

**Australian Pipeline Research Program
Keynote Address
Keeping the Australian Pipeline Standards Up to Date**

**PRCI-EPRG-APIA
15th Joint Technical Meeting On Pipeline Research
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by

Max Kimber* M.J. Kimber Consultants Pty. Ltd., Chairman APIA Research and Standards Committee, PO Box 5121, Garran, ACT 2605, Australia

Philip Venton Venton & Associates Pty Ltd., Chairman Standards Australia Committee ME38 Pipelines Gas & Liquid Petroleum, PO Box 472, Bundanoon, NSW 2578, Australia

* Presenter

Abstract

The Australian co-operative pipeline research program has been administered through the Australian Pipeline Industry Association since 1996. During that time the research program has been directed to the improvement of safety and reliability of pipelines and the reduction in design, construction and operating costs. So that the Australian pipeline industry and the community can reap the benefits of the results of research, it is important that the Australian Standards reflect the best and latest results of scientific and engineering research. These Australian Standards determine, by statute, the way in which pipelines are designed, built and operated.

This paper will review the results of the Australian pipeline research program, demonstrate the ways in which those results have been translated into the Australian Standards and estimate the benefits gained by the industry and the community.

Purpose

This paper will serve three purposes:

- the first will be to report on the on-going relationship between the PRCI, the EPRG and APIA;
- secondly, we will provide a summary of the results of APIA's Australian Pipeline Research Program since the last Joint Technical Meeting; and finally
- we will address the close links between our research program and the Australian Standard for pipeline design, construction, operation and abandonment.

History

It's always important to provide the historical context in which certain events occur or processes develop. We have written before on the subject of the links between PRCI, EPRG and the Australian pipeline industry, but it is worthwhile to recap.

Two companies from the Australian pipeline industry joined the PRC (as it was then) in 1983 following strong representations to management by one of the authors (Kimber), support from the PRC Executive Committee for international membership, and a recent failure of a major pipeline due to stress corrosion cracking. Perhaps the SCC failure was the major influence, just as the problems of propagating brittle fracture was the impetus for the US pipeline industry in 1952, and propagating ductile fracture captured the attention of the Europeans in 1972 for each begin their co-operative research programs [1]. The dual problems of stress corrosion cracking and fracture control are still with us, so one might wonder whether the millions of dollars and euros we have spent collectively on research into these aspects have been well spent.

Our answer to that assertion, is "yes"; while the problems are still with us, we now know a lot more about their management and control. What's more, we know a lot more than we did, and we know there is more to be known, so we must continue on new and better lines of enquiry.

In the words of a US political figure: *"there are known knowns; there are things we know we know. We also know there are known unknowns; that is to say we know there are some things we do not know."*

So we have made a lot of progress on *knowledge* of the problems that beset pipelines and we have made lots of progress on hundreds of other aspects that help us design, construct and operate our pipelines in ways that make them safer, cheaper and more reliable. But there is more to know, and that's what our combined research programs are about.

Since the early 1980s, the Australian pipeline industry has had a small but targeted research program managed by volunteers from a number of pipeline companies. In 1996 we formalised our approach through the APIA Research and Standards Committee (in a similar arrangement to that which existed for many years between the American Gas Association and PRC). Through our international connections, we tried to ensure that we did not carry out research on subjects already addressed by PRCI or EPRG and available in the public domain, but by 2000 it became obvious that we needed to establish more formal links with EPRG and PRCI. This was accomplished at the New Orleans JTM with the co-operation and dedication of Dr Gerhard Knauf and Mr George Tenley. At the New Orleans JTM, one of the authors (Kimber) presented a paper [2] that catalogued the APIA RSC's research work from 1996 to 2001.

Just because we – PRCI, EPRG and APIA – each have a robust research program, we, and our respective industries cannot afford to be complacent about the subjects of our research. We must not do research for research's sake nor should we be doing "catch-up" research where the public or the government has forced us to defend our designs or operations. We must be pro-active and anticipate safety, economic and reliability issues so that we can solve them on our own terms.

The Australian pipeline industry has endeavoured to do this since the first liquid petroleum pipeline was built in 1964 and the first high pressure gas pipeline was built in 1969. In general we consider that we have been successful in staying ahead of public and government fiats, which, in other countries, have cost the industry dearly.

The vehicles for this pro-active approach are the APIA RSC Australian Pipeline Research Program and the Australian Standard for petroleum pipelines – AS2885 *Pipelines – Gas and Liquid Petroleum*. The Standard is driven by research – both Australian and international [3] – and the research is driven by the needs of the community and the pipeline industry.

APIA Research Program – 2003 to 2005

Sulphur Deposition

The APIA RSC research program on sulphur deposition in pipelines was reported on at the 14th Joint Technical Meeting in Berlin [4]. Since that time further work has been done and a report completed. APIA has recently funded additional work to develop a Technical Note on the application of the research work to pipeline regulator and meter station design to assist designers and operators to reduce the risk of sulphur deposition.

In his report [5] to the APIA RSC, the researcher summarised his findings as follows:

The research work has taken a holistic approach to the 'elemental sulphur' problem. It is not only the transmission pipeline operators that are affected. Production, transportation and distribution operations together with industrial usage facilities of natural gas can all be impacted by this problem.

The prime aim of this research project has been to elucidate the mechanisms associated with the 'elemental sulphur' formation and deposition processes. Through a better understanding of the kinetics involved it is believed greater confidence will be gained to more effectively and efficiently design and operate a transmission pipeline system, and associated infrastructure, through minimization of the 'sulphur deposition' process.

The 'elemental sulphur' deposition problem is a fairly recent phenomenon for gas transmission pipelines. Although known for a number of decades to cause plugging in reservoir wellhead facilities, it is since about 1990 that 'elemental sulphur' deposition has openly been acknowledged as a problem in natural gas pipelines and other facilities downstream of gas processing plants. Within the past ten years this formation/deposition process has progressively been more widely observed – See Figure 1. The increasing trend to have transmission pipeline systems operating at higher pressures is a significant factor in this increase.

The 'elemental sulphur' formation and deposition process (desublimation) occurs within a very dynamic environment. Natural gas flow within a high-pressure transmission pipeline system is accompanied by a variety of physical-chemical processes. For example, there will be multiple pressure, temperature and density conditions. The velocity of the gas will vary, as will the composition. The pipeline may, at times, be subject to small quantities of liquids, with the possibility of traces of chemically reactive fluids and/or components being present.

