Duisburg, August 2009

EPRG-PRCI-APIA
17th JOINT TECHNICAL MEETING ON PIPELINE RESEARCH

11 – 15 May 2009

TECHNICAL WORKSHOPS AND THEIR OUTCOMES

Brief summaries of ongoing, recently completed and planned projects by PRCI, EPRG and APIA are listed below, grouped according to the topics for the six Workshop Sessions

These summaries do not constitute a complete or comprehensive description of the research plans of PRCI, EPRG and APIA, nor are the individual summaries in any way complete. The material was provided as an aide memoire, serving as a background to the Workshop discussions.

Workshop 1: Advanced design methods

PRCI Project ABD-1: Validation and documentation of tensile strain limit design models for pipelines
Pipelines that are subjected to large ground movements (slope movement, frost heave and settlement or seismic activity) can only be economically designed using strain-based design methods. The project aims to develop next-generation tensile strain limit models to support strain-based design procedures. The outcome will be a guideline that can provide a defensible method to determine a safe relationship between girth weld flaws and the applied strain.

PRCI Project ABD-2-1: Reliability-based design and assessment for liquid pipelines and gas facility piping.
In 2002 PRCI initiated a multi-year program to establish reliability-based methods as a viable alternative for making decisions on pipeline design, assessment and maintenance. Since then a RBDA approach has been successfully developed and implemented for sweet natural gas transmission pipelines. This project will extend the methodology to liquids pipelines.

PRCI Project API-1-2: Interpretation and guidelines for application of API 1104
The objective of the project is to develop a commentary section or companion document for API 1104 that will allow users and regulators to better understand the intent regarding interpretation of some requirements in API 1104, the rationale behind the requirements and their applicability to higher-strength pipelines

PRCI Project MATI-7: Alternative to pre-service hydrotest
Over time there have been significant technological advancements in pipeline design, pipe manufacturing and installation practices. This improved quality management has resulted in a decrease in hydrotest failures and points towards an alternative approach for demonstrating pipeline strength. The deliverables from this project will be guidelines for an alternative to the pre-service hydrotest.

PRCI Project PR-269-074505: Influence of pipe material properties on strain demand
This project will describe the stress-strain database, the measures and procedures used to characterize pipe steel anisotropy, the effects of anisotropy on pipe strain demands, and how these might be used to guide pipe material specifications with the aim of minimising the undesirable effects of anisotropy on pipe deformation under strain-controlled loading.

PRCI Project ENV-5: Full-scale buried pipe tests to determine and reduce soil loads on buried pipelines
Previous work identified several areas where further investigations were required to better define the effectiveness of geofabrics for reducing soil loads. This project will conduct additional horizontal buried pipe tests to support new recommendations for utilization of geofabrics, for incorporation in PRCI's seismic design guidance.

APIA Project 1.1.2: Understanding hydrostatic testing
Increasing the design factor to 80% SMYS whilst retaining the hydrostatic test factor of 1.25 means that all affected pipelines must be tested to above nameplate strength. Coupled with this the yield/tensile ratio in high strength pipe can be very high, especially when measured using tests such as the ring expansion test and when the pipe is coated using processes such as FBE which cause strain ageing. These circumstances led to concerns that the available ductility could be diminished or exceeded in volume controlled hydrostatic tests.
A program of testing was undertaken to establish the real strength and ductility of pipe as manufactured and after coating, and this was supplemented by full scale burst testing. The behaviour of hydrostatic test sections comprising known strength populations in different hydraulic gradients was modelled and software was developed that could predict test section behaviour. The project led to a better awareness of the effect of coating on strength and toughness properties and of the need to consider this effect in design and specification.

APIA Project 1.1.4: Pipeline hydrostatic testing: pressure/temperature correlation
The uncertainty of measurement of temperature affects the accuracy of leak detection in hydrostatic leak testing. The cost of hydrotesting is also affected by the time taken for stabilisation of the temperature of the fill water which causes delays before testing can be undertaken
The project involved a study of the thermal behaviour of a pipeline during filling and pressurisation and a model was developed to determine longitudinal variations in temperature. A series of charts were developed that can be used to predict optimum stabilisation times depending upon starting conditions. Recommendations were also made for changes to the hydrostatic testing standard including allowing the use of a wider range of testing fluids for leak detection

APIA Project 1.2.8: Low temperature excursions due to operating transients
There is a lack of guidance to industry on prediction of the magnitude of low temperature excursions that accompany pipeline venting and re-pressurising operations of high-pressure gas pipelines.
The first phase of the work is concerned with establishment of metal and gas temperatures in natural gas pipelines during transients. The work comprises a combination of computer modelling and both laboratory and field measurement including comparison of commonly used computer simulation programs with physical measurement. The project will establish a methodology by which the minimum temperatures for pipeline and pipeline component design can be accurately predicted

See also in the JTM Programme Booklet:

Paper 5: Assessment of work-hardening behaviour of HFI-welded pipes for strain-based design approaches
Paper 6: An advanced innovative approach for strain behaviour assessment in pipelines subjected to severe plastic deformation
Paper 7: Recent developments in strain-based design of pipelines
Paper 8: Measurement of fracture resistance of pipelines for strain-based design
Paper 9: Pipeline design and construction research
Paper 10: On-bottom stability of submarine pipelines
Paper 16: An alternative to the pre-service hydrotest

Workshop 2: Corrosion prevention and management

PRCI Project EC-1-2: Detailed procedures for comparing successive ILI runs to establish corrosion growth
The project will develop a users guide to assist operators in understanding how corrosion growth rates are generated from successive ILI runs, addressing the uncertainties and issues to be aware of, and providing procedures for verifying the growth rates reported by vendors.

