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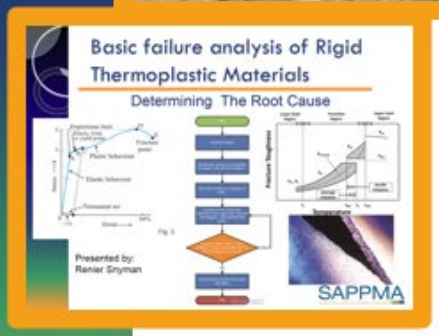
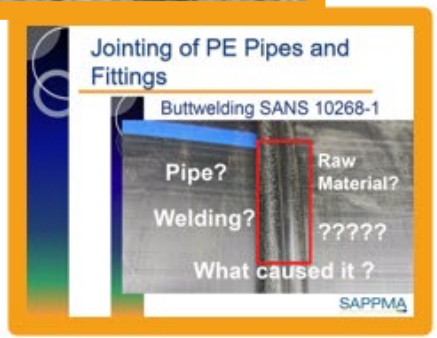
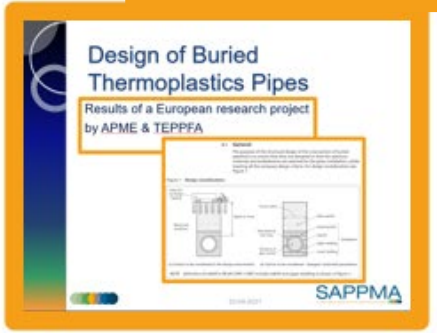
WEBINAR V

June 2021

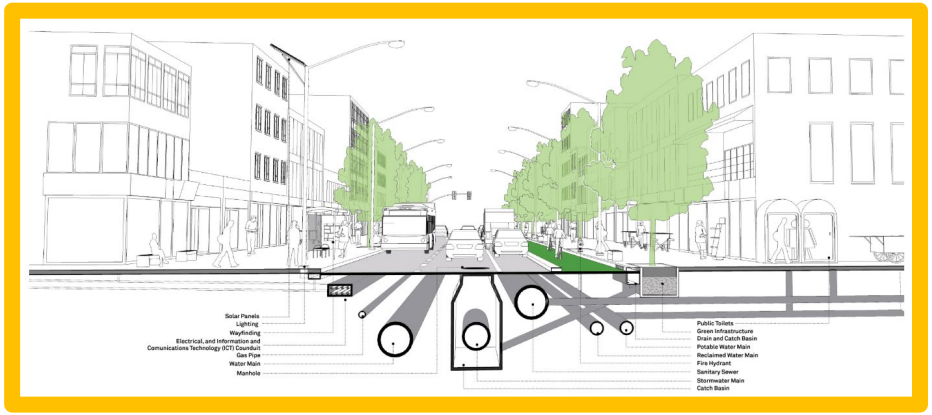
SAPPMA Webinar I & IV on SAPPMA Web site







Mining & Civils applications



Know how to make your choice

The answer remains the same

24-06-2021

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How can you improve your odds?

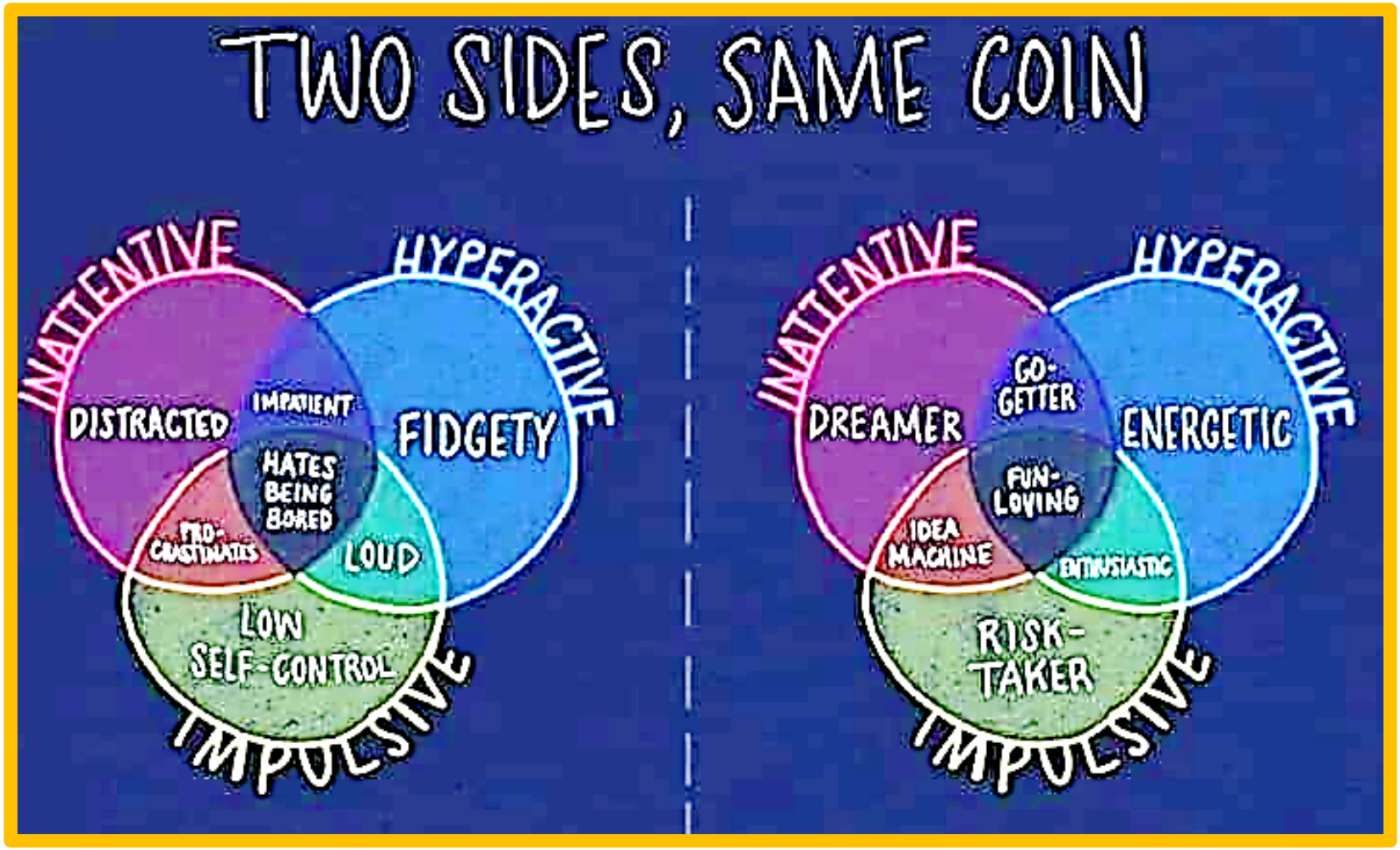
What is at stake?

Running out of water

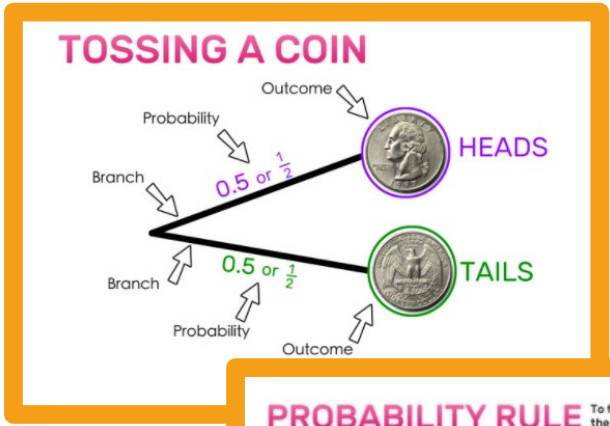
What is at stake?

Repeatability/Reproducibility
Life Expectancy

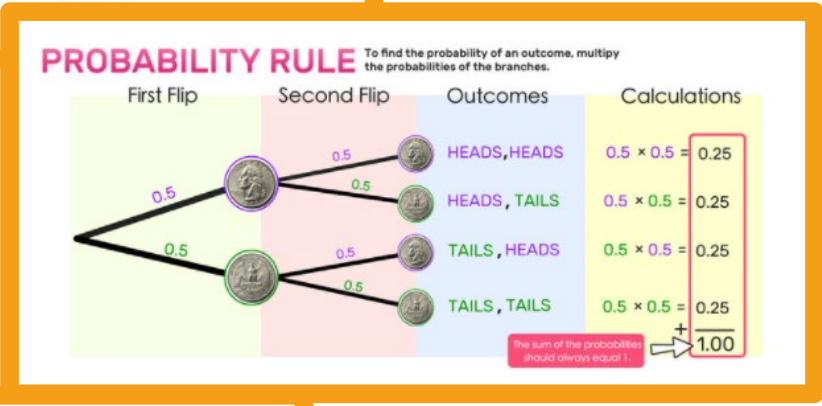
Do you know how to distinguish between ?

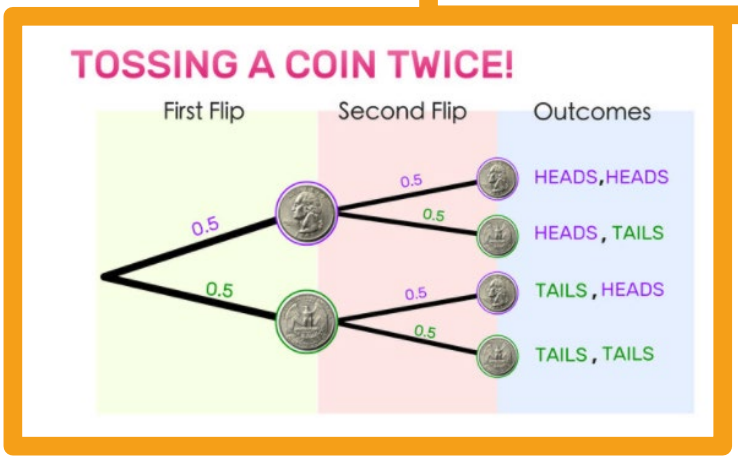


Are you sure you are flipping a fair coin?



If not





Can you see product performance by just looking at the product?

It can be a serious waste of money

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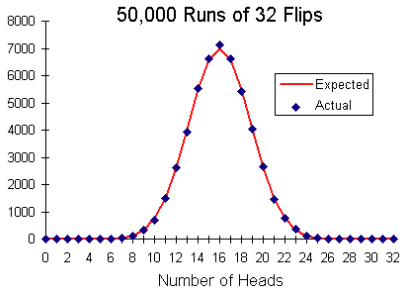
You will not know the result of your choice in the next few years !

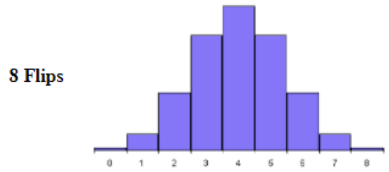
What will you do with the time on your hands ?

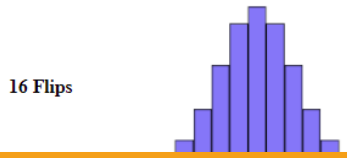
Learn and Prevent

Continue and find out later

Heads or Tails/Right or Wrong



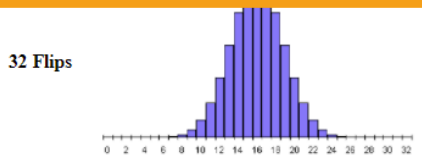


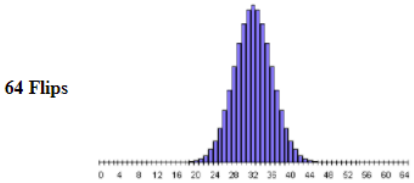


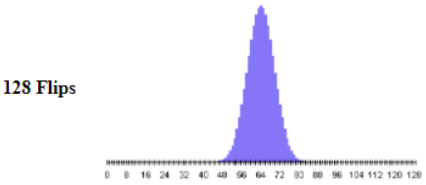
How many contracts are the same

It only holds true when you flip a fair coin enough times

event #1	event #2	event #3	event #4	probability
H 0.5000	H 0.5000	H 0.5000	H 0.5000	0.062500
			T 0.5000	0.062500
		T 0.5000	H 0.5000	0.062500
			T 0.5000	0.062500
	T 0.5000	H 0.5000	H 0.5000	0.062500
			T 0.5000	0.062500
		T 0.5000	H 0.5000	0.062500
			T 0.5000	0.062500
T 0.5000	H 0.5000	H 0.5000	H 0.5000	0.062500
			T 0.5000	0.062500
		T 0.5000	H 0.5000	0.062500
			T 0.5000	0.062500
	T 0.5000	H 0.5000	H 0.5000	0.062500
			T 0.5000	0.062500
		T 0.5000	H 0.5000	0.062500
			T 0.5000	0.062500
				1.000000







How many times are the same team working on a similar project

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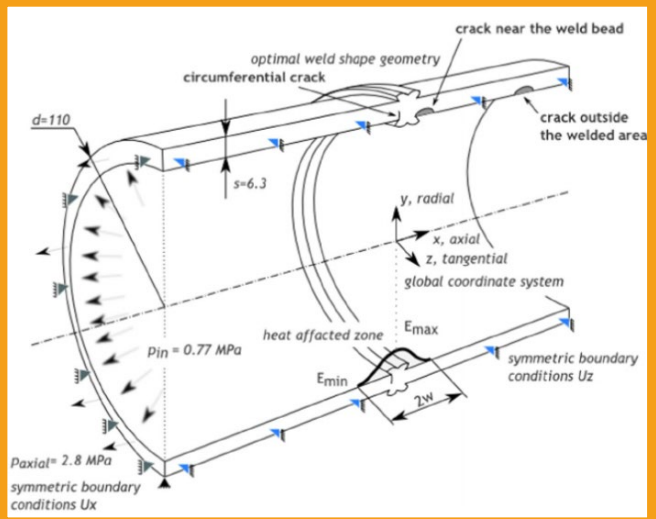

The effect of contaminants on Polyethylene pressure pipe performance

George Diliyannis, Technical Service Leader and Subject Matter Expert for PE100 materials at Safripol (Pty) Ltd, will be addressing the effects of contaminants on the performance of Polyethylene pipe materials with a specific focus on stress crack resistance.

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Presenter

24 June 2021

SAFRIPOL
shaping your world, responsibly

George Diliyannis

Agenda

- Who is Safripol
- What is high density polyethylene (HDPE)
- HDPE pipe materials and their benefits
- Pipe extrusion
- Pressure Pipe Standards
- Pipe failure mechanisms
- Effects on contamination on performance
- Conclusion

Who we are

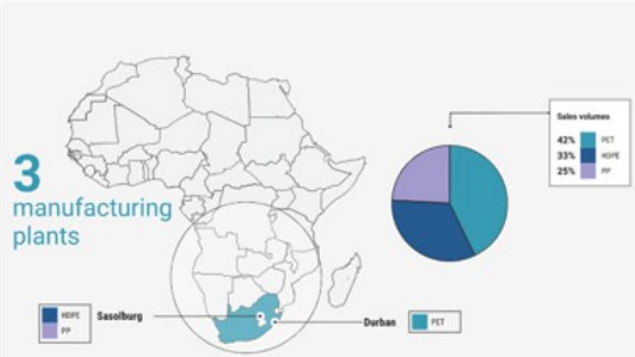
Founded in 1972

1 PET 2 HDPE 5 PP

Significant local polymer producer

Our polymers are used to support the plastics converting industry

420 Employees



~540kton/a Capacity

KAP

Let's plastic responsibly

What we are going to avoid

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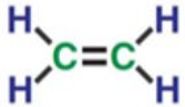
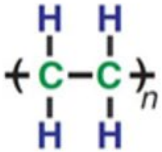
Structure

Ethylene



Polyethylene



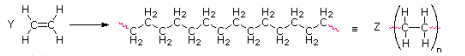
Ethylene is converted into polyethylene using a catalyst and controlled reactor and process conditions

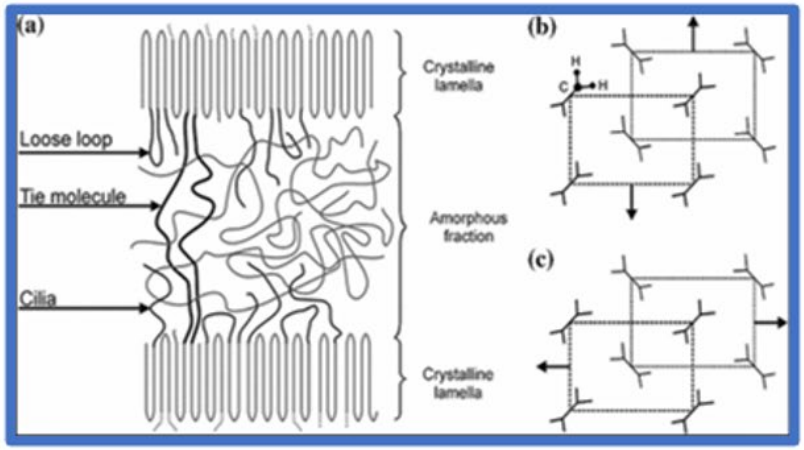
A co-monomer is used to disrupt crystallinity and form tie-chains

Polymerisation of ethylene under mild conditions
November 1953

Karl Ziegler

Giulia Natta

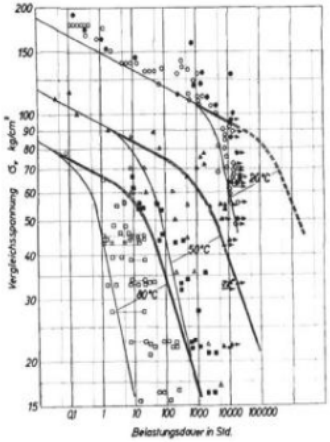




HDPE as a pipe material

Two years from invention to mainstream use:

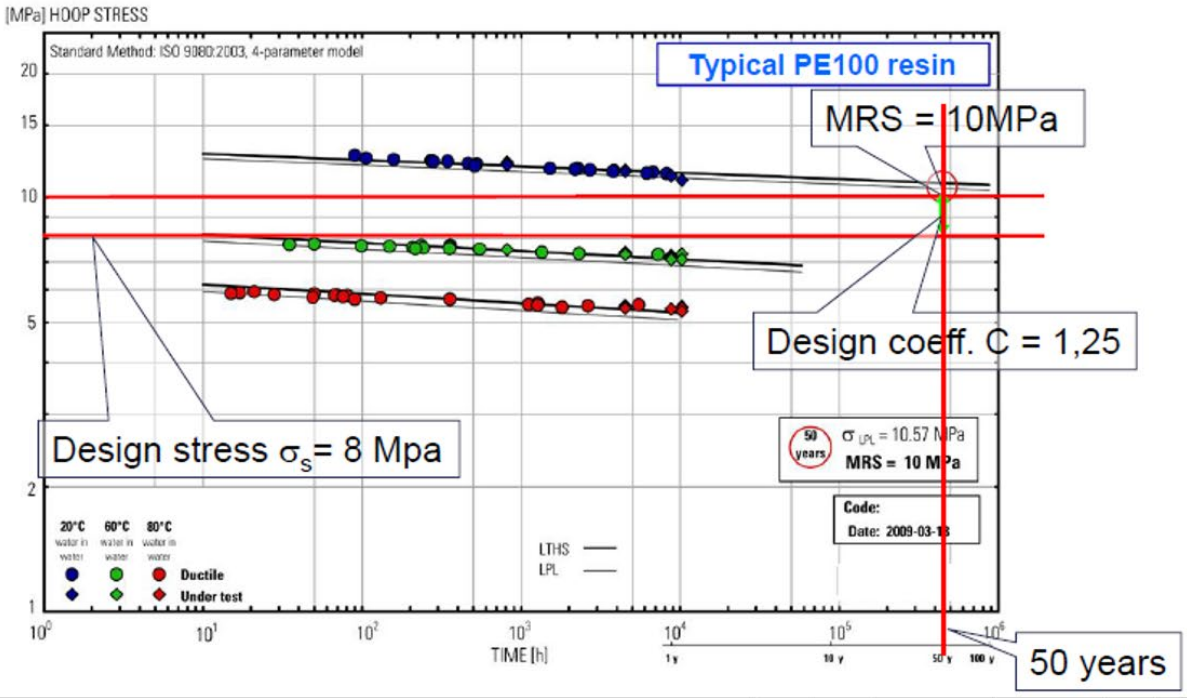
The first creep rupture tests on pipes made from HDPE were already started in 1955



Dissertation by Dr. Erwin Gaube, 1959: "Given a permissible hoop stress of 50 kg/cm², the pipes will still have a 1.3-fold resistance to cracking after 50 years

On October 18th 2012, two pipe specimens in this "historical" test have celebrated their 56th anniversary of continuous testing!

Classification and design stress



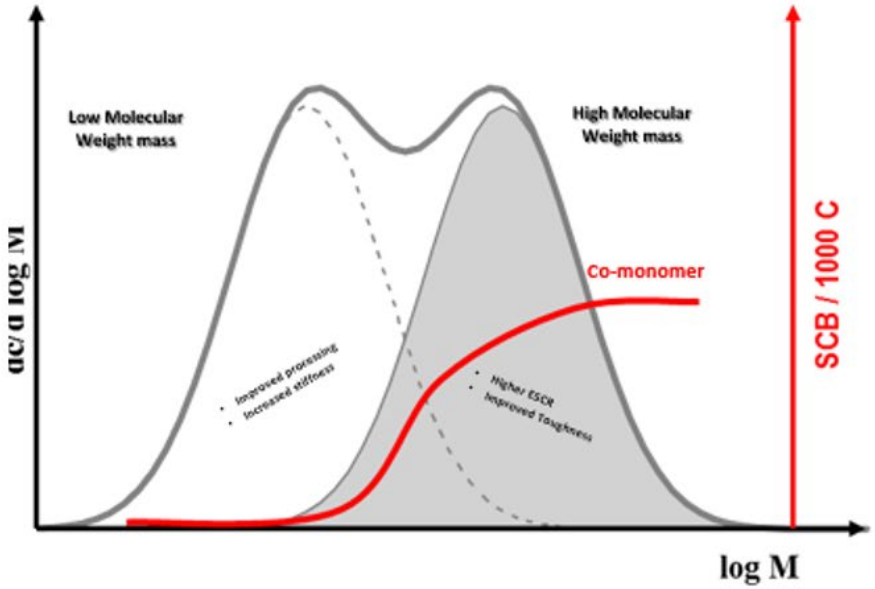
- Example of regression curve for modern day PE100:

HDPE Pressure pipe evolution

Graphic illustration of a bi-modal material:

Bimodal product features

- Bimodal Molecular weight distribution (MWD)
- "Inverse" co-monomer composition distribution (CCD)
- Overcome constraints imposed by unimodal HDPE Resins



Safripol uses the Hostalen bi-modal process, now licenced by LyondellBasell to produce iMPACT100® PE100 pipe material

HDPE Pressure pipe evolution

How polyethylene pipe material has improved over the years:

Creep Rupture tests on HDPE pipes started already in 1955

Type 50
1955
First Pressure pipes produced

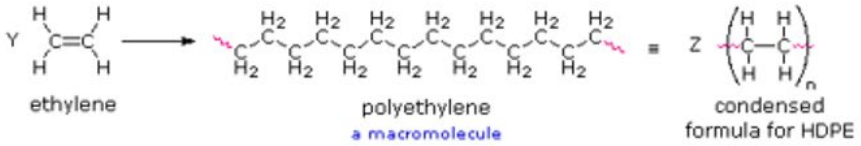
PE 63
1959
Continuous Pressure pipes

PE 80
1977
Improved stiffness
Improved Resistance to cracking

PE 100
1990's
Bimodal developments further improve resistance to cracking and also stiffness

PE 100 RC
2000's
Next Generation pressure pipe material

Polymerisation of ethylene under mild conditions
November 1953
Karl Ziegler **Giulia Natta**

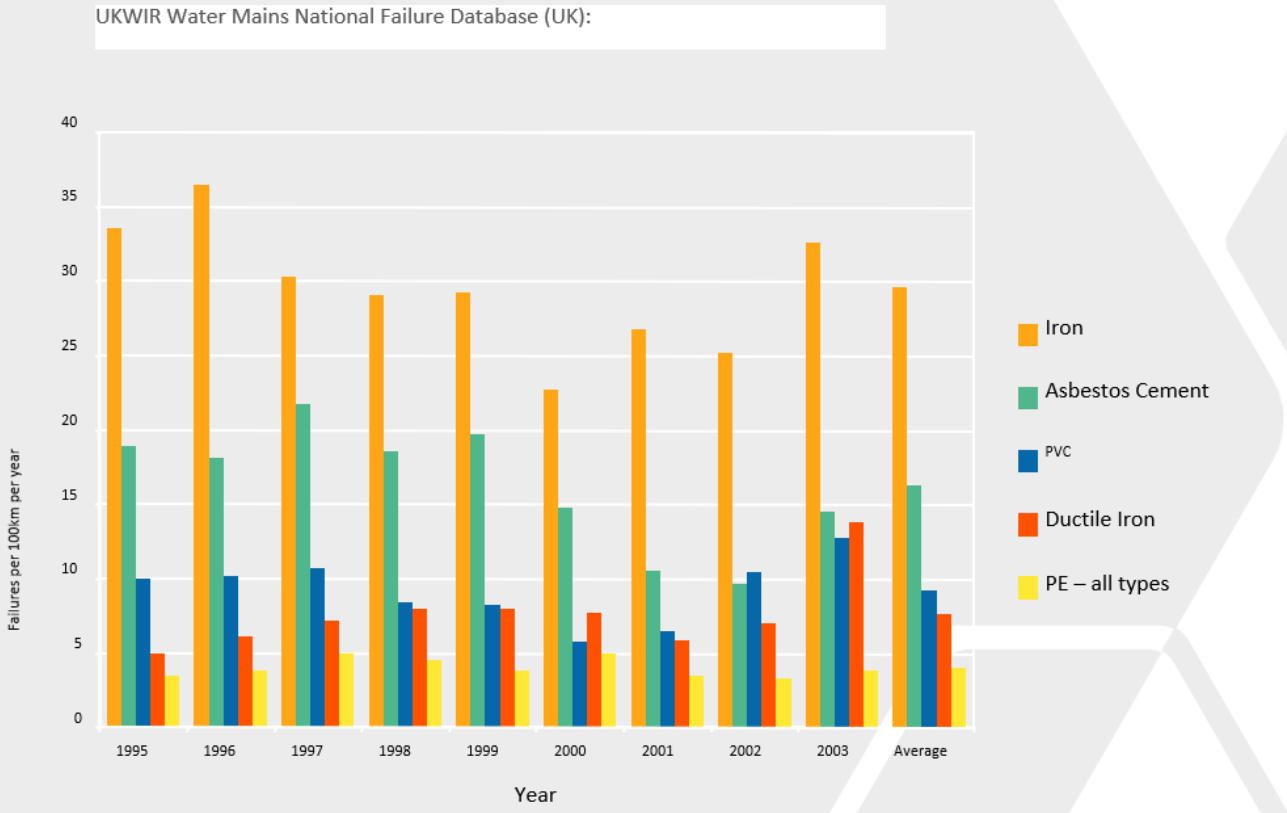


Benefits of polyethylene piping systems

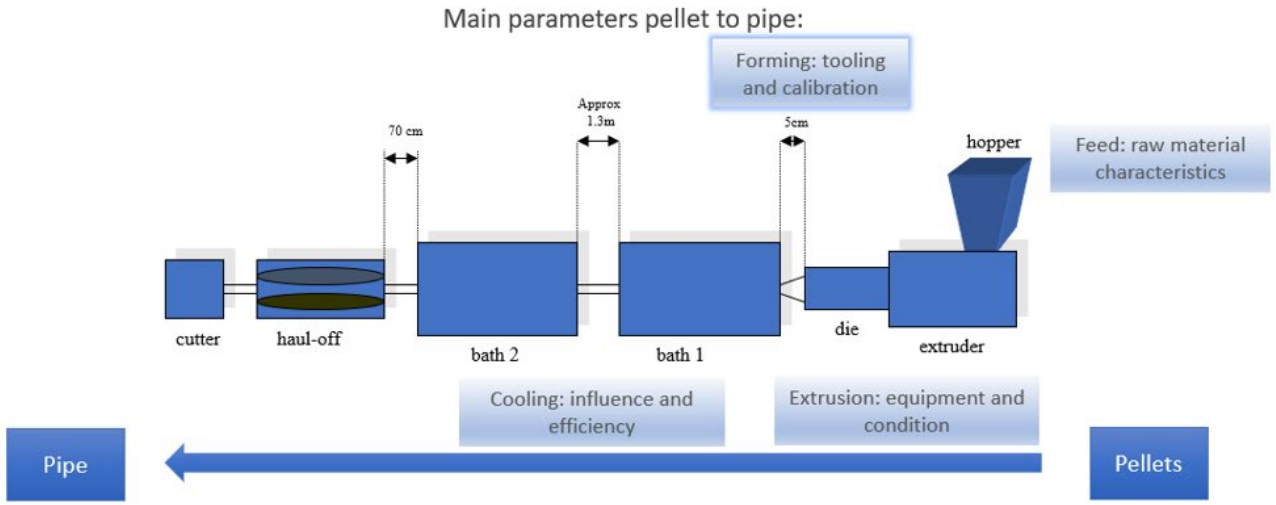
Many benefits speak for themselves:

- Corrosion resistant
  - No external protection systems required
- Virtually leak free due to welded joints
  - Lowest leakage rate of any pipe material
- Excellent flow characteristics for lifetime of pipe
  - Superior chemical resistance
  - Resistant to microbial growth
- Lightweight and flexible – easy to handle
  - Lengths or coils
- Ductile and tough
  - Resists external soil loads and internal water hammer/pressure surges
- Manufactured under ISO / SANS 4427 Parts 1, 2, 3 and 5

Very low leakage rates



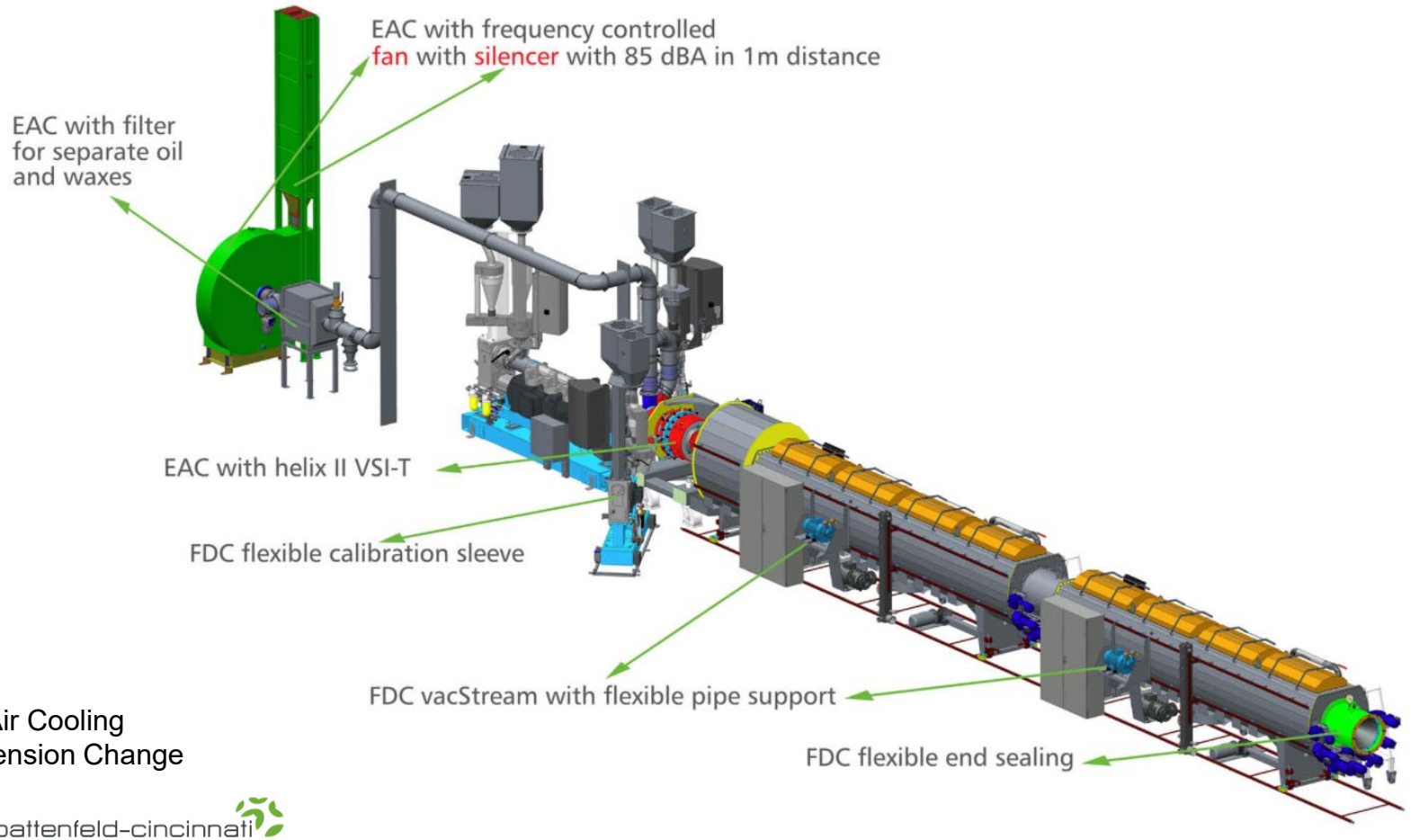
Pipe extrusion set up



A typical pipe extrusion plant

"Green Pipe" System with the energy saving line components

A typical pipe extrusion plant

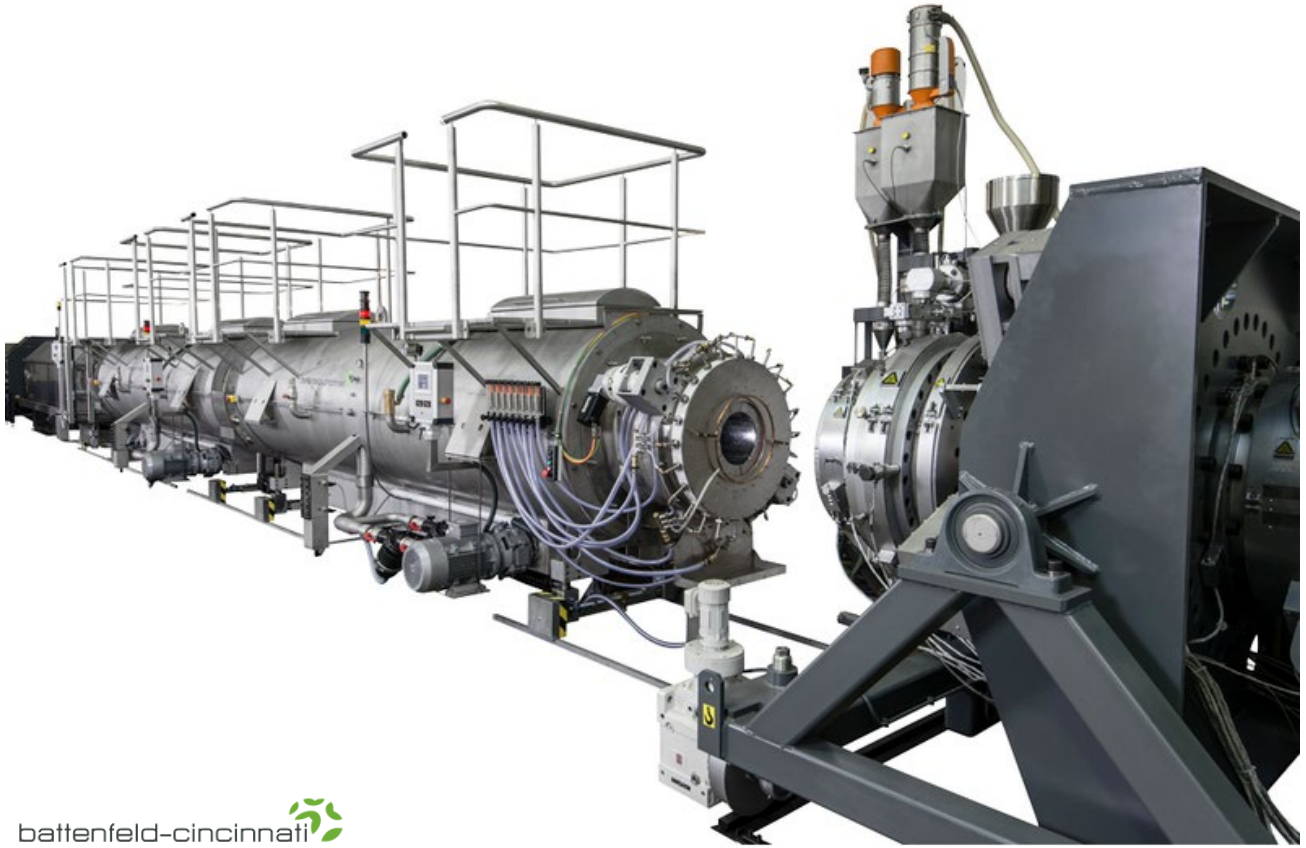


EAC Efficient Air Cooling
FDC Fast Dimension Change

battenfeld-cincinnati

Schematic depiction: EAC (Efficient Air Cooling) components in a pipe extrusion line

A typical pipe extrusion plant



FDC Fast Dimension Change

ISO/SANS Standards – what are the material requirements?

- Extract from ISO/SANS 4427-1:

4.2.2 Black compound

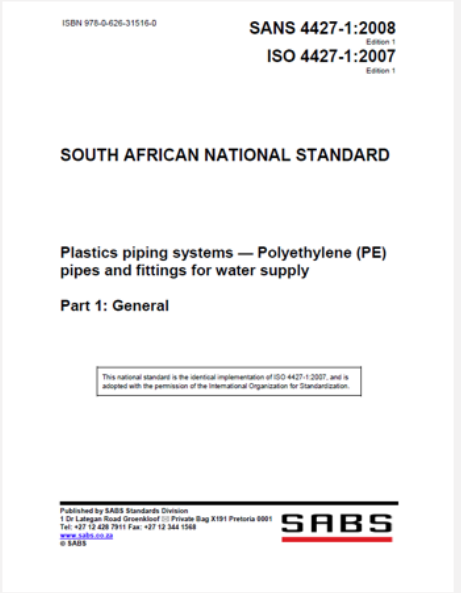
The carbon black used in the production of black compound shall have an average (primary) particle size of 10 nm to 25 nm.

4.3 Use of reprocessable and recyclable material

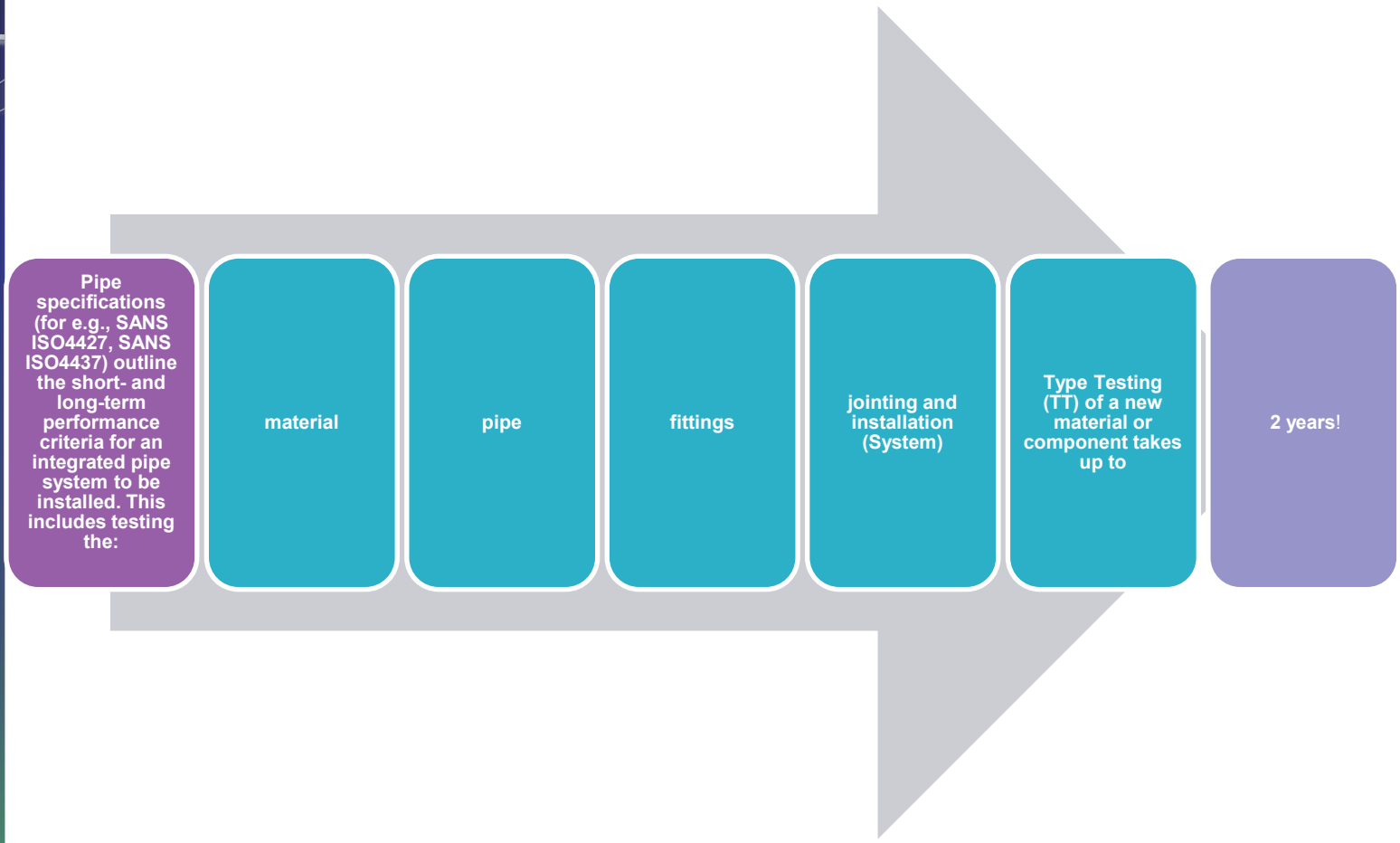
Clean, reprocessable material generated from a manufacturer's own production and works testing of products according to ISO 4427 may be used if it is derived from the same compound as used for the relevant production. Reprocessable material obtained from external sources and recyclable material shall not be used.

4.4 Physical characteristics of the compound

The compound used for the manufacture of pipes, fittings and valves shall be in accordance with Table 1 as granules and Table 2 in the form of pipe.



Specifications



Material Type Tests (TT)

How to ensure that raw material is compliant:

- Classification (ISO 12162, ISO 9080)
- CB content / dispersion (for black resin)
- Pigment dispersion (for other colours i.e. blue / yellow)
- Melt Flow Rate (MFR)
- Thermal stability
- Resistance to gas condensate (gas applications)
- Water quality (taint & odor, microbiological growth etc.)
- RCP resistance (rapid crack propagation)
- SCG resistance (slow crack growth)

Material Type Tests (TT) carried out on pipe

How to ensure that pipes are compliant:

- Slow Crack Growth (SCG) on notched pipes
- Rapid Crack propagation (RCP) via S4 / full scale tests
- Tensile properties
- Thermal stability
- Melt Flow Rate (MFR)
- Weldability
- Weathering resistance (for colours other than black)

SANS Standards – what are the material (TT) requirements?

Table 1 — Characteristics of PE compound as granules

Characteristic	Requirement [a]	Test parameters		Test method
		Parameter	Value	
Compound density	⩾ 930 kg/m^3	Test temperature	23 °C	ISO 1183-2
		Number of samples	According to ISO 1183-2	
Carbon black content (black compound only)	(2 to 2,5) % by mass	In accordance with ISO 6964		ISO 6964
Carbon black dispersion (black compound only)	⩽ grade 3	In accordance with ISO 18553 [c]		ISO 18553
Pigment dispersion (blue compound only)	⩽ grade 3	In accordance with ISO 18553 [c]		ISO 18553
Water content [d]	⩽ 300 mg/kg	Number of test pieces [b]	1	ISO 15512
Volatile content	⩽ 350 mg/kg	Number of test pieces [b]	1	EN 12099
Oxidation induction time	⩾ 20 min	Test temperature	200 °C [e]	ISO 11357-6
		Number of test pieces [b]	3	
Melt mass-flow rate (MFR) for PE 40	0,2 to 1,4 g/10 min Maximum deviation of ± 20 % of the nominated value [f]	Load	2,16 kg	ISO 1133:2005, Condition D
		Test temperature	190 °C	
		Time	10 min	
		Number of test pieces [b]	According to ISO 1133	
Melt mass-flow rate (MFR) for PE 63, PE 80 and PE 100	0,2 to 1,4 g/10 min Maximum deviation of ± 20 % of the nominated value [f]	Load	5 kg	ISO 1133:2005, Condition T
		Test temperature	190 °C	
		Time	10 min	
		Number of test pieces [b]	According to ISO 1133	

- **From ISO/SANS 4427-1:**
- **Raw material requirements in the form of granules**
- **As demonstrated by PE compound manufacturer**

SANS Standards – what are the material requirements?

Table 2 — Characteristics of the PE compound in pipe form

Characteristic	Requirement [a]	Test parameters		Test method
		Parameter	Value	
Tensile strength for butt-fusion [b]	Test to failure: Ductile — Pass Brittle — Fail	Pipe diameter	110 mm	ISO 13953
		Pipe diameter ratio	SDR 11	
		Test temperature	23 °C	
		Number of test pieces [c]	According to ISO 13953	
Slow crack growth pipe size 110 mm or 125 mm SDR 11	No failure during test period	Test temperature	80 °C	ISO 13479
		Internal test pressure for:		
		PE 63	6,4 bar	
		PE 80	8,0 bar	
		PE 100	9,2 bar	
		Test period	500 h	
		Type of test	Water in water	
		Number of test pieces [c]	According to ISO 13479	
Effect on water quality	According to existing national regulations			
Resistance to weathering [e]	Weathered test pieces shall have:	Cumulative solar radiation	$\geqslant$ 3,5 GJ/m^2 [d]	ISO 16871
a) Decohesion of electrofusion joint	Percentage of brittle failure: $\leqslant$ 33,3 %	Temperature	23 °C	ISO 13954
		Assembly procedure	f	
b) Elongation at break	According to ISO 4427-2:2007, Table 5			ISO 6259-1 ISO 6259-3
c) Hydrostatic strength at 80 °C	According to ISO 4427-2:2007, Table 3			ISO 1167-1

- **From ISO/SANS 4427-1:**
- **Raw material requirements in the form of pipe**
- **As demonstrated by PE compound manufacturer**

Material Quality Control (QC)

Additionally, for every batch of raw material supplied:

Melt Flow Rate (MFR)
Density
Pigment / carbon black dispersion
Carbon back content
Thermal stability
Volatile content
Pellet quality
The first 6 characteristics should be declared on the raw material
manufacturers Certificate of Analysis (COA)

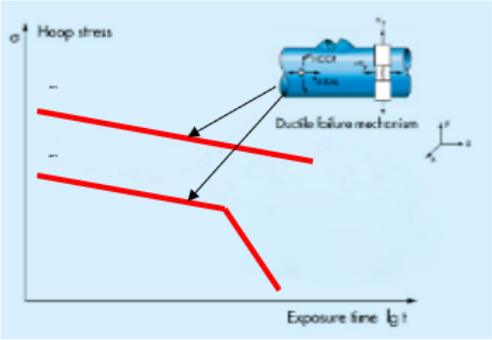
Pipe Quality Control (QC)

As demonstrated by pipe converter:

- Dimensions
- Appearance
- Stress rupture testing
- Thermal stability
- Thermal reversion
- Tensile properties

HDPE pressure pipe failure mechanisms

Polyethylene has three failure modes:



Ductile Failure:

Plastic – Viscoelastic Mechanical property

Long Term Hydrostatic Strength (MRS)

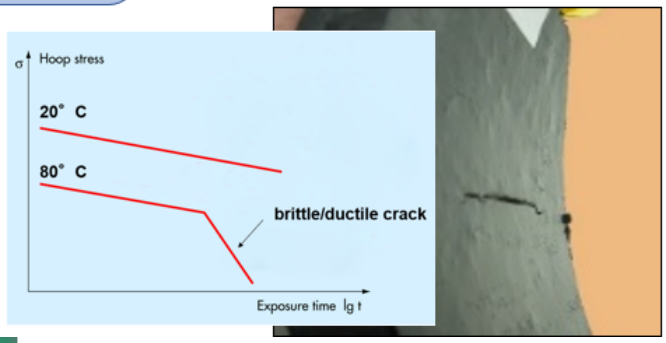
Brittle Failure:

Slow Crack Growth

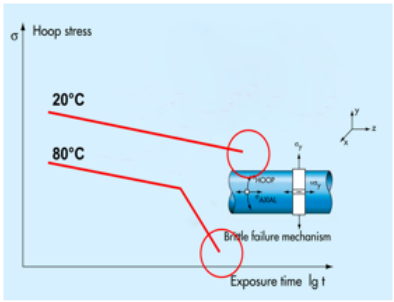
Brittle Failure:

Oxidative degradation of the polymer

Slow Crack Growth (SCG)

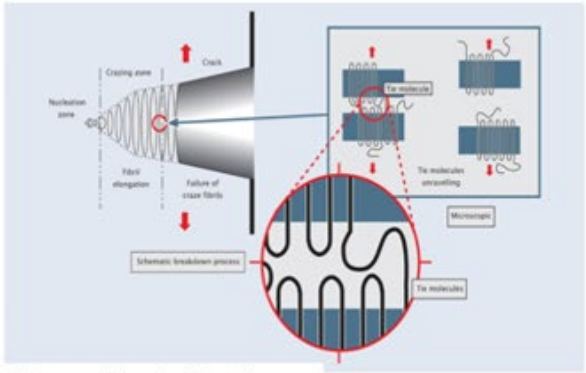


Rapid Crack Propagation (RCP)

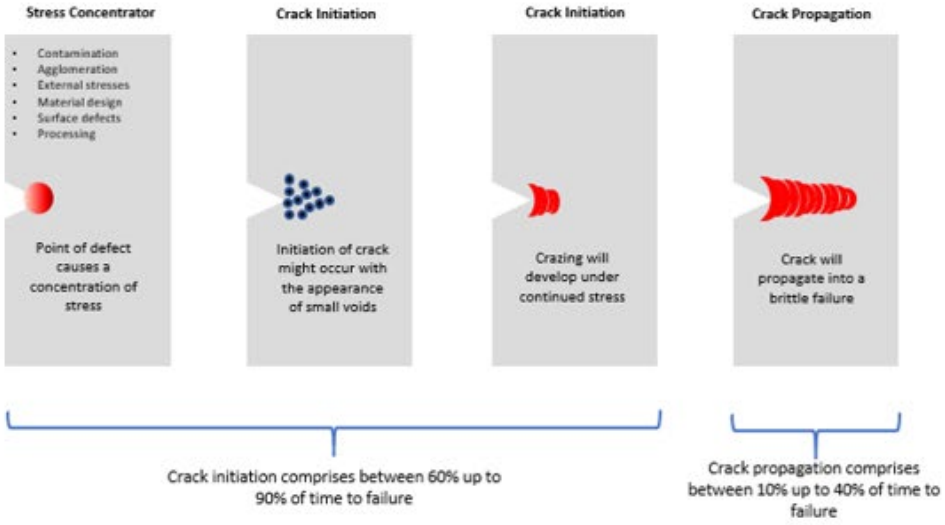


HDPE pressure pipe failure

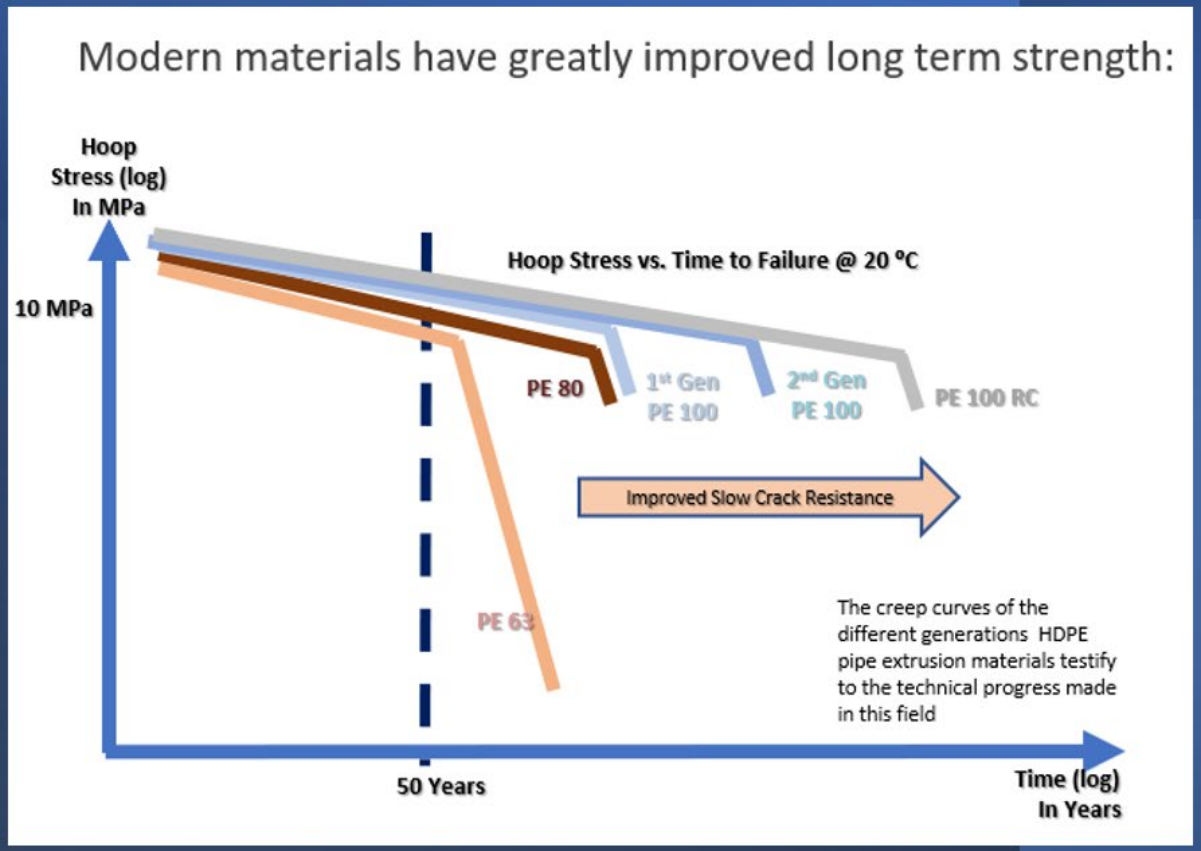
What is slow crack growth (SCG) and how does it occur:



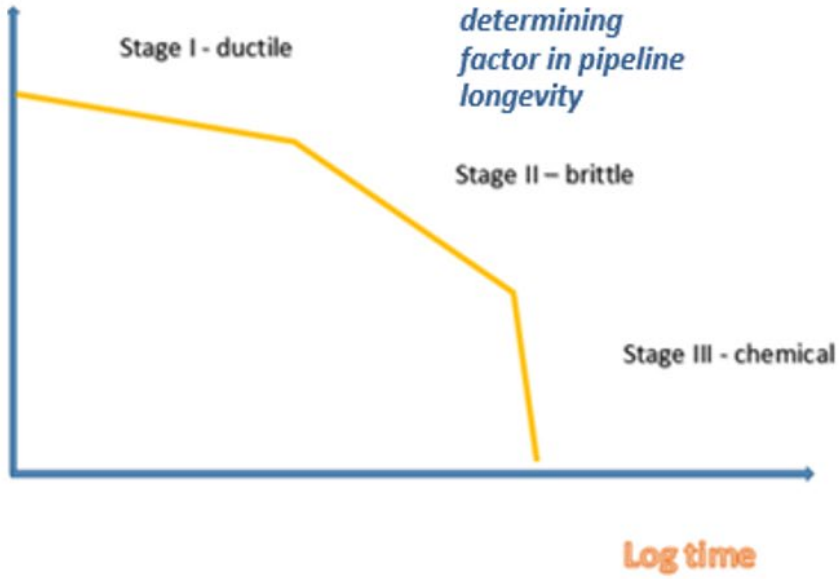
The Process of Slow Crack Growth



HDPE Pressure pipe evolution



3 Failure modes of polyethylene



In practise, modern PE pipe materials way exceed the minimum SCG requirements of SANS ISO 4427:1 i.e. 500 hours notched pipe test (NPT)

So, what causes premature stage 2 failures?

Contamination and definition

Contamination is the **presence of a constituent, impurity**, or some other undesirable element that spoils, corrupts, infects, makes unfit, or makes inferior a material, physical body, natural environment, workplace, etc.

Reference: en.wikipedia.org/wiki/Contamination

- Definition of contamination:

Contamination in pipe

- **In the case of polyethylene (PE100) pipe, contamination could be:**

Foreign particles such as sand

Incorrectly dispersed carbon black

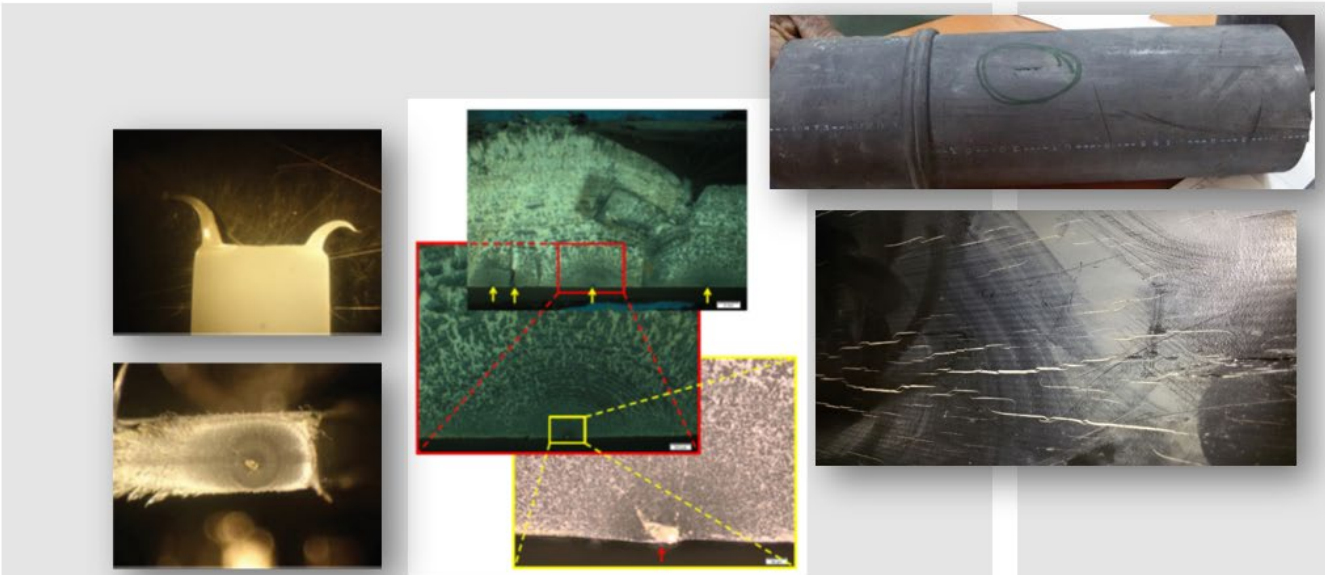
Moisture

Entrapped air

Use of non-pipe (non-PE100) materials

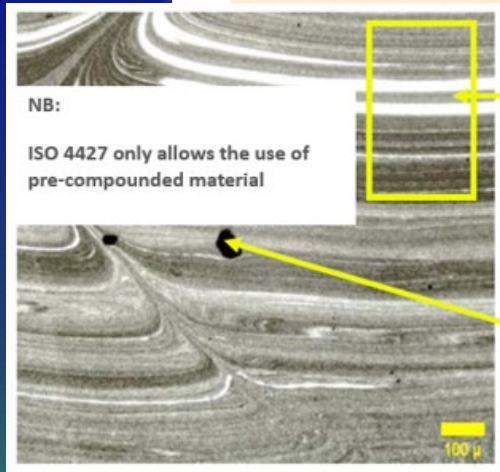
Contamination

Examples of contamination induced failures:



M. Pluimer, et al., Field Performance of Corrugated Pipe Manufactured with Recycled Polyethylene Content, NCHRP Research Report 870, 2018

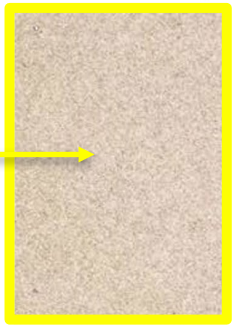
Protection of PE pipes by the addition of carbon black at resin manufacturing phase



Poor dispersion of carbon black

Good dispersion of carbon black

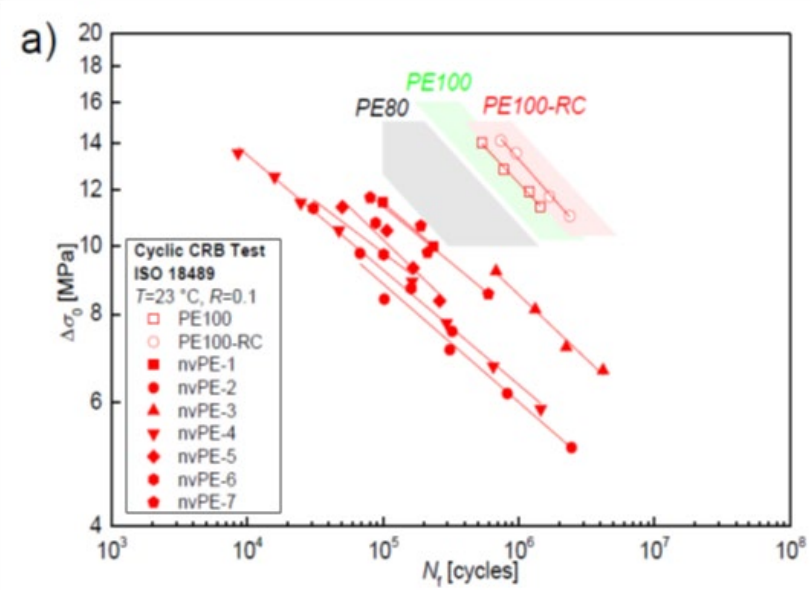
Agglomeration of carbon black

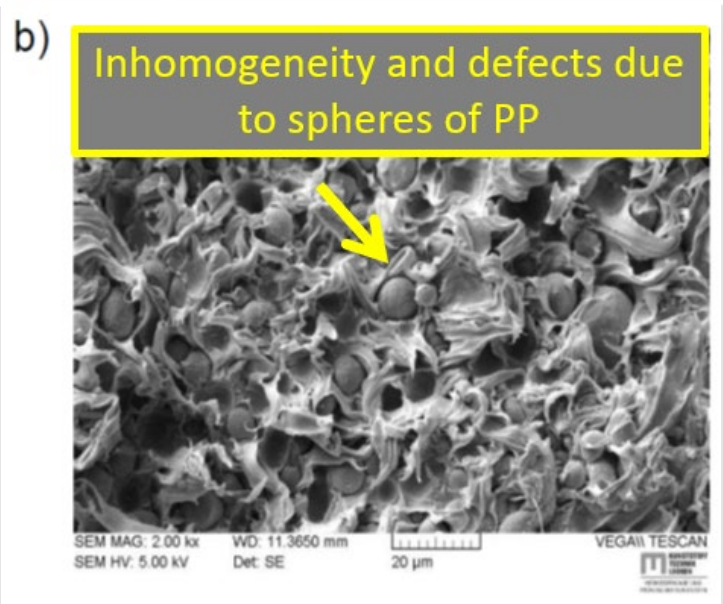


- Polyethylene pipes and fittings protected by the addition of 2 – 2.5% carbon black are not sensitive to ultra-violet light
- Carbon black prevents the penetration of the UV rays into the pipe wall and coverts UV to Infrared (heat). Very limited surface 'chalking' may occur after prolonged exposure, but this will not affect the performance of the pipes

Other research: non-virgin PE (with PP)

Resistance to Cracked Round Bar (CRB) testing:





A. Frank, et al., *Slow Crack Growth Resistance of Non-Virgin Polymers*, Plastic Pipes XIX, Las Vegas (USA), 2018

Volatiles (moisture)

Volatiles/moisture management of PE100 carbon black containing materials:

- Carbon Black is hygroscopic and readily absorbs moisture from surrounding atmosphere
- Excessive volatile content (≥0.035%) in the pipe resin affects quality of the finished pipe product
- ISO/SANS 4427 stipulