EPRG RESEARCH PROGRAMME – SUMMARY

Introduction

EPRG’s overall aims and objectives are:

- To identify methods and practices for improving the integrity of existing and new pipelines, thereby ensuring the continued excellent record of pipeline safety and reliability demonstrated by gas transmission pipelines in Europe and elsewhere
- To establish research programmes in response to the identified needs and priorities, and to develop recommendations and guidelines based on the results obtained
- To promote and encourage the acceptance and implementation of the recommendations and guidelines by the gas pipeline industry

EPRG’s Research Programme is administered by three Technical Committees - Materials, Corrosion and Design.

EPRG’s overall budget amounts is currently allocated between the Technical Committees as follows:

![Pie chart showing allocation of budget between Materials, Design, and Corrosion]

Ongoing and recently-completed research projects, and projects under development, are listed below under four headings:

1. Materials and Manufacturing
2. Corrosion and Corrosion Prevention
3. Design and Operations
4. Collaborative projects with PRCI and APIA
1. Materials and Manufacturing

1.1 Projects in progress

<table>
<thead>
<tr>
<th>Project No:</th>
<th>137</th>
<th>Title:</th>
<th>Assessment of delayed failure under constant pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPRG Manager:</td>
<td>Paul Roovers</td>
<td>Start date:</td>
<td>July 2007</td>
</tr>
<tr>
<td>Contractor:</td>
<td>Atkins Boreas</td>
<td>Duration:</td>
<td>6 months</td>
</tr>
<tr>
<td>Status:</td>
<td>Interim work complete</td>
<td>Funding:</td>
<td>€150k</td>
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Summary:
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.

<table>
<thead>
<tr>
<th>Project No:</th>
<th>138</th>
<th>Title:</th>
<th>Clarification of the European view towards ISO and EN line pipe standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPRG Manager:</td>
<td>Paul Roovers</td>
<td>Start date:</td>
<td>April 2009</td>
</tr>
<tr>
<td>Contractor:</td>
<td>BMT Fleet Technology</td>
<td>Duration:</td>
<td>4 months</td>
</tr>
<tr>
<td>Status:</td>
<td>Report approved</td>
<td>Funding:</td>
<td>€20k</td>
</tr>
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</table>

Summary:
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.
## Project No: 146
### Title:
Development of a reliable model for evaluating the fracture propagation resistance for high grade steel pipelines

<table>
<thead>
<tr>
<th>EPRG Manager: Carlo Spinelli</th>
<th>Start date: August 2008</th>
<th>Funding: €110k</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contractor: CSM</td>
<td>Duration: 24 months</td>
<td>Status: In progress, Draft report submitted</td>
</tr>
</tbody>
</table>

### Summary:
A recent EPRG desk study on the available toughness parameters and laboratory methods to quantify the resistance of steel to the ductile fracture propagation event, together with the published results of full scale burst tests on API X80 and X100 pipes, shows that the applicability of the Battelle Two Curve Method based on the Charpy-V energy and its straightforward extrapolation from API X80 pipes to X100 grade operating at very high hoop stress values (≥ 500 MPa) is highly questionable.

Moreover the worldwide experience has confirmed that:

- for very high strength steels (grade ≥X100, with very high value of Charpy-V, shelf energy > 200 J) large-diameter pipes fracture propagation resistance can no longer be specified by relying on Charpy-V energy only;
- the Charpy-V fracture parameter exhibits some intrinsic limitations that preclude its use when high strength steels are considered.

There is a general consolidated conviction that it is due to both the geometry of the specimen (the small size of specimen ligament) and the intrinsic value of ductility of very high strength steel (as low work-hardening and low value of the strain at maximum load).

Moreover, also by adopting alternative/available fracture toughness parameters more physically related to the fracture process in pipe (such as the DWTT total energy, DWTT propagation energy, and CTOA angle), no unambiguous predictions of the fracture behaviour of high grade steel pipe can be found.

