POLYETHYLENE PIPE STANDARDS ARE CHANGING – WITH CRITICAL IMPLICATIONS TO ASSET OWNERS AND CONTRACTORS

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ABSTRACT (500 WORDS MAXIMUM)

The creation in 2015 of PIPA NZ (Plastic Industry Pipe Association) heralded a polyethylene pipe industry group devoted to leading the correct specification and installation of polyethylene pipe systems. Group members have presented to past Water NZ conferences; in 2017 focusing on the creation of new New Zealand Unit Standards for fusion welding of PE pipe, and in 2020 on the global implementation of PE100-RC becoming recognised in polyethylene pipe materials and manufacturing standards.

As we approach the NZ Water October conference a re-draft of one of the most critical conjoint standards used in the industry – ASNZS2033 "Installation of Polyethylene Pipe Systems" will have been out for public discussion. Comprehensive amendments have been proposed to the current 2008 standard which will have significant implications for contractors and asset owners alike. For the first time, all polyolefin materials - not just Polyethylene - will be included in the standard.

There is a clear view prevailing in Australia as there is in New Zealand that PE Fusion welding practice needs to be improved and training formalised. A practical way to reach that objective is via pipe standards. This standard re-draft will look to adopt measures that include formal welder training. In Australia the relevant qualification set is PMBWeld301E, PMBWeld302E which are equivalent to the New Zealand qualification set US31524, 31525. Further to this, there is a possibility to reference the acceptability of fusion joints and make specific reference to butt welding parameters' validation by test prior to commencement of work.

In addition, ASNZS2033 will include focus on renovation and trenchless replacement of underground networks by inclusion of recently adopted international standards. This should more rigorously frame the discussion on acceptable pipe installation especially when using advanced materials that are available today.

This paper will present information on the accessibility and adoption of the New Zealand Fusion Unit Standards, their place in the NZQA framework and how retention of the learned skills will become critical to ongoing work on PE

pipelines. It will also further illustrate how new generation PE pipe materials may be utilised once they are ratified and published in new standards.

KEYWORDS

Polyethylene, Polyolefin, Electrofusion, Butt Fusion, PIPA NZ

PRESENTER PROFILE

1 Alan Shore

Alan is the Manager of Ravago NZ, a leading supplier of PE Pipe materials to the New Zealand market. From 1998 to the present he has been responsible for marketing and sales of Borouge and Borealis Polyolefin pipe compounds.

Alan is chair of PIPA NZ and also a director of PIPA Australia.

2 Frank O'Callaghan

Frank O'Callaghan is a professional pipeline engineer and National Technical Manager of Iplex Pipelines (NZ), with over 45 years experience with manufacturing, development and construction of infrastructure plastic pipelines; in New Zealand, Pacific, USA, and UK.

He represents Plastics New Zealand on several joint Australian / New Zealand technical committees for pipe standards.

3 Leon Tabachnik

Leon Tabachnik, PhD (Technology and Processing of Plastics), is Plastics Technical Manager of Waters & Farr for over 30 years. Previous experience in Latvia's Research Institutes involved development of plastics based building materials, their technology and applications.

Leon represents Plastic Pipe Industry in Gas Association of NZ, Standards technical committees.

1. INTRODUCTION

1.1 The influence of Standards on Polyethylene Pipe Systems

Your smartwatch's alarm just went off. A new day begins. A light switch clicks and the lights go on instantly. You rock into the shower where the water jets out immediately. On goes another tap for mixing your shaving cream. The toilet flushes – out of sight and out of mind. More water arrives for your morning coffee. Before heading out, you program in a start time for the automatic lawn irrigation system. As you leave, rainwater flows from the house roof to gutters and down pipes, away into the underground stormwater attenuation and infiltration system.

During your commute, the wet road safely drains away surface water during your road trip.

You don't give it moment's thought – you simply expect the water to flow, the toilet to flush, lights to shine, the road to be drained and the lawn to stay green.

From the time you awakened in the morning, and throughout the day you've benefited from literally dozens of product and installation Standards, controlling the expected performance of everything you've encountered.
This is a major reason why Standards exist: to make your everyday life healthier, safer and easier.

You also benefited directly from the installer training and construction skills used to join, install and commission those pipes, so they actually deliver the outcome the Standards specify.

Polyethylene pipelines that provide our daily water services exist because of industry Standards. These Standards control every aspect of these pipes, including the raw materials used, pipes' manufacture and performance, installation requirements – and the construction techniques required to join the pipes and build them into asset systems, all working together to deliver the safety, durability and expected performance in use, that we have every right to expect.

1.2 Standards for Polyethylene Pressure Pipelines

The development of polyethylene (PE) materials and their use in pipeline systems is one of the most significant infrastructure technologies of the modern era.

We should recognise the circle of developments from which the industry has progressed, and especially in the last 20 years, rather more rapidly. From the 1933 invention of Low Density Polyethylene (LDPE) to the 1950's when High Density Polyethylene (HDPE) was introduced, there was a slow adoption of the polyethylene material in a pipe form. It reached its first significant audience with Medium Density Polyethylene (MDPE) materials which became a necessity in the British Gas industry with the regulated replacement of lead jointed cast iron gas pipes. These pipes were rendered unsafe as the lead solder joints were drying out from the new reticulated natural gas in use.

As the science of polymer production progressed through the '1990's so too the current threshold of MRS10 (PE100) material was reached. There was no hindrance for pipe manufacturing plants to deal with these newer raw materials but the significance of applying batch release tests to a higher performance threshold came to be fully appreciated.