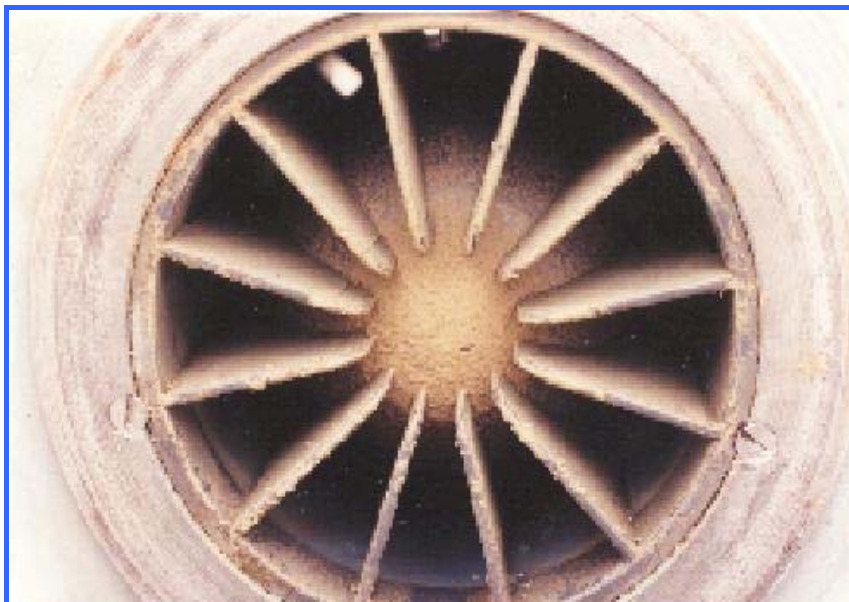


Figure 1 150mm Turbine Meter with 'Elemental Sulphur' Deposition

The current research project commenced as an investigation into the formation of elemental sulphur – being believed to be the sole cause of the observed depositions within natural gas transmission pipelines. Prior investigations by other researchers, together with the chemical analysis results from investigations on individual natural gas transmission pipelines, all pointed to sulphur being the root cause of the deposition processes. Results from this research show that

although the formation of elemental sulphur is a key factor in the pipeline deposition processes, it is just part of a significant number of very complex operations that are conducted within the transmission pipeline environment, together with operations in upstream facilities.

At the desublimation conditions for sulphur vapour, there is a high probability that some simultaneous retrograde condensation of the heavier hydrocarbon components within the gas stream may also take place. This is further complicated by the fact that there will be small but variable concentrations of contaminant particle matter in the gas. Add to this the fact that, in all probability, the desublimation process is not continuous and that the flow regime is most likely subjected to flow profile distortions prior to the pressure reduction facility (point of desublimation), with the sulphur vapour of unknown concentration, provides a very challenging subject to research.

Effect of Composition and Cooling Rate on Maximum HAZ Hardness for In-Service Welding of Pipelines

The project on the effect of composition and cooling rate on maximum HAZ hardness for in-service welding of pipelines is a joint project between APIA RSC and PRCI and is being carried out by researchers at the University of Wollongong and the Edison Welding Institute (EWI).

Most previous research work relating to the avoidance of hydrogen cracking for in-service welding has focussed on prediction of weld cooling rates. This effort has been fruitful providing important information on thermal effects, but other important factors have not been explored. Two of these factors are the effects of weld metal diffusible hydrogen levels and the effect of material composition.

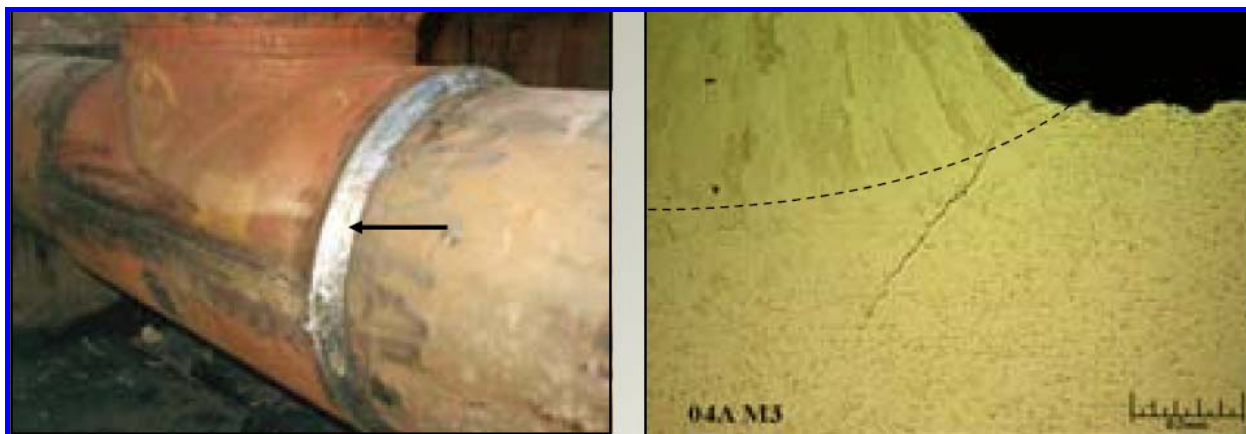


Figure 2 Example of in-service welding crack

Source: Presentation by David Nolan to APIA Forum 11 on 6 December 2004

The work investigated the most appropriate methods for rapid compositional analysis and has reported trials on suitable field testing systems. The work has also developed an improved understanding of applicability of current carbon equivalent formulae for weldability evaluation of typical line pipe and fitting materials, and has identified carbon equivalent limits that could be provided to manufacturers for different types of fittings.

The University of Wollongong has conducted a program of dilatometric investigations to characterize the behaviour of weld and base metals subjected to the typically high cooling rates experienced during in-service welding. Other important factors considered include the effects of austenite grain size (lower than conventional/out-of-service welding) and multipass welding effects.

A recent paper by the researchers has described an improved approach to HAZ hardness prediction [6]. EWI has been granted an extension of funding by PRCI in order to conduct a series of simulated in-service welding cracking tests on pipe steel materials under various conditions of hydrogen content. The University of Wollongong is currently conducting parallel dilatometer studies on the same material to correlate microstructures and hardness levels, and further develop a small scale, low strain rate fracture resistance test in which specific HAZ microstructures can be evaluated in terms of mode and level of fracture resistance.

The results will be cross-referenced with the results from EWI's simulated in-service welding crack tests. This work represents a novel approach to the investigation of HAZ fracture resistance for in-service welding applications and offers a unique opportunity to pursue validation through correlation with the work being conducted at EWI.

This project will be reported on in more detail at the 15th Joint Technical Meeting Orlando USA 16-18 May 2005 [7]

Adhesion of Field Joint Coatings to Extruded Polyethylene

Many Australian pipelines coated with extruded polyethylene have suffered coating disbonding and corrosion at the joints as a result of poor adhesion between the field joint coating material and the parent coating. Polyethylene is produced in a vast range of grades, all of which consist primarily of CH_2 units joined in linear chains. At room temperature it is semicrystalline with most of the linear runs of CH_2 units to be found as lamellar crystallites which can only interact with other materials by Van der Waals bonds; there is no possibility of forming hydrogen bonding or acid-base interactions.

There are no strong solvents for polyethylene, no solvents that can melt the crystallites and hence dissolve the material at room temperature. It follows also that the surface energy is low and, without chemical modification of the surface, there is no chance of obtaining the strength of interaction with a second material that is required to give good adhesion. Hence the normal techniques for joining polyethylene involve either welding or some form of surface treatment that makes the surface energy higher and/or make the surface reactive. The APIA RSC funded a research project that aimed to investigate the feasibility of activating the surface of the parent coating on the pipe adjacent to the field joint to effect a stronger bond to the field applied joint coating, which usually takes the form of a shrink sleeve.

The research yielded useful results that determined that a grafting process could be used which involved the irradiation of the parent coating with high intensity ultra-violet radiation and the application of an activation chemical. This allowed good adhesion to be achieved between the parent coating and an epoxy resin coated shrink sleeve.

A patent has been applied for and there may be opportunities to commercialise the process. However, there is much more work to be done to develop the laboratory process to a commercial standard, applicable to coating mill and field conditions.

Pipeline Hydrostatic Strength Test Behaviour

The aim of this project is to provide the ability to predict the behaviour of a pipeline section during hydrostatic pressure strength testing, and to predict the hoop strains (elastic and plastic) in each pipe making up the section. The need for the research has arisen because of the desire to increase the design factor for determining MAOP from 72% to perhaps 80% SMYS without at the same time reducing the hydrostatic test factor of 1.25, while retaining a tolerable variation in elevation change along the hydrostatic test section. An increase in the hydrostatic test pressure without more effective control of the hoop strains experienced by the pipes making up the test section leads, especially in the case of stronger pipe, to a greater risk that the reserve ability of the pipe to undergo deformations in service may be prejudiced.

This work has recently been reported [8] at a WTIA/APIA conference in Wollongong, Australia.

This project has been completed and the prediction software that was contemplated has been tested under field conditions. The software, named PipeStrain©, enables the accurate prediction of the gross volume/strain and individual pipe hoop strain behaviour of hydrostatic test sections including elevation effects on the actual pressure applied to each pipe.

The software allows designers and constructors to optimise the design of hydrostatic test sections in advance with respect to length, number of sections on any pipeline, elevation difference and elevation profile. The software has already demonstrated savings in hydrostatic test section design. The software also has the important ability to manage and mitigate the risk of excessive hoop strains in individual pipes in the test section.

Perhaps one of the most important outcomes from the research project has been to recommend a change to the hydrostatic test end point for non-expanded pipe from 0.4% to 0.2%.

Further, the application of the software will minimise the risk that the end point will be reached before the pressure at the highest point in the section reaches 1.25 times the MAOP. If 1.25 times MAOP is not reached, then the maximum operating pressure of the pipeline will have to be set below the design MAOP, resulting in a significant economic loss.

The Australian pipeline industry is planning to increase the maximum design factor for pipelines to increase from 72% to 80% and the results of this research work and the application of PipeStrain© will fulfil one of the necessary (but not by itself sufficient) conditions to allow this increase in design factor.

The hydrostatic test research program has also led to a greater understanding of the effect of ageing in coating on yield strength, yield/tensile ratio, and hence on the pressure limit state. Although strain ageing is well known and understood, it was previously a concern principally because of its effect on transition temperature. This research has highlighted and shown the need for further work on the effect of Y/T and

the processes that affect it in other failure modes such as those associated with metal loss and other defects, and in the ductile fracture process.



Figure 3 Full scale burst test

Notes to Figure 3: 2% strain to failure; in-situ Y/T = 0.98; pipe mill Y/T = 0.86

The APIA RSC is building on this work in its current project on strain ageing and other influences on Y/T.

The very large body of work undertaken by others on Y/T has concentrated on the measurement of Y/T in the pipe mill. This has resulted in the establishment of acceptable values of Y/T based upon demonstrated relationships between Y/T and strain to failure in burst tests.

While the limited work we performed in the hydrostatic test project tended to support that relationship, it did show that the Y/T of the pipeline in the ground after coating and ageing was possibly substantially higher than had been hitherto expected. We have concluded that it is very likely that the strain to failure will be a lot less than one might have expected, based on pipe mill tests of Y/T.

It could be asserted that that lower strain to failure is inconsequential for pipe without defects and subject only to pressure loads. However, it is most important for displacement controlled loading – for example, in land slip and mine subsidence circumstances – and for pipe with incipient defects.

We have found that using the mill test Y/T values in analytical methods, or those Y/T values that do not take into account the influence of strain ageing can seriously overestimate the strain to failure and this places a pipeline at needless risk.

This project will be reported on in more detail at the PRCI-EPRG-APIA 15th Joint Technical Meeting On Pipeline Research Orlando, Florida, USA 16-18 May 2005 [9]

Disposal Procedures for Hydrostatic Test Water

The aims of the project on disposal procedures for hydrostatic test water were to investigate the technical and environmental aspects of supply, discharge and disposal of water used for hydrostatic testing of pipelines, to establish and document the constraints on the process and their management. The study also monitored the effect and dynamics of water quality from different sources on the pipeline, including the determination of contaminants generated in the process and the impact of their disposal in the

environment. The project compared practices used worldwide for benchmarking purposes and developed procedures for test water disposal to minimise the risk of adverse impacts to the environment

While the integrity of practically every transmission pipeline in the world is proved prior to commissioning by hydrostatic test, there remains general lack of understanding among technical and environmental regulators in particular, and in the environmental community at large, of the issues related to supply and discharge of water used to hydrostatically test a pipeline. This lack of understanding is manifested by delays to project (and construction) approvals, complex disposal requirements, and ultimately increased pipeline cost.

APIA RSC embarked on a research project to prepare a technical report that will provide a researched and documented basis for management of hydrostatic test water to fill the information gap between the pipeline industry and the community.

The project studied 8 hydrostatic tests and assessed the quality of the source water and compared it with the water that was to be discharged after the test.

Contaminants such as the following were assessed:

Direct Stressors for plants and organisms	Indirect Stressors for plants and organisms	Nutrients
Metals	pH	Nitrogen
Non-metallic inorganics	Particulate matter	Phosphorus
Organic compounds	Dissolved oxygen	
Pesticides, biocides	Salinity	
Aromatic carbons	Temperature	
Nitrobenzenes	Organic matter	

It was no surprise to find that:

- The quality of the water to be disposed of was directly related to the quality of the water source
- The primary metallic contaminant was iron
- Turbidity of the water to be disposed of depended on the cleanliness of the pipeline and the water source
- The presence of nutrients was dependent on the water source
- The presence of oxygen scavengers was dependent upon the period of time the water remained in the pipeline and the degree of aeration on disposal
- Biocides added to the water to prevent algal growth in the pipeline represent a problem on disposal

The research project will also develop a Code of Practice for supply, discharge and disposal of hydrostatic test water. This will be incorporated into the APIA Code of Environmental Practice. The research will provide benefits to the Australian pipeline industry by:

- Reduced environmental approval costs at project development and construction phases.
- Reduced delay in gaining approval for supply and discharge of hydrostatic test water which impacts on the schedule of a new project.
- Increased awareness of environmental regulators and community members by demystifying the process.

Effect of Transient Loss of CP

This project – the effect of transient loss of cathodic protection – was undertaken for two primary purposes:

- the transient loss of cathodic protection potential is common where pipelines are installed in the vicinity of direct current traction systems or are under the influence of telluric effects¹; and

¹ Telluric Effects: the induction of currents in linear metallic structures caused by changes to the earth's magnetic field, often as a result of sun spot activity and/or solar flares

- there was some concern expressed by a number of cathodic protection practitioners that the Australia Standard needed some modifications to address the effects of long and short transients

In some situations, cathodically protected pipelines may be subject to short term loss of cathodic protection due to stray direct current or telluric influences. The duration of the loss may range from less than one minute to several hours, and the transients may be of sufficient intensity to change the pipeline potential by many hundreds of millivolts.

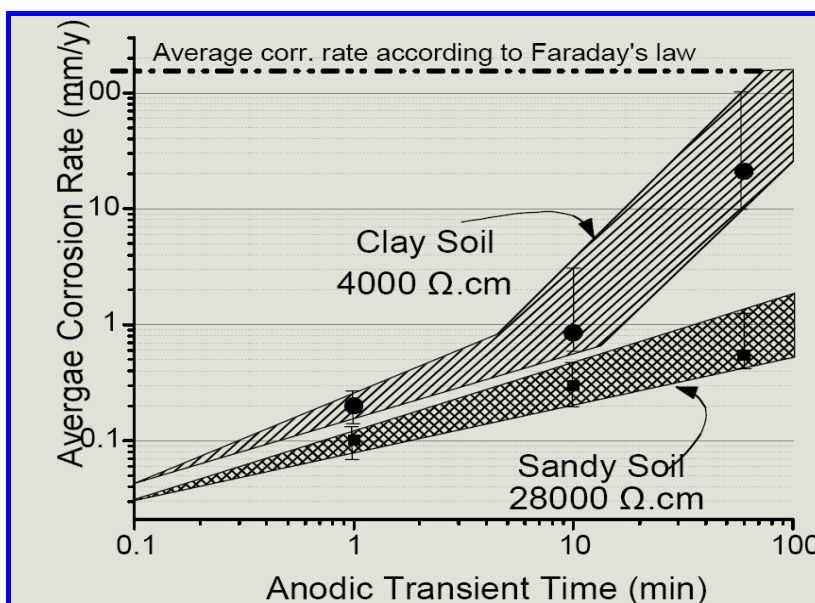


Figure 4 Corrosion rates under transient conditions compared with Faraday's Law
Source: Presentation to Research and Standards Committee Forum 11 on 6 Dec. 2004

The research work found

- For a given amount of total anodic exposure, the longer the duration of each transient the greater the likelihood of corrosion
- For a given amount of total anodic exposure, higher resistivity soils lead to less corrosion
- The greater the magnitude of the anodic transient the greater the likelihood of corrosion

Furthermore the research work

- Developed a simpler, more cost effective probe to monitor corrosion both in the laboratory and potentially the field
- Established the potential for a new electrochemical monitoring procedure based on the analysis of galvanostatically induced voltage transients
- Concluded that the current standards may be restrictive in the case of very short transients and possibly too lenient in the case of long ones.

This project will be reported on in more detail at the PRCI-EPRG-APIA 15th Joint Technical Meeting On Pipeline Research, Orlando, Florida, USA 16-18 May 2005 [10]

Field applied coatings to cold, damp valves/pipework

The aim of the project – Field applied coatings to cold, damp valves/pipework – was to identify various proprietary coating-repair products purportedly capable of being applied to a wet steel-substrate and able to adequately cure in minimal “open-trench time” at various temperatures down to just above the water freezing-point. The outcome of the research should be the selection of an appropriate coating repair material that can be used on high pressure gas transmission lines carrying cold contents at high velocity, (eg downstream of pressure-reduction regulators), and in cold and high-humidity environments where condensation is usually unavoidable and it is impractical to dry and warm the pipe surface for the application and adequate cure of ordinary coating products.