The aim of this project is to “give”, with reference to the ductile fracture propagation event, a fracture parameter(s) and laboratory methods to define the toughness of high grade steels (≥APIX80 grade) using small scale specimens. Moreover a result of this work will be also the assessment of existing alternative fracture mechanical parameters (and test methods) proposed in the last twenty years to evaluate the real toughness of high grade steel pipes.
## Project No: 148

**Title:**
Investigation of automated ultrasonic testing concept for longitudinally SAW pipe and coupling control

**EPRG Manager:**
Kersting

**Start date:**
May 2009

**Funding:**
€52k

**Contractor:**
GE Krautkramer

**Duration:**
12 months

**Status:**
In progress

**Summary:**
The project aims are:

- Examination of the influence of weld shape factors, material variations, UT machine effects etc. that can lead to Ultrasonic beam energy loss, coupling failures and over sensitivity when carrying out Automated Ultrasonic Testing of Submerged Arc Welded line pipe.

- Define principals of inspection procedure and probe configuration to achieve reliable detectability of typical weld seam defects in SAW pipe. Typical weld seam defects as undercut, gas defects, slag and lack of penetration have to be detected reliably.

- To cover the cross section of the weld, different angles and skip distances have to be used. It is necessary to define a common reference standard which is applicable and which can be economically machined.

The project will lead to a better understanding of the response of SAW welds on pipes to an Ultrasound beam and will lead to higher linepipe safety as defect detectability will be improved. In addition there is a potential to make cost savings. This cost reduction may result from reduced additional manual ultrasonic re-check and associated manning, or extra radiography of indications, all of which add to processing costs without an increase in defect detection.

## Project No: 152

**Title:**
The effect of toughness on the integrity of HFI seam welds

**EPRG Manager:**
Chris Thornton

**Start date:**
May 2009

**Funding:**
€20k

**Contractor:**
BMT Fleet Technology

**Duration:**
3 months

**Status:**
Report approved
Project to be closed

**Summary:**
EPRG member companies have reported problems with ERW and HFI welded pipe where the bond line toughness has shown low Charpy impact energies. In some cases the issue has been discovered when pipe removed from service (in some cases after many years service without problems) has been tested and found to have low toughness on the bond line. It is accepted that for Quality Control a Charpy impact requirement should be specified and achieved by the mill. However, where the problem is discovered during construction there may be severe delays and financial penalties if the pipe is rejected. For pipe that is in service replacement may be extremely difficult and expensive.

It may be possible to demonstrate that pipe showing low Charpy impact energy on the bond line is acceptable for specific applications on a fitness for purpose basis.

An initial desk study will be undertaken to determine current knowledge and define the work required to show if it is possible to use HFI pipe with a low bond line toughness safely for specific applications.
Project No: 153  
**Title:** Definition of ‘rich gas’ for ductile crack arrest predictions  

**EPRG Manager:** Bob Andrews  
**Start date:** October 2009  
**Funding:** €55k

**Contractor:** Atkins Boreas  
**Duration:** 6 months  
**Status:** In progress

**Summary:**
The EPRG recommendation for crack arrest toughness for high strength line pipe steels gives toughness recommendations (Charpy V-notch impact energy) to ensure the arrest of long running ductile fractures. The recommendations are limited to the transportation of natural gas; pipelines for rich gas are not included. The term ‘rich gas’ is not defined. Similarly, ISO 3183 and ANSI/API Spec 5L refer to the need to consider possible two-phase effects when specifying toughness levels, but give no specific guidance. The toughness requirements in DNV-OFS-F101 are only applicable to pipelines carrying essentially pure methane, but again the definition is unclear.

This project aims to define the term ‘rich gas’ for the range of realistic gas compositions, design pressures and temperatures for onshore and offshore pipelines, applicable to the design factors, pipe diameters and material grades addressed by the EPRG recommendations.

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Project No: 156  
**Title:** Guidelines for mechanised GMAW welding  

**EPRG Manager:** Chris Thornton  
**Start date:** May 2010  
**Funding:** €20k

**Contractor:**  
**Duration:** 5 months  
**Status:** Starting

**Summary:**
Industry standards for pipeline welding generally have their origins in cellulosic welding of onshore pipelines. Over the years they have been adapted to include new material grades, processes and more demanding applications. Even though mechanised gas metal arc welding (GMAW) is the dominant process for offshore pipelines, and is widely used for large-diameter long distance cross-country pipelines, the industry standards still do not fully reflect the subtleties of this process. This results in owner/operators having to issue amending company specifications.

Subsequent to the workshops held at the EPRG/PRCI/APIA Joint Technical Meeting in May 2009, an opportunity has been identified within EPRG to review the industry standards and a selection of company standards to produce some industry guidelines focussed on mechanised GMAW. The benefit of this project will be to identify best practice across the industry and to provide an input to the Working Group currently involved with the revision of ISO 13847. The output could form the basis for EPRG guidelines for the mechanised GMAW welding of pipelines.
### Project No: 157
**Title:** DWTT for small-diameter thick-walled pipe – seamless pipe

**EPRG Manager:** Tanja Schmidt  
**Start date:** September 2010  
**Funding:** €125k  
**Contractor:** SZMF  
**Duration:** 24 months  
**Status:** Approved – contract placed

**Summary:**
Battelle Drop Weight Tear (BDWT) testing is an important quality test to ensure the safety of pipelines transporting compressive media. Intensive research has shown that DWTT test results show good correlation with pipe behaviour in West Jefferson tests on welded pipe.

Customer demands for DWTT testing on seamless pipes with small diameters (DN<500mm) are increasing. Up to now there is insufficient experience in interpretation of test results, and the statistical database is very small. Furthermore, recently performed drop weight tear tests on seamless pipe show unusual fracture appearance, with huge plastic deformation under the notch in the upper shelf (ductile fracture) and ductile-to-brittle transition regime before crack initiation. The origin of this unusual fracture appearance, and the applicability of DWTT on quenched and tempered seamless pipe with small diameters are not clear; it is not known if the problem is a material issue or due to the test method.

The aim of the project is to determine whether DWTT results on quenched and tempered pipes correlate with West Jefferson test results. The usability of the standard test specifications will be rechecked and, based upon the obtained knowledge, adaptations and/or extensions to the testing specifications may be proposed.

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### Project No: 158
**Title:** DWTT for small-diameter thick-walled pipe – inverse Fracture

**EPRG Manager:** Simon Slater  
**Start date:** September 2010  
**Funding:** €119k  
**Contractor:** SZMF  
**Duration:** 24 months  
**Status:** Approved – contract to be placed

**Summary:**
Inverse fracture is being observed with increasing frequency on heavy-wall, ostensibly high toughness linepipe and plate. Inverse fracture is a phenomenon, apparent on high toughness material, where the impact side of the specimen undergoes a significant amount of strain hardening, leading to the occurrence of ‘false brittle fracture’ on the specimen assessment area. If it is not addressed there is a risk that ‘tough’ pipe will fail to meet BDWTT shear area requirements (typically 85% average).

There are no current guidelines in the relevant standards on how to deal with the phenomenon, and it is left to the manufacturer (plate or pipe) to deal with it internally. Many proposals have been put forward by individual suppliers, but none have been agreed upon or incorporated in the relevant standards.

This project will
- Define the conditions for the occurrence of inverse fracture
- Characterise BDWTT on a material exhibiting inverse fracture
- Investigate the use of instrumented BDWTT test data for the assessment of propagating fracture in linepipe
- Correlate the results with West Jefferson tests
- Propose a BDWTT assessment method that accounts for inverse fracture and can be submitted for inclusion in the relevant standards
1.2 Projects under development

<table>
<thead>
<tr>
<th>Project No:</th>
<th>155</th>
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<tbody>
<tr>
<td>Title:</td>
<td>Assessment of delayed failure under constant pressure</td>
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<table>
<thead>
<tr>
<th>EPRG Manager:</th>
<th>Paul Roovers</th>
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<tbody>
<tr>
<td>Start date:</td>
<td>Funding:</td>
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<td></td>
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<table>
<thead>
<tr>
<th>Contractor:</th>
<th>Battelle (Phase 1) and others</th>
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<tr>
<td>Duration:</td>
<td>Status: SOW being prepared</td>
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</table>

**Summary:**

Recent events in Belgium have shown that modern linepipe steel can sustain significant defects that can go undetected and as a result may give significant consequences because of stable crack growth. It is generally assumed that older linepipe steels are less defect tolerant, but even in low ductile materials some time delayed failures have been recorded.