PRCI Project EC-1-3: Guidelines for reliability-based pipeline integrity methods
The project will develop a step-by-step methodology for using reliability methods to prioritise and schedule inspection, remediation and maintenance activities directed at metal loss corrosion, based on information from ILI and targeted excavation programs. Issues addressed will include probability of failure by leak/burst, measurement error, probability of detection and probability of false indication.

PRCI Project EC-1-6: Field demonstration and benchmarking work for reliability-based guidelines for pipeline integrity
This project will conduct field trials to validate and demonstrate the newly-developed reliability-based methodology using both ILI and ECDA data

PRCI Project EC-1-7: Evaluation of the current understanding of external MIC, and gap analysis
This project is a state-of-the-art review and gap analysis providing improved understanding of the factors and influences that contribute to MIC and potential methods for control and mitigation, based on NACE documents and research reports, operator experience and practices.

PRCI Project EC-2-3: Develop leak/rupture boundary for corrosion in low-toughness pipe
This project will develop a new understanding and methodology for determining the leak/rupture boundary for corroded pipes with low toughness/ductility, based on new analytical and experimental data

PRCI Project EC-3-1: MFL tools and sensors that assess coating condition (disbondment and shielding)
The work will develop technologies enabling operators to accurately identify and evaluate the effects of disbanded and shielding coatings, for assessing ILI re-inspection intervals in pipelines with SCC. Work will focus on developing new sensors and instrumentation for use during MFL surveys

PRCI Project EC-3-4: Large-scale cathodic disbondment testing
This project will determine the overall extent of coal tar epoxy coating disbondment by analysing CP applied current information for aged coatings. The results will enable operators to make informed decisions concerning coating quality in 50-80 year old pipe.

PRCI Project EC-3-5: Variable CP criteria
Data and operator experience indicate that there are situations where using the existing CP criteria may not assure that the pipe is effectively protected, and there are some pipe/soil environments where no criterion exists. Based on previous studies and operator experience, this project will develop a protocol for determining the severity of the environment and deliver a matrix linking severity of environment with acceptable CP criteria.

PRCI Project EC-3-6: Determine effectiveness of –850 mV ON cathodic protection criterion
There is concern at the proposed revisions to NACE SP-0169, particularly the possible change from –850 mV ON to –850 mV POLARIZED. This project will compile operator experience to substantiate the effective application of the –850 mV ON criterion

PRCI Project EC-3-7: Determine effect on FBE coatings of operating at greater than 150ºF
This project will evaluate the performance\ and longevity of FBE coatings if subjected to operating temperatures above 150ºF, and will determine the maximum limits of continuous operation at temperatures between 150ºF and 200ºF

PRCI Project EC-3-8: Determine an upper limit to cathodic protection for FBE coatings
Higher-than-necessary CP potentials may be damaging to FBE coatings. This project will provide operators with the technical information required to establish a maximum level for CP on FBE-coated pipelines, taking into account coating thickness, polarized CP potential level and soil type.

PRCI Project EC-3-10: Methods for addressing and mitigating corrosion under failed shrink sleeves and disbonded coatings
This project will identify cost effective alternatives to the present method whereby full excavation is necessary to repair shrink sleeves. Alternatives could include modified CP systems, innovative removal techniques etc.

PRCI Project EC-4-1: Performance of ILI and in-ditch tools for characterization of corrosion defects
There is currently no generally-available independent information concerning the performance (as defined by API 1163 metrics) of different ILI systems. This project will collect and analyze information reported from ILI and in-ditch measurements, to establish performance metrics for specified MFL systems. The work will build on an earlier JIP by Advantica supported by several European PRCI members.

PRCI Project EC-5-4: Above-ground surveys for difficult-to-access areas
There is an industry need to assess piping in difficult-to-access locations. This project extends previous work (EC-5-1) and will identify new or existing technologies, together with an understanding of their accuracy and limitations.

PRCI Project UP-2-3: Use of long-range guided wave ultrasonics for fitness-for-service determination of pipelines (including cased crossings)
At present, guided wave tools and technologies do not offer the kind of information needed by pipeline operators. At best the approach is only semi-quantitative, and the measurement parameters (% cross section area) are not those required for integrity assessments. This project aims to determine the relationship between guided wave response and flaw size, and to validate the accuracy of the relationship.

PRCI Project EC-5-5: External corrosion Direct Assessment in dynamic stray current areas

The aim of the project is to verify that ECDA can be effectively applied to maintain pipeline integrity in areas where dynamic stray currents are present, based on equipment evaluations and field studies.

PRCI Project IC-1-1, IC-1-2: Define operating conditions in which internal corrosion is extremely unlikely to exist, and develop internal corrosion threat assessment guidelines

This project will collate operator experience and relevant research information to define gas pipeline operating conditions under which internal corrosion is extremely unlikely and presents no integrity threat, avoiding the need for regular re-inspection or testing. A guidance document will be produced.

PRCI Project MATR-3-3/4: Assuring the permanency of composite systems for repair of corroded pipe

This project is part of a program to confirm the long-term performance of composite repair systems on pipes subject to corrosion, dents and mechanical damage. Samples of repaired damage have been buried; they will be retrieved at regular intervals over three years and destructively tested to confirm there is no long-term degradation of properties.

PRCI Project PR-218-05404: Guidance for repair of pipeline defects

The aim of this project is to catalogue generally-available methods for assessing defects and damage discovered during pipeline service – corrosion and cracking – and show by worked examples how they can be applied.

PRCI Project PR-244-9827, JTM Paper 21: Local buckling and collapse of corroded pipelines

This project provides guidance on methods for assessing the structural significance of corrosion damage when significant secondary loads (axial, bending) are present in addition to the hoop load.

PRCI Project PR-273-0323; Remaining strength of corroded pipe

This project evaluates the accuracy and applicability of the commonly-used Level 1, 2 and 3 corrosion assessment methods, including the range/limitations of applicability in terms of strength (up to X100), toughness (down to ~15 J), cyclic loading and secondary/biaxial load. A guidance document will be prepared. See also JTM Paper 19.

