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WEBINAR VIII

21-10-2021

Thermoplastic Pipe Systems:

Important aspects to understand and keep in mind during design and specification

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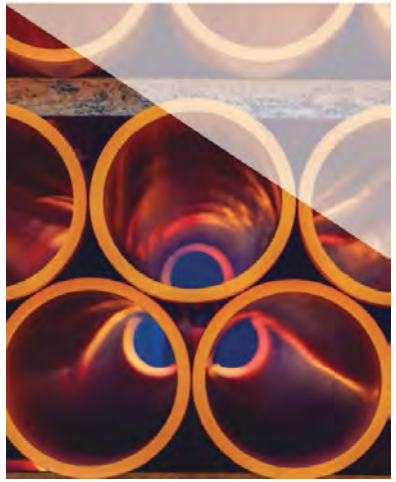

IFPA
Installation and Fabrication Plastics Pipe Association

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THE FUTURE OF WORK – CHALLENGE OR OPPORTUNITY?

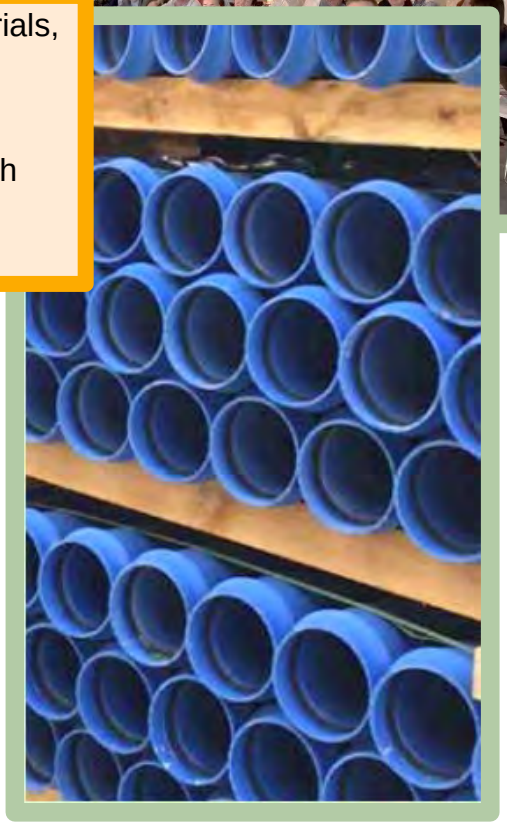
zoom Video Conferencing

SAPPMA Webinar VIII

Thermoplastic Pipe Systems –PVC-O

The presentation explains how the two dominant thermoplastic pipe materials, PVC and PE, have undergone significant improvements since their introductions in 1935 and 1955 respectively.

The basis of the increase in PVC-O's strength is explained together with design considerations, the manufacturing process, QA/QC systems, environmental innovations and installation considerations.



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Improvement in Thermoplastic Pipe Technology

PARTICULARLY PVC-O

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1865 RED FLAG ACT
1896, 31 years later, Act repealed

Material Strength Improvement

1936 First major PVC pipe project – Berlin Olympic Stadium

APPROXIMATE MATERIAL INCREASES			
Common Construction Material	Initial Allowable Design Stress MPa	Current Allowable Design Stress MPa	Allowable Design Stress Increase %
Steel	140	350	**150**
Concrete	21	60	**185**
PE	3,2	8,0	**150**
PVC	**10**	**36**	**260**

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PVC Pressure Pipe Systems 1935 – 2021

Note: PVC-U and **PVC-M –** as **C** decreases **σ** increases (**σ = MRS/C**)

PVC Type	Applicable Standard SANS	OD (mm)	Pressure (bar)	MRS (MPa)	Design Coefficient C	Design Stress σ (MPa)
PVC-U	966-1	16 – 90	4 to 20	**25**	**2,5**	**10**
PVC-U	966-1	110 – 630	6 to 20	**25**	**2,0**	**12,5**
PVC-M	966-2	50 – 630	6 to 25	**25**	**1,4**	**18**
PVC-O	**16422**	**110 - 800**	**10 to 25**	**50**	**1,4** or 1,6 or 2,0	**36** or 32 or 25

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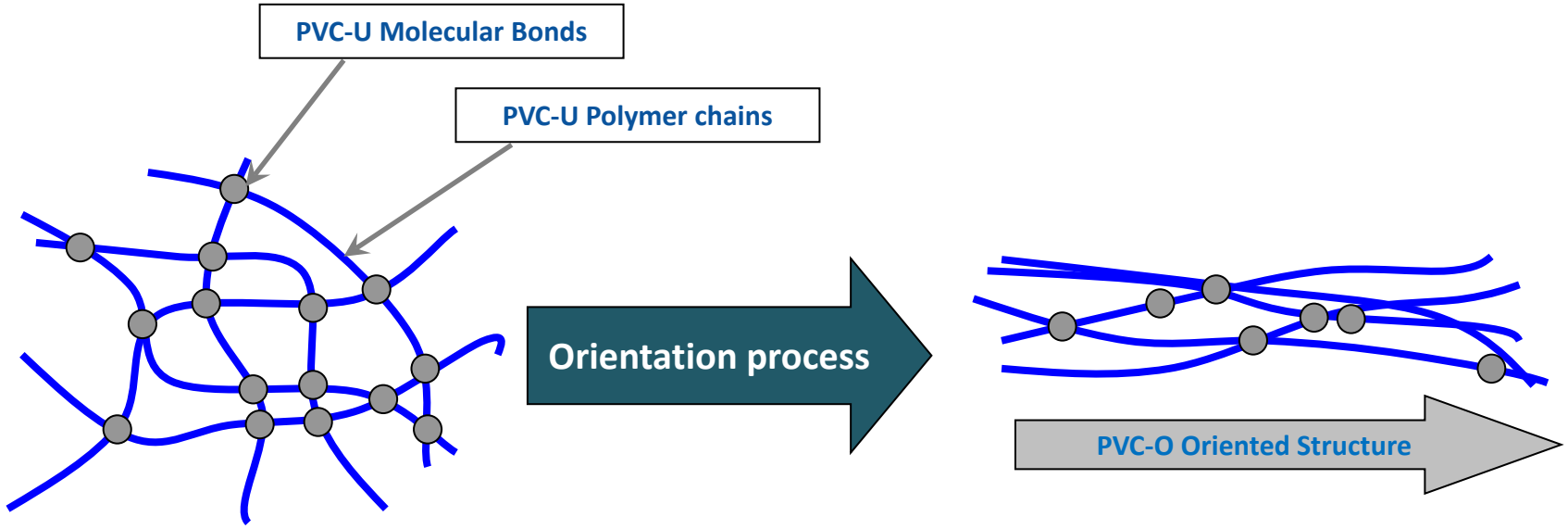
Molecular Orientation

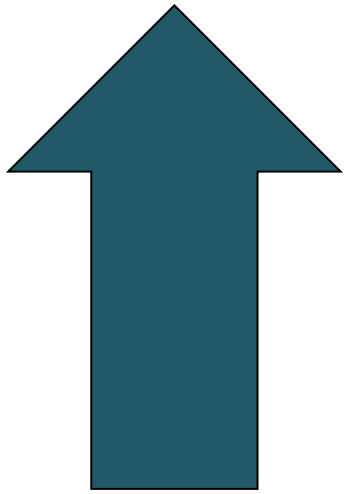
SANS 16422: PVC-O states, "Molecular Orientation of thermoplastics results in improvement of physical and mechanical properties. Orientation is carried out at temperatures well above the glass transition temperature".