Since a defect in highly strained material can extend at a constant load it is important for the operator to quantify the future behaviour of the defect on the basis of their knowledge of the steel, the pressure history since detection or presumed date of contact and the damage size. This would allow the operator to give guidelines concerning:

- Pressure reductions needed before inspection/ during inspection taking into account that the situation might deteriorate
- Intervention time to take mitigating measures

To establish guidelines with respect to time delayed failure, EPRG commissioned Atkins Boreas and the Battelle Memorial Institute to develop guidelines for the assessment of delayed failures under constant pressure (EPRG Project 137). During this investigation it was found that:

- the Ductile Flaw Growth Model (DFGM) gives good predictions of the burst pressure for low and high toughness steels
- the DFGM does not give good predictions of stable crack growth for high toughness steels

This brought the project to a turning point since good predictions of stable crack growth are essential for characterizing time dependent behaviour. Therefore Battelle revisited past test results with respect to crack growth and developed an alternative model which gives better predictions of stable crack growth (than the DFGM) for low and moderate toughness steels, and for higher toughness steels. However additional validation of the alternative model especially for high toughness steel is required.

The aim of the present project is to perform additional validation of the alternative model through materials testing. The results will be used to complete Project 137 with a parameter study using this alternative model. This work complements other projects in PRCI and EPRG as well as being of interest to APIA and therefore it is proposed that the first phase of the work will be co-funded by the three organisations, guaranteeing that materials tested are relevant to the three organisations.
### Project No: 159
#### Title:
CO₂ pipelines – fracture and corrosion – development of collaborative project proposal

<table>
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<th>EPRG Manager:</th>
<th>Start date:</th>
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<tbody>
<tr>
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</thead>
<tbody>
<tr>
<td>CSM</td>
<td></td>
<td>Proposal; SOW to be finalised</td>
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</tbody>
</table>

**Summary:**
EPRG have collaborated in the development and submission of two unsuccessful proposals to develop an understanding of the issues and obtain the information needed to support the construction and operation of pipelines transporting CO₂. A further attempt to secure European co-funding will be made, involving cooperation with a Joint Industry Project proposed by DNV. This small project aims to develop the rationale, framework and detailed submission of a project proposal to the appropriate European funding body.

### Project No: 160
#### Title:
CO₂ pipelines – fracture and corrosion – main project

<table>
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<tr>
<th>EPRG Manager:</th>
<th>Start date:</th>
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</thead>
<tbody>
<tr>
<td>Carlo Spinelli</td>
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<tr>
<td></td>
<td>~36 months</td>
<td>Proposal; Final agreement by EPRG and DNV expected in August 2010</td>
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**Summary:**
Preparatory research by EPRG and others has identified that two of the issues of uncertainty concerning the transportation of supercritical CO₂ in pipelines are the response of the pipeline materials (metallic and non-metallic) to the internal environment, and the safety of the surrounding region in the event of pipeline rupture. These two issues will be the subject of a proposed cooperation between EPRG and a Joint Industry Project to be undertaken by DNV. EPRG’s involvement will include support for programmes of corrosion tests and full-scale fracture tests.
<table>
<thead>
<tr>
<th>Project No:</th>
<th>Title:</th>
<th>EPRG Manager:</th>
<th>Start date:</th>
<th>Funding:</th>
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<tr>
<td>161</td>
<td>CO₂ pipelines – shock tube testing</td>
<td>Carlo Spinelli</td>
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<tr>
<td>Contractor:</td>
<td>Duration:</td>
<td>Status:</td>
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**Summary:**
Research by EPRG and others has identified that one of the issues of uncertainty concerning the transportation of supercritical CO₂ in pipelines is the safety of the surrounding region in the event of pipeline rupture. In this context, one of the identified uncertainties concerns the decompression wave speed in pipelines containing CO₂ mixtures with N₂, O₂, CO and N₂ impurities, typical of carbon capture streams from power stations and other industrial sites. Decompression wave speed is an essential element for achieving effective fracture control design, which is required for all pipelines transporting hazardous substances.

