number of new initiatives in 2009 that will advance the energy pipeline industry through research:

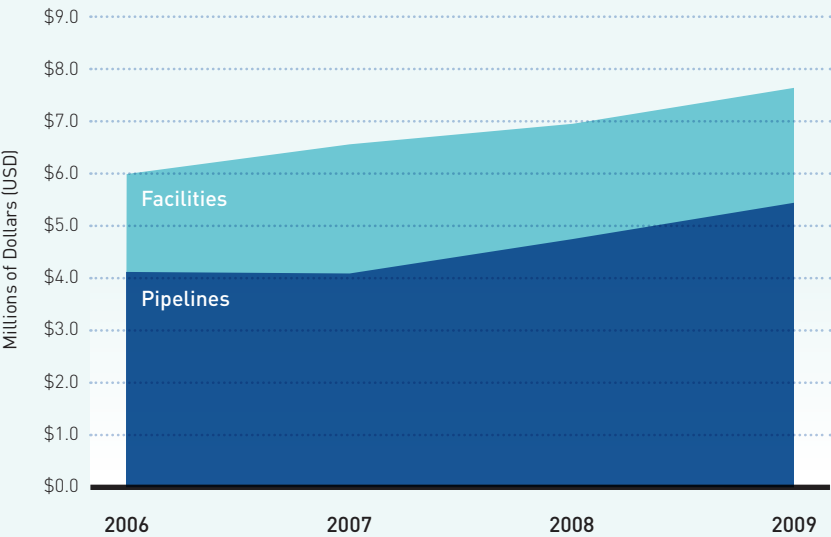
- The integrity management program will be enhanced through new projects aimed at improving non-destructive evaluation methods and subsea pipeline integrity.
- An assessment of CO₂ transportation in pipelines will be made as part of a broader strategy to reduce the environmental impacts of industrial activity.
- A second phase of research will proceed on ethanol transportation pursuant to a comprehensive roadmap developed by PRCI members, government and industry.
- Comprehensive strategies will be researched for pipeline protection and monitoring in existing rights of way with a focus on unmanned, airborne capabilities.
- New means, mechanisms, and processes for pipeline construction will be reviewed in both traditional and challenging environments.
- Cost-effective emissions reductions for compressor station engines and increased fuel efficiency at both gas compressor and liquid pump stations will be developed.
- Improved measurement components and practices will be established to reduce lost and unaccounted for gas and improve the accuracy of custody transfers.
- New approaches will be pursued to ensure the integrity of underground storage facilities while improving operating flexibility and deliverability.

The 2009 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.

2009 Research Program — \$8 Million Member Funding



27% Increase in Research Spending Since 2006



finding the value in research

To understand the challenges in achieving value from energy pipelines research, it may help to consider the realm of product development. Think of the cell phone, the safety razor, and medical devices.

A great deal of leading edge research has gone into all three and the end result in each case is a large market, dominated by a relatively small number of key players generating billions in sales worldwide. However, the value generated is not the physical product itself but the collateral “product” it enables. So, the value derives from the razor blades, the monthly cell phone services, and the medicine that flows through the device.

In contrast, there has been a reduction in the amount of investment in research for energy pipelines over the last 25 years. Companies have eliminated entire research departments. But, at the same time, there has been growing investment in research in the exploration and production of the hydrocarbon energy that pipelines transport. While seemingly everyone has a razor, a cell phone, and has benefited from medical devices, relatively very few people understand the essential value they derive from pipelines. Achieving widespread understanding of the role and value of energy pipelines and how (if at all) they are perceived, both within and outside the energy industry, is one of the most difficult hurdles to overcome in making the case for energy pipeline research.

However, as PRCI has demonstrated for 56 years, collaboration is the best means for matching available resources with essential research needs because it best enables the cost of research to be optimized and justified. Industry collaboration provides the greatest benefit to the greatest number of operators, the customers they serve, and the public trust that grants them their “license to operate.”

Energy pipeline research will remain a viable and sustainable resource for the world’s vital energy lifelines to the extent it yields clearly recognizable benefits that translate directly to the corporate bottom line. Increasingly the bottom line for energy pipelines is a function of the interplay between several core needs and opportunities, including:

- Sustaining and growing the productivity of pipeline assets operating well beyond their originally projected design life;
- Building new pipelines to reconcile the rapidly growing demand for energy and the unconventional and more difficult to access sources of that energy; and,
- Assuring the safety and environmental performance of pipelines in the presence of population encroachment and the intrusive activities it brings.