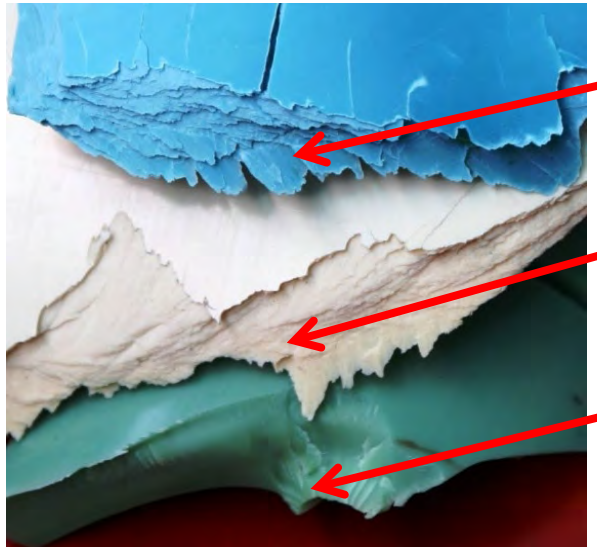
Molecular Orientation DOES NOT change chemical properties

Molecular Orientation

Laminar Structure



Amorphous Structure



PVC-O Classification 500
Laminar structure well defined

PVC-O Classification 400
Laminar structure

PVC-U
Amorphous (not clearly defined) structure

MRS (Minimum Required Strength) determines Material Classification

“Classification” is NOT pressure “Class”

Modified Structure cf. Altered Molecular Structure

- Cast Iron cf. DI – both **iron**
- Cast Iron cf. DI – magnesium **modifies DI mechanical properties**

- PVC-U cf. PVC-M – both **PVC**
- PVC-U cf. PVC-M –**PVC-M modified impact strength; "behaves" tough**

Impact modified PVC-M – DOES NOT increase resistance to cyclic loading

- Coal cf. Diamonds – both **carbon**
- Coal cf. Diamonds – heat and pressure **alters molecular structure**

- PVC-U cf. PVC-O – both **PVC**
- PVC-U cf. PVC-O – heat and pressure **alters molecular structure**

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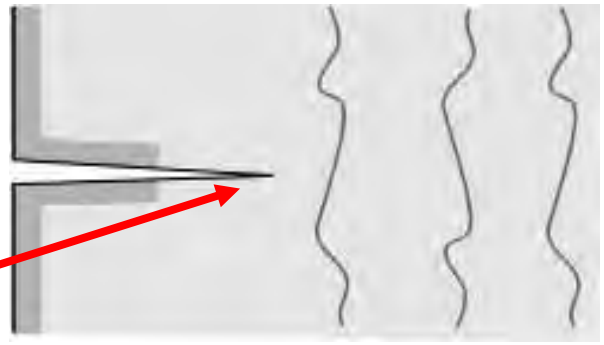
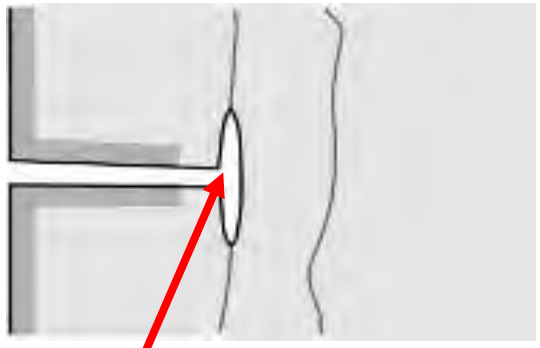
Toughness Mechanism of PVC-O

- **Laminar structured** materials are tough
  - PVC-O **altered molecular structure**
- Crack stress **opens layer interface**
  - crack **blunted**; crack tip increases; **reduces "stress concentration"**

High **"stress concentration"** at microscopic crack tip

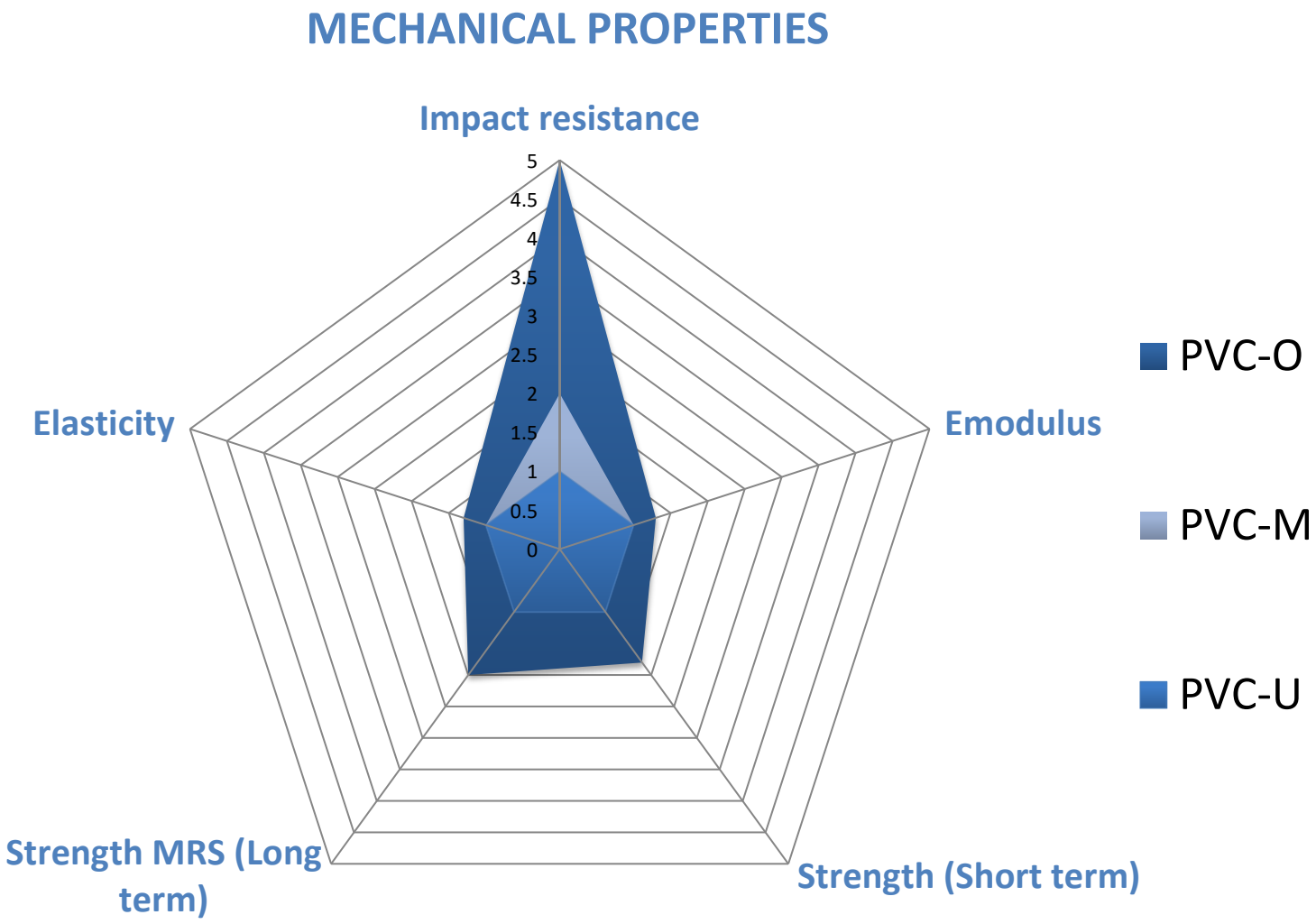


Laminar structure



Molecular interface opens; **reduces "stress concentration"**; prevents failure

PVC Mechanical Properties Matrix



SANS 16422 PVC-O Standard Classifications

Annex A: MRS (Minimum Required Strength) and **C** (Design Coefficient)