EPRG will join with PRCI and APIA in co-funding a collaborative project to be conducted at the TransCanada Gas Dynamic Test Facility in Alberta. The shock tube tests will generate gas decompression measurements that provide the essential information to allow CO₂ pipelines to be designed with appropriate material toughness to prevent long-running fractures.
## 2. Corrosion

### 2.1 Projects in progress

<table>
<thead>
<tr>
<th>Project No:</th>
<th>Title:</th>
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<tbody>
<tr>
<td>134</td>
<td>Development of tests for assessment of long term resistance to adhesion loss of 3-layer polyolefin external pipeline coatings</td>
</tr>
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<table>
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<tr>
<th>EPRG Manager:</th>
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<td>Schoeneich</td>
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<tbody>
<tr>
<td>SZMF</td>
<td>12 months</td>
<td>Work complete, Report approved</td>
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**Summary:**
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 90°C. An intermediate temperature of 60°C 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.

<table>
<thead>
<tr>
<th>Project No:</th>
<th>Title:</th>
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<tbody>
<tr>
<td>149</td>
<td>HIC assessment of low alloy steel line pipe for sour service application – Phase 2</td>
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<table>
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<tr>
<th>EPRG Manager:</th>
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<tr>
<td>John Martin</td>
<td>April 2009</td>
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<tbody>
<tr>
<td>IFP</td>
<td>12 months</td>
<td>Work complete, report prepared. Second year approved in principle</td>
</tr>
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</table>

**Summary:**
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 at 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.
Project No: 150  
Title: HIC assessment of low alloy steel line pipe for sour service application – Phase 3

EPRG Manager: John Martin  
Start date: April 2009  
Funding: €75k

Contractor: SZMF  
Duration: 12 months  
Status: In progress. Second year approved in principle

Summary:
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 at 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.

Project No: 151  
Title: Assessment of sensitivity to hostile environments of damaged pipe under cathodic protection and internal pressure

EPRG Manager: Paul Roovers  
Start date: April 2009  
Funding: €85k

Contractor: CSM  
Duration: 12 months  
Status: In progress. Second year planned

Summary:
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.
2.2 Projects under development

<table>
<thead>
<tr>
<th>Project No:</th>
<th>Title:</th>
<th>EPRG Manager:</th>
<th>Start date:</th>
<th>Funding:</th>
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<tr>
<td>154</td>
<td>Survey of sulphide stress corrosion cracking testing methodologies</td>
<td>Jackson</td>
<td></td>
<td>€20k</td>
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<tbody>
<tr>
<td>Corus</td>
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<td>SOW being finalised</td>
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Summary: Will follow
3. Design

3.1 Projects in progress

<table>
<thead>
<tr>
<th>Project No: 143</th>
<th>Title: Extension of fitness-for-purpose and puncture resistance criteria to X80</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPRG Manager: Robert Owen</td>
<td>Start date: July 2009</td>
</tr>
<tr>
<td>Contractor: CSM</td>
<td>Duration: 6 months</td>
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Summary:
There is a general trend to the greater use of higher strength steel linepipe for conveying large amounts of gas over long distances. Among higher strength steel grade pipes (X80-X100-X120), X80 has been used for a number of gas pipelines in the world (Canada, UK, USA, Germany) for many years. In spite of this, there is a need to extend current fitness for purpose methods for higher strength steel:

1) Defect assessment criteria as highlighted in a previous EPRG review ‘State of the art review of the existing fitness for purpose assessment methods for damaged pipes, Advantica report R3976, December 2000’;

2) Puncture resistance criteria (i.e. resistance to immediate failure as a consequence of an impact by a third party, e.g. excavating machinery) as implemented in the EPRG Methods for Assessing the Tolerance and Resistance of Pipelines to External Damage, 3R International, 10-11/1999.

In particular, there is a strong requirement to extend the criteria to X80 grade steel

Note this project excludes combined dent + gouge damage and girth weld defect acceptance criteria; these are considered in other projects.

<table>
<thead>
<tr>
<th>Project No: 144</th>
<th>Title: Revision of EPRG guidelines on weld defect acceptance criteria</th>
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</thead>
<tbody>
<tr>
<td>EPRG Manager: Mures Zarea</td>
<td>Start date: November 2008</td>
</tr>
<tr>
<td>Contractor: BMT Fleet Technology</td>
<td>Duration: 16 months</td>
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Summary:
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.
**Project No:** 145  
**Title:** Assessment of bending wrinkles

**EPRG Manager:** Brahim Ouissa  
**Start date:** August 2008  
**Funding:** €14k

**Contractor:** GDF SUEZ  
**Duration:** 6 months  
**Status:** Work complete  
Report approved. Follow-on work being planned

**Summary:**
Cold field bending of welded pipes can lead to severe wrinkles. Particularly, spirally welded pipes may need a specific approach (weld reinforcement), as there always exists an interaction with the weld. The acceptance of those wrinkles often depends on operator construction rules that differ from one to another. The background for these criteria may partially rely on experience, and partially on mechanical strength criteria. Therefore, a clear understanding of the existing criteria and of their background is necessary, so as to apply criteria that ensure safety, but are not too conservative.