In the current era, further developments of Polyethylene material physical properties have been displayed, showcasing the advance of polymer science. This is what we refer to as the "Circle of Developments"; advanced material invention needs extrusion machine improvements for successful manufacture, and in turn longer duration testing regimes and newer laboratory test methods. In turn the fusion welding Standards demand more scrutiny as do the types of moulded fusion fittings that need to be produced. All the while none of these development milestones are of any use unless included in the industry Standards.

It is prudent now to note for the record that Polyethylene pressure pipe compounds are no longer classified as MDPE or HDPE and are only referred to as PE80 or PE100.

1.3 Industry Standards For Polyethylene Pipes And Fittings

In Australasia, several joint Australian & New Zealand (AS/NZS) Standards specific to PE pipes, underpin the required properties, performance, and installation of PE100 and PE80 pipe systems for pressure applications. Standards are living documents which reflect progress in science, technology and systems. To maintain their currency, all Standards are periodically reviewed, and new editions are published. Between editions, amendments may be issued. Standards may also be withdrawn. It is important that readers assure themselves that they are using a current Standard, which should include any amendments that may have been published since the Standard was purchased.

AS/NZS 4131:2010 specifies requirements for polyethylene compounds (PE80 and PE 100) suitable for manufacturing polyethylene pipes and fittings for pressure applications. Minimum requirements are given for materials, composition and long-term pressure performance.
PIPA Industry Guideline POP004 is a listing of PE pipe compounds evaluated against the requirements of AS/NZS 4131 and compounds with increased long term stress crack resistance.

AS/NZS 4130:2018 is the specification for manufacturers and purchasers of polyethylene pipes used for the conveyance of fluids under pressure. Such fluids include, but are not restricted to, water, recycled or reclaimed water, waste water, slurries, compressed air, and fuel gas.

AS/NZS 4129:2020 specifies requirements for fittings to be used with polyethylene pipe
manufactured in accordance with the above standards.

1.4 Installer Skills And Training U

Installers' skills specific to Polyethylene pipe jointing are supported by several Unit Standards including:

New Zealand Qualifications Framework (NZQF) Unit Standards

- US 31524 Carry out butt fusion jointing on polyethylene pipes for water networks
- US 31525 Carry out electrofusion jointing on polyethylene pipes for water networks
- US 31532 Demonstrate knowledge of fusion jointing of polyethylene pipes for water networks

Training.gov.au – Units of Competency

- PMBWELD301E - Join Polyethylene Plastic Pipelines using Butt Welding (Release 1)
- PMBWELD302E - Join Polyethylene Plastic Pipelines using Electrofusion Welding (Release 1)

2. ORIGIN AND EVOLUTION OF AS/NZS 2033 – INSTALLATION OF POLYETHYLENE PIPE SYSTEMS

In 1972, AS CA69:1972 - Installation of Polyethylene Pipe Systems , was prepared by the Standards Association of Australia Committee PL/6 with input from scientific, industrial and governmental organisations across Australia. AS CA69 was initiated to meet the need for a code of rules to assist in the installation of polyethylene (PE) Pipe systems. The rules in this Standard covered handling, transport and storage of PE pipes. They also stated a number of properties of PE pipe and indications of areas where PE pipe were not recommended. They dealt with installation and jointing techniques applicable to PE pipes above and below ground

The Standard first appeared designated as AS 2033 in 1972, and again as a 2nd edition in 1980.
This covered the adoption of ISO 161 nominal outside diameter series of PE pipe manufactured in accordance with AS 1159:1979. It provided separate sections for pressure applications, Soil/Waste/Vent pipes, sewer and drain pipes, for above and below ground and for pipeline liners.

In 2008, AS 2033:1980 was superseded by a new revised and Joint Standard, designated AS/NZS 2033:2008, prepared by the Joint Australia/Standards New Zealand Committee PL-006, comprising committee members that represent both New Zealand and Australian stakeholders.

Further amendments appeared in October 2008 and June 2009, which now brings us to the current major draft revision and update of AS/NZS 2033:2008 this year, designated at the time of writing this Paper as DR AS/NZS 2033:2023

In the first decades of the 21st Century, AS / NZS 2033:2008 has been the principal go-to Standard throughout Australasia for installation of PE pipe systems, referenced throughout industry, including New Zealand Local Authority engineering and construction standards, Subdivisional specifications and the New Zealand Building Code. In accordance with the regular Standards review program, early in 2021, the Joint Standards Committee PL 006 commenced a new project to undertake a full revision of AS/NZS 2033:2008, which was more than ten years old, and to take account of new learning, and technology.

The DR AS/NZS 2033:2023 Draft document proposes updates to current practice and primarily addresses the installation of PO pipes and fittings for plumbing, industrial and irrigation applications, although it is not intended to replace industry specific installation codes or regulations.

The scope of the Draft has been expanded to incorporate all polyolefin (PO) pipe materials; Polyethylene (PE), Polypropylene (PP), Polybutylene (PB), and Cross-linked Polyethylene (PE-X)
New sections covering Design, Trenchless Technology, Earthquake Performance Guidelines, and training requirements for Fusion Jointing methods have been included.