Annex B: Socket length for applicable Allowable Design Stress **σ** = MRS/**C**

Applicable PVC-O Standard	ISO 9080 MRS (MPa)	ISO 12162 Classification Designation	ISO 12162 Design Coefficient **C**	Allowable Design Stress **σ** (MPa)
SANS 16422	31,5	315	1,6 or 2,0	20 or 16
SANS 16422	35,5	355	1,6 or 2,0	22 or 18
SANS 16422	40	400	1,6 or 2,0	25 or 20
SANS 16422	45	450	1,4 or 1,6 or 2,0	32 or 28 or 23
SANS 16422	**50**	**500**	**1,4** or 1,6 or 2,0	**36** or 32 or 25

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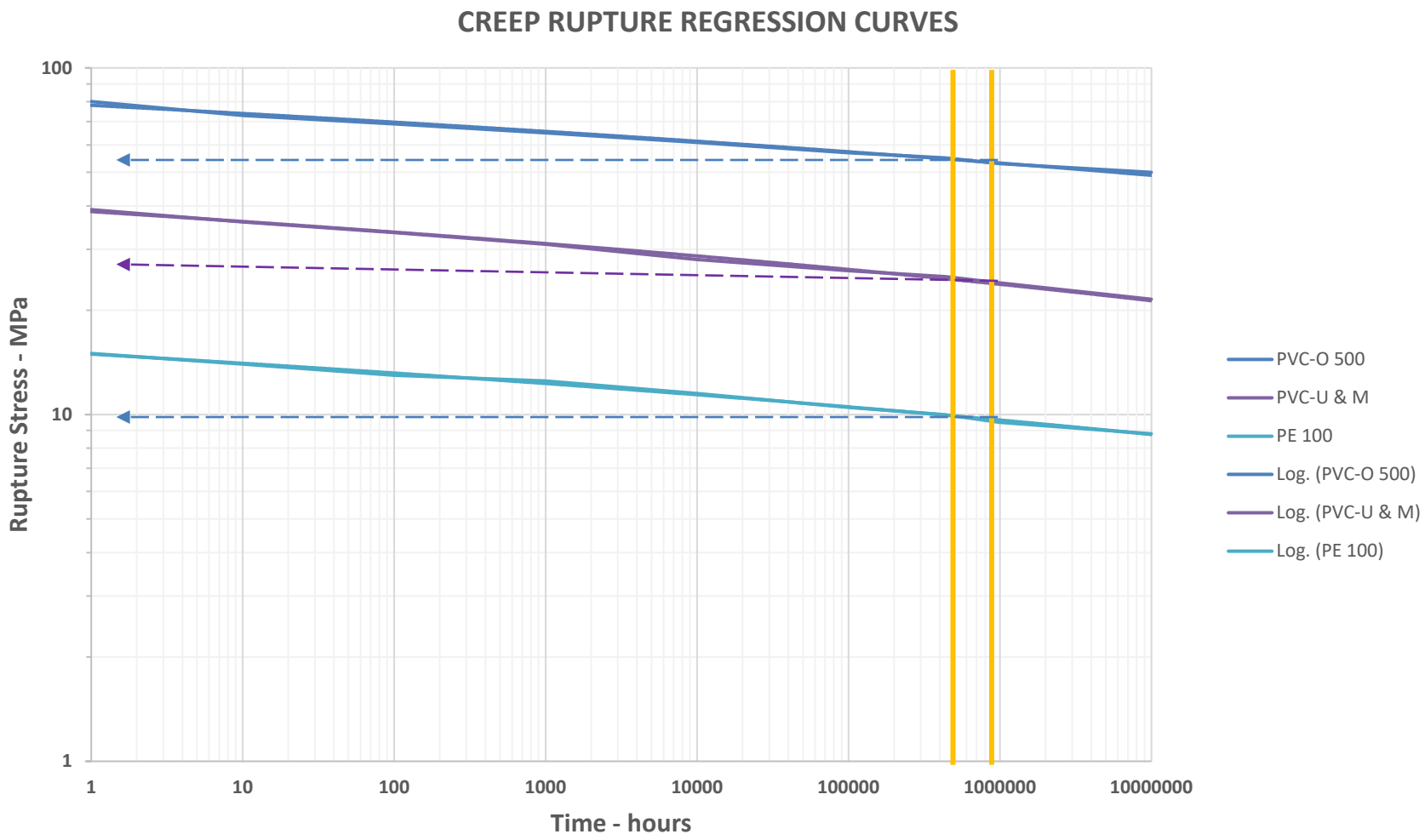
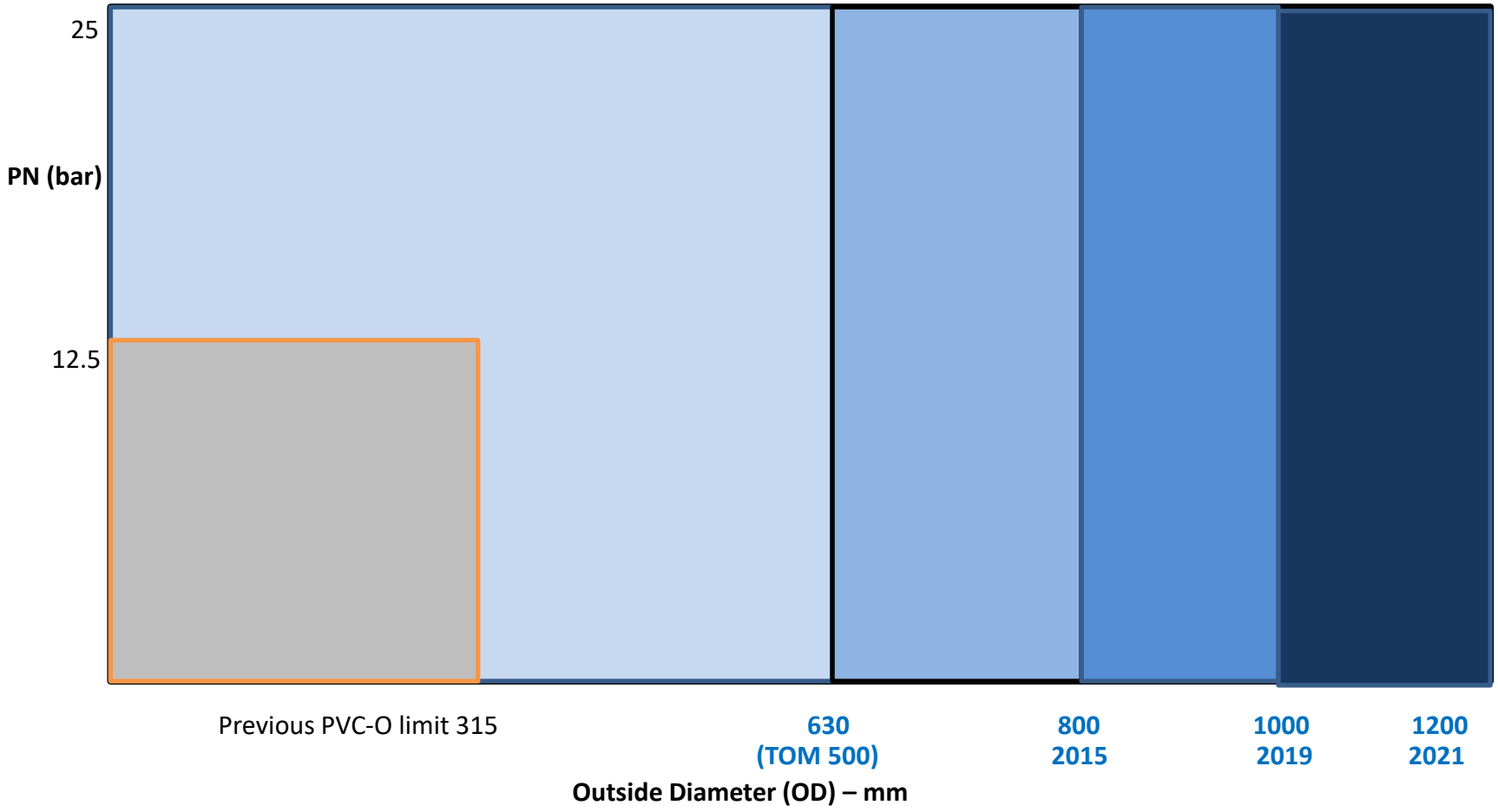
Creep Rupture Regression Curves - 20°C

