iPLEX Pipelines

AUSTRALIA'S PIPELINE SPECIALISTS

EST. 1938

TECHNICAL GUIDE

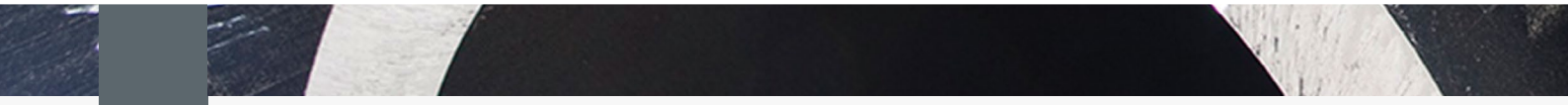
IPLEX MILLENNIUM®

THE EVOLUTION OF PE100

IPLEX MILLENNIUM® DELIVERS PIPELINE SOLUTIONS IN

DISCLAIMER

IPLEX PIPELINES AUSTRALIA PTY LIMITED ABN 56 079 613 308



CONTENTS

iPLEX Pipelines

IPLEX MILLENNIUM®

THE EVOLUTION OF PE100

1.0 INTRODUCTION

Over the past decade Australia's water utilities have become increasingly reliant on trenchless methods of pipeline installation and rehabilitation. This trend has in-turn resulted in a demand for higher performance, long-life polyethylene pipes that will provide reliable service for 100 years or more...It is this requirement that motivated Iplex to look toward the next generation of PE100 pipe materials. Materials that can withstand the inevitable damage and abuse that will occur in trenchless directional drilled, slip lined and pipe burst installations or even in open trench installations, where undetected rock impingement may occur during construction.

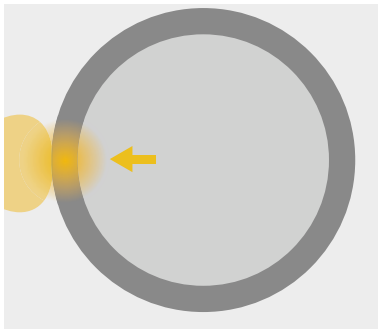
For the past five years Iplex has collaborated with Australia's resin manufacturer, Qenos, to develop a superior PE100 resin; a resin with exceptional resistance to slow crack growth. The product of this research and testing program is Iplex Millennium®.

Iplex Millennium® is a high stress crack resistant (HSCR) grade of PE100 pipe that provides up to ten times greater resistance to slow crack growth than conventional PE100 pipe. It has the same pressure burst strength of conventional PE100 pipe, but is specifically formulated for use in critical or high value pipeline assets where the risk of premature failure from slow crack growth is possible. Millennium® may also enable significant construction cost savings to be realised through the use of "as-dug" bedding, especially in areas where granular materials would otherwise need to be imported.

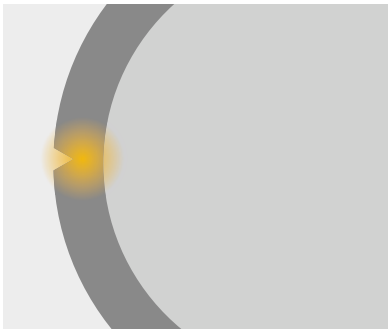
Iplex Millennium® provides designers with the opportunity to increase the pipeline's service life without increasing the wall thickness, providing a safer option and 'peace of mind' for the project engineer/system owner.

2.0 CAUSES OF STRESS CONCENTRATION IN THE PIPE WALL

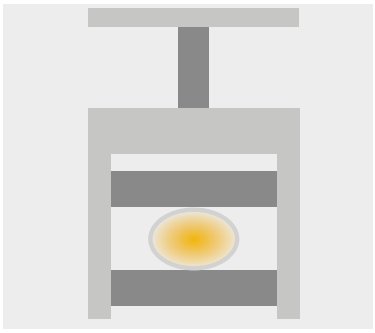
Excluding third-party damage, brittle failure through slow crack growth (SCG) is the most commonly detected failure mode in PE pressure pipes. The initiation of SCG arises from stress concentration in the pipe wall brought on by damage resulting from harsh installation conditions or squeeze-off stoppling practices, which can initiate a stress crack and ultimately lead to premature failure.