2.1 Summary of the principal changes proposed in DR AS/NZS 2033:2023(in draft form at the time of writing this paper).

Table 2.1: Comparison of principal changes AS/NZS2023:2008 to 2023 Draft

AS/NZS 2033:2008 (Current)	**DR AS/NZS 2033:2023 (Draft)**	**Commentary**
Section 1 Scope, definitions, and material requirements	**Section 1** Scope and General	Expanded normative references and definitions
Section 2 Products and materials	**Section 2** Products and materials	Minor changes – UV Resistance clause covers all listed Polyolefin materials
Not covered	**Section 3** Design	- Calculation of maximum allowable operating pressures - Design Coefficients

		- Material temperature ratings - Surge and fatigue ratings - Disinfection effects - **Seismic risk area design** - External load design - Effects of sunlight and fire
Section 3 General requirements	**Section 4** General requirements	- New clause covering buckling under external load and vacuum
Section 4 Jointing Methods	**Section 5** Jointing requirements	- **Competence and training requirements for fusion jointing** - Expanded range of fusion jointing techniques - Expanded range of mechanical fitting types
Section 5 Installation of buried pipes and fittings	**Section 6** Installation of buried pipes and fittings	- new clause for 'Structural Design' of buried Pipes and fittings - Clause for Engineered Structural Design with reference to the relevant AS/NZS Standard for Structural Design **-** Installation of buried PO Pipelines using Trenchless Technology with references to the relevant AS/NZS/ISO series of Standards covering techniques for Renovation and Trenchless Replacement -Minimum bending radius for PE pipes
Section 6 Installation of pipes above ground	**Section 7** Installation of pipes above ground	-support of pipe systems
Section 7 Testing of pipe systems	**Section 8** Hydrostatic pressure acceptance testing of PO pipe systems	Major updates are included in this section
Not covered	**Section 11** Gaseous fuels	New short section
Not covered	**Appendix B** (informative) Guidelines for PE pipe installation in earthquake zones	Major new section, based on first hand observations and experiences from major New Zealand Earthquakes from 1987 to 2015

[Source: PIPA Australia discussion document July 2023]

DR AS/NZS 2033:2023, Section 5, includes these draft requirements for training and competency, for jointing polyethylene pipes and fittings using butt fusion and electrofusion techniques**.**

3. FUSION

3.1 Butt Welding

Butt welding should be carried out in accordance with the welding machine manufacturer's operating instructions for the specific machine, and each pipe diameter and wall thickness. Refer to ISO 21307, or other validated welding parameter systems.

Butt welding parameters shall be validated by test before welding commences on site. Welding shall be performed by competent persons.

In Australia, the competent person shall have completed PMBWELD 301 training within the last three years.

In New Zealand, the competent person shall have completed PMBWELD 301, or other training approved by the relevant authority, (e.g. US31524 & US31532 by NZQF) within the last three years.

Butt weld joints shall conform to destructive tensile tests conducted primarily in accordance with ISO 13953, with a minimum 90 % parent pipe strength and ductile behaviour in all test coupons
A field welding QA plan shall be submitted and approved before welding commences.

3.2 Electrofusion

Electrofusion should be carried out in accordance with the manufacturer's instructions for each specific size and type of fitting. Electrofusion control boxes should conform to ISO 12176-2. Electrofusion shall be performed by competent persons.

In Australia, the competent person shall have completed PMBWELD 302 training within the last three years.

In New Zealand, the competent person shall have completed PMBWELD 302, or other training approved by the relevant authority, (e.g. US31525 & US31532 by NZQF) within the last three years.

When tested, electrofusion joints shall meet the requirements of AS/NZS 4129:2020 Clause 3.5.

A field fusion quality assurance (QA) plan shall be submitted and approved before commencing fusion.

3.3 Jointing Methods, Training Requirements and Performance Criteria for Polyethylene Pipe Fusion Jointing systems

Jointing methods and trained qualification of the operator to perform those methods are fundamental to the success of any Polyethylene (PE) pipe system in practice.

PE pipe is used extensively in the New Zealand Water industry. It is a very versatile product that may offer numerous advantages such as: corrosion resistance, lighter weight, greater flexibility, and a longer expected life cycle compared to other types of pipe.

Critical to the inception of PIPA NZ was the acceptance that welding issues existed and misinformation as well as inconsistent training and practice was an ongoing problem that needed to be resolved. We saw illustrations of this in practice in Auckland, Christchurch (through SCIRT as part of the earthquake re-build), and other projects and regions.

Current training is ad hoc:

- Training may or may not be done to unit standards
- Training does not take into account larger pipe diameters, and pipe wall thicknesses
- Little or no field assessment

The view of PIPA NZ is that full compliance with the training requirements of DR AS/NZS 2033:2023 is essential to achieving consistently successful fusion joints.

There are no shortcuts – operators who do not comply to these training requirements should not be performing fusion joints.

3.4 What Does Success Look Like In A Butt Fusion Joint?

Butt Fusion PE pipe joints are quality tested primarily to ISO 13953:2001: *Polyethylene (PE) pipes and fittings — Determination of the tensile strength and failure mode of test pieces from a butt-fused joint*

A specified number of equidistant Test Pieces (Joint Group) are taken around the circumference of the weld. The specified Pull Rate of 5 mm/min is critical to the test validity - faster pull rates to "speed up" the test will induce the false appearance of non-ductility, when the true result is ductile.