PE, PVC-U, PVC-M and PVC-O (Classification 500: MRS 50 at 50 Years)



PVC-O (TOM500®) Size and Pressure Range

Improved in-line molecular orientation technology made increases possible



PVC-O (TOM500®) Diameters and Pressures

OD		PN 12.5		PN 16		PN 20		PN 25	
Min	Max	Min e	Ave ID	Min e	Ave ID	Min e	Ave ID	Min e	Ave ID
110.0	110.4	2.2	104.4	2.4	104.0	3.1	103.2	3.8	101.4
140.0	140.5	2.8	133.0	3.1	132.4	3.9	131.2	4.8	129.2
160.0	160.5	3.2	152.0	3.5	151.4	4.4	150.0	5.5	147.6
200.0	200.6	4.0	190.0	4.4	189.2	5.5	187.4	6.9	184.4
225.0	225.7	4.5	213.6	5.0	212.8	6.2	210.8	7.7	207.4
250.0	250.8	5.0	237.4	5.5	236.4	6.9	234.2	8.6	230.6
315.0	316.0	6.3	299.2	6.9	298.0	8.7	295.2	10.8	290.6
355.0	356.1	6.2	337.4	7.8	336.0	9.8	332.4	12.2	327.2
400.0	401.2	8.0	379.8	8.8	378.4	11.0	374.8	13.7	369.0
450.0	451.4	7.9	427.6	9.9	426.0	12.4	421.4	15.4	415.0
500.0	501.5	9.9	474.6	11.0	472.8	13.7	468.6	17.1	461.2
630.0	631.9	12.6	597.8	13.8	595.8	17.3	590.4	21.6	581.0
710.0	712.0	14.2	681.6	15.4	679.2	19.2	671.6	24.4	654.7
800.0	802.0	16.3	760.4	17.4	757.8	21.6	750.4	27.4	733.0
900.0	902.7	15.7	855.4	19.6	850.6	24.3	839.5	30.9	824.1
1000.0	1003.0	17.5	950.5	21.7	945.1	27.0	932.8	34.3	915.6
1100.0	1103.3	-	1045.5	-	1039.6	-	1026.1	-	1007.2
1200.0	1203.6	21.1	1140.6	26.2	1134.1	32.4	1119.4	41.4	1098.8

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HDPE, PVC-U, PVC-M and PVC-O Pipe Design

FIRST PVC-O CONSIDERATION – CAPACITY

- **Barlow's Formula** computes minimum wall thickness (e):

$$e = \frac{P \times OD}{2\sigma_s + P}$$

P = Pressure (MPa)

OD = Outside Diam. (mm)

Material	Design stresses (σ_s)	Standard
PE 100	σ_s = 8 MPa	– (SANS 4427)
PVC-U	σ_s = 12,5 MPa	– (SANS 966-1)
PVC-M	σ_s = 18 MPa	– (SANS 966-2)
PVC-O	σ_s = **36**, 32 or 25 MPa	– (SANS 16422)

- **PVC-O** cf. HDPE – ID +17%; CSA +37%; V +10%; Q +51%
- **PVC-O cf. PVC-M** **– ID +5%; CSA +9%; V +3%; Q +12%**

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Low Celerity=Low Surge Pressure ($\Delta P = \alpha \Delta V/g$)

SECOND PVC-O CONSIDERATION – SURGE

PVC-O α = PN12.5 – 281; PN16 – 318; PN20 – 356; PN25 – 398. Total ΣP = 2PN – CEN 15223

Pipe Material DN 500 mm	E – Modulus MPa	Wall Thickness (e) mm	Celerity (α) m/s
Ductile Iron	170 000	9	**1140**
Steel	210 000	5	**970**
GRP	20 000	7	**460**
PVC-M	3 000	21,3	**363**
PE	1 000	45,4	**360**
PVC-O	**4 000**	**13**	**318**

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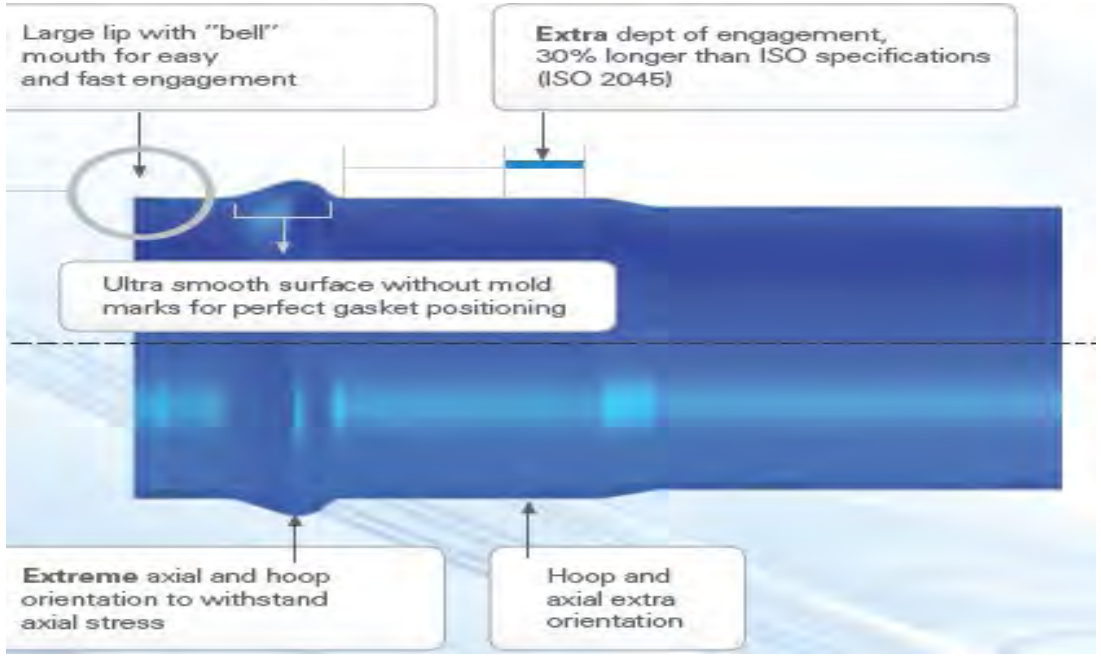
TOM500® Socket Details – length using σ

THIRD PVC-O CONSIDERATION – SOCKET

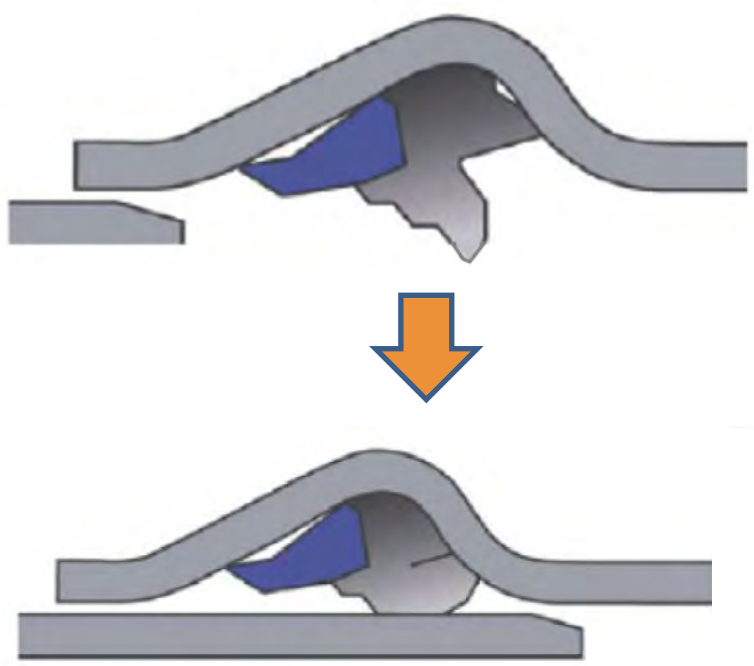
- **Simultaneously** formed during orientation – no reheat and expand
- **Extreme** orientation seal housing – withstands stress
- **Extra** orientation socket – prevents deformation
- **Socket** length 30% more than ISO 2045 – absorbs deformation
- **Longer** lip length with belled entry – fast and easy insertion