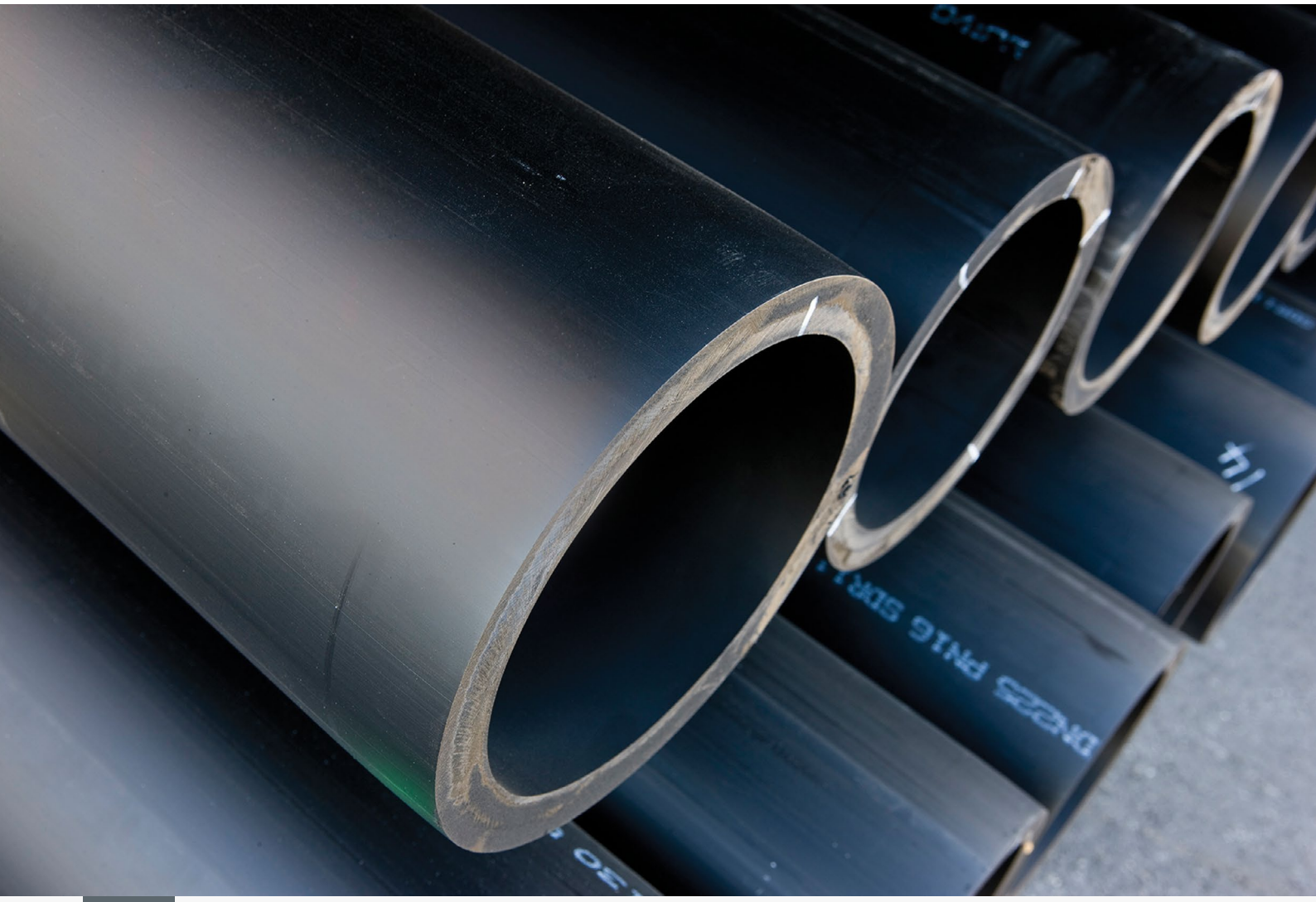
A POINT LOAD



A SCRATCH OR NOTCH IN THE PIPE SURFACE



AGGRESSIVE TREATMENT DURING SQUEEZE-OFF



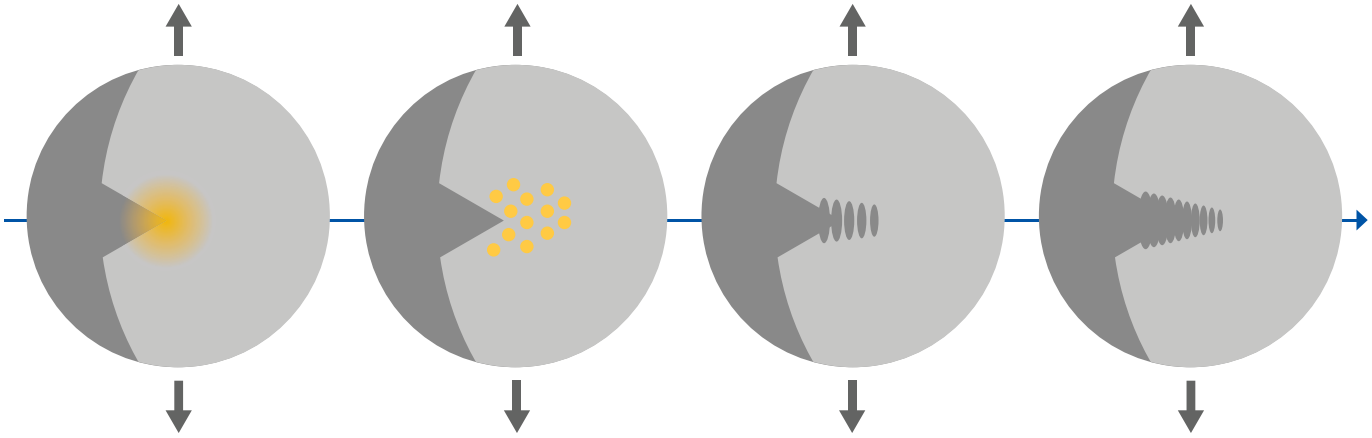
3.0 HOW DOES SLOW CRACK GROWTH PROGRESS?

There are three phases in slow crack growth development.

Phase one is the creation of a stress concentrator, the point of damage causing a concentration stress.

Crack initiation is the second phase. Under sustained stress microscopic voids may form, which develop into fibrillar crazing leading to crack initiation.

Phase three, crack propagation will lead to brittle fracture and result in the pipe bursting.



PHASE 1
STRESS CONCENTRATION
The point of damage causes a concentration of stress

PHASE 2A
VOID FORMATION
Concentration stress results in microscopic void formation

PHASE 2B
CRACK INITIATION
Under continued stress these voids may develop into crazing

PHASE 3
CRACK PROPAGATION
Eventually a crack will propagate leading to brittle failure

TIME ZERO

60-90% OF FAILURE TIME

10-40%

Up to 90% of the time to ultimate failure is occupied by Phase 2 void formation and crack initiation.

The most effective way of minimising risk of failure therefore, is to enhance resistance to crack initiation. This is a far more effective solution to the conventional approach that relied on increasing wall thickness as a means of reducing risk of brittle failure.

Iplex Millennium® is up to ten times more resistant to Phase 2 crack initiation than conventional PE100 pipe.

4.0 BENEFITS OF MILLENNIUM®

Iplex's Millennium® performance provides greater confidence to the designer, constructor and owner of polyethylene pipelines installed with trenchless technologies.