The project has carried out tests on proprietary epoxy products available from local sources. These were all of an amine-cured epoxy-based chemistry. None of the other coating-chemistries, such as dual-pack, single-pack or moisture-cured polyurethane varieties, styrenated polyesters, polysiloxanes, or vinyl-esters was regarded as suitable for difficult environmental conditions.

The research program found that only one product meets the criteria set by the industry advisers for the project, has the required adhesion and hardness (when cured) and acceptable cathodic disbonding performance. It demonstrated exceptional curing-rate suitability as well as a final extent of cure, consistent with a minimal open-trench time even at 3°C. This performance was developed in conjunction with excellent adhesion characteristics to both wet and dry substrates as determined by both its cathodic disbonding resistance, and the “knife-adhesion” test following 30 days immersion at 98-100°C.

Further field trials are in progress and will be reported in due course.

Fracture Propagation Control

A particular feature of the designs in current use in Australia is the combined use of medium diameter 356 mm [14"] to 457 mm [18"] pipelines carrying rich gas at high design pressures (in 1980 the typical design pressure was 10.2 MPa [1480 psi] and since 1990 the typical design pressure is 15.3 MPa [2220 psi]). There are also proposals to operate pipelines at even higher pressures. These diameter/pressure/gas combinations are not included in any of the comparatively large data base of full scale burst tests that have been carried out to derive the empirical relationships between fracture arrest and toughness.

The APIA RSC is not of the view that current designs can be validated by a reasonable degree of extrapolation of historical results. Apart from some special tests carried out on large diameter very high strength pipelines recently, the maximum pressure that has been assessed in full scale fracture tests is 12 MPa [1740 psi] compared with our common use of 15.3 MPa [2220 psi]. In expectation that even higher pressures will soon be used up to 22 MPa [3190 psi], the APIA RSC and overseas pipeline research groups have carried some recent work that has raised further questions about the current methods of predicting the decompression behaviour of rich gas at high pressures.

The RSC is concerned that the fracture control plans of a number of recently constructed pipelines (as required by the Australian Standard AS2885) are not necessarily able to be substantiated from the world-wide data base of full scale burst tests.

The new Australian pipeline design standard, AS2885.1, issued as a Draft for Public Comment in December 2004, allows the use of an 80% design factor. A number of pipeline owners have well advanced plans to use this provision to increase the design factor for new pipelines and/or to up-rate existing pipelines to take advantage of the economic benefits of the higher design factor.

These two factors would seem to support the need for full scale pipeline burst tests to be carried out on pipe operating under the following parameters:

Linepipe grade	API 5L X80
Manufacturing method	High frequency ERW
Specified minimum yield strength (SMYS)	552MPa
Pipe diameter	18" (457mm)
Pipe wall thickness	Test 1: 7.92mm (ANSI Class 900) Test 2: 11.28mm (ANSI Class 1500)
Pipe sections length (nominal)	10 - 12m
External coating	The pipe shall be provided bare of coating but shall have been submitted to a heating cycle consistent with the application of a fusion bonded epoxy coating.

High Y/T ratio and low strain to failure effects in coated high strength pipe

The capacity of a pipeline to withstand damage, such as that due to external interference or ground movement, depends upon the ability of the steel to accommodate strain without failure. The lack of understanding of the strain to failure behaviour of high strength line-pipe steels means that the current methods of designing, specifying and assuring sufficient levels of ductility need addressing in the context of increasing the pipeline design factor from 72% SMYS to 80% SMYS.

The project seeks to address this problem by examining the required minimum levels of strain to failure at both local defects and in general yielding, and the measuring and testing of relevant parameters such as yield strength to tensile strength ratio (Y/T) and uniform strain. The effect of strain ageing on pipe coating, circumferential property variations and dimensional tolerances will also be examined.

Progress extends to completion of a literature review, pipe property survey (4800 pipes) and successful predictive analysis of a previous unexpectedly low strain burst test. Current activity is sampling and characterisation of pipes for a four test burst test program to validate the predictive analysis and organisation of test piece welding and instrumentation.

Test methods and analytical models have been developed to examine and understand the effect of thickness and property variations that occur around the pipe circumference to the overall burst strength and strain to failure. A series of burst tests will be completed over the next few months on pipe with carefully selected properties and known distributions of properties around the circumference.

The project will also provide guidance on methods of measuring and limiting Y/T for pipe specification purposes.

This project was extended to include a finite element investigation on the behaviour of ERW welds manufactured with the maximum internal and external trim removal, when subject to hydrostatic test at 100-110% of SMYS, to address a concern identified as part of the development of the Standard to adopt a design factor of 0.80.

This will be reported on in detail at PRCI-EPRG-APIA 15th Joint Technical Meeting On Pipeline Research Orlando, Florida, USA 16-18 May 2005 [11]

Pipeline Resistance to External Interference Phase III

This project continues research into the puncture resistance of pipelines, focusing particularly on the resistance to damage from excavator machinery. This project was initiated in response to the release of AS2885 (1997), in which pipeline designers are allowed to use penetration resistance as one physical measure against puncture. While the Standard allows use of penetration resistance, it gives no guidance on how to quantify this resistance and incorporate it into design.

Phase I of this project consisted of a comprehensive review of the worldwide literature on the topic, and also collated a database of damage sources and pipeline characteristics applicable in Australia. Phase II extended this research through numerical analysis of the external interference by excavators.

In the recently completed phase of work, there are several areas of research that complement and develop the research undertaken to date:

- Verification of the numerical results on puncture resistance through experimental test work. This specifically analyses the relationship between commercially available excavator tooth dimensions and the puncture force, focusing particularly on small, sharp teeth profiles and thin-walled high strength pipe, compares the measured puncture force with that predicted by numerical analysis.
- Development of an excavator loading model that makes use of manufacturer data to calculate the possible magnitude of the load applied by excavators.
- A survey on equipment types that are used in Australia, aimed at developing guidance on the most common machine size and tooth dimensions.