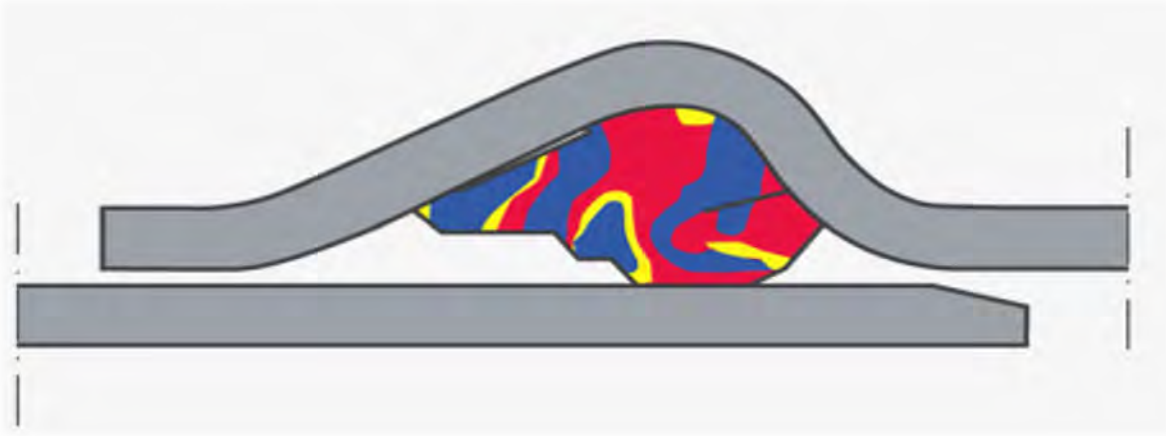
TOM500® VRR Anger-Lock Seal Details

FORTH PVC-O CONSIDERATION – SEAL

- **Negative pressure** capacity (ISO 13844) – SANS 16422 13.3 **-0.8 bar** test + D.2
- **25 bar** pressure seals – **all** pipes
- **EPDM VRR** Anger-Lock seal – **lip** and compression
- **Double** ring gasket – **retains and seals** joint
- **PP** rigid retaining ring – prevents **dislocation**
- **Seal** fills housing – accommodates **deformation**



Seal design and Function



Embedded Energy – Thermoplastic Pipes

FIFTH PVC-O CONSIDERATION – EMBEDDED ENERGY

Definition: "**Embedded energy – all energy** consumed by **all processes** associated with **raw material manufacture** and **pipe production**."

EMBEDDED ENERGY	
Pipe Material	**Energy – kWh**
DI	**419**
STEEL	**319**
PE 100	**83**
PVC-U	**70**
PVC-M	**50**
PVC-O	**30**

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PVC-O (TOM500®) Superior Hydraulics

SIXTH PVC-O CONSIDERATION – FRICTION FACTOR

Pipe Material	Prandtl-Colebrook (k) – mm		Hazen-Williams (C)		Manning (n)	
	New	Old	New	Old	New	Old
DI	0,030	0,200	130	115	0,012	0,017
Concrete	0,300	3,000	120	100	0,013	0,017
Steel	0,030	0,100	125	107	0,008	0,011
PE	0,005	0,030	150	140	0,007	0,009
PVC-O	**0,003**	**0,060**	**150**	**140**	**0,007**	**0,009**
GRP	0,030	0,060	130	100	0,009	0,010

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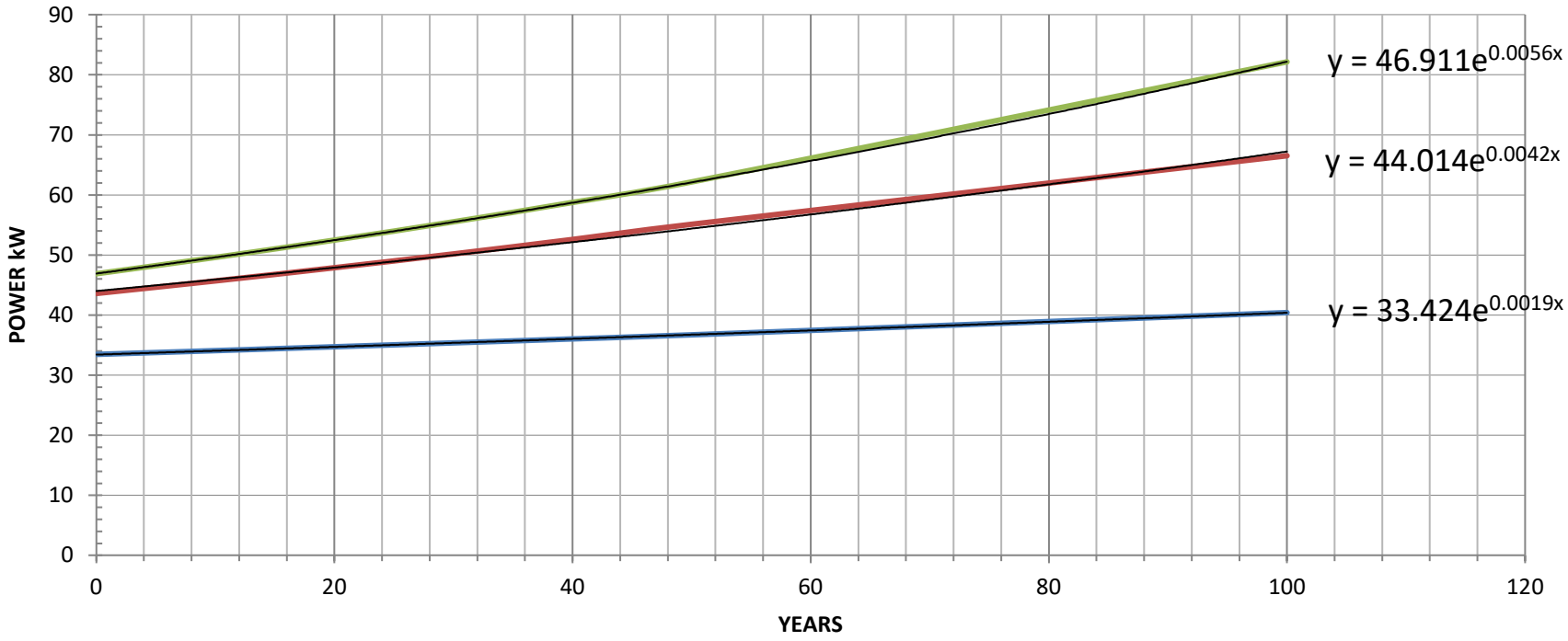
Pipe Life Cycle Cost – kW vs Years

SEVENTH PVC-O CONSIDERATION – LIFE CYCLE COST

Pipeline **operating energy** proportional to: - pipe material friction coefficient

Material	Start	50 Years	100 Years
Steel	+15%	+30%	+75%
Ductile Iron	+10%	+25%	+50%
Thermoplastics	Unity	+10%	+20%



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Thermoplastic Pipes Low Environmental Impact