A fully ductile response in any test coupon at 5mm/min pull rate is considered a pass for that coupon and a non-ductile response is considered a fail. Failure of any one Test Piece in the Joint Group is considered a failure of the whole joint – the example of ductile ruptured samples and just one sample failing in brittle mode is shown below:

Photograph 3.1: Ductile and Brittle Failure Examples in Butt Fusion Test Coupons

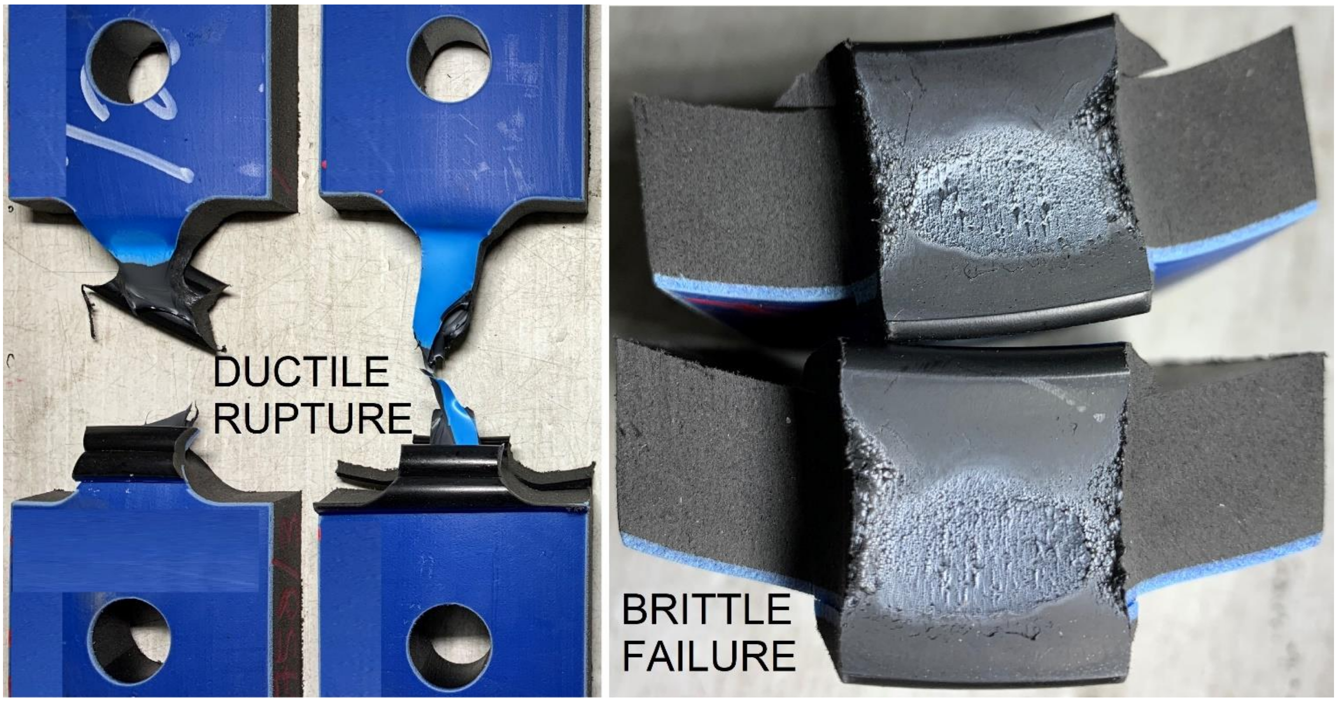


Image courtesy of Waters & Farr

DR AS/NZS 2033:2023 specifies that all weld samples are to demonstrate strength of not less than 90% of the parent pipe, and ductile behaviour in all samples therefore a sample of the parent pipe from which the joint is made is tensile tested for a comparison.

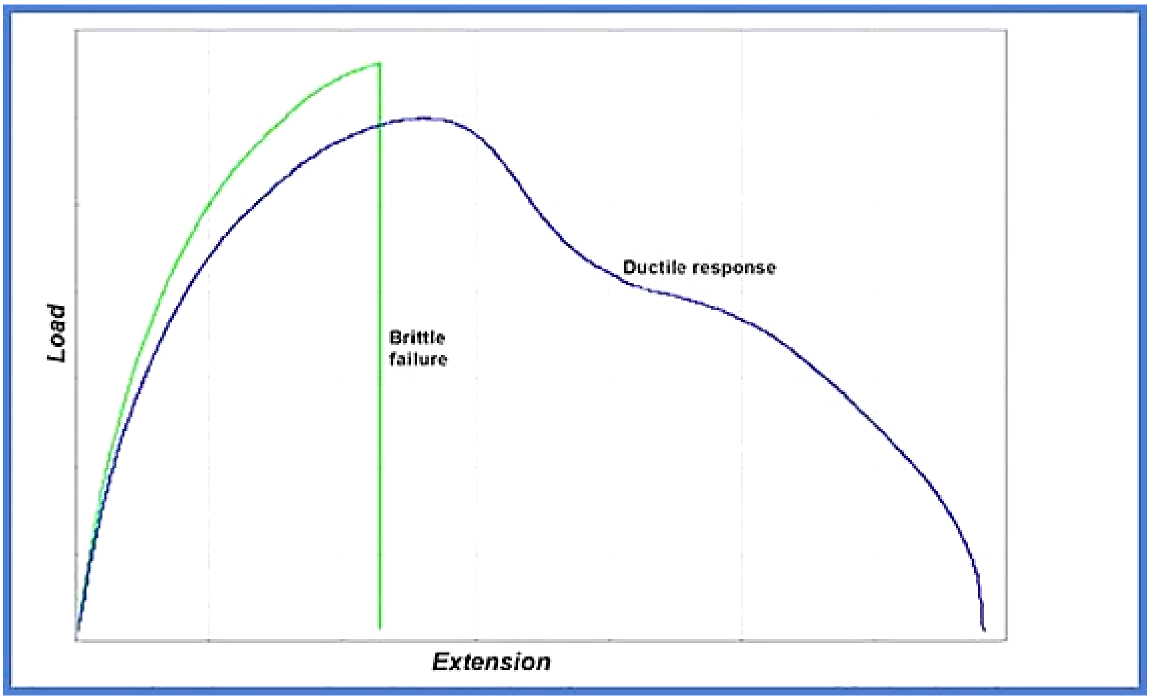
Many factors may cause non-ductility in a Butt welded joint – significant factors to avoid include

