INTERNATIONAL

NO-DIG

SOUTHAFRICA2018

NO-DIG – Purpose Engineered Pipes

International **No-Dig** Conference

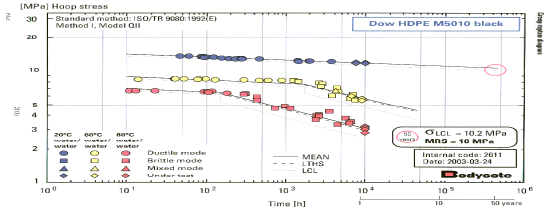
Cape Town International Convention Centre

TT Techniques and HDPE PE100 Pipes

- **TT** techniques: - **HDPE** product of choice because of attributes
- **SASTT** Technical Standards: - **SASTT Part TT1**: Sliplining of pipelines
  - **SASTT Part TT2**: Pipe bursting
  - **specifies SANS 4427** conforming HDPE
- TT Contractors **"go up one class":** - **increases** wall thickness (e) **23%**
  - **cost increases**
  - **capacity decreases**

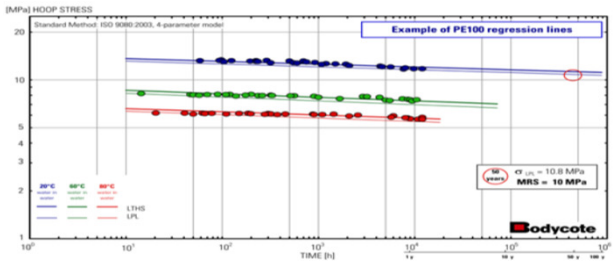
First PE100 Creep Rupture Regression Curves

80° Celsius curve "knee" at about 150 hours



Latest PE100 Creep Rupture Regression Curves

80° Celsius curve no "knee" at over 10 000 hours



Latest PE100 Pipes

- Long term **hydrostatic strength** (ISO 9080): - **no "knee"** before 5,000 hours at 80° Celsius
- Increased **toughness**: - better **SCG** (Slow Crack Growth)
  - better **RCP** (Rapid Crack Propagation)
- **TT** techniques are **aggressiveness**:

- directional drilling	**extreme**
- pipe bursting (2D = 6Q)	**severe**
- close fit swage lining	**aggressive**
- close fit deformed pipe	**tough**
- slip lining DI/concrete	**difficult**

TT demands exceed improved PE100

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Co-Extruded (RPC) Pipe Developed
Engineered to perform damaged

- **TT** some **failures** despite 1,23e: - where **"ordinary" PE100** used
- **TT** short and long term **damage**: - to installed **pipes**
- **TT** requires pipe whose service life is **unaffected**: - by **external damage** caused
- **TT** requires pipe whose service life is **unaffected**: - by **imposed point** loads
- **PAS 1075** "Pipes made from polyethylene for AIT": - **service lifetime preserved** damaged

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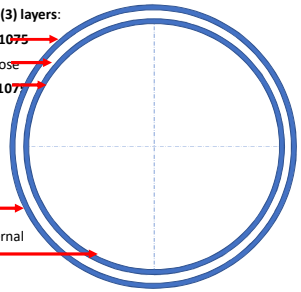
Co-extruded (RPC) Pipe Cross-Section

- RPC pipes (e according to SANS 4427) have **three (3) layers**:
  - PE100-RC outer layer according to **PAS 1075**
  - **PE100** pipe wall core designed for purpose
  - PE100-RC inner layer according to **PAS 1075**
- Layers **inseparably bonded**, fused together by co-extrusion
- **Outer layer** (2.5 mm min.) protects pipe from **external damage**
- **Inner layer** (2.5 mm min.) protects pipe from external point loads that initiate **cracks on the inner wall**



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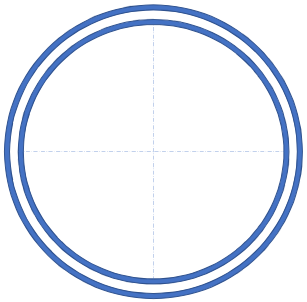
Co-extruded (RPC) Pipe Cross-Section

- RPC engineered with **Borealis'**, world renowned polymer manufacturer, PE100-RC technology
- RPC pipes require **specialised manufacturing** equipment
- RPC **locally made TT** pipe since 2015
- RPC , IAW Borealis, engineered specifically for **local TT** market



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Comparison of Attributes – RPC about 5 x PE100