EIGHTH PVC-O CONSIDERATION – ENVIRONMENTAL IMPACT

- Manufacturers may utilise their own scrap – cannot outsource
- Recycled material conformance – SANS 16422, Clause 5.2
- Manufacturers generate about 5% scrap – high scrap rates N/A
- Manufacturers recycle in-house – maintain quality control
- Recycled material control audits – ISO 9001 QMS, AENOR/SAPPMA

SIZABANTU'S TECHNOLOGY PARTNERS MOLECOR CONFORM TO:

- Circular, not linear, Economy – recycle and reuse
- OCS (Operation Clean Sweep) initiative – eliminate raw material spillage
- Sustainability – Environmental; Economic; Social
- EPD (Environmental Product Declaration) – impact statement
- PEF (Product Environmental Impact) – EN 15804 Construction Products

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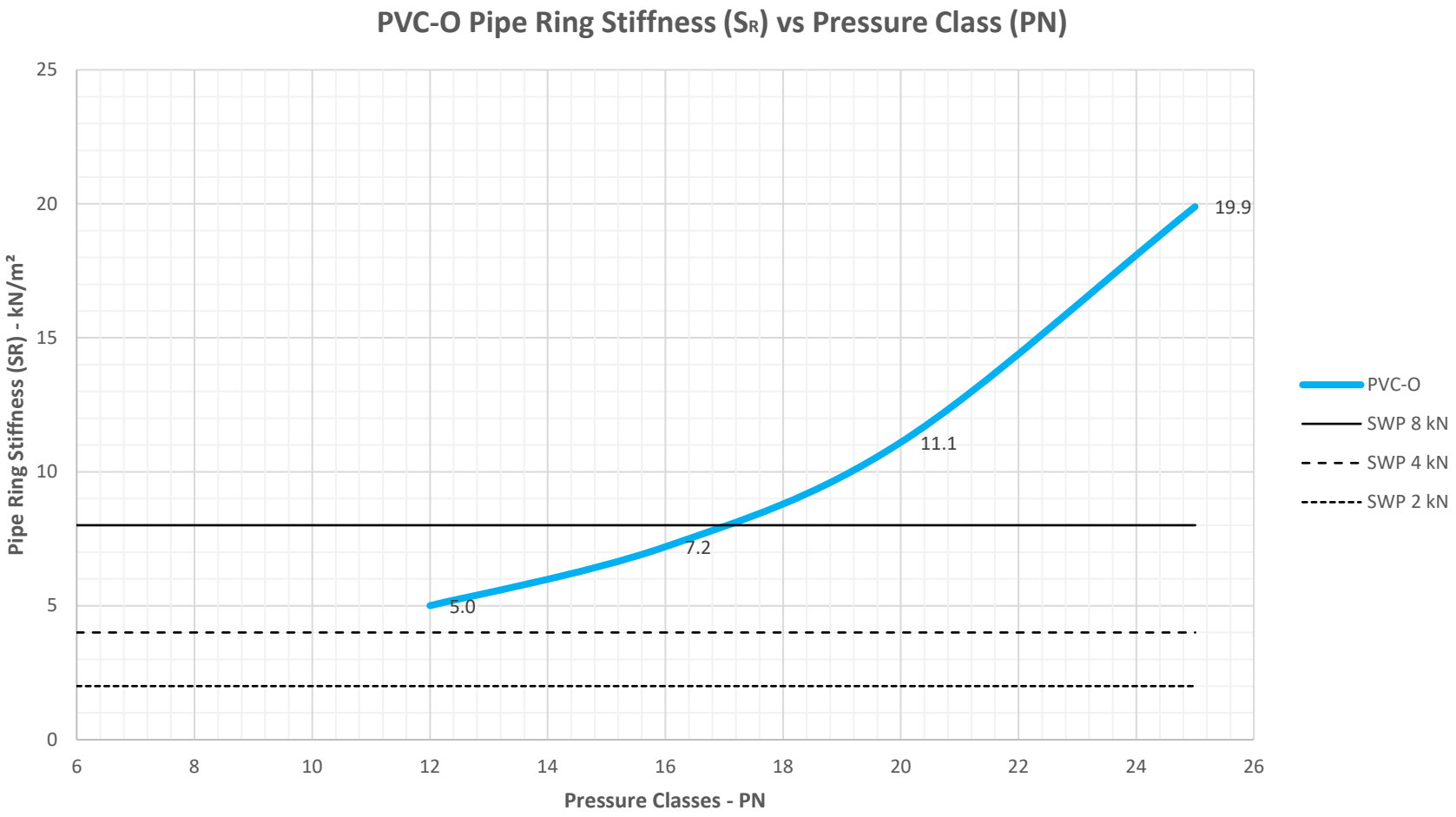
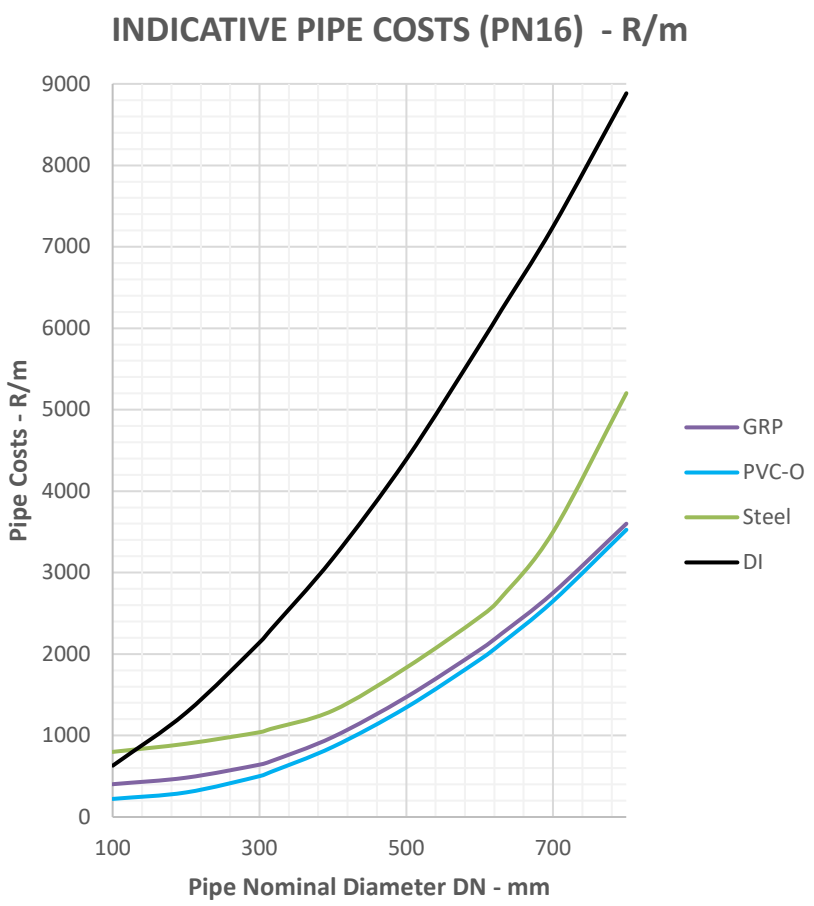
Ring Stiffness (S_R) – SANS 16422 Clause 11.3