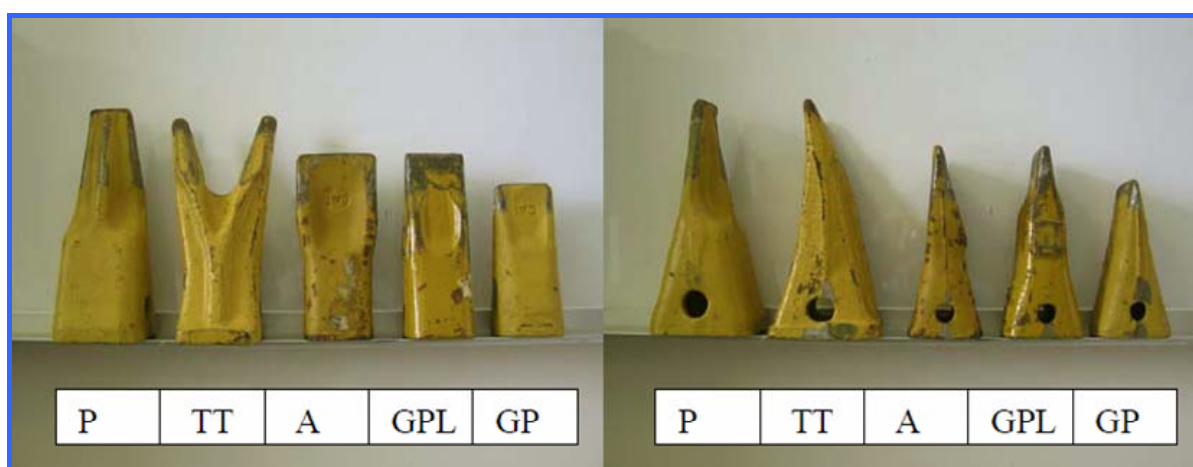


Figure 5 Excavator teeth used for research project

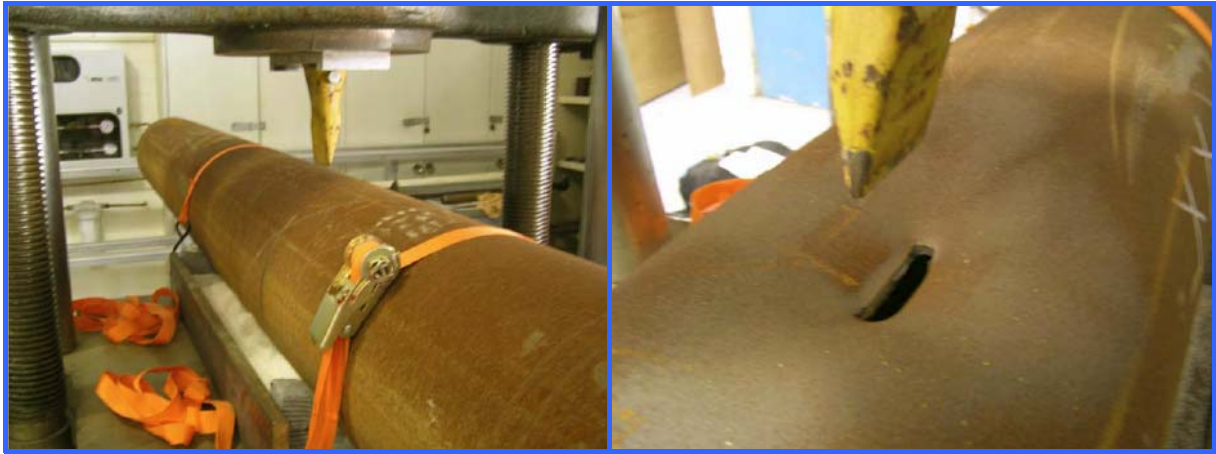


Figure 6 Experimental set-up and puncture due to abrasion tooth

Source of photographs: Report to RSC Pipeline Resistance to External Interference Phase III – Final Report

The principal objective of this phase of work is to provide a design method combining both the loading and resistance parameters. In particular, to develop an understanding of the level of protection that is provided by a given pipe thickness and grade using probabilistic methods that can be used within risk assessment procedures.

This project will be reported on in more detail at the PRCI-EPRG-APIA 15th Joint Technical Meeting On Pipeline Research Orlando, Florida, USA 16-18 May 2005 [12]

Statistical Analysis of Pipeline Incident Database

The Pipeline Operators' Group/APIA pipeline incident database was developed and implemented around 1970 and now covers some 27,000 km of pipeline. The database appears to be incomplete for some years but contains about 120 incidents which the RSC considers to be sufficient for useful conclusions to be drawn. However, only data since 1985 has been used to determine average incident rates because it is more representative of current practice.

Incidents reported comprise coating damage, steel damage, leaks & ruptures. Causes of incidents include external interference, corrosion, ground movement, construction defects, material defects and lightning.

In summary:

- External interference is by far the most common cause of pipeline damage and accounts for 76% of all incidents. Corrosion is the next most common cause and remaining causes have resulted in very few incidents.
- There have been no deaths or injuries.
- There have been only 6 ruptures and about 20 leaks. Pipe deformation (scratches, gouges and dents) accounts for two thirds of incidents.
- The overall average incident rate is 0.13 per 1000 km-yr
- The average incident rate for loss of containment is 0.015 per 1000 km-yr
- The average incident rate for loss of containment is an order of magnitude lower than the loss of containment rates in Europe and the USA.
- The incident rate for external interference varies with location class, ranging from 0.05 per 1000 km-yr in remote rural areas to 0.48 per 1000 km-yr in rural residential and suburban areas.