APIA Project 1.2.2: Investigation into pipeline coating deterioration by the collection, analysis and interpretation of cathodic protection

There is little information to confirm that the coating deterioration allowances used in the design stage are likely to match the actual degradation experienced. This can result in substantial initial over-design, with correspondingly higher initial cost, or substantial initial under-design, resulting in the need for unplanned expenditure in future years.
Data will be collected from APIA members on the performance and deterioration of various pipeline coatings over time, to enable realistic estimates of the cathodic protection requirements over the life of new pipelines and enable planning of future cathodic protection requirements on existing pipelines.

APIA Project 1.2.3: Requirements for effective holiday detection on FBE coatings

Phase 1 of the project provided information on voltages for holiday testing FBE coated pipe in the field, and identified a number of issues with the nature of the outputs and the means of measuring them. In this Phase a range of commercially available holiday detectors will be investigated to determine their compliance with AS 3894.1. The effect of different holiday detector output waveforms on the ability to detect defects and their propensity to cause damage to FBE coated pipes will then be investigated. Finally methods and equipment for measuring and/or observing the output waveforms in the field will be investigated. The work

will improve confidence in the testing undertaken to determine the occurrence of holidays in FBE coated pipe

APIA Project 1.2.4: Investigation onto the effect of variable stray currents on cathodic protection for buried pipelines

Stray currents and telluric influences can reduce the pipeline potential above the desired -850 mV level for frequent short periods. These effects are accentuated by modern high quality pipeline coatings that although greatly assisting in the effective application of cathodic protection, can make the ramifications of inadequate CP more severe.
In an earlier APIA project, a method for measuring small amounts of corrosion using a small coupon and applying weight loss techniques was developed. In this present project further laboratory studies will be accompanied by data from field installations. The aim is to develop guidelines and recommendations for adequate cathodic protection levels, and provide the basis for revised industry Standards

APIA Project 1.2.12: Evaluation of Commercially Available Joint Coatings for 3 Layer Pipeline Coatings

Joint coatings provide the basis for buried pipelines to achieve their design life with minimum operator intervention – yet their selection is shrouded in mystery, personal preference, and lowest cost – even though the joint coating is a very small portion of the overall pipeline cost. Joint coatings have also been the source of major problems on Australian pipelines.
The project will evaluate the application methods and subsequent performance of joint coating systems offered by coating manufacturers as being products suitable for application to pipes coated with 3 layer pipeline coatings, with a view to providing an improved basis for selection.

APIA Project 1.2.13: AC corrosion of pipelines

Corrosion on cathodically protected pipelines due to steady state AC induction from adjacent power lines is becoming a significant problem worldwide due to the trend towards using common corridors for multiple utilities and the high quality pipeline coatings that are now generally employed to otherwise improve the effectiveness of cathodic protection. Gaps in the current state of knowledge will be identified and highlighted, with a view towards subsequently initiating research to rectify any deficiencies.

EPRG Project 121. Coating degradation and long-term performance

As the pipeline age increases, the ability to maintain corrosion-free conditions is related to the resistance of the coating to ageing processes and local degradation. Among EPRG members, 60% of existing pipelines have thermoplastic coatings (asphalt, coal tar and bitumen), with the majority of the remainder being polyolefin coatings (extruded polyethylene and polypropylene). For these coating systems the main causes of premature degradation are found to be an inappropriate specification, inadequate control of metal surface cleaning and preparation, high operating temperatures, and excessive loading due to the surrounding soil. Areas identified for further research include the long-term adhesion of coatings, and the relationship between coating condition and CP shielding.

EPRG Project 134, JTM Paper 20: Assessing long-term resistance to coating adhesion loss

A review of existing international standards showed that there is no reliable test method for evaluating the long-term service performance of pipe coatings. EPRG undertook a programme to develop a suitable accelerated test method, focusing on the known disbonding mechanisms in 3-layer polyolefin and epoxy pipe coatings:

- Water permeation through the intact topcoat material
- Cathodic disbonding originating from a defect in the coating
- Penetration of water into the primer layer

The main objective of the work was to find the basis for an accelerated test. The main concern arose from the significantly differing adhesion performance over the temperature range between 40 and 90ºC. An intermediate temperature of 60ºC was eventually selected, with a test duration of 28 days.

Further planned work will extend the range of coating types and pre-treatments, focusing on 3-layer coating systems. The relationship between behaviour in the accelerated laboratory test and long-term service exposure will also be explored.

See also in the JTM Programme booklet:

Paper 18: Coatings and cathodic protection – corrosion mitigation in the field
Paper 19: The assessment of corrosion damage in pipelines subjected to cyclic pressure loading
Paper 22: Understanding and accounting for corrosion growth rates
Paper 23: Developments in reliability-based corrosion management and the significance of ILI uncertainties
Paper 24: The pipeline defect assessment manual – R&D needs

Workshop 3: Pipe materials and properties (including fracture control)

PRCI Project MAT-4-4
The objective is to develop an enhanced model, based on the J-T analysis approach, to predict the start of ductile tearing (initiation of the fracture event) and maximum failure pressure of an axial crack in a high strength line pipe. The model will be validated via small-scale fracture specimens and full-scale pipe tests.

PRCI Project MAT-8: Criteria for determining seam failure susceptibility due to crack defects
Research is aimed at developing methodologies for assessing the significance of crack-like defects in ERW pipelines. The methodology is developed from the principles in BS 7910, but with significant differences in detail at Level 2. The Level 3 methodology is J-based rather than FAD-based.