- **RPC** pipes are **superior** to PE100 pipes because of **PE100-RC layers**
- The **SCG, notch and point load** properties of **PE100-RC** are **superior** to **PE100** (SANS 4427)

TEST	PE100 - hours	PE100-RC - hours
Notch Pipe Test (NPT)	2 200	11 580
Full Notch Creep Test (FNCT)	1 600	8 552*
Point Load Test (PLT)	2 200	>9 000

*NB: Ductile failure not brittle failure

- Pipes pass **PAS 1075 rigorous tests**:

FNCT (Full Notch Creep Test ISO 16770)
PLT (Point Load Test Hessel Ingenieurtechnik)
TAT (Thermal Ageing Test DVS 2205-1:19)
PT (Penetration Test DIN 8075)
NPT (Notch Pipe Test ISO 13479)

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PAS (Publicly Available Specification) 1075

Pipes made from Polyethylene for AIT (Alternative Installation Techniques)

TEST	REQUIREMENT	RPC RESULT
Full Notch Creep Test (FNCT)	>8 760 hours (80° C; 4 N/mm²)	8 552* hours
Accelerated Creep Test (ACT)	>320 hours (90° C; 4 N/mm²)	926 hours
Point Load Test (PLT)	>8 760 hours (80° C; 4 N/mm²)	>9 000 hours
Thermal Ageing Test (TAT)	>100 years at 20° Celsius	>100 years
Penetration Test (PT)	Test stress = Design Stress (σ)	Test stress > Design Stress (σ)
Notch Pipe Test (NPT)	>8 760 hours	>11 580 hours
Melt Flow Rate (MFR)	0.2 to 0.4 g/10 minutes	0.26 g/10 minutes

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PE100-RC Material Approval Tests

Raw Material Manufacturer – ISO 17025 Laboratory

TEST	REQUIREMENT	STANDARD
Full Notch Creep Test (FNCT)	>8 760 hours (80° C; 4 N/mm²)	ISO 16770
Point Load Test (PLT)	>8 760 hours (80° C; 4 N/mm²)	J. Hessel
Thermal Ageing Test (TAT)	>100 years at 20° Celsius	DVS 2205-1 supp. Sheet 19
Notch Pipe Test (NPT)	>8 760 hours	ISO 13479
Density	≥ 945 kg/m³	ISO 1138/ISO 1872-1
Melt Flow Rate (MFR)	0.2 to 0.4 g/10 minutes	ISO 1133

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PE100-RC Material Quality Assurance

Raw Material Manufacturer Verifies Stress Crack Resistance – COA

TEST	REQUIREMENT	INTERNAL	EXTERNAL
Full Notch Creep Test (FNCT)	>8 760 hours or 320 hours for ACT procedure (80° C; 4 N/mm²)	Each batch	
Point Load Test (PLT)	>8 760 hours (80° C; 4 N/mm²)		Every 3 years
Notch Pipe Test (NPT)	>8 760 hours		Staggered 1 to 3 years

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TT Pipe Approval Testing
Raw Material Manufacturer – ISO 17025 Laboratory

TEST	REQUIREMENT	STANDARD
2NCT (Two Notch Creep Test)	>3 300 hours (80° C; 4 N/mm²; 2% Arkol N-100)	110 SDR 11 Smallest and largest wall thickness (e)
Point Load Test (PLT)	>8 760 hours (80° C; 4 N/mm²; 2% Arkol N-100)	J. Hessel
Penetration Test (simulates sharp fragment of burst cast iron pipe)	Residual wall thickness after 9 000 hours > 50% of original wall thickness	DVS 2203-4; Supplementary sheet 3

TT Pipe Quality Control
Pipe Manufacturer – ISO 17025 Laboratory

TEST	REQUIREMENT	FREQUENCY
2NCT or FNCT on 3 samples	>3 300 hours (80° C; 4 N/mm²; 2% Arkol N-100) or correlated to ACT procedures	Every 6 months or yearly per manufactured group
Point Load Test (PLT)	>8 760 hours (80° C; 4 N/mm²; 2% Arkol N-100)	Manufactured groups 1 and 2 annually, manufactured group 3 every 3 years

Conclusions

- **PE100** substantial improvements — - TT techniques **requirements exceed improvements**
- **PAS 1075** standard — - TT techniques **specifically engineered pipes**
- Pipeline **service life** — - **>100 years** damage notwithstanding
- Pipeline **owner** — - **investment preserved**
- **Consulting Engineer** — - specifies the **specifically engineered pipes**
- TT **Contractor** — - specifically engineered product **reduces defect risk**
- **RPC pipes** — - **manufactured in South Africa**

Many Thanks for Your Attention
Are there any questions?