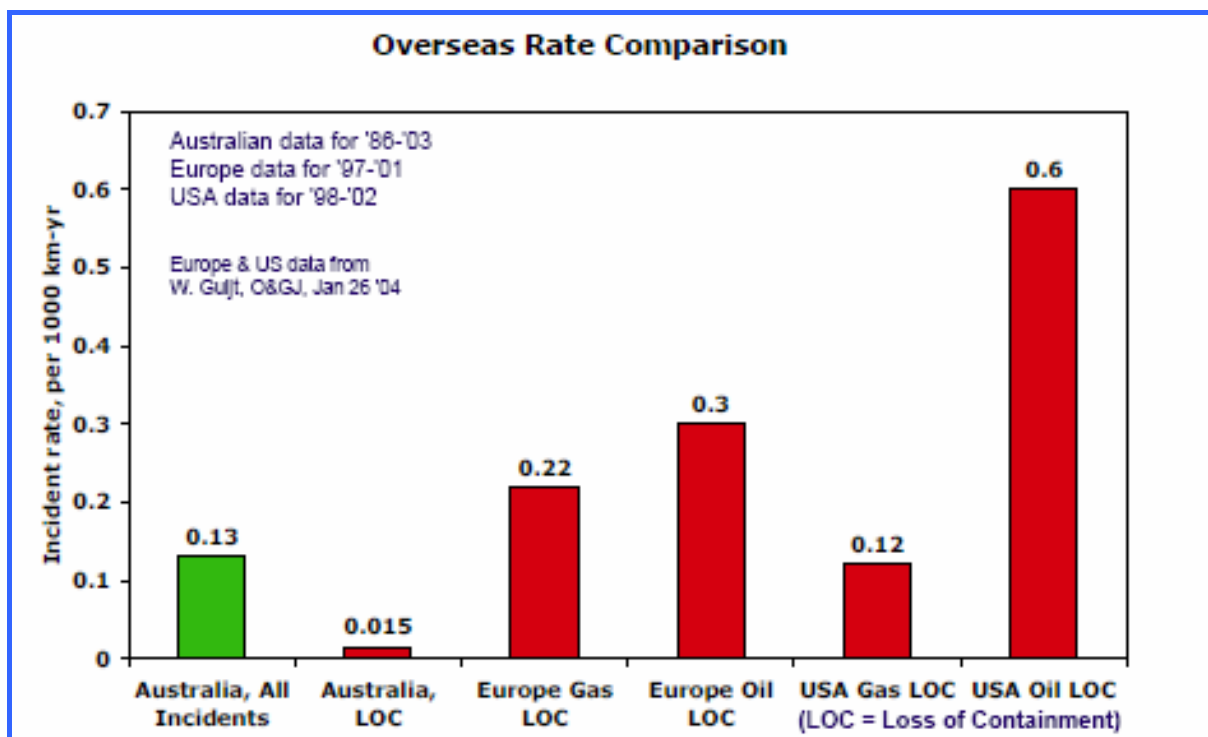


Figure 7 Comparison of rate of pipeline incidents in Australia, Europe and USA

Source: Presentation by P. Tuft to Seminar on release of Draft of AS2885.1 December 2004

Recent quantitative risk assessment studies for Australian outback pipelines but based on European data have predicted loss-of-containment rates around 0.2 per 1000 km-yr. However this is one to two orders of magnitude higher than the actual rates for remote area pipelines, which are around 0.014 and 0.003 per 1000 km-yr for leak and rupture respectively.

The APIA RSC proposes to prepare a report on pipeline incidents each year in a non-attributable form in a similar way to that used by organisations in the United States and Europe.

Application Of The Results Research Work To The Australian Standard

For those in the audience who did not attend the 14th Joint Technical Meeting in Berlin on 20-22 May 2003, several of the Australian contingent, including the authors [13] presented a paper that drew attention to the way in which the Australian Standard for petroleum pipelines (AS2885 – *Pipelines – Gas and Liquid Petroleum*) has been influenced by science and engineering, rather than empiricism.

In 1987, one of the most telling and prescient comments about the direction a pipeline standard should go was made by a member of the Committee responsible for AS2885. He said, “*A design factor of 72% is deemed to protect the people from the fluid, other means must be applied protect the fluid from the people*”. This concept has driven the Standards Committees, users and technical regulators. Of course, there is still empiricism in setting a design factor of 72% and the Australian pipeline community has now met the challenge of increasing the design factor to 80%, based on science and engineering.

In December 2004, Standards Australia and APIA released a new draft of the design and construction section of AS2885 – *Pipelines – Gas and Liquid Petroleum* - referred to as AS2885.1. This draft was prepared under the chairmanship of one of us (Venton) and encompasses what the industry has learnt since the last issue of that section in 1997 and also permits the use of an 80% design factor.

Like its predecessors since 1987, the new draft uses an integral risk assessment and threat mitigation process in design and for the whole of the life of the pipeline in all aspects of design, construction operation, maintenance and abandonment. It has explicit requirements for the design, documentation, and approval of key processes such as prevention of external interference, control of fracture, and welding procedure qualification. It assigns responsibility for the key processes to suitably qualified, experienced, and trained people who take responsibility for their actions in writing.

By reference to benchmarks and input from our international colleagues, we are of the view that the Australian Standard AS2885 represents the current international state of the art in the design, construction, testing, operation and maintenance of petroleum pipelines. The process of benchmarking was ably assisted by papers and presentations from a number of our international colleagues at a conference held at Wollongong on 7-8 December 2004 [14].

The draft is due to be finalised in the next few months and expected to be accepted by all of the members of the industry and technical regulators as the single and sufficient set of technical requirements for petroleum pipelines in Australia.

We have to acknowledge that we have a rather streamlined system for the development of Australian Standards for pipelines. We have relatively small and agile committee process, and the involvement of many of the key contributors to the Standard, some of whom are technical regulators, while others are involved in every aspect of the pipeline industry, including direct responsibility for industry sponsored research projects.

We also must pay tribute to our international colleagues for their readiness to provide comment and constructive criticism. We may be able to repay some of that input by assisting other jurisdictions to approve the use of an 80% design factor, based on science, engineering and the intelligent application of risk management processes.

There are number of examples of the ways in which APIA RSC's Australian Pipeline Research Program has been applied to AS2885, some of which have already been addressed in the descriptions of the APIA RSC research subjects. These are set out below.

External Interference

Throughout the world, the most common cause of pipeline damage and loss of containment is that of external interference. External interference can be caused by the pipeline owner, can occur in the presence of, and under the direction of the pipeline owner, or it can be caused by third parties, despite the best efforts of the owner's right of way management processes.

The Australian Pipeline Research Program has carried out a number of research programs into third party interference, some of which were reported by Kimber [15] at the 13th EPRG PRCI Joint Technical Meeting in 2001, and more recently by Venton and Brooker at PRCI-EPRG-APIA 15th Joint Technical Meeting On Pipeline Research Orlando, Florida, USA 16-18 May 2005 [16]

These papers show that the prevention or limitation of the effects of third party damage is complex and is best managed by a combination of:

- understanding the sociology of communication with all stakeholders in the pipeline's right of way and the need for thoroughness, consistency and frequency in that communication. Many pipeline companies fail this test. This aspect prompted the Standards Committee to alter the wording on the pipeline marker signs from WARNING to DANGER, reflecting both a societal / legal responsibility, but also the community awareness of the meaning of the words. The study also reported that there is a tendency to rely on statutory protection (legislation that sets fines and other penalties for damage to pipelines) rather than proper management.
- design of the pipeline to incorporate an understanding of the threats to the pipeline at particular locations and to mitigate the effects of external interference – “protect the fluid from the people”

The current version and new draft of the design section of AS2885 take these aspects of research and make them essential for the design and operating phases of a pipeline's life.