PRCI Project PR-276-04505: Improvements in two-curve ductile fracture arrest models
The project aims to improve the accuracy of the two-curve ductile fracture model by accounting for different types of soil backfill, based on a series of full-scale burst tests with different soil types and moisture content

PRCI Project MATH-4-6: Validation of dry-fibre wrapped steel pipe
The project aims to qualify the fabrication, long-term performance, damage tolerance, repair, corrosion control and installation techniques for dry fibreglass wrapped steel pipe, to promote approval of the product by NEB and PHMSA for high pressure gas pipeline applications.

APIA Project 1.2.10: The effect of pipe diameter on the decompression velocity of rich gas
The Battelle two curve model (BTCM) does not account for diameter in the determination of decompression velocity and hence fracture arrest toughness levels. Limited data generated by PRCI suggests that decompression is significantly slower in small diameter pipelines. This needs confirmation. If it is so then the fracture control methods used for small diameter pipelines may not be safe.
The APIA-RSC is preparing to undertake shock tube tests at a diameter intermediate to the very small (DN50) pipe and the typical large diameter pipelines (> DN750) for which data currently exists. It is hoped to be able to involve PRCI and/or EPRG in a new proposal under development.

EPRG Project 123. Pipe properties: strength de-rating factors at elevated temperatures
Strength de-rating factors are used for line pipe and fittings located in the vicinity of compressor discharges, where the operating temperatures can be above ambient. Several codes provide such strength de-rating factors, but they are inconsistent in both the magnitude of the reduction and the temperature below which such effects can be discounted. EPRG commissioned a review and limited experimental project to address these shortcomings. For most of the steels studied there was a sharp reduction in proof strength at 60°C compared with the room temperature value, but little further change as the temperature increased to 150°C

EPRG Project 126: X100 Grade steel for pipelines
In recent years EPRG has played a significant role in supporting initiatives to enhance the knowledge base for X100 line pipe and its applicability to highly-rated pipelines. In particular, EPRG has partially sponsored a Demonstration Project – Demopipe - to establish the pipe production and properties, field welding, field bending and fracture control methodology. Some 50 full-length seam-welded pipe joints were produced, and welding procedures were developed and qualified for automated and manual girth welds. Field bending procedures were developed and tested. Two full-scale fracture propagation tests

were conducted, demonstrating that extrapolation of the standard fracture propagation methods to higher strengths is very questionable, and that crack arrestors will be needed for highly-rated applications.

EPRG Project 130: Drop Weight Tear Testing Procedures

The Drop Weight Tear (DWT) Test is a universally-used quality control test for gas pipes. Arrowhead-like areas found on the fracture surfaces can lead to mis-interpretation of the proportion of shear fracture; in some instances the arrowhead areas are sufficiently large that their classification as shear or brittle changes the result of the DWT test from pass to fail.

EPRG launched a project to investigate different aspects of the DWT test procedure and test set-up. As the test is not standardised it became evident that different laboratories may use different procedures and evaluation methods that may have a significant influence on results. The best correlation was obtained with a pendulum-type testing machine where the energy was measured accurately by a mechanical pointer.

EPRG Project 132: Calculating the yield and burst pressure, and circumferential failure elongation, of flaw-free pipes

To make maximum use of the properties of highly-rated pipe steels, it is essential to model precisely the ultimate limit states and thereby to calculate accurately their yield and burst pressure and circumferential elongation at failure. To provide a basis for identifying the optimum calculation method, the available calculation methods for yield, burst and circumferential elongation were compared with experimental data from defect-free pipes with Y/T ratios ranging from 0.70 to 0.95. For burst pressure, models incorporating descriptions of strain hardening and uniform elongation were more accurate than those based solely on yield and tensile strength, but models incorporating a full description of stress-strain behaviour showed little further improvement. The von Mises criterion proved very good for determining yield behaviour.

EPRG Project 131: Crack arrestor design for high-strength and low-toughness pipelines

The avoidance of long-running fracture propagation is an essential issue for pipeline design. A short study reviewed the applicability of existing approaches for crack propagation control, either based on material properties like brittle-to-ductile transition temperature and upper shelf toughness energy, or in case these are not sufficient, based on crack arrestors. The review highlighted the current gaps in knowledge about fracture propagation and crack arrestor design, both in older low-toughness pipelines and in recently developed high-strength steels, for which the methods developed in the 1980s may not be conservative. It also identified current work on numerical simulation for crack propagation and crack arrest behaviour as a way forward.

EPRG Projects 133, 149 & 150, JTM Paper 27: Hydrogen-induced Cracking

Following a review of laboratory and service experience, EPRG commissioned an experimental programme of HIC exposure tests on five different steel types. Experiments consisted of HIC exposure tests based on the NACE TM0284-2003 standard method. A good correlation was found between diffusible hydrogen content and HIC; when diffusible hydrogen was below 1 ppm, no HIC was observed but at above 1 ppm all steels showed severe HIC. In tests al low severity (around 10 mbar hydrogen sulphide), longer than standard exposure times were required to reach sufficient levels of diffusible hydrogen for HIC to form. The results provide the basis for developing a 'regions of environmental severity' diagram, similar to that developed for sulphide stress corrosion cracking in the 1990s and later incorporated into NACE MR0175 and ISO 15156. Further laboratory and full-scale testing will substantiate the Environmental severity Diagram.

EPRG Project 138: Comparison of European (EN) and International (ISO) linepipe standards

When the European Standard EN 10208-2 was issued in 1996, the International Standards Organisation also issued an equivalent standard, ISO 3183:1996. The ISO standard has since been revised and reissued in 2007, and the EN standard is now in the process of being revised. EPRG has undertaken a thorough comparison of the requirements of the two standards to identify areas for harmonisation, to identify differences and to form the basis of an opinion as to whether the ISO standard should be adopted in Europe, particularly for gas transmission pipelines.