Improvements PE100 Polymer – σ = MRS/C

POLYMER DESIGNATION	MINIMUM REQUIRED STRENGTH (MRS) – MPa	DESIGN COEFFICIENT (C)	ALLOWABLE DESIGN STRESS (σ) – MPa
1st GENERATION – (PE63)	6.3	1.25	5.0
2nd GENERATION – (PE80)	8.0	1.25	6.3
3rd GENERATION - (PE100)	**10.0**	**1.25**	**8.0**

RPC Pipe Diameters, SDR (PN) and Lengths

OD mm	LENGTH m	PIPE MINIMUM WALL THICKNESS (e) mm SANS 4427		
		SDR 11 (PN 16)	SDR 13.6 (PN 12.5)	SDR 17 (PN 10)
110 - 180	100	10.0 – 16.4	8.1 – 13.3	6.6 – 10.7
110 – 250	12	10.0 – 22.7	8.1 – 18.4	6.6 – 14.8

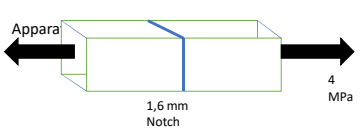
SLOW CRACK GROWTH: FNCT (Full Notch Creep Test)

- **External** scratches, notches, gouges, cuts - **TT** techniques
- Cut specified notch (**ISO 16770**) plane - around **4 sides** of sample in same
- Depth of notch (n) **1,6 mm** - **17%** ±2% of sample thickness
- **Clamp** sample in jaws - of test apparatus
- **Immerse** sample in test tank - water solution **80° Celsius**
- Water **solution** - **2% Arkopal** (wetting agent)
- Apply constant **tensile stress** - **4 N/mm²** ± 0,02 N/mm²
- **Record** - **time** to failure

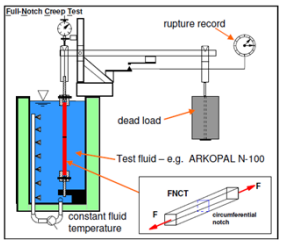
Time to failure - shall be **not < 8,760 hours** (1 year)

SLOW CRACK GROWTH: FNCT (Full Notch Creep Test)

Notched sample 110 x 10 x 10 mm



Test



STRESS CRACK INITIATION: PLT (Point Load Test)

- Point load (rock impingement) **no embedment** - creates stress at pipe **inner wall**
- **Pressurise** sample - **maximum** rated pressure
- **Immerse** maximum pressurised sample - in **2% Arkopal solution at 80° Celsius**
- Press **10 mm diameter** piston into sample **Yield** wall - displacement sufficient to produce **Stress** at inner
- **Time** to failure - shall be **not < 8,760 hours** (1 year)

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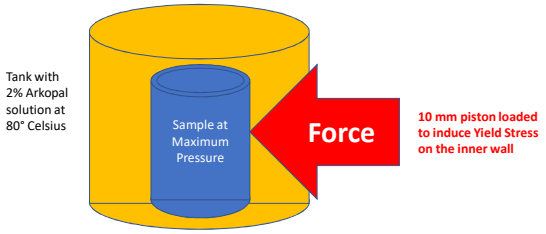
STRESS CRACK INITIATION: PLT (Point Load Test)

Test conducted by Hessel Ingenieurtechnik (Dr. Hessel)



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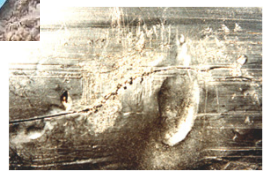
External Point Loads



Laboratory PLT test

Pipe outer surface

Pipe inner surface

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STRESS CRACK INITIATION: PLT (Point Load Test)

- **Plot PLT and FNCT** time to failure - **log/log graph** in hours
- Draw **LCL** (Lower Confidence Limit) Curve - **97.5% LCL** (2.5% failure probability)
- Time to **thermal ageing** - **8,760 hours** (1 year) at 80° Celsius
- Draw **PLT 8,760** hour line - **intersect** with 97.5% LCL line
- Record **FNCT time at intersection** - shall **not be less than 3,300 hours**
- With sample at **maximum pressure** - and **Yield Stress** at point load
- If FNCT **not less than 3,300 hours** - pipe life **not < 100 years** without selected or imported embedment