- Equipment inadequacy
- Contamination of the weld area
- Pipes' misalignment
- Shortening of the specified t4 ramping up pressure time

A practical method of conclusively distinguishing Ductility from Non-ductility is to capture and graph the relationship between Load vs Extension in the Test Piece

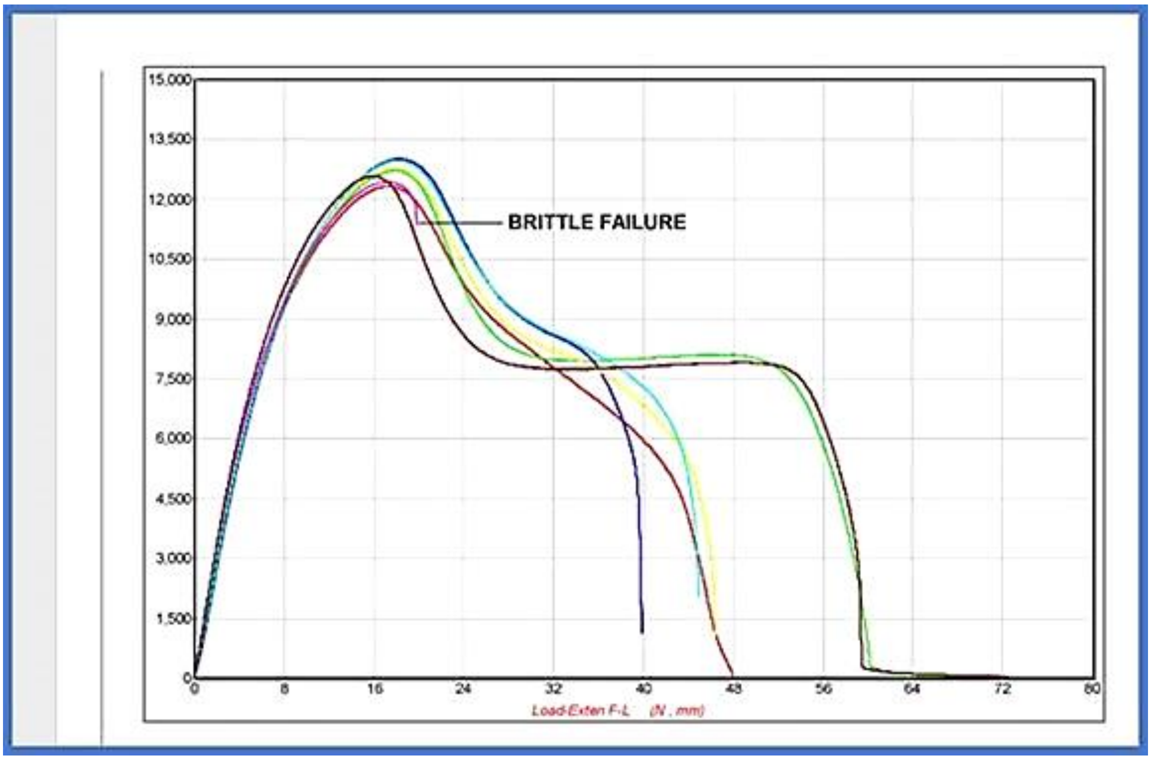
Some small variation in the shape of the ductile test graph is normal and expected but the difference between Ductile and Non-ductile is visually clear. This distinction is difficult or impractical to determine simply from a subjective visual examination of the failed weld surface alone

Figure 3.1 Shows the Non-Ductile response , in comparison with Ductile response.



Images courtesy of Waters & Farr

Figure 3.2 Shows the normal variation in Ductile response



3.5 What Does Success Look Like In An Electrofusion Fitting Joint?

Electrofusion fitting PE pipe joints are quality tested primarily to the following standards:

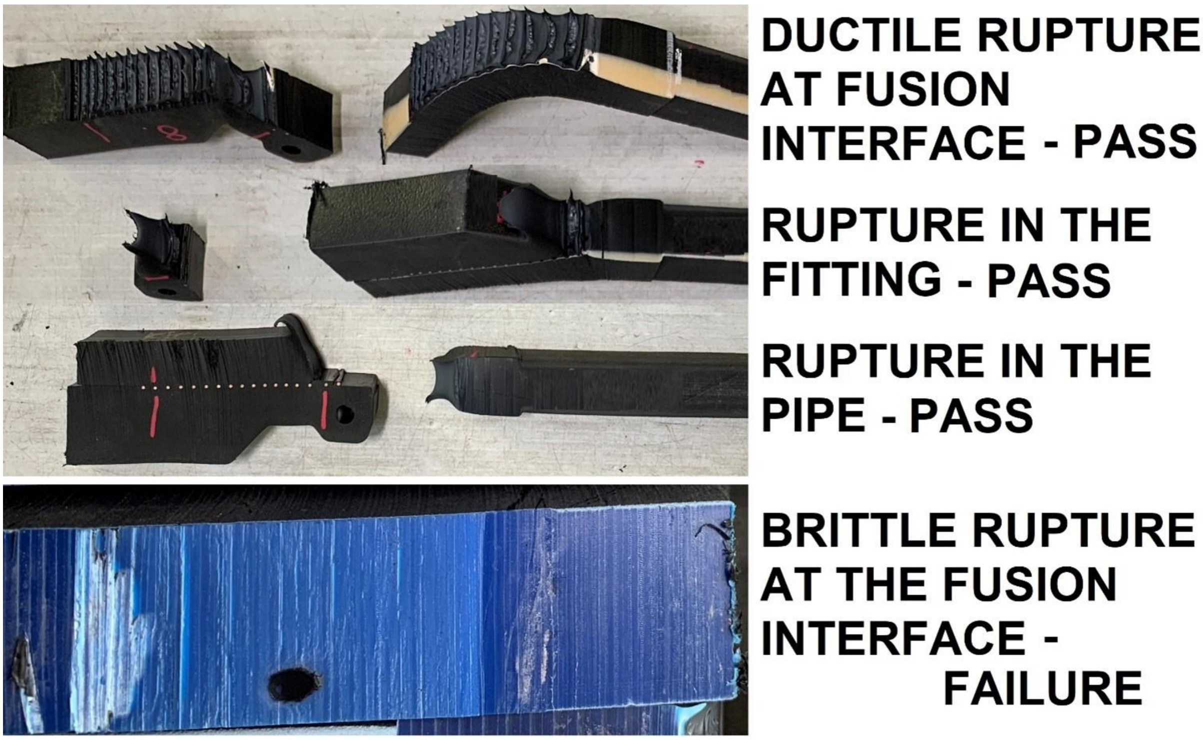
- ISO 13954:1997: *Plastics pipes and fittings — Peel decohesion test for polyethylene (PE) electrofusion assemblies of nominal outside diameter greater than or equal to 90 mm*
- ISO 13955:1997: *Plastics pipes and fittings — Crushing decohesion test for polyethylene (PE) electrofusion assemblies*
- ISO 13956:2010: *Plastics pipes and fittings — Decohesion test of polyethylene (PE) saddle fusion joints — Evaluation of ductility of fusion joint interface by tear test*
- ISO 21751:2011: *Plastics pipes and fittings — Decohesion test of electrofusion assemblies — Strip-bend test*
- *AS/NZS 4129:2020 provides guidelines for pass/fail criteria.*

Many factors may cause non-ductility in an Electrofusion Fitting joint – significant factors to avoid include

- Equipment inadequacy
- Contamination of the weld area
- Pipes and Fitting misalignment
- Omitting pipe surface peeling and use of pipe re-rounding clamps from the process

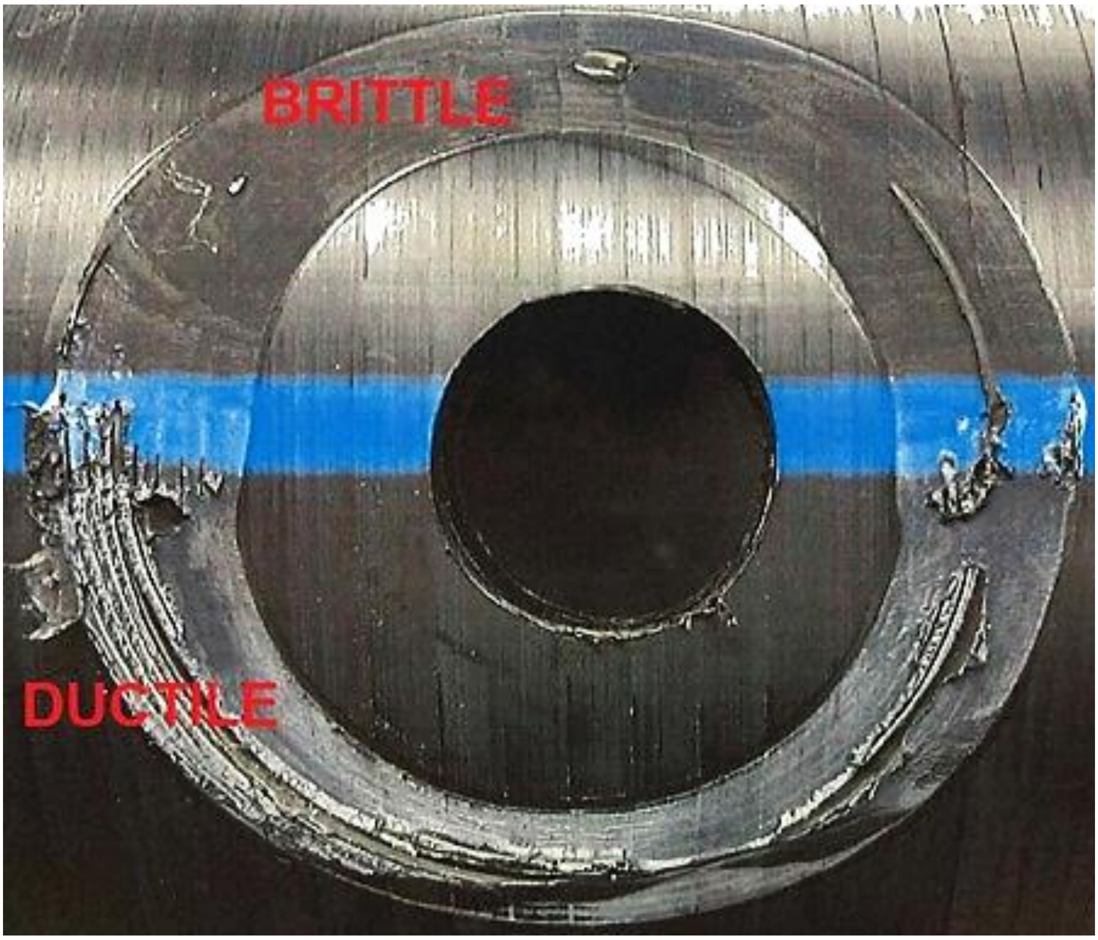
A specified number of equidistant Test Pieces (Joint Group) are taken around the circumference of a socket fitting joint. A test piece passes the test when the decohesion brittle length including voids is not exceeding 33.3% of the fusion length. Failure of any one Test Piece in the Joint Group is considered a failure of the whole joint –examples of pass and failure shown below:

Photograph 3.1: Ductile and Brittle Failure in Electrofusion Coupons



For a saddle fitting joint, the decohesion brittle length including voids is not exceeding 50% of the fusion length and the decohesion brittle area including voids is not exceeding 25% of the fusion area. Rupture through the pipe/fitting wall is regarded as a ductile result.

Photograph 3.2: Ductile and Brittle Zones of a Saddle Fitting Joint



4. DR AS/NZS 2033:2023 -STRUCTURAL DESIGN OF BURIED POLYETHYLENE PIPE AND FITTINGS

Section 6 sets out draft requirements for the installation and structural design of buried PO pipes and fittings.

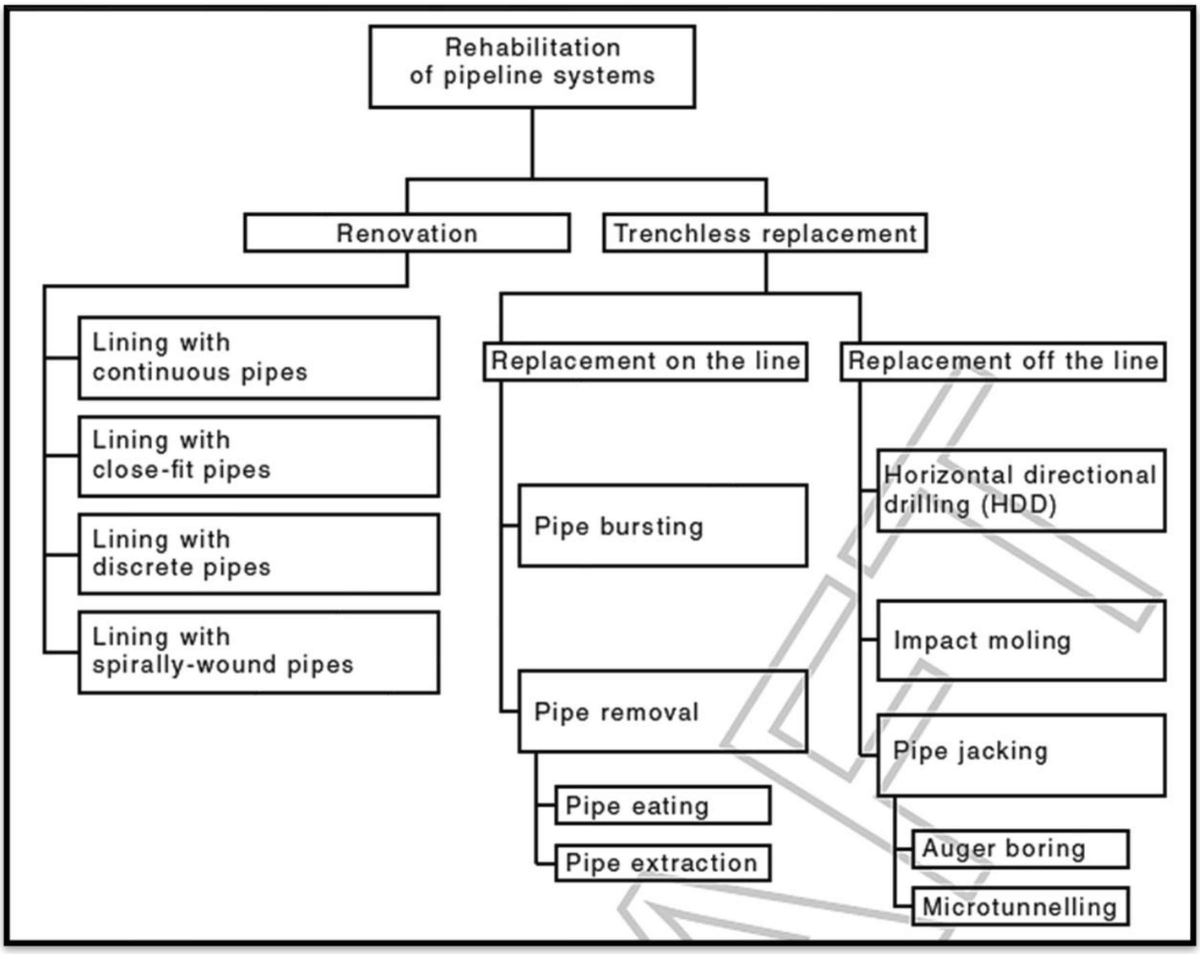
There are two methods proposed for assessing the predicted long term structural performance of polyethylene pipes, the *Graphical Design Method,* or the *Engineered Structural Design Method* in accordance with AS / NZS 2566.1 *"Buried Flexible pipelines – Structural Design"*