EPRG Project 136: Methods for evaluating the fracture resistance of high grade steel pipelines

Recent studies by EPRG have focused on thoroughly reviewing the underlying principles of fracture propagation and arrest prediction methods, and the limitations encountered when they are used to characterise high grade steel pipes and predict their fracture arrest behaviour. The results of these reviews show that, while the applicability of the Battelle Two-Curve Method is very questionable for the highest steel grades, no unambiguous alternative fracture parameters are available. To move from this 'stalemate' will require further attention to the relationship between the dynamic behaviour of laboratory specimens and full-scale pipes, in order to understand the effects of constraint (ligament length, wall thickness and geometrical bending etc) on crack propagation and arrest, and the role of material ductility in the failure process.

See also in the JTM Programme booklet:

Paper 1: Nord Stream Project – a challenge for a pipe manufacturer
Paper 2: Investigations on microstructure, mechanical properties and weldability of a low-carbon steel for high strength helical linepipe
Paper 3: Overview of materials compatibility issues with fuel-grade ethanol
Paper 4: Does extensive HAZ testing lead to enhanced pipeline safety?
Paper 5: Assessment of work-hardening behaviour of HFI-welded pipes for strain-based design
Paper 16: An alternative to the pre-service hydrotest

Workshop 4: Welding and weld inspection (including installation)

PRCI Project MATH-1, JTM Paper 14: Welding of high strength steel pipelines
The aim of the project is to provide a fundamental understanding of the factors that affect the mechanical properties of welds in high strength (X100) steel pipelines; particularly weld design, testing and assessment procedures.

PRCI Project CNST-2-1: Modernizing onshore pipeline construction
This project will consider the entire onshore pipeline construction process and will identify new/existing technologies with the potential to achieve significant reductions in the time/cost of construction. The work will identify the most promising opportunities to achieve step changes in pipeline construction efficiency.

APIA Project 1.1.1: In-service welding on thin-walled pipelines
Existing methodologies for welding on in service pipelines were restricted to thicknesses above some of the common thicknesses encountered on Australian pipelines. New burn through prediction and HAZ hardness modelling software was developed targeting thicknesses as low as 3.2mm and grades up to X80. The models were confirmed by experiment. The project was conducted in collaboration with PRCI.

APIA Project 1.1.2: Understanding hydrostatic testing
Increasing the design factor to 80% SMYS whilst retaining the hydrostatic test factor of 1.25 means that all affected pipelines must be tested to above nameplate strength. Coupled with this the yield/tensile ratio in high strength pipe can be very high, especially when measured using tests such as the ring expansion test and when the pipe is coated using processes such as FBE which cause strain ageing. These circumstances led to concerns that the available ductility could be diminished or exceeded in volume controlled hydrostatic tests.
A program of testing was undertaken to establish the real strength and ductility of pipe as manufactured and after coating, and this was supplemented by full scale burst testing. The behaviour of hydrostatic test sections comprising known strength populations in different hydraulic gradients was modelled and software was developed that could predict test section behaviour. The project led to a better awareness of the effect of coating on strength and toughness properties and of the need to consider this effect in design and specification.

APIA Project 1.1.4: Pipeline hydrostatic testing: pressure/temperature correlation
The uncertainty of measurement of temperature affects the accuracy of leak detection in hydrostatic leak testing. The cost of hydrotesting is also affected by the time taken for stabilisation of the temperature of the fill water which causes delays before testing can be undertaken
The project involved a study of the thermal behaviour of a pipeline during filling and pressurisation and a model was developed to determine longitudinal variations in temperature. A series of charts were developed that can be used to predict optimum stabilisation times depending upon starting conditions. Recommendations were also made for changes to the hydrostatic testing standard including allowing the use of a wider range of testing fluids for leak detection

APIA Project 1.2.6, JTM Paper 13: Boron in EXX10 weld metal
Although there is no published research and no manufacturer product data information in the public domain describing the use of boron as an alloying element it has come to the notice of the APIA-RSC that some manufacturers are routinely adding B to some electrodes. B is the most potent and potentially the most fickle of all the alloying elements that can be added to steel. It is reasonable to expect that it can have a major impact on HACC, and that the degree of uptake into the weld metal, and hence the weld metal properties, will be affected by process conditions such as arc length and coating moisture
The project seeks to determine whether boron is being used in commercial cellulosic electrodes used for welding pipelines, and if so, how the welding conditions affect the pickup of boron from the consumable into the weld metal.

APIA Project 1.2.9: Measurement Uncertainty in Hydrostatic Leak Tests

Usually the largest contributor to pressure change during a leak test is the change in temperature. The averaging of infrequent and uncertain measurements affects the assessment of whether a test section contains a leak or otherwise. This uncertainty limits the maximum volume of a test section; either the test section length must be reduced, or the duration of the leak test increased.

The purpose of the project is to develop an appreciation of each measurement uncertainty and to establish a methodology where these components can be combined to enable better design of each test section for hydrostatic leak test. The data will be used to fill knowledge gaps in base data required for AS 2885.5 – Field Hydrostatic testing

.

EPRG Project 144, JTM Paper 15: Extension of the EPRG guidelines for assessing girth weld defects

Guidelines for assessing defects in girth welds were published by EPRG in 1996. They contained a number of restrictions on their application; in particular, the through-wall depth of a defect was assumed not to exceed 3 mm, wall thickness was restricted to between 7 mm and 25 mm, and the material strength was restricted to X70 or below.

Recently-completed work by EPRG now supports extension of the guidelines up to X80 grade material. Using a reference stress (collapse) analysis, through-wall depths of 5 mm can be allowed so long as the defect length is reduced, and the same approach can be used to extend the range of allowable wall thickness. A simple approach based on elastic stress concentration has been used to relate allowable misalignment to the applied stress.