The aim of the project is to identify the impact of field cold bending wrinkles on the integrity of welded pipes (longitudinally and spirally SAW ones), and to determine acceptance criteria that guarantee fitness for service, without excessive conservatism.

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**Project No:** 147a  
**Title:** Development of an improved model for the burst strength of dent-gouge damage under sustained internal pressure loading, Phase 2 - modelling

**EPRG Manager:** Richard Espiner  
**Start date:** April 2009  
**Funding:** €83k

**Contractor:** Andrew Francis and Associates  
**Duration:** 8 months  
**Status:** Contract placed – on Hold until test results available

**Summary:**
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.
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### 3.2 Projects under development

none
4. Collaborative projects with PRCI and APIA

4.1 Projects in progress

<table>
<thead>
<tr>
<th>Project No:</th>
<th>Title:</th>
<th>EPRG Manager:</th>
<th>Start date:</th>
<th>Funding:</th>
<th>Contractor:</th>
<th>Duration:</th>
<th>Status:</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPRG 137, 147a, 147b, 155</td>
<td>Virtual Joint Industry Project on mechanical damage assessment</td>
<td>Paul Roovers and Mures Zarea</td>
<td>May 2009</td>
<td></td>
<td>CSM, GDF SUEZ, AFAA, GL, Battelle, BMT Fleet Technology</td>
<td>Ongoing</td>
<td>In progress</td>
</tr>
</tbody>
</table>

Summary:
Mechanical damage due to impact by mechanical equipment or rocks is the most frequent cause of in-service damage and loss-of-gas incidents involving European gas pipelines. Extensive research regarding this topic has been undertaken during the last 50 years; nevertheless, there is still considerable scatter in the predictive models, particularly for dents with secondary features such as gouges and cracks, and large factors of safety have to be applied (eg see PDAM).

Recently-initiated work by EPRG and PRCI aims to develop and validate improved models for determining the burst pressure and delayed failure life of damaged pipes; this work will need to continue for several years, and the ‘Virtual JIP’ provides an agreed framework for the exchange of all the results from these projects as they emerge. The eventual outcome from this collaborative programme will be:

- Development of improved models for determining the burst strength and delayed failure life of damaged pipes
- Validation of the models using full-scale tests on pressurised pipes containing a representative range of mechanical damage
- Development of improved methods and industry guidance for the assessment of damage discovered during service:
  - Initial screening (Level 1)
  - Assessment using measured damage characteristics (Level 2)
  - Engineering critical analysis (Level 3)
### 4.2 Projects under development

<table>
<thead>
<tr>
<th>Project No: (Link to Project 156 above)</th>
<th>Title:</th>
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<tbody>
<tr>
<td></td>
<td>Requirements for the application of mechanised GMAW to pipeline girth welds</td>
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</tbody>
</table>

**EPRG Manager:** Roger Howard and Chris Thornton  
**Start date:**  
**Funding:**  
**Contractor:**  
**Duration:**  
**Status:** SOW to be prepared  
**Summary:**  
The absence of a specialised Standard for procedure qualification and production welding for automated/mechanised GMAW and AUT has been identified several times in recent years.  
The welding technology is established but a specialist standard is missing. Some standards and company specs are established, e.g. Z662. But existing standards attempt to cover all welding methods.  
**Deliverables and tasks required to address the need/gap:**  
Production of an industry guideline taking into consideration:  
- existing company national and international standards  
- input from relevant welding and NDT contractors, pipeline contractors and pipeline owners  
- defect acceptance criteria  
**Areas for inclusion in the guideline include:**  
- all weld metal qualification  
- workmanship standards for AUT, ECA, personnel competency and operator qualification etc  
**Development of an ISO standard based on the guideline**