Additionally, considerable construction cost savings may be realised in open trench applications through the elimination of imported sand bedding, by utilising as-dug soil with Millennium® pipe.

Owners of gas pipe networks that are subject to squeeze-off can be confident that the stress induced in these operations will not result in premature failure of their networks.

REDUCED WALL THICKNESS

Compared to the conventional trenchless design factor approach that is commonly applied to compensate for potential surface damage, Iplex Millennium® pipe can be confidently used in the SDR determined by pressure and temperature factors alone. With thinner walled Millennium® pipe, substantial installation and pump energy costs can be realised.

INSTALLATION COST SAVINGS

The high stress crack resistance of Iplex's Millennium® pipe allows the use of excavated spoil, eliminating the need to import granular embedment in open trench applications. This can save a contractor up to 20% of the pipeline construction costs.

INCREASED SERVICE LIFE EXPECTATION

Iplex's Millennium® pipe can easily achieve an anticipated service life of 100 years due to its greater tolerance of surface damage. This is a substantial benefit to pipeline owners who are required to make accounting provisions for the replacement of assets.

SAFER GAS PIPELINES

In gas networks where 'squeeze-off' is used to manage pipeline flows for planned or emergency maintenance, Iplex's Millennium® pipe increases resistance to the initiation of slow crack growth wherever these stress concentrators are present, leading to a longer service life and enhanced network dependability.