See also in the JTM Programme booklet:

Paper 16: An alternative to the pre-service hydrotest

Workshop 5: Mechanical damage

PRCI Project MD-1-1: Dual-field MFL inspection technology to detect and Characterize mechanical damage

This project will establish the capability of dual-field MFL technology to detect mechanical damage and discriminate between critical and benign anomalies. A tool will be bukilt and tested in an operating pipeline. It is expected that dual-field MFL technology will significantly reduce the number of false positive indications (thus reducing needless digs) and false negative indications (significant anomalies that are missed)

PRCI Project MD-1-2, JTM Paper 28: Performance characteristics of current ILI technologies for mechanical damage detection

This project collates and evaluates field ILI data to determine the ability of different current MFL technologies to detect, characterize and size various types of mechanical damage in pipelines, with a view to providing performance measures and guidance for using existing ILI technology to find and assess mechanical damage.

PRCI Project MD-1-3: Understanding MFL signals from mechanical damage

This ongoing work is developing an improved fundamental understanding of magnetic flux signals emanating from damaged pipe, including the separate effects of shape change, elastic and plastic deformation, to enable better identification of the features found during field runs.

PRCI Project MD-1-6: Ultrasonic measurements of strains in pipelines

The project aims to evaluate and demonstrate the vfield capability of a hand-held device designed to measure local strains in distorted or damaged pipe. Initial work will focus on specifying the measurement requirements and device performance, and evaluation of prototype instruments

PRCI Project MD-2-2: Model for Predicting the Likelihood and Severity of Newly Created Damage

The pipeline industry needs to develop and implement practices and technologies that are effective in managing the risks of failures of dents, dents with secondary features, gouges and dents combined with gouges. The overall outcome of this project will be a validated state-of-the-art mechanics-based probabilistic model for determining the severity of damage (rupture, leak, or dent/gouge) based on pipeline attributes and aggressor characteristics. The model will be used both to aid risk-based evaluations of overall pipeline safety and to aid decisions on the safe assessment, excavation and repair of individual defects.
.

PRCI Project MD-4-1, JTM Paper 29: Full-Scale Experimental Validation of Mechanical Damage Assessment Models

The aim of this project is the development of an experimental database for validation of mechanics-based models incorporating the effects of dent/gouge geometry, pipe geometry, ground constraint and material properties on the burst pressure of pipes containing dents combined with gouges. The principal deliverables will be a database of full-scale cyclic load and monotonic load tests on pipe samples containing dents combined with gouges, complementing the first year tests under monotonic load. The results will enable validation of state-of-the-art mechanics-based models for determining the failure behavior of dents combined with gouges. The experimental results and model will be used to aid decisions on the safe excavation and repair of such defects.

PRCI Project MD-4-2, JTM Paper 29: Full-Scale Demonstration of the Interaction of Dents with Localized Corrosion Defects

The aim of this project is the development of an experimental database for validation of mechanics-based models incorporating the effects of dent geometry, pipe geometry, ground constraint and material properties on the burst pressure of pipes containing dents with localized corrosion or in the vicinity of welds. The development of a validated engineering model and acceptance criteria for dent damage, particularly for dents containing corrosion or threat of delayed failure and develop general guidance for the industry.

PRCI Project MD-4-3: Improved Model for Predicting the Burst Pressure of Dent + Gouge Damage

The aim of this project is the development of a mechanics-based model incorporating the effects of defect geometry, pipe geometry, ground constraint and material properties on the burst pressure of pipes containing dent+gouge damage representative of that found in service. Validation of the model will be by comparison with the results to be made available from recent and ongoing tests programs for PRCI by Gaz de France, Stress Engineering and Southwest Research Institute, and where possible by reference to the earlier databases of full-scale test results. The development of an engineering model and acceptance criteria for the evaluation of dent+gouge damage will provide a significantly improved technical basis to evaluate the threat of delayed failure and develop general guidance for the industry to enable safe working pressures for operation before and during excavation and repair.

PRCI Project MD-4-4: Improved Model for Predicting the Time/Cycle Dependent Behavior of Dent+Gouge Damage

The aim of this Project is the development of a mechanics-based model incorporating the effects of defect geometry, pipe geometry, ground constraint material properties and operational loading spectrum on the time-dependence and cyclic-load-dependence of the pressure of pipes containing dent+gouge damage representative of that found in service. Validation of the model will be by comparison with the results to be made available from recent and ongoing tests programs for PRCI by Gaz de France, Fleet Technology and Stress Engineering Services, and where possible by reference to the earlier databases of full-scale test results. The development of an engineering model and acceptance criteria for

the evaluation of the time-dependent and/or cyclic-load-dependent behavior of dent+gouge damage will provide a significantly improved technical basis to evaluate potential threats and develop general guidance for the industry to enable determination of safe working pressures for operation before and during excavation and repair.

PRCI Project MD-4-5: Acoustic source level and signature measurement of pipeline scratches and gouges

One of the limitations with acoustic monitoring is determining the relationship between operational severity of the impact and the corresponding acoustic response. This project will evaluate the acoustic responses when test samples are created (MD-4-1) with a view to determining the threshold for impact detection and the relationship between damage severity and acoustic signal features.

PRCI Project MD-5: Inspection and Repair Procedures for Dent+Gouge Damage

The aim of this project is the development of new guidance for safe inspection and repair of damage based on recently developed mechanics-based models describing the burst and delayed failure behavior of dents, gouges and dent+gouge damage. The main benefit to operators from this work will be soundly-based procedures for safe and timely interventions to undertake repairs, and guidance on maintaining safe operating pressures between the point of damage discovery and the completion of damage mitigation.

PRCI Project MATR-3-5: Evaluating the use of composite materials in reinforcing mechanically damaged pipes

This project is part of a program to confirm the long-term performance of composite repair systems on pipes subject to corrosion, dents and mechanical damage. Samples of repaired damage have been buried; they will be retrieved at regular intervals over three years and destructively tested to confirm there is no long-term degradation of properties.

