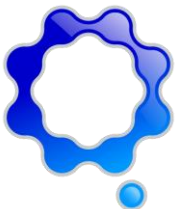




Minimum Performance Requirements of HDPE Pressure Pipes



Qenos Webinar Series
15/06/2021



– Introduction

AS/NZS 4130/4131 requirements

Demonstrating Conformance

Summary



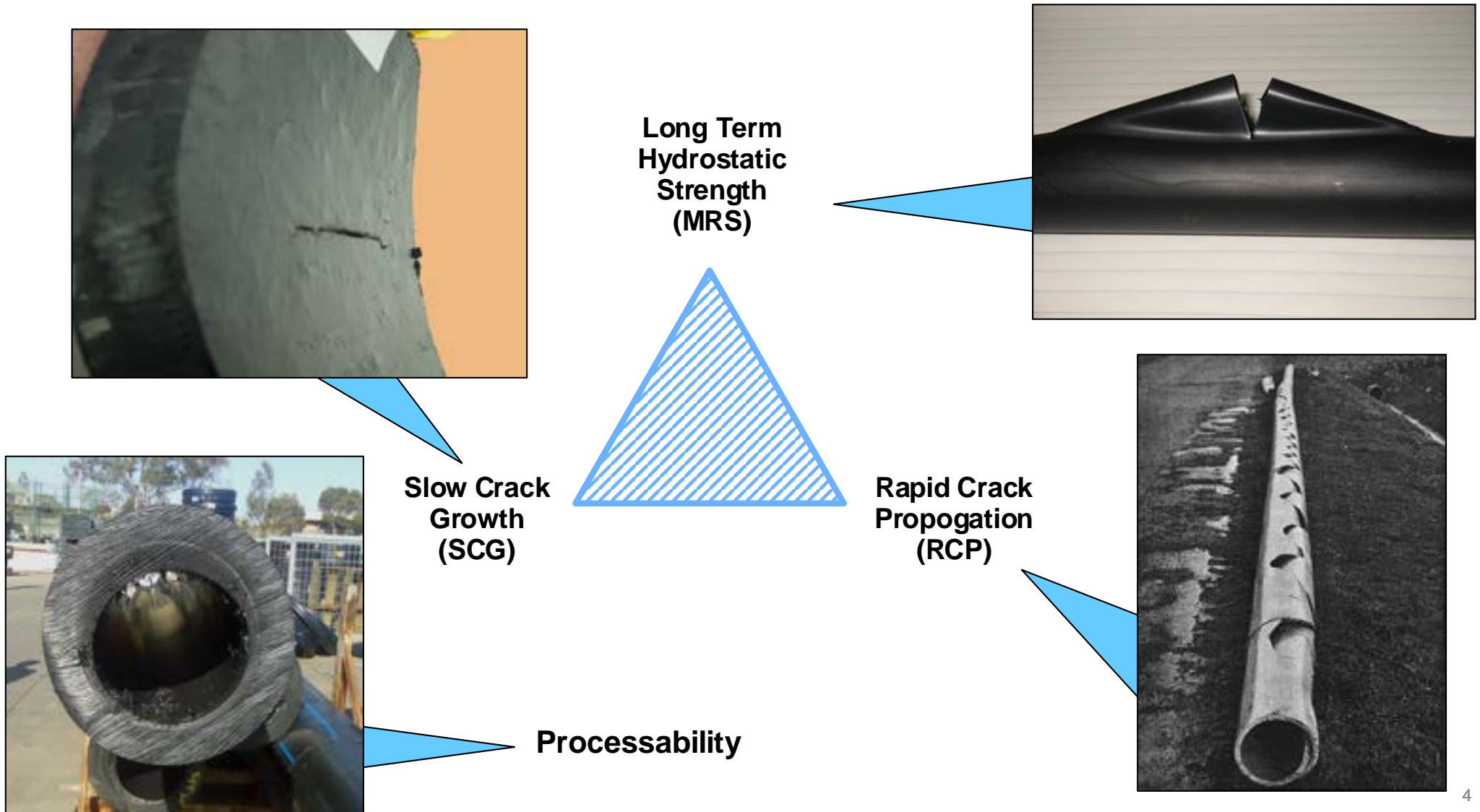
HDPE has emerged in Australia as the leading pipe material in a range of applications