For 56 years, the energy pipeline industry has collaborated on research to confront these issues and the needs they generate. The future success of this collaborative effort can only be sustained if it can provide solutions to the industry that generate value across the entire pipeline operation. That value is being assured through the research program of PRCI covering every aspect of pipeline operations conducted by its members in North America, Europe, Central and South America, and Asia, as well as the wider industry worldwide.

appendix

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Human Factors Analysis of Pipeline Monitoring and Control Operations

The monitoring and controlling of pipeline operations from a remote control room is similar to system operations in several other complex process control industries, such as nuclear power, petroleum refinery, and air transportation. The operators are required to maintain awareness of the status of a complex system as they control an ongoing process so that it remains within prescribed limits of safety and efficiency. In most cases, these monitoring and control operations are performed with the aid of remote sensors, automated display and control systems, and communications with other individuals who monitor and control interacting elements of the larger, integrated system.

Research in process control safety and efficiency has resulted in an increasing awareness of the many “human factors” in the operational environment that directly affect the monitoring and control performance of the system operator. Since operator performance is often critical in maintaining a process within limits and responding to abnormal conditions, these human factors can have a substantial effect on the ultimate safety and operational

effectiveness of an entire system. As a result, systematic and long-term efforts have been undertaken in several high-risk process control industries to mitigate the risks associated with human factors by modifying the operator’s job, tasks, and work environment to better support operator performance; as well as to introduce additional system defenses to reduce the consequences of human error.

Investigations of severe pipeline accidents conducted by the National Transportation Safety Board (NTSB) have identified human factors as contributors to some of those accidents. However, prior to the present project, a comprehensive investigation of the human factors that affect pipeline monitoring and control operations had not been conducted. Consequently, pipeline operators have had limited empirical evidence to guide their efforts to reduce operational risks resulting from human factors that adversely affect pipeline Controller monitoring and control performance.

Source: McCallum, M. & Richard. C. (2008). Human Factors Analysis of Pipeline Monitoring and Control Operations: Final Technical Report.

KEY PROJECT RESULT

First-generation “Liquid Pipeline Operator’s Control Room Human Factors Risk Assessment and Management Guide,” resulting in a comprehensive methodology that could be applied by pipeline operators to assess and manage human factors risks in their operations.

Acceptance Criteria for Mild Ripples in Pipeline Field Bends

Field bends in large diameter pipe are routinely used in the construction of oil and gas pipelines. Mild ripples are often unavoidable where such bends have a high D/t or high yield strength. Present regulations and industry standards differ in their treatment of mild ripples, ranging from silence to prohibition, depending upon interpretation. Consequently, the application of acceptance standards for such features is inconsistent, leading to variable standards of inspection and probable scrapping of

otherwise sound bends. Finite element analysis (FEA) was used to estimate the effect of ripple magnitude and spacing on stresses due to pressure and bending. Stress concentration factors derived from the models were used with a suitable fatigue damage rule to estimate the effect of ripple parameters on service life.

Source: Rosenfeld, M. J., Hart, J. D. & Zulfqar, N. (2008). Acceptance Criteria for Mild Ripples in Pipeline Field Bends.

KEY PROJECT RESULT

Results were benchmarked against the available test data. The results indicate that

- 1 mild or shallow ripples up to two percent of the pipe diameter in crest-to-trough dimension would not be expected to be harmful in gas transmission pipelines operating under conditions normally encountered in the gas transportation industry;
- 2 mild or shallow ripples up to one percent of the pipe diameter in crest-to-trough dimension would not be expected to be harmful in hazardous liquid transportation pipelines operating under conditions normally encountered in the liquid transportation industry; and
- 3 the presence of ripples could eventually be harmful to long-term integrity in a severe cyclic loading (pressure, thermal expansion, flow-induced vibration) environment, or where soil movement could take place.

Recommendations were made for ASME Code criteria specifically permitting mild ripples within stated limits.