PRCI Project ROW-2-1: measuring the effectiveness of current right-of-way monitoring techniques/practices

The project aims to measure the effectiveness of techniques currently used by operators to prevent unauthorized encroachments and excavations on their right-of-way. First steps include development of a data collection worksheet to document hits and near misses.

PRCI Project ROW-3: Right-of-way automated monitoring

This major co-funded project aims to develop a framework and methodology for an integrated remote pipeline monitoring system. It will demonstrate technologies to remotely detect, in near-real-time, encroachment and intrusions, ground disturbance/movement and leaks of liquids and gases. The first objective is to use technology deployed by fixed-wing aircraft, then to migrate to unmanned aerial systems and satellites, as they become available and cost effective.

PRCI Project ROW-5: Field tests and development of pipeline intrusion sensor system

The project aims to design, build and demonstrate a prototype sensor system for detection of intrusions and excavation activity in sufficient time to prevent pipeline damage, based on already-developed technology

PRCI Project DP-3-2: Influence of human factors on pipeline damage prevention

The project will develop an understanding of the contribution of human factors to pipeline damage, recommend intervention steps to counter the high priority issues, and evaluate their effectiveness during implementation trials

PRCI Project SPDA-1-2: Develop guidelines for evaluating damage to subsea pipelines

The aim of the project is to provide operators with definitive guidelines on how to respond when their offshore pipeline is damaged; what pressure reduction is appropriate, what parameters are important when addressing damage, what epair strategies can be considered. The guidance will initially be based on existing company best practice, followed by research to address any identified gaps.

EPRG Projects 135, 140, 147: Burst strength of pipes containing dent + gouge damage

The method currently recommended by EPRG for assessing the remaining strength of pipes with such damage is based on the 'British Gas Model' developed in the early 1980s using a combination of fracture mechanics and empirical relationships derived from a database of 122 experimental tests.

A recent study for the United Kingdom Onshore Pipeline Association (UKOPA) developed an improved limit state function to address some of the perceived shortcomings of the British Gas Model, notably the stress concentration and residual stresses associated with the dent, and the micro-cracking at the base of the gouge. Recognising the potential for further developing and improving the predictive model, EPRG commissioned a study applying the UKOPA model to the wider set of 224 test results now available in the public domain, enabling recalibration and further refinement of the factors determining failure behaviour. This confirmed that differences between the methods used for simulating the dent+gouge damage in the experimental tests were responsible for much of the extensive scatter still evident in the predictions.

A subsequent EPRG study has examined in more detail the factors identified during the recalibration study. While a significant reduction in scatter and bias can be achieved for individual datasets by refining the definitions of toughness and micro-crack depth, the improvements are still masked by the variations between different datasets.

EPRG Project 137, JTM Paper 30: The assessment of delayed fracture under constant pressure

Recent events in Belgium have shown that modern steel can sustain quite significant defects that might go undetected and as a result may give significant consequences because of stable crack growth. For older steel, even in the case of low ductility material, some time-delayed failures have been recorded. Qualitative models developed in the past indicate that only a complex combination of parameters will lead to delayed failure. The aim of the project is to evaluate the sensitivity of time-delayed failure to pipe diameter, wall thickness, toughness and operating pressure, including pressure fluctuations due to normal pipeline operation.

EPRG Projects 129, 139, 151: Hostile environmental effects on residual mechanical resistance of damaged pipes

Mechanical damage due to excavator impact usually results in damage to the pipeline coating. In this situation, cathodic over-protection can be present and a potentially hydrogen charging environment can be created at the damage location. Among the EPRG members, five pipeline incidents were identified in which a combination of mechanical damage and cathodic over-protection could lead to rapid failure due to hydrogen embrittlement.

EPRG commissioned an experimental project to explore how the effect can be simulated and measured in laboratory tests. The work utilised test specimens cut from the wall of pipes containing artificial dent and dent+gouge damage, and subjected them to a variety of monotonic and cyclic load tests, with and without corrosive liquid environments and cathodic over-protection.

The results of these studies have qualitatively confirmed the effects seen in service; they have also pointed to the need for testing full pipe sections rather than laboratory specimens. Further experimental work is planned in order to pursue these issues.

See also in the JTM Programme booklet:

Paper 24: The pipeline defect assessment manual – R&D needs

Workshop 6: Stress corrosion cracking (SCC)

PRCI Project SCC-1: Development of guidelines for identification of SCC sites and estimation of re-inspection intervsls for SCC direct assessment

Development of quantitative guidelines for identifying when and where SCC is an integritty threat to gas and liquids pipelines. Work will include review of the expressions for crack growth, and the development of a relationship for estimating re-inspection intervals

PRCI Project SCC-2-12: Effect of pressure fluctuations on growth rate of near-neutral pH SCC

Crack growth rates in high pH and near-neutral pH environments will be measured under a wide range of cyclic frequencies and amplitudes, to clarify how growth rates and crack dormancy are influenced by the nature of pressure fluctuations, and determine whether SCC can be prevented by controlling pressure fluctuations.

PRCI Project SCC-2-4: Define operating conditions in which no SCC exists

The operators' experience of SCC in North America, Western Europe and elsewhere will be collated and reviewed to determine the conditions (material and microstructure, coating, operating pressure and temperature etc) under which high pH and near-neutral pH SCC are not expected to develop.

PRCI Project SCC-2-5: SCC in areas of local deformation

Company surveys and published literature, together with limited FEA modeling, will be used to determine the causes and driving forces of SCC in areas of local deformation, and to develop guidelines for addressing the problem if it arises

PRCI Project SCC-2-8: Crack depth knowledge and experience filters for improved quantitative SCC risk assessment procedures

The project aims to combine eddy current mapping of SCC depths with procedures based on frequency domain analysis, to develop an improved understanding of crack severity distributions, enabling decisions on which cracks may require action following excavation, and which cracks may require further investigation within the next re-inspection interval.

PRCI Project SCC-3-4: Detection, sizing and characterization of SCC and other cracks in dents in liquids pipelines

This project will develop an understanding of the capabilities and limitations of commercial ILI for detecting, characterizing and sizing SCC and other cracks in dents in liquid pipelines, and will provide recommendations for improvements. A prototype 24-inch ILI tool based on ultrasonic sensor technology will be built.

PRCI Project SCC-3-5: External surface breaking SCC crack mapping using a flexible eddy current probe

This project will determine if existing eddy current array technologies currently in use can be developed for location and assessment of SCC in pipelines. Experimental trials have determined the critical design elements and reference standards, and probe options have been trialled. An array has been built and its performance vaslidated, indicating that eddy current arrays are a viable option.

PRCI Project SCC-3-7: Evaluation of EMAT tools by monitoring industry experience

The project has reviewed field and laboratory data for EMAT technology. The current focus is on evaluating the reliability of current EMAT technology for locating, identifying and sizing SCC in gas pipelines, using data from field trials.

PRCI Project SCC-3-12: Characterization of measurement uncertainties associated with ILI crack detection tools

This project will develop mpractical and defensible methodologies to verify the vendor-claimed detection and sizing accuracies of crack detection tools (elastic wave and shear wave ultrasonics, electromagnetic acoustic transducers) for both gas and liqiuds pipelines. The work will be based on comparison of ILI and excavation data from field operations.

PRCI Project SCC-4-3: Identify environmental factors that produce SCC in ethanol

Previous workusing laboratory tests has indicated the need for longer term tests under more realistic loading conditions, in actual fuel-grade ethanol from different sources. SCC growth measurements will be conducted under static and cyclic loading in flowing ethanol. Representative pipe flow and mixing/batching conditions will be simulated. Several commercially-available inhibitors will also be tested.

PRCI Project SCC-4-4: Determine the requirements necessary to allow existing pipeline systems to transport ethanol without cracking

This project will provide better understanding of the operating conditions (pipe material, load profile) that will promote initiation and growth of SCC in ethanol pipelines, leading to the identification of operating conditions that will avoid SCC

PRCI Project SCC-4-5: Determine the requirements necessary to allow new pipeline systems to transport ethanol without cracking

This project will determine if current pipeline design practices require modification for new pipeline and tank designs to mitigate integrity threatsdue to the transportation of fuel grade and neat ethanol. Work will focus on pipe material and welding specifications, surface treatments, internal linings and\seals etc.

PRCI Project EC-3-1: MFL tools and sensors that assess coating condition (disbondment and shielding)

The work will develop technologies enabling operators to accurately identify and evaluate the effects of disbonded and shielding coatings, for assessing ILI re-inspection intervals in pipelines with SCC. Work will focus on developing new sensors and instrumentation for use during MFL surveys

APIA Project 1.1.5: Fatigue crack extension and repair of pipelines with SCC cracks

Current standards do not allow cracks to be left in operating pipelines. Cracks must be removed by grinding as part of any repair process. In pipelines suffering from SCC there can be very large areas of shallow cracking that is no threat to structural integrity. Growth of these cracks by SCC can be prevented by recoating and thus removal of the environment essential to growth by that mechanism. The only other available growth mechanism is fatigue. The project set out to determine whether fatigue crack growth of SCC is likely under typical gas pipeline pressure cycling.

Pipe samples containing SCC identified by ILI were removed from an operating pipeline. The extensive colonies of SCC contained individual cracks up to 6.4 mm deep (70% wall thickness). The fatigue testing was terminated by a small leak after the equivalent of approximately 8000 years of daily and maintenance related pressure cycling for the pipeline concerned and showed that fatigue crack extension of SCC is not an issue for normal gas pipelines. The equivalent number of 0 to 72% SMYS pressure cycles required to cause leakage was 8800.

APIA Project 1.2.1: Durability of coatings for in service remediation of SCC damage

This project follows on from the fatigue of SCC project which showed that SCC cracking could be repaired by recoating so as to exclude the environment that allowed the formation and extension of SCC.

The aim is to determine how effective field applied coatings are in excluding the external environment from the surface of the pipe when a coating repair is undertaken over an SCC

colony and whether these coatings remain intact over the colony during cycling loading over the lifetime of the pipeline.

APIA Project 1.2.16: Materials contribution to SCC susceptibility of pipelines

The mechanism of crack development and growth has been the subject of extensive research and several key factors have been identified in the initiation and growth of SCC. To date these factors have been primarily environmental and operational, however no obvious unique metallurgical characteristic of line pipe manufacture or metallurgical properties has been definitively identified. There is very little understanding why two adjacent sections of pipe with coating in apparently similar condition can exhibit very different levels of damage.

Extensive material property, manufacturing and operational data will be generated on apparently identical sections of adjacent line pipe cut from an operating pipeline to determine any significant differences that may explain why some lengths exhibit severe SCC and others do not

EPRG Project 120: External stress corrosion cracking

External SCC has been an issue for pipeline operators since the first in-service failures occurred in the US in the mid-1960s, although it has been extremely rare in Europe. EPRG's activities have concentrated on exploring the relationship between steel type (strength and microstructure) and the likelihood of near-neutral pH SCC developing. The results showed that steels with ferrite-pearlite banded microstructures were more prone to crack initiation than a steel with a fine ferrite-bainite microstructure, and that different inclusion distributions in the steels did not have a significant influence. However, all the steels showed similar crack propagation characteristics, with a 'dynamic' threshold stress intensity that was considerably lower than the static threshold

See also in the JTM Programme booklet:

Paper 3: Overview of materials compatibility issues with fuel grade ethanol
Paper 25: The practical application of APIA's SCC research to the Moomba-Sydney pipeline
Paper 26: Validation of mechanistic guidelines for the identification of SCC sites and the prediction of re-inspection intervals by comparison with field experience.