Key benefits: lightweight, flexibility, weldability, toughness, abrasion, corrosion & chemical resistance



PE100 is a demanding pipe specification for pressure applications that is based around a design life of more than 50 years



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HDPE pressure pipes are governed by AS4130 (pipe) and AS4131 (compound) to ensure fitness for purpose



PE100 Compound
AS/NZS 4131:2010
(Type Test Requirements*)



Pipes AS/NZS 4130:2018
(Type Test Requirements*)

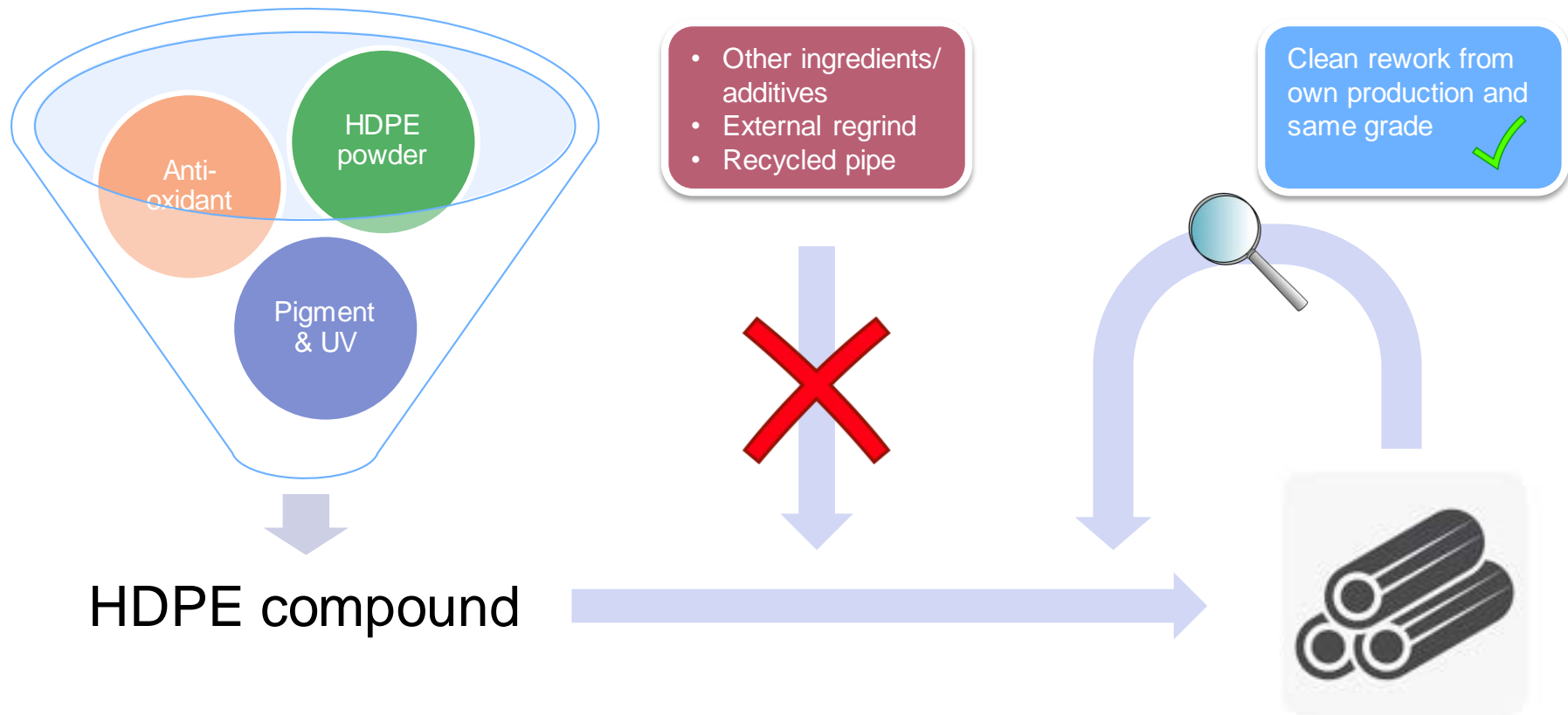
Classification	PE100: MRS >10MPa (@ 20°C)
Composition	HDPE + antioxidant + UV stabiliser + pigment
Dispersion	Agglomerates <60 µm
Volatile content	≤350 mg/kg
Rapid crack propagation	Critical pressure > 1.0MPa
Effect on water	AS 4020 pass
Internal pressure	>165 h (@80°C, @5.4MPa) & >1000 h (@80°C, @5.0MPa)
Thermal stability	>40 min (@ 200°C)
Slow crack growth	>500 h (@80°C, @920kPa)

Classification	PN 3.2 – PN25
Composition	AS 4131 compound (PE100)
Rework	Internal only
Striping	AS 4131 base resin + pigment + UV stabiliser
Dimensional Tolerance	Depending on size ca. 5% wall thickness variation
Effect on water	AS 4020 pass
Internal pressure	>165 h (@80°C, @5.4MPa) & >1000 h (@80°C, @5.0MPa)
Thermal stability	>20 min (@ 200°C)
Slow crack growth	>500 h (@ 80°C, @ 920kPa)

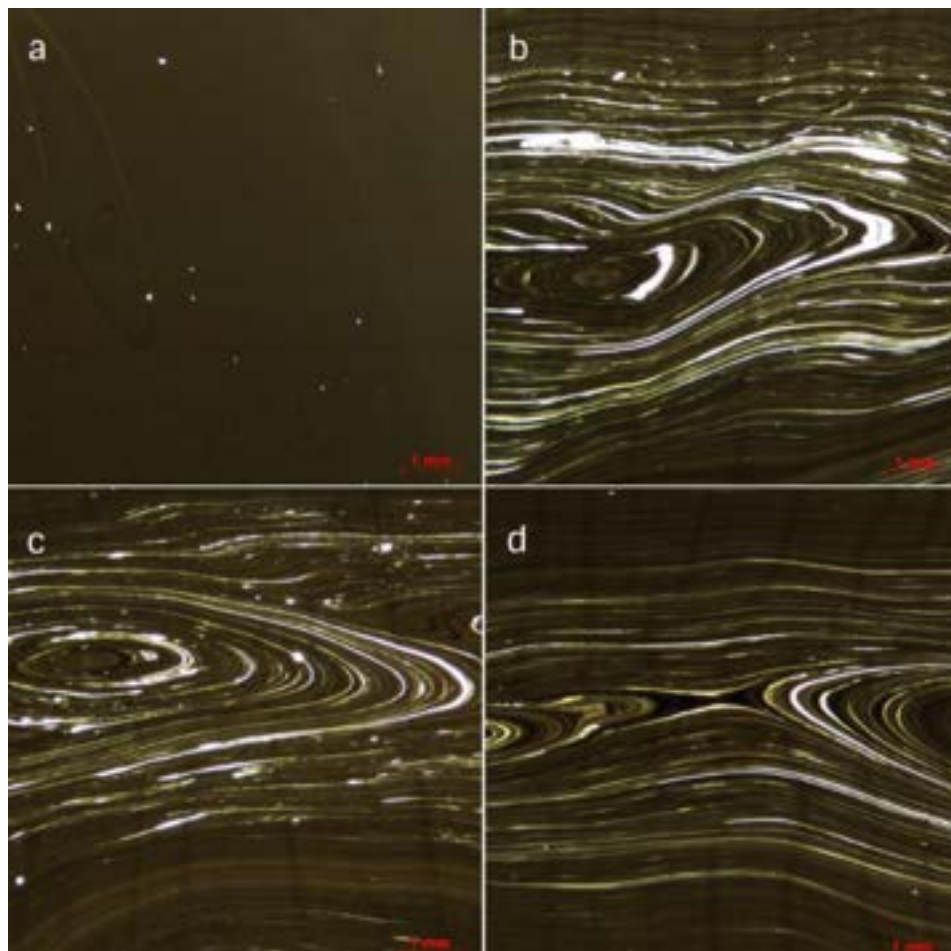
* Non-exhaustive



Only virgin HDPE compounds and internal rework from the same material are permitted inputs for pressure pipes



The prescribed use of a PE100 compound in pressure pipe extrusion ensures good dispersion of the pigment



Microscopy images of 15µm slices (cross-flow) taken from pipe specimens made from:

Sample	Composition*	Extrusion speed
a	PE100 black compound	100%
b	Natural HDPE + CBMB	100%
c	Natural HDPE + CBMB	80%
d	Natural HDPE + CBMB	60%

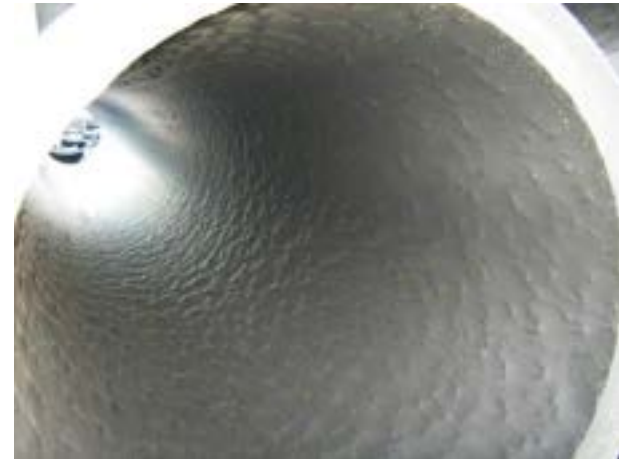
* CBMB = Carbon Black Masterbatch

Source: Deveci et al. "Effect of carbon black distribution on post yield deformation properties of polyethylene pipes for water transport", OzPipe XIX, Sydney, 7-8 November 2019



Ensuring resin is dry prior to extrusion avoids defects

- Carbon black is hygroscopic and will absorb water if PE100 black is stored without adequate precautions for prolonged periods
- Moisture content above 350 mg/kg may cause uneven inner surface and even holes in the pipe wall
- Precautions
 - Protection during transport (liner, manufacturer packaging)
 - Storage inside or in silo (<1 year)
 - Drying with heated dehumidified air prior to extrusion



The decrease in OIT from compound to pipe is a key quality control parameter for PE pipe extrusion to safeguard long term properties

Pipe Compound	Pipe Size	Melt Temperature (°C)	Extruder Throughput (Kg/Hr)	OIT @ 200°C to ISO 11357-6 (Min)
Alkadyne HDF145B	Compound	-	-	80
	DN450 SDR13.6	200	800	78
	DN450 SDR13.6	206	1150	78
Alkadyne HDF193B	Compound	-	-	81
	DN450 SDR13.6	209	800	83
	DN450 SDR13.6	220	1000	74

Pipes made on Battenfeld 120mm line

- Drop in oxidation induction time (OIT) is minimal when turning compound into pipe for a well-controlled extrusion process
- Drop in OIT more important than absolute OIT being above minimum required by standard
- Significant drop in OIT indicates potential consumption of long-term stabilisers and degradation of polyethylene



HDPE pipe compounds are classified by their minimum required strength (MRS)

- A pipe's internal pressure resistance is governed by material MRS:

$$MAOP = \frac{2 \cdot MRS}{C \cdot (SDR - 1)}$$

MAOP = maximum allowable operating pressure in MPa

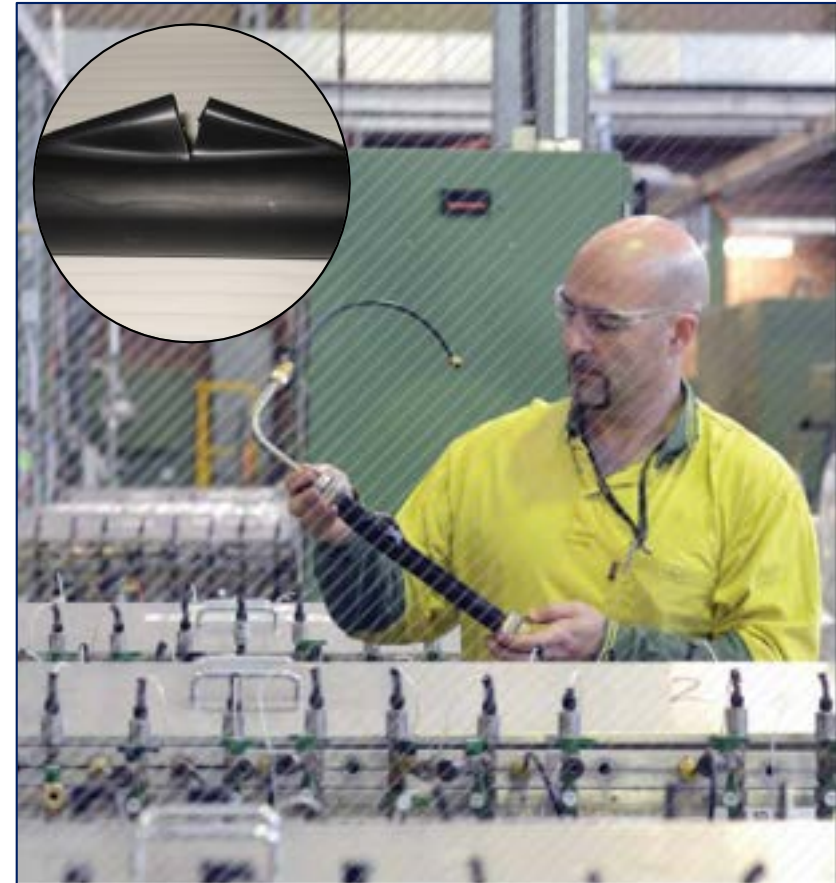
MRS = minimum required strength in MPa

C = safety factor = 1.25

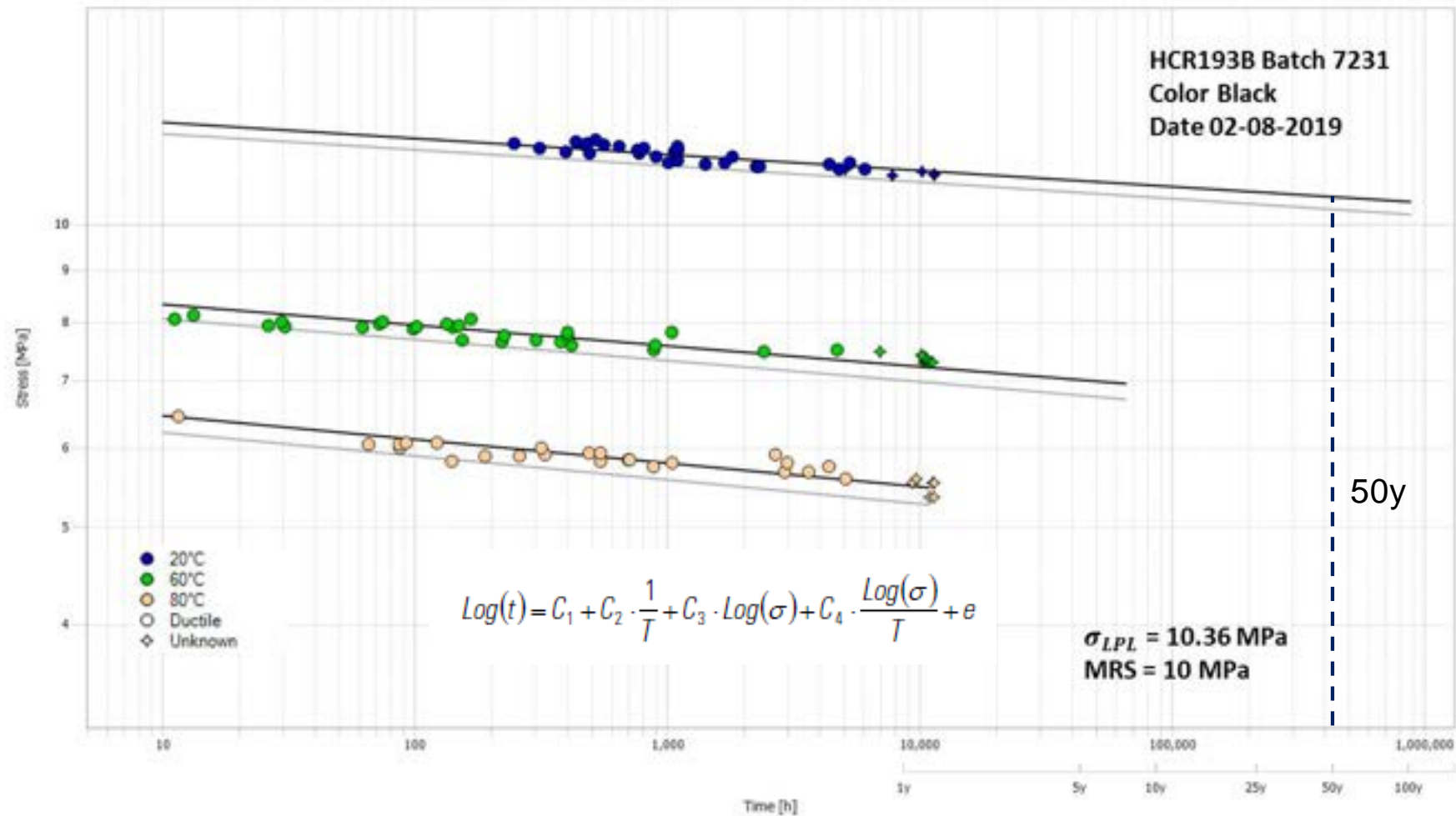
SDR = standard dimension ratio

$$SDR = \frac{\text{outside diameter}}{\text{wall thickness}}$$

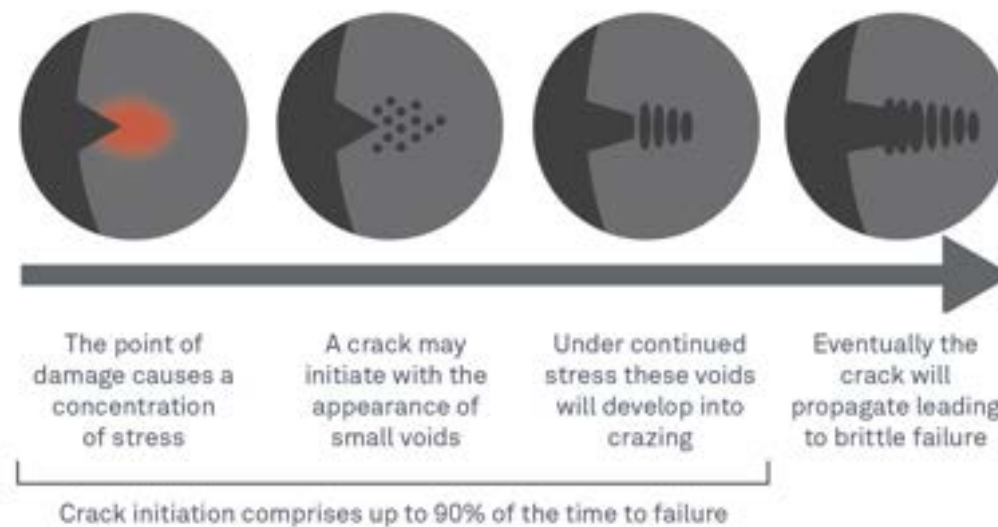
- ISO 9080 regression analysis will allow fitting of data to 4-parameter model
- Minimum 3 temperature required (typically 20°C, 60°C, 80°C)



The ISO 9080 method allows to calculate the strength at 50y at 20°C, which for a PE100 is between 10-11.2 MPa



Slow crack growth failure is the major concern for pipeline integrity, particularly for non-conventional laying techniques

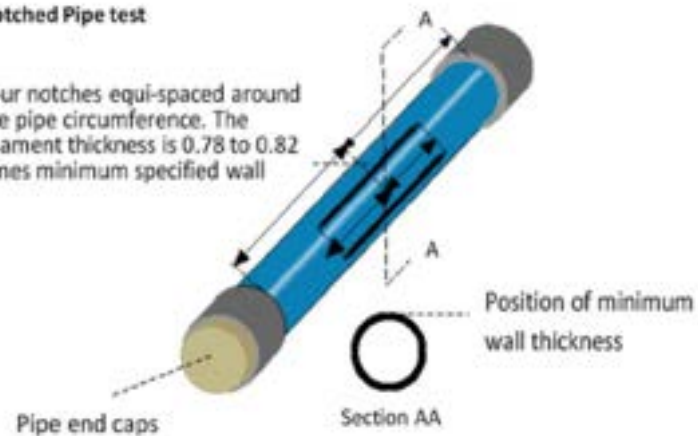


The notched pipe test is the recognized method for benchmarking SCG performance

Slow Crack Growth

Notched Pipe test

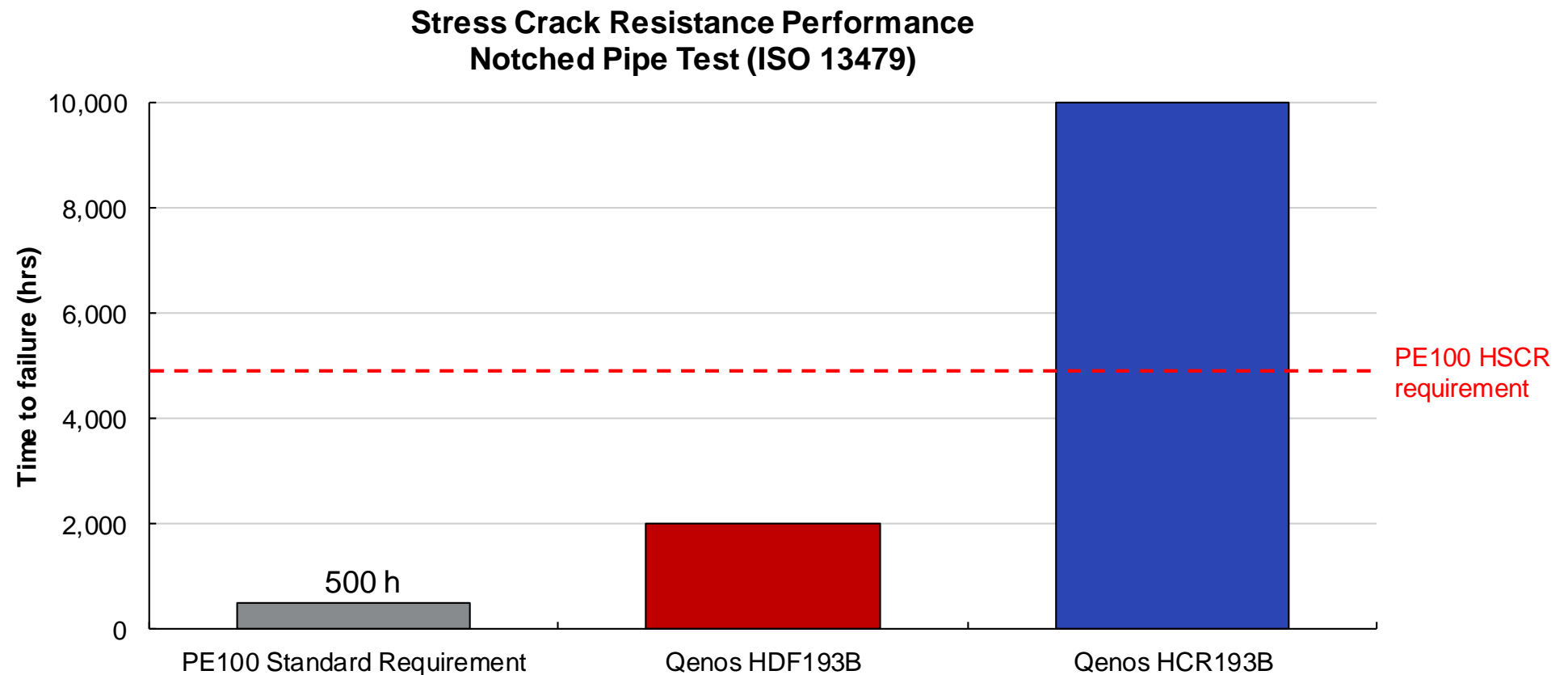
Four notches equi-spaced around the pipe circumference. The ligament thickness is 0.78 to 0.82 times minimum specified wall



- ISO 13479 using SDR11 pipe sample
- 4 notches of 20% depth
- Conditions: $T = 80^{\circ}\text{C}$, $P = 920 \text{ kPa}$ (Hoop stress = 4.6 MPa)



The requirement for PE100 materials is to pass 500h in the Notched Pipe Test



Rapid Crack Propagation failure is relevant for gas pipes at temperatures below zero and high pressures

- A fast growing crack may occur upon impact of a pressurized pipe below a critical temperature and above a critical pressure
- Test methods
 - Full scale (see right)
 - Small-scale steady-state (S4, ISO 13477)
 - Critical pressure of >10 bar at 0°C



S4 test setup



Full scale test with PE 315SDR17



Low slump PE100 is required for pipes with wall thickness exceeding 60mm

- Standard PE100 grades can be used up to 60mm wall thickness
- Example of DN500 PN25 pipe made with:
 - a) Standard PE100
 - b) Low slump PE100
- Control of temperature during extrusion process also critical



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Quality pipe and compound is assured through continued quality monitoring in three test regimes

- Ongoing quality control and assurance is critical to compound and pipe manufacturing processes
- The following test regimes are used to verify conformance of pipe or compound with the standard:

Test	Applies to	Frequency
Type Test (TT)	All requirements	Once or every 5 years, unless change of product
Process Verification Test (PVT)	Some requirements	Every 3 years
Batch Release Test (BRT)	Some requirements (short term tests)	Once per batch and/or time period

- Compound manufacturers will often complement minimum standard test requirements with accelerated BRT tests for long term properties (hydrostatic strength, slow crack growth) and other parameters such as pellet geometry



Minimum periodic QA testing is specified in Australian Standards

Periodic QA requirements for PE pressure pipes and compounds to AS/NZS 4130 & 4131*

Test	Property	Frequency Pipe	Frequency Compound
TT	Effect on water	5 years	5 years
PVT	Internal Pressure	3 years	3 years
	Slow Crack Growth	-	3 years
BRT	Colour	Every batch	Every batch
	Dispersion	Every compound batch	Every batch / week
	Freedom from defects	4 hours	-
	Internal Pressure (165h)	Every batch	-
	Reversion	Every batch	-
	Thermal stability (OIT)	Every batch	Every batch / week
	Dimensions	Every hour**	-
	Melt flow rate	-	Every batch / week
	Density	-	Every batch / week
	Carbon black content	-	Every batch / week
	Volatile content	-	Every batch / week

* Excluding change of composition. ** For diameter and wall thickness and start and end of coil. Other dimensions every 4h.



Third party verification and certification ensures assessment of conformity against minimum standard requirements

- Type Test Certification
 - Carried out by JAS-ANZ accredited certification body
 - Will assess conformance with standard
- Watermark certification through Australian Building Codes Board (ACBC)
 - Principally for plumbing products
- Water Services Association of Australia (WSAA) product appraisal scheme
- PIPA
 - Listing on POP004 for compounds
 - May include verification against temperature derating (POP013) & assessment of high stress-crack resistance (POP016)



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Key takeaways

- PE pressure pipes are always made from a compound containing all required pigments and additives
 - Only internal rework from the same grade is allowed to be incorporated
- Drop in OIT from compound to pipe is a critical parameter for pipe extrusion and should be minimal for a well-controlled process
- Demonstrating conformance is not a once-off exercise but requires daily focus and attention
- Standards describe minimum requirements – excellence in product performance is achieved by outperforming the standards



Useful links

- White paper minimum requirements
 - https://alkadyne.com.au/wp-content/uploads/2020/12/209-qen-wp-hdpe-pressure-pipes_final.pdf
- Technical Centre video
 - <https://youtu.be/ha9kwqRnAhl>
- SAI global registry of certified Qenos Alkadyne pipe grades
 - <https://register.saiglobal.com/client/schedule.aspx?setID=SF01&custID=AS122634&appCertNo=PST20138>
- Slow crack growth video
 - <https://youtu.be/-d3GnV8CugQ>
- Alkadyne website
 - <https://alkadyne.com.au/>