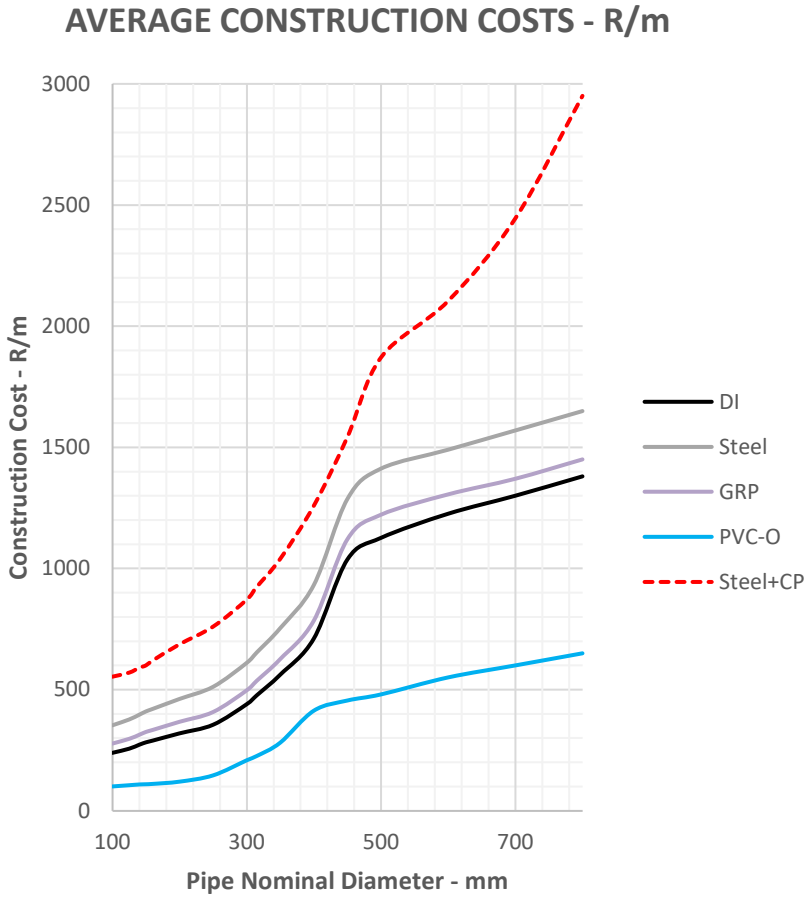
NINTH PVC-O CONSIDERATION – RING STIFFNESS



Indicative Pipe Costs (PN16) – R/m

TENTH PVC-O CONSIDERATION – COSTS





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Oriented PVC (PVC-O TOM500®)

EIGHT PVC-O ADDITIONAL CONSIDERATIONS

1. PVC-O (TOM500) seal lifetime – 380 years ISO11346 (EPDM ISO3384)
2. PVC-O (TOM500) fast jointing time – spigot and socket cf. welding
3. PVC-O (TOM500) stray currents no affect – power line and railway servitudes
4. PVC-O (TOM500) no cathodic protection – saves capital and maintenance costs
5. PVC-O (TOM500) flexible and lightweight – labour intensive construction
6. PVC-O (TOM500) thermoplastic advantages – no corrosion, negligible friction increase
7. PVC-O (TOM500) endurance limit (fatigue) – 10^7 cycles, 50 years = 438 000 hrs
8. PVC-O (TOM500) reduced construction cost – 50% of DI cost and 35% of steel cost

PVC-O pipe production >100 000 tonnes annually in >25 countries

PVC-O (TOM500®) is manufactured in SA and 13 other countries

PVC-O technology has been "tried and tested" for 45 years

PVC-O designs do not require one pressure class higher

NO (RED FLAG) REQUIRED WITH PVC-O!

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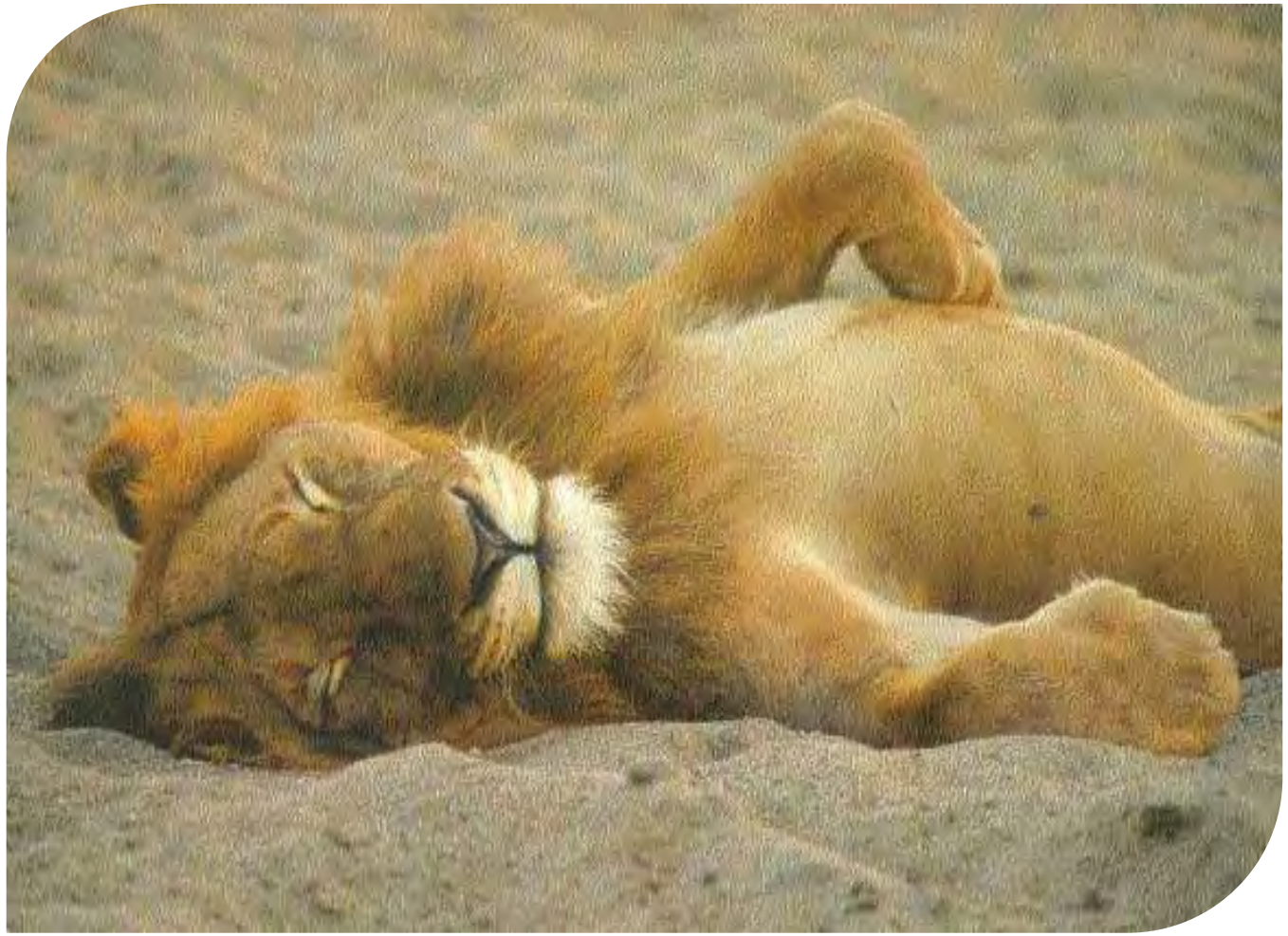
Many thanks for your attention!

Are there any questions?