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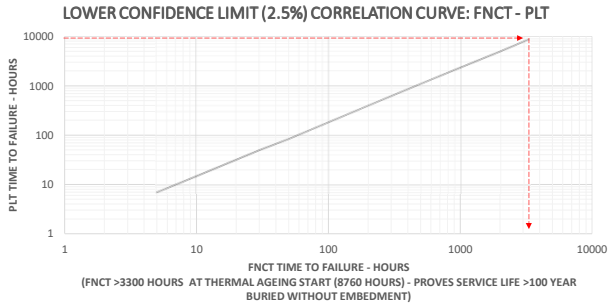
CORRELATION PLT and FNCT



THERMAL AGEING: TAT (Thermal Ageing Test)

- **Temperature and stress** causes ageing - **Mechanical creep** (Stress)
  - **SCG** (Environmental Stress Cracking)
  - **Thermo-oxidative** ageing (TAT)
- **Thermal stability** of the pipe - **pipe service life** under thermal ageing effect
- **32 mm OD SDR 11** (PN 16) - **PE 100-RC** material sample
- **Temperatures** of circulating water - **80° C; 90° C; 100° C; 110° Celsius**
- **Overpressure** - **1,0 bar** (100 kPa)
- **Activation energy** for thermal ageing - **rupture times** and **Arrhenius Law**

- Thermal ageing at LCL of **100 years at 20° C** - **extrapolation** using Arrhenius Law

ARRHENIUS LAW – reaction rate temperature dependence

- **Svante Arrhenius** (1859-1927) Swedish - Nobel Prize winning **physicist and chemist**
- **Chemical** and **physical** (creep) processes - overcome energy barrier "**activation energy**"
- Relationship between **Rate Constant (k)** - **Activation energy (E_A)** and **absolute temp (T)**

$$k = const.\ exp.\ (-E_A / R\ .\ T)$$

- **R** = universal gas constant
- To **extrapolate**, insert difference between - **test temp. (T_T)** and **service temp. (T_S)**

$$\Delta T = T_T - T_S$$

- **Extrapolation Factor (E_F)** for pipe service life

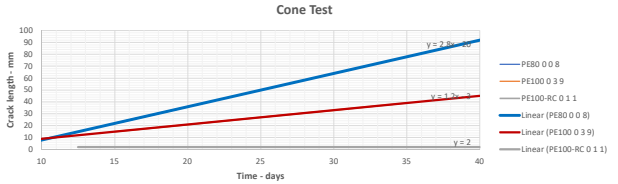
$$E_F = exp.\ [(E_A\ .\ \Delta_T) / R]$$

- Correlation between **time-to-failure** - at **test temp. (t_T)** and **service temp. (t_S)**

Actual Service Life $t_S = E_F\ .\ t_T$

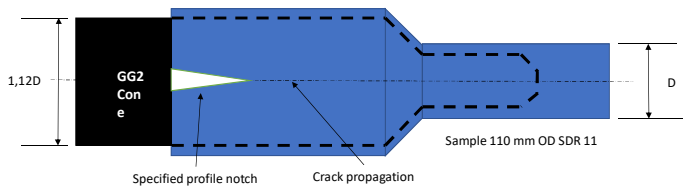
SLOW CRACK GROWTH: PT (Penetration Test)

- Damage from sharp **pipe bursting** fragments - **cast iron, earthenware**, CAF, pitch fibre
- Cut specified profile **notch** - one end of **110 mm OD SDR 11** sample
- Press standard **GG2 cone** (1.12 x OD) - into **notched end** of sample
- Record time to start of **crack initiation** - **crack propagation** speed (PE100-RC none)



SLOW CRACK GROWTH: PT (Penetration Test)

Record time to crack initiation and speed of crack propagation



SLOW CRACK GROWTH: NPT (Notch Pipe Test)

- Penetration from **directional drilling** - **chert**, dolomite, quartz, granite, shale
- Cut 4 longitudinal notches **(ISO 13479)** sample - **equally** circumferentially around
- Remaining wall thickness **0,78e to 0,82e** - **notch 0,22e to 0,18e**
- Clamp **end caps** on sample - without end load restraint
- **Immerse** sample in test tank - **80° Celsius**
- Apply constant **pressure** - **4,6 N/mm²**

- **Time** to failure - shall be **not < 8,760 hours** (1 year)

SLOW CRACK GROWTH: NPT (Notch Pipe Test)

4 Specified Longitudinal Notches spaced equally circumferentially around the sample