A Review of Methods for Assessing the Remaining Strength of Corroded Pipelines

When corrosion damage in pipelines is detected by in-line inspection (ILI), a replace, repair, or ignore decision must be made. This decision is based on the prediction of the failure pressure of the corroded pipe. This prediction must be accurate without being over conservative. Methods used to assess the failure pressure of corroded pipe include ASME B31G, Modified ASME B31G, and RSTRENG. Using a burst test database, sensitivity studies were completed to investigate failure pressure predictions using these common assessment methods against the recorded test burst pressures. These methods have been successfully used and in the vast majority of cases give conser-

vative predictions of the failure pressure of corroded pipelines. Where defects are being screened or ranked following an ILI, then the assessments completed showed that in for tests conducted on pipe with real corrosion defects, the ASME B31G or the Modified ASME B31G methods give conservative failure predictions. However, for a very small percentage of tests reviewed in this report, non-conservative failure predictions were obtained; these were on tests conducted on pipe with machined defects. This is when relatively deep defects (greater than 40%, but increasingly above 60% of the pipe wall) are assessed in line pipe of strength grade X52 and above.

KEY PROJECT RESULT

The ASME B31G or the Modified ASME B31G methods can continue to be used to rank/screen defects following ILI, as both methods predict conservative failure pressures for tests conducted on pipe with real corrosion defects. However, the test database for pipe with real corrosion defects is limited to pipe generally below grade X65. Analysis using data from burst tests conducted on pipe of higher grades has resulted in some non-conservative predicted failure pressures when the ASME B31G and Modified ASME B31G methods have been used. These tests were conducted on pipe with machined defects. The RSTRENG method has been shown to be the most accurate in predicting the failure pressure of pipe up to grade X100. In the absence of burst test data on higher strength pipe (above grade X65) with real corrosion defects, remaining strength assessments can be conducted using either RSTRENG or SHELL92 as both methods are shown to predict conservative failure pressures in pipe up to grade X100. Specified minimum material properties should be used as required by the assessment methods.

Investigate Fundamentals and Performance Improvements of Current In-Line Inspection Technologies for Mechanical Damage Detection

Detecting, characterizing, and assessing mechanical damage (MD) to operating energy pipeline systems is an important component of an operator's Integrity Management Plan (IMP). In the process of selecting ILI technologies that are best suited for detecting and sizing the types of mechanical damage (MD) that may pose integrity concerns, it is critical to understand the capabilities of current ILI technology. Data and information provided by partici-

pating ILI vendors, in conjunction with the extensive volume of previous work and studies on ILI tools and techniques, provided the basis for determining the capabilities and deficiencies of the current MD ILI technologies, and for validating performance claims. The performance measures evaluated were dent depth sizing accuracy, probability of detection, and sizing tolerance for gouge and metal loss within dents.

KEY PROJECT RESULT

The methods and procedures specified in API 1163, namely, Binomial Distribution Analysis, Binomial Confidence Interval Analysis and Least Square Linear Regression Analysis, were used for the analysis and evaluation. The capabilities of current technologies were evaluated in terms of their sizing and probabilities of detection, identification and false call (POD, POI and POFC) based on the available data. Most of the plain dents that require repair or evaluation by the current PHMSA/OPS Integrity Rules can be detected and sized by commercially available ILI tools specialized to detect either deformation or metal loss. Mechanically induced gouges without dents can also be reliably detected and sized by some of the MFL tools.

appendix

Understanding Magnetic Flux Leakage Signals from Mechanical Damage in Pipelines

In-line inspection using the Magnetic Flux Leakage (MFL) technique is sensitive both to pipe wall geometry and pipe wall stresses. Therefore, MFL inspection tools have the potential to locate and characterize mechanical damage in pipelines. However, the combined influence of stress and geometry make MFL signals from dents and gouges difficult to interpret. Accurate magnetic models that can incorporate both stress and geometry effects are essential to improve the current understanding of MFL signals from

mechanical damage. MFL signals from dents include a geometry component in addition to a component due to residual stresses. If gouging is present, then there may also be an additional magnetic contribution from the heavily worked material at the gouge surface. The relative contribution of each of these components to the MFL signal depends on the size and shape of the dent in addition to other effects such as metal loss, wall thinning, corrosion, etc.

KEY PROJECT RESULT

Magnetic Finite Element Analysis (FEA) can be applied to model MFL signals from mechanical damage defects having various sizes, shapes, and configurations. These models included geometry effects, contributions due to elastic strain (either residual strain or strain due to in-service loading), and also magnetic behavior changes due to severe deformation. The modeled results were then compared with experimental MFL signal measurements on dents and gouges produced in the laboratory as well under “field” conditions. Magnetic FEA models were produced of circular dents as well as dents elongated in the pipe axial and pipe hoop directions. Residual stress patterns were predicted in and around the dent using stress FEA modeling. The magnetic effects of these predicted residual stresses were incorporated into the magnetic FEA model by modifying the magnetic permeability in stressed regions in and around the dent. The modeled stress and geometry contributions to the MFL signal were examined separately, and also combined for comparison with experimental MFL results. Agreement between modeled and measured MFL signals was generally good, and the measured MFL signals were used to validate and refine the models.

Precombustion Chamber Development

A critical element of reliable, low-NOx operation for reciprocating engines is the ignition system. In many units, precombustion chambers, sometimes known as torch ignitions, are required to provide the very high ignition energy needed to light the relatively dilute main charge. This minimizes the NOx produced from the main cylinder, but the sometimes variable performance of pre-chambers can create combustion instability and impede an engine

from maintaining low emissions output. Through investigation and testing of a number of existing prechambers, a solution was identified that simultaneously minimized the NOx formed within the prechamber itself and provided excellent combustion stability. This small volume, fueled prechamber demonstrated significant engine-out NOx reductions vs. commercially available options. Work will proceed in 2009 for full engine testing and eventual commercialization.

KEY PROJECT RESULT

A precombustion chamber design was developed for large bore pipeline engines that shows consistent large NOx reductions vs. existing options, and also affords excellent combustion stability. This ignition component would be a significant element of an ultra low-NOx retrofit engine system to meet future NOx and Ozone control regulations.

appendix

Hydrocarbon Dew Point Analyzers

The well-established Bureau of Mines chilled mirror method to determine the temperature at which hydrocarbons condense out of a gas stream is both labor intensive and subject to operator variability. In recent years, equipment has been introduced to automate this process. However, the equipment has not been rigorously tested independently

under controlled conditions to compare its performance vs. the chilled mirror method. Controlled laboratory testing confirmed the repeatability, uncertainty, recovery time (between samples), and impact of sample filtration on the dew point calculations of streams both free of contaminants (Phase 1) and containing a methanol/water mixture and water vapor (Phase 1).

KEY PROJECT RESULT

In gas streams free of water and methanol, the analyzers performed in good agreement with the Bureau of Mines (BOM) chilled mirror method, particularly in the range of dew points the units were designed to detect. Contaminated streams were more challenging to characterize, both for the chilled mirror method and the analyzers, however the main deviation between the BOM manual and the automated approaches was with methanol/water mixtures. Additional work has been recommended to better characterize this performance, but the results for the clean gas streams clearly showed the analyzers to be functionally equivalent to the BOM method.

Meter Station Uncertainty Analysis Tool

Through a literature search and review of the uncertainty tool requirements, it became apparent there were deficiencies in the tools and techniques available to measurement station designers, and that an uncertainty tool would be applicable to both the design of new meter stations and to audit existing facilities. This required obtaining and entering equipment error specifications and their associated uncertainties over the operating range of the equipment selected. Individual component uncertainty can be amplified if proper design approach is not employed, and the tool identifies these cases and indicates optimum overall

configurations for meter station equipment in order to reduce the overall station uncertainty.

The Multi-Run Uncertainty Calculator follows the GUM uncertainty calculation standard guidelines and definitions, and provides a summary of the station uncertainty calculation along with individual data sheets for the station and each meter run. Entry of the meter and equipment specifications into the data sheets provides the user with graphical feedback of equipment selection specifications on the uncertainty calculations. Documentation of optimal designs is easy and automatic.

KEY PROJECT RESULT

The tool helps the user understand that the decisions made during the specification stage have a significant effect on the final results. It tries to balance simplicity of specification input with the effect of the equipment selected process on the final station uncertainty and draws attention to critical components, their configuration, and key design decisions.

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