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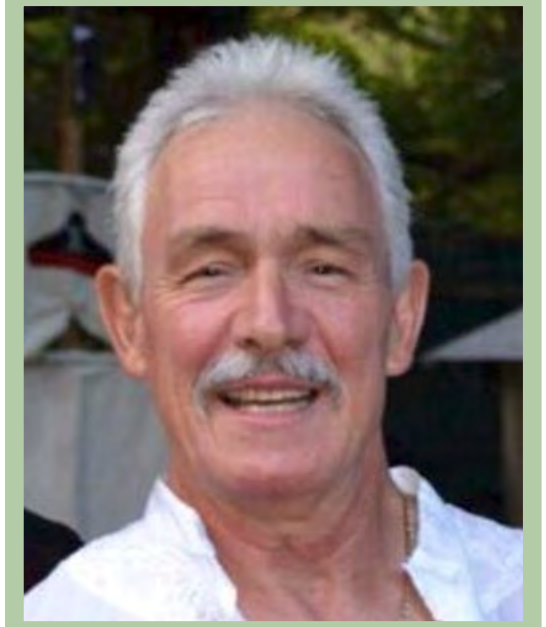
Questions and Answers



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Mike Smart

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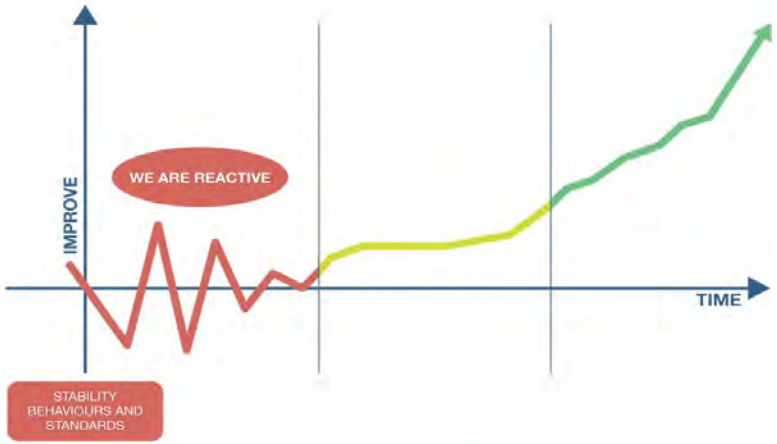
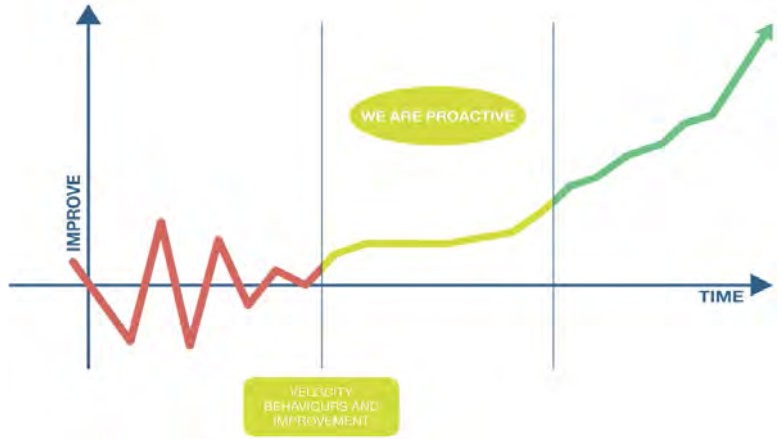
It brings Together

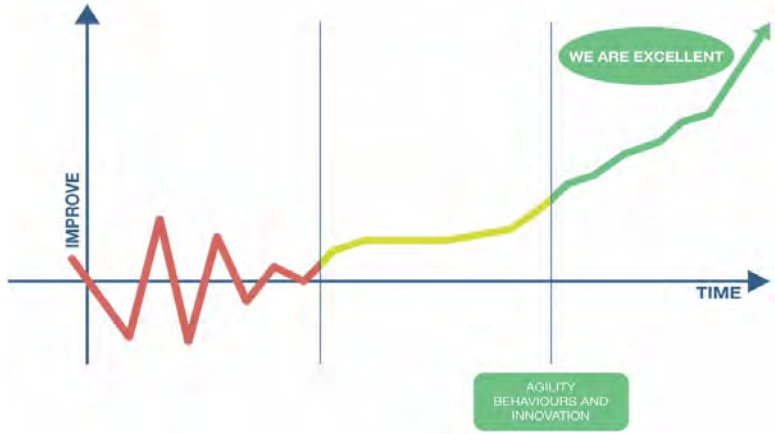
Local Needs

International Support

Satisfied End users







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Introduction to Member Categories

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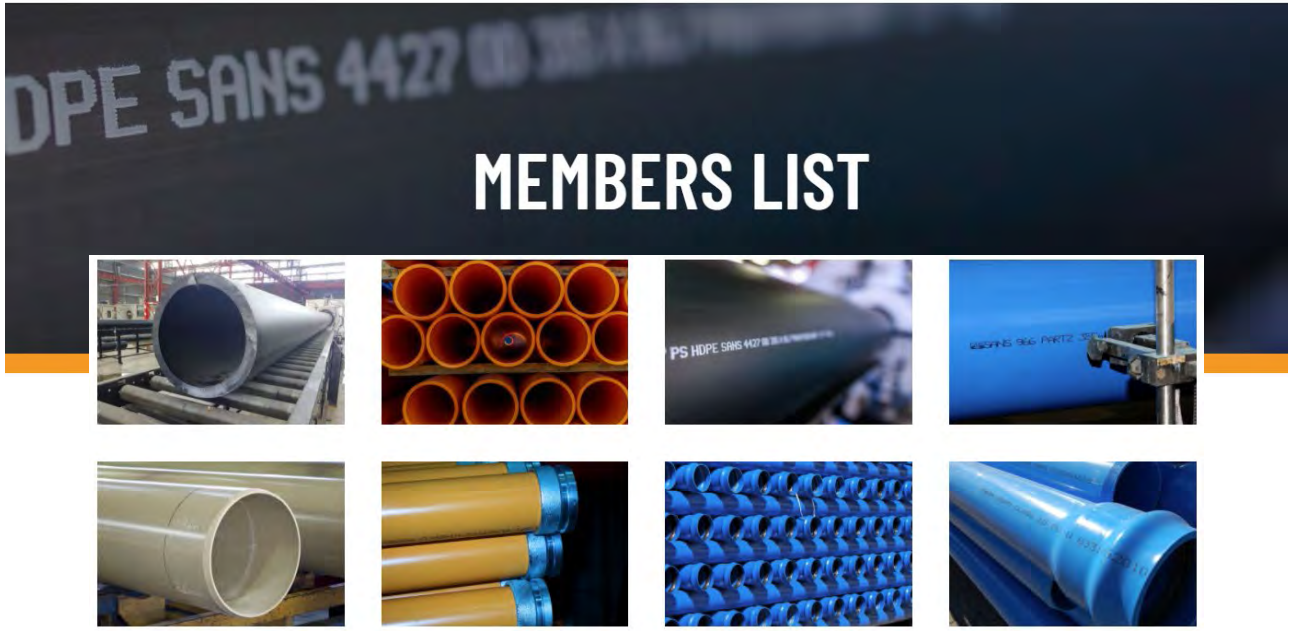

PIPE MANUFACTURERS	POLYMER MANUFACTURERS	SUPPLIERS
CERTIFICATION BODIES	SPECIALISED MANUFACTURERS	INDIVIDUAL MEMBERS

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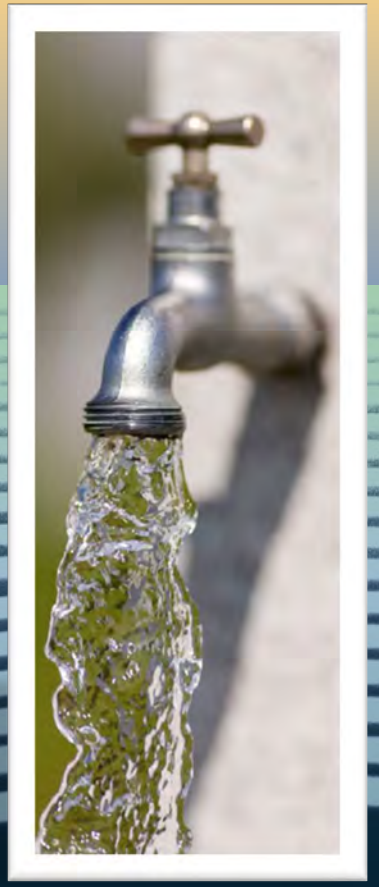
"Someone's sitting in the shade today because someone planted a tree a long time ago."

Warren Buffett



Questions and Answers

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