5.0 COMPARISON OF CONVENTIONAL PE100 TO MILLENNIUM®'S PERFORMANCE

Iplex's Millennium® performance is identical to conventional PE100 pipe with the exception of Slow Crack Growth (SCG) resistance. In independent testing, Millennium® has demonstrated 10 times greater time to failure due to SCG than that which is required of conventional PE100 pipes.

	CONVENTIONAL PE100 PIPE PERFORMANCE	IPLEX'S HSCR
50 YEAR MRS @ 20°C	10 MPa	10 MPa
HOOP STRENGTH 5.4 MPa @ 80°C	165 h	165 h
HOOP STRENGTH 5.0 MPa @ 80°C	1,000 h	1,000 h
STRAIN AT YIELD	10%	10%
ELONGATION AT BREAK	≥ 350%	≥ 350%
SLOW CRACK GROWTH (NPT/ ISO 13479)	**≥ 500 h**	**≥ 5,000 h**

6.0 MILLENNIUM® SPECIFICATIONS

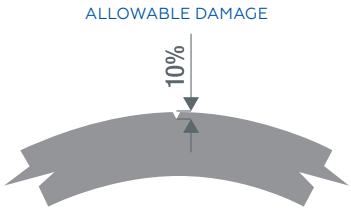
In Australian pressure applications, polyethylene pipe is covered by AS/NZS 4130 and material Standard AS/NZS 4131. Iplex Millennium® conforms in all respects with AS/NZS 4130. The Plastics Industry Pipe Association of Australia (PIPA) have published guideline POP016 (High Stress Crack Resistant PE100) outlining the four tests which polyethylene compounds must meet to be defined as PE100 HSCR. A copy of this guideline can be downloaded from the PIPA website www.pipa.com.au.

Iplex Millennium® has also been appraised by Water Services Association of Australian (WSAA) - Product Appraisal Report 1610.

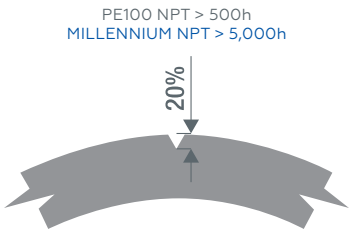
7.0 ALLOWANCE FOR EXTERNAL DAMAGE

Included in POP016 is the Notched Pipe Tests (ISO 13479). It is the most common type-test used to demonstrate the tolerance of HSCR pipe.

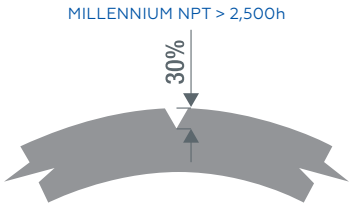
AS/NZS 2033 limits pipe installation surface damage (notch depth) to 10% of a pipe's wall thickness.



Passing ISO 13479 Notched Pipe Test requires a minimum of 500 hours at 80°C with pressure of 920kPa and a 20% pipe wall notch depth. Millennium® pipe achieves >5,000 hours resistance under these conditions, a factor of ten times that required of convention PE100 pipe.



Millennium® pipe tested at 30% notch depth showed it can sustain ≥2,500 hours.

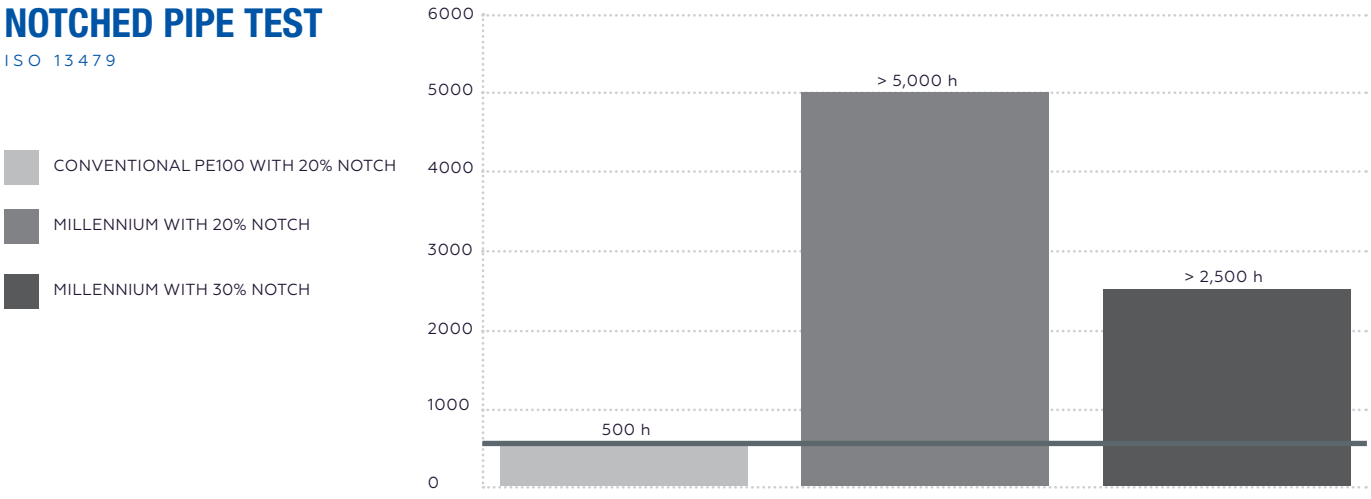


The Millennium® resin testing program demonstrates SCG resistance >10 times that of conventional PE100 and confirms its ability to withstand scratches far deeper than currently permitted under Australian installation Standards.

This fact supports the use of Millennium® where there is a risk of surface damage greater than the 10% wall thickness currently accepted.

NOTCHED PIPE TEST

ISO 13479



For more comprehensive information on testing HSCR grade of PE100 material please refer to Qenos' HCR193B technical package available on the Iplex website **www.iplex.com.au**

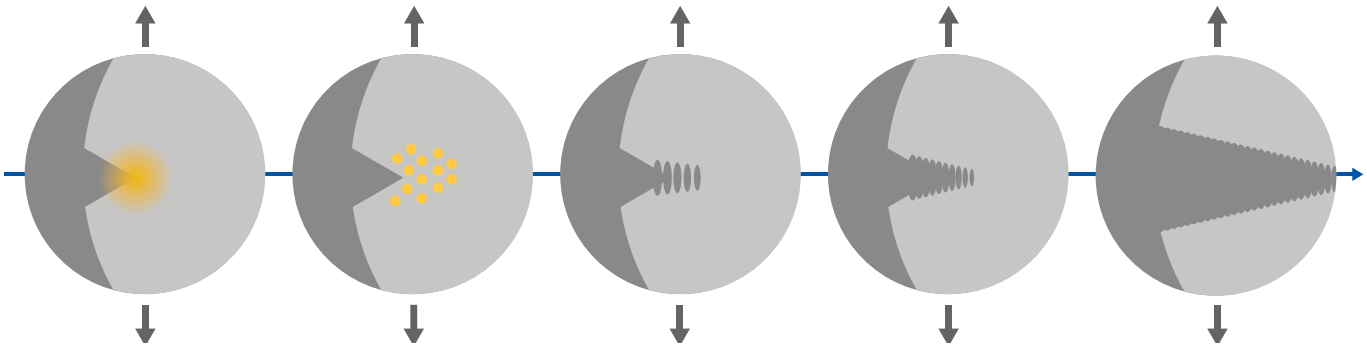
8.0 COMPARISON OF DESIGN FACTORS OF CONVENTIONAL PE100 AND MILLENNIUM®

Iplex's Millennium® pipe may be confidently designed with reduced design factors to those nominated for conventional PE100 pipe.

EXAMPLE COMPARISON OF DESIGN

Installing conventional PE100 pipe using AS/NZS 4130 Design factor f_3 for horizontal direction drilling (HDD) installation method requires a design factor of 1.2. Applying f_3 typically results in 'one higher' pressure class being selected for HDD installations (e.g. instead of using PN16 – PN20 would be specified).

The diagram below shows hypothetically the scenario of PE100 pipe suffering Slow Crack Growth mean time to failure due to severe surface damage in 10 years, comparing the usage of conventional PE100 pipe, the effects of increasing the wall thickness to PN20 and using Iplex Millennium®.



PHASE 1
STRESS CONCENTRATION

PHASE 2
VOID FORMATION & CRACK INITIATION

PHASE 3
CRACK PROPAGATION AND FAILURE

	PHASE 1	PHASE 2	PHASE 3	**TOTAL TIME TO FAILURE**
PE100 PN16	0 Y	6-9 Y	1-4 Y	**7-13 Y**
DESIGN OPTION 1 PE100 PN20 (f_3)	0 Y	6-9 Y	1-5 Y	**7-14 Y**
DESIGN OPTION 2 MILLENNIUM® PN16	0 Y	60-90Y	1-4 Y	**61-94 Y**

By applying design factor f_3 in design option 1, the hypothetical time to failure is increased by only one year. However by substituting Millennium® pipe (design option 2) in place of design factor f_3 the hypothetical time to failure is increased to between 61 and 94 years.

Installing Millennium® pipe made from Qenos HCR193B resin in areas of high damaged risk provides greater service life than that achieved by increasing wall thickness.

9.0 EXPERT OPINION

The claims and information contained within this document have been reviewed by specialist plastic pipe consultant Mr Michael Stahmer MIE (Aust) CPEng. Mr Stahmer's professional opinion and comments support Millennium® pipe's claimed benefits in terms of cost, handling, flow characteristics and consequential jointing time reduction.

8 May 2017
The Technical Manager
Iplex Pipelines (Aust) Pty Ltd
PO Box 5160
Brendale QLD 4500

STAHMER CONSULTING
82 LUDSTONE STREET
HAMPTON 3188
AUSTRALIA

Dear Sir/Madam

Ref: Millennium HSCR PE100 Pipe Design Factors

On the basis of the research and testing that has been undertaken, it is my professional opinion that the enhanced slow crack growth resistance inherent in Millennium pipe, utilising Qenos HCR193B resin (HSCR PE100), provides greater protection against potential long-term failure due to slow crack growth than that afforded by increased wall thickness.

This is particularly important for harsh installation conditions, such as trenchless construction, especially involving pipe cracking, HDD, submarine installations and in sand-less bedding applications with bedding material of maximum 20 mm particle size.

In order to account for the potential effects of installation technique on MAOP, design factors are available to apply to the PN rating - e.g. AS/NZS 4130 Appendix B, AS/NZS 4645.3 Appendix B and APGA Code of Practice V4.0 Section 4.4.

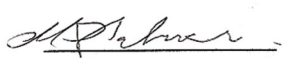
These factors are not scientifically derived however, but are rather estimates based on experience. In particular, long term experience is somewhat lacking with respect to trenchless and submarine applications, especially when considering the various techniques used in these.

The use of HSCR PE100 enables design factors of 1.0 for f2 and f3 in AS/NZS 4130, f0, f1, and f3 in AS/NZS 4645.3, and f1 and f3 in APGA Code of Practice, gas and water.

Note that AS/NZS 4645.3 is a "deemed to comply" solution in accordance with AS/NZS 4645.1, which is performance based and specifically allows for the introduction of new materials.

The APGA CoP V4.0 allows for "fit for purpose" design for gas and water - Section 4.6.

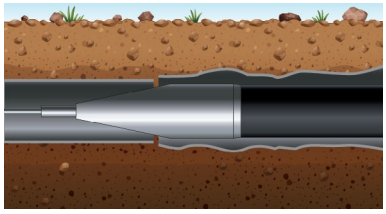
The resulting reduced wall thickness of Millennium pipe confers benefits in terms of cost, handling, flow characteristic, and jointing time, provided design is based on the use of HSCR materials, such as Qenos HCR193B, complying with PIPA POP004 and POP016.



Michael Stahmer MIE (Aust) CPEng (Ret)
Specialist Consultant Plastics Pipes

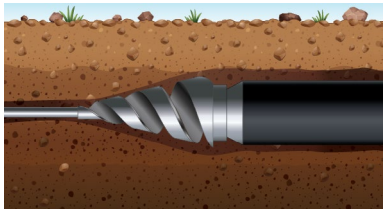
10.0 APPLICATIONS BENEFITED BY MILLENNIUM® PIPE

PIPE BURSTING AND SPLITTING



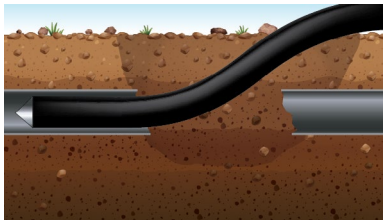
A conically shaped bursting head is winched through an iron, clay or concrete pipe to shatter and displace its fragments into the surrounding soil. The PE100 liner pipe is simultaneously pulled into the void. There is a risk that shards of fractured cast iron or earthenware host pipe will scratch the replacement pipe's wall beyond the 10% allowed for conventional PE100 pipe. Millennium® mitigates slow crack developing from these scratches.

HORIZONTAL DIRECTIONAL DRILLING (HDD)



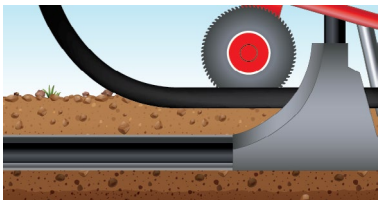
A steerable drilling head is plunged into the earth and driven along a shallow-arc trajectory. The head surfaces at a point beyond the obstacle that is being drilled beneath. Along the drilling path, rock is frequently drilled through. Following back reaming, a PE100 pipe string is pulled into the bored hole. Where hard rock is encountered, there is a risk of pipe surface damage beyond the 10% allowed for conventional PE100 pipe. Millennium® tolerates much greater pipe surface damage.

SLIP LINING/ SWAGE LINING



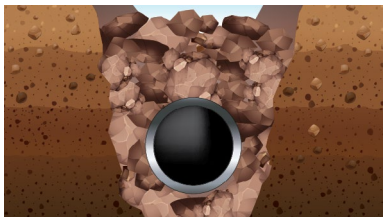
A close fitting PE100 pipe is winched through the corroded steel host pipe. Friction causes a slight reduction in the liner pipe's diameter during winching that eases installation. The PE100 expands to match the host pipe bore once the winching strain is released. Swage lining is similar except the liner pipe is pulled through a reducing die. The liner pipe's surface is scored and scraped by corroded host pipe lining beyond the allowable limits of 10% wall thickness. Millennium® resists cracks developing from surface scoring and scaping.

PLOUGH IN



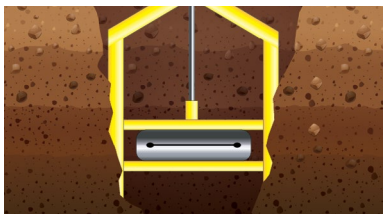
A blade is towed or pulled behind a powerful tug, which cuts through the earth in a knife-like action. PE100 pipe is fed into the void through a chute at the rear of the blade. There is potential for buried rocks to impinge on the PE100 pipe's surface leading to stress cracks. Millennium® has far superior resistance to brittle failure resulting from rock impingement.

AS-DUG BACKFILL (SAND-LESS BEDDING)



As-dug backfill reduces the cost of pipeline construction by up to 25% through eliminating the need for sand or granular embedment. The native soil is screened to ensure a maximum particle size of 20mm before placing and compacting around the pipe. Millennium® pipe is suited to using as-dug backfill.

SQUEEZE OFF



Squeeze-off is used to stop flow in gas pipes. The PE100 pipe is compressed between cylindrical bars with force applied by a screw or hydraulic press. During squeeze and release, excessive stress may be applied to the pipe wall. Millennium® reduces the risk of micro-cracking leading to premature brittle failure.

11.0 MILLENNIUM® SIZE AND RANGE

Millennium® is available in sizes ranging from DN16 to DN1200. Pipes can be manufactured with or without colour identification stripes, internal and external coloured jackets.

12.0 ENVIRONMENTAL CREDENTIALS

Iplex Pipelines has published verified Environmental Product Declarations (EPD) on our range of polyethylene pipes, including Iplex Millennium®.

EPD's are third-party certified documents based on ISO 14025 and EN 15804 Standards that communicate transparent and comparable information about the life-cycle environmental impact of a product or service. Specifically, product declarations include information on the environmental impact of raw material acquisition, energy use and efficiency, composition of materials and chemical substances, emissions to air, soil and water and waste generation.

Most importantly, EPD®'s are of great assistance to our customers; the builders and developers seeking to construct environmentally responsible infrastructure, because EPD®'s present key environmental product performance data in a uniform format that facilitates comparison between alternate materials.

Access to the Iplex Polyethylene Pipe EPD® provides constructors, operators and owners with the evidence they require to claim credit points under the Green Building Council of Australia and the Infrastructure Sustainability Council of Australia's rating systems.

To view a copy of Iplex Pipelines suite of EPD's visit the Iplex website www.iplex.com.au and to learn more about the International and Australasian EPD System visit www.epd-australasia.com.

Iplex Millennium® offers designers with the opportunity to increase the pipeline's service life of 100 years without increasing the wall thickness, providing a greater asset life and 'peace of mind' for the project engineer/system owner.

iPLEX Pipelines

FOR ALL ENQUIRIES AND ORDERS CONTACT IPLEX PIPELINES

WWW.IPLEX.COM.AU

Plumbing and Irrigation **1300 0 IPLEX**

Civil **13 10 86**

Email **info@iplexpipelines.com.au**

V012017