Understanding Hydrostatic Testing and High Y/T Ratio and Low Strain to Failure Effects in Coated High Strength Pipe

As a precursor to permitting a design factor of 80%, it was decided to retain the test pressure factor of 1.25 times the MAOP of a pipeline. This meant that hydrostatic testing would have to be accomplished at or above the specified minimum yield stress in sections of the pipeline wherever a design factor of 80% was used. As a result the APIA RSC embarked on several interlinked research projects – Understanding Hydrostatic Testing and High Y/T Ratio and Low Strain To Failure Effects In Coated High Strength Pipe.

We have reached the stage where we now have software that will predict the behaviour of hydrostatic test sections and intend that this software or a suitable alternative will need to be used for planning and carrying out hydrostatic test for pipelines to be operated at a design factor of 80%.

Application of Automatic Welding to Small Diameter Pipelines

At the time we began a research project on application of automatic welding to small diameter pipelines, very few manufacturers, if any, supplied automatic welding equipment suitable for pipelines less than 457 mm (18") diameter, in rugged field conditions and able to make 350+ welds per 10 hour shift. Such a machine was developed, but not commercialised. However, the project led to a better understanding of the automatic welding process, the development of improved heads and wire feeding equipment and gave us a suite of instrumentation and software to provide real-time monitoring of the welding process.

The use of real-time weld monitoring and improved methods of non destructive testing were incorporated in the welding section of AS2885 as a result of these research projects.

Weld Cracking

The APIA RSC has carried out a considerable body of work on weld cracking – both hydrogen assisted cold cracking and solidification cracking – the results of this work has also been extensively incorporated into AS2885. Current work on cracking of in-service welds being carried out jointly by PRCI and APIA RSC will also provide guidance for further updating of the welding section of AS2885.

Coatings and Cathodic Protection

Since the early 1980s the Australia pipeline industry has carried out co-operative research into pipeline coatings and cathodic protection. This work resulted in the development of pipeline coating standards (now associated with the AS2885 suite of standards) and improved methods of management of stress corrosion cracking.

New work on transient loss of cathodic protection, to be reported on at PRCI-EPRG-APIA 15th Joint Technical Meeting On Pipeline Research Orlando, Florida, USA 16-18 May 2005 [17] shows that some of the criteria included in the current cathodic protection standards in respect of transient voltages and alternating current have been found to be in error. The next version of the appropriate Australian Standard will be modified accordingly.

Summary

In summary, the work of APIA RSC and the activities of the various Australian Standards committees for pipelines are collaborative, interactive have on-going synergies that we feel continue to be of great benefit to the Australian pipeline industry.

Wernher Von Braun is reported as saying, "Research is what I'm doing when I don't know what I'm doing"

On the contrary, the APIA RSC considers that it knows what it is doing and if the APIA RSC had a mission statement and a strategic plan – which are often more honoured in the breach – it would simply say:

To promote better, cheaper, safer and more reliable pipelines through the sponsorship of targeted research and the progressive application of the results of research to practical Australian Standards.

We continue to do that. Our links with the two greats of pipeline research, EPRG and PRCI, help us do it.

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- 3 Fletcher L., Venton P., Kimber M., Haddow I., Bilston K., Australian Standard AS2885: A modern Standard for design, construction, welding, operation and maintenance of high integrity petroleum pipelines, 14th Biennial Joint Technical Meeting, Berlin 20-22 May 2003
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- 12 Venton P., Brooker D., *Development and application of external interference research to the Australian Pipeline Standard*, 15th Biennial Joint Technical Meeting 16-18 May, 2005 Lake Buena Vista, Florida
- 13 Fletcher L., Venton P., Kimber M., Haddow I., Bilston K., Australian Standard AS2885: A modern Standard for design, construction, welding, operation and maintenance of high integrity petroleum pipelines, APIA EPRG PRCI 14th Biennial Joint Technical Meeting, Berlin 20-22 May 2003
- 14 APIA Launch of the Public Comment Draft of the Revision of the Australian Standard "Pipelines - Gas & Liquid Petroleum Part 1: Design & Construction (AS2885.1)", Wollongong Australia, 7-8 December 2004 which included the following international papers:
 - *Benchmarking AS2885 - Risk Assessment & Design Integrity* - Brian Rothwell, Former Chair Canadian Standards Committee & Integrity Specialist, TransCanada Pipelines; Alan Glover, Integrity Specialist, TransCanada Pipelines and Bob Coote, President, Coote Engineering Ltd
 - *Benchmarking AS2885 - Operational Integrity* - Phil Hopkins, Pipeline Integrity Expert, Penspen UK
 - *Benchmarking - Technical Regulation of Pipelines in the UK* - Alan Thayne, HM Principal Inspector of Health & Safety, Pipelines & Gas (England & Wales)
 - *International Selection & Usage of Design Factors Above 72% SMYS for New Pipelines* - Brian Rothwell, Former Chairman Canadian Standards Committee & Integrity Specialist; Alan Glover, Integrity Specialist, TransCanada Pipelines and Bob Coote, President, Coote Engineering Ltd
 - *The USA View of Higher Design Factors* - Bob Eiber, USA Pipeline Research & Integrity Specialist

Note: these papers may be available to non-members of APIA at:
<http://www.apia.net.au/>
- 15 Kimber M., *Research in the Australian pipeline industry*, 13th EPRG PRCI Biennial Joint Technical Meeting, New Orleans, LA, USA, 30 April - 3May, 2001
- 16 Venton P., Brooker D., *Development and Application of External Interference Research to the Australian Pipeline Standard*, 15th Biennial Joint Technical Meeting 16-18 May, 2005 Lake Buena Vista, Florida, USA
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