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<thead>
<tr>
<th>Project No:</th>
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<tr>
<td></td>
<td>Welding of X80 pipelines</td>
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</tbody>
</table>

**EPRG Manager:** Roger Howard  
**Start date:**  
**Funding:**  
**Contractor:**  
**Duration:**  
**Status:** SOW to be prepared  
**Summary:**  
In conventional design pipelines the technology is already mainly developed, however there can be issues in achieving matching strength. The barrier to overcome is the perceived higher technical risk of welding X80 pipe (at decision maker level including construction contractors). The Workshop Team agreed that this perception is misplaced. The application to strain based design requires development.  
**Deliverables and tasks required to address the need/gap:**  
- A formal technical and economic risk assessment report aimed at decision makers.  
- Guidelines for the welding of X80 pipe  
- different design conditions, e.g. strain based design  
- different welding processes
### Girth weld defect acceptance criteria

**Project No:** (Link to Project 144 above)  
**Title:** Girth weld defect acceptance criteria

<table>
<thead>
<tr>
<th>EPRG Manager:</th>
<th>Start date:</th>
<th>Funding:</th>
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<tbody>
<tr>
<td>Roger Howard</td>
<td></td>
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<td></td>
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<td>SOW to be prepared</td>
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</table>

**Summary:**
Current status of technology:
- Various assessment methods available
- Excessive conservatism with different test methods
- Treatment of residual stresses – probably conservative (especially for plastic collapse)
- No agreed method for assessing overmatching

**Deliverables and tasks required to address the need/gap:**
- Rationalisation of the assessment methods
- Development of agreed method for defining and measurement of matching / overmatching
- Treatment of residual stresses.
- For brittle fracture
- For plastic collapse

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### Delayed failure of mechanical damage

**Project No:** EPRG 155  
**Title:** Delayed failure of mechanical damage

<table>
<thead>
<tr>
<th>EPRG Manager:</th>
<th>Start date:</th>
<th>Funding:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paul Roovers</td>
<td></td>
<td>€80k (EPRG contribution). Equal contributions by PRCI, APIA</td>
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</table>

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<thead>
<tr>
<th>Contractor:</th>
<th>Duration:</th>
<th>Status:</th>
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<tbody>
<tr>
<td>Battelle (Phase 1) and others</td>
<td></td>
<td>SOW being prepared</td>
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</table>

**Summary:**
A tri-partite approach to small, medium scale and full scale characterisation of the delayed failure behaviour of modern steels higher strength steels.  
PRCI, EPRG and APIA will perform tests each on one pipe type & material on these three scales to gather data on:
- Isochronous stress-strain behaviour
- Medium scale delayed failure behaviour
- Full scale delayed failure behaviour

Defects for the last two cases will be introduced in the least disturbing way, i.e. via spark-erosion  
Results will be shared and interpreted along the lines defined in EPRG project 137/155 “Assessment of delayed Failure under constant pressure”
<table>
<thead>
<tr>
<th>Project No:</th>
<th>Title:</th>
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<tbody>
<tr>
<td>161</td>
<td>CO₂ pipelines – shock tube testing</td>
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</tbody>
</table>

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<thead>
<tr>
<th>EPRG Manager:</th>
<th>Start date:</th>
<th>Funding:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carlo Spinelli</td>
<td></td>
<td>€50k</td>
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<tr>
<td></td>
<td></td>
<td>Funding agreed, contract to be placed with PRCI</td>
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</table>

**Summary:**
Research by EPRG and others has identified that one of the issues of uncertainty concerning the transportation of supercritical CO₂ in pipelines is the safety of the surrounding region in the event of pipeline rupture. In this context, one of the identified uncertainties concerns the decompression wave speed in pipelines containing CO₂ mixtures with N₂, O₂, CO and N₂ impurities, typical of carbon capture streams from power stations and other industrial sites. Decompression wave speed is an essential element for achieving effective fracture control design, which is required for all pipelines transporting hazardous substances.

EPRG will join with PRCI and APIA in co-funding a collaborative project to be conducted at the TransCanada Gas Dynamic Test Facility in Alberta. The shock tube tests will generate gas decompression measurements that provide the essential information to allow CO₂ pipelines to be designed with appropriate material toughness to prevent long-running fractures.