PIPA NZ recommends that the *Engineered Structural Design Method* is used for all complex installations or where detailed knowledge of soil conditions and controlled monitoring of the installation are available.

5. DR AS/NZS 2033:2023-INSTALLATION OF BURIED POLYETHYLENE PIPES USING TRENCHLESS TECHNOLOGY

The Draft includes references to recently adopted ISO Standards specifying renovation and trenchless replacement techniques using PO pipes.

Figure 5.1 Renovation and trenchless replacement technique families using PO pipes;



Source; DR ASNZS2033:2023 / American Society of Trenchless technology, https:// nastt .org/ resources/ glossary/

More details in the Draft are provided for installation of PO pipes in a trench and for bending the pipes (with references to AS/NZS 2566.2 and PIPA POP202).

6. DR AS/NZS 2033:2023 – PE PIPE INSTALLATION IN EARTHQUAKE ZONES

Informative Appendix B contains draft recommendations for the design and installation of PE pipe systems, installed in areas subject to earthquake events or seismic risk. The recommendations are based on first-hand observations and experiences, specific to pipe systems during major New Zealand seismic events in a 28-year period, from 1987 to 2015, including the Christchurch/Canterbury area earthquake sequence during 2010 to 2012.

7. DR AS/NZS 2033:2023 – INSTALLATION OF PIPES ABOVE GROUND

Section 7, sets out draft requirements for the installation of pipes above ground.

Tables specifying maximum spacing of supports are setting different values (and amended compared to the current standard) for pressure and non-pressure pipes.

8. DR AS/NZS 2033:2023 – TESTING OF PIPE SYSTEMS

Section 8, provides methods of Hydrostatic pressure acceptance testing of PO pipe systems, after installation or repair works. Main attention is paid to the testing of PE pipelines, and methods to distinguish the pressure loss that occurs due to viscoelastic creep of the pipe material and the pressure loss due to true leakage.

New in the Draft are ways to account for the elevation and temperature differences when conducting pressure testing of PE pipelines.

Pressure acceptance testing of PE pipe systems shall only be carried out under the direct supervision of a competent person. The allowable loss of water for a pipe system with significant elevation change may be significantly less than for a pipe system that has little elevation change. PE pipe systems should not be tested when the temperature of the pipes or water exceeds 40 °C. Where necessary to test pipes when the temperature exceeds 20 °C, the STP shall be reduced.

The competent person shall —

(a) be on site throughout the duration of the test;
(b) closely observe the pipe surface temperature at any exposed areas; and
(c) watch the pressure in the system during the test so that damage to the pipe (i.e. non-recoverable stretching from over pressurization) does not occur.

Table 8.1 Pressure Test Methods

Clause	Name of test	Comments
8.10.1	Constant pressure test (water loss method) for viscoelastic pressure pipe systems	Test applicable to PE pressure pipe systems of any size.
8.10.2	Pressure rebound method for viscoelastic pressure pipe systems	Test applicable to PE pipe systems up to DN 355.
8.10.3	Visual test for small pipe systems	Test applicable to small pipes and pipe systems where all joints have been left exposed for the test duration.

[Source DR AS/NZS 2033:2023]

There is enhanced interpretation of test results and acceptance criteria which has never before been attempted in this standard.

9. CONCLUSIONS

Since 90 years has now elapsed from the invention of polyethylene and 70 years have elapsed since the creation of a pipe product made from the raw material, scientific and standards bodies have continued to collaborate on advancement and enhancement of the utility value of what we now see and reliably use today.

Acknowledging mistakes along the way is part and parcel of that advance. Learning how to properly design, use and install the product is a hallmark of an enduring and professional industry.

The purpose of writing this paper was to draw attention to the new Draft Standard for Installation of Polyolefin Pipe Systems and accentuate the long term objectives of the PIPA NZ trade body which is to lead the correct specification and installation of polyolefin pipe systems in New Zealand. It is instructive to see internationally that 100 years design life is now the platform from which polyolefin pipes are being viewed. So too in New Zealand will such thinking become the norm if correct trade practice and specifications are adhered to.

It is appropriate that Water NZ is encouraging input to Cabinet on proposals to enhance and potentially regulate critical infrastructure resilience. Polyolefin Pipe Systems are without doubt part of New Zealand's critical infrastructure. Territorial Authorities have long held ASNZS2033 as a touchstone for their Polyethylene Pipe systems that are installed. This latest draft, once adopted will ensure that these pipe systems display the resilience which is sought after and take our communities and various stakeholders in underground infrastructure to the justified belief that what has been installed is safe and enduring for generations to come.

ACKNOWLEDGEMENTS

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3. Unit Standard 31525 version 1 "Carry out electrofusion jointing on polyethylene pipes for water networks"' New Zealand Qualifications Authority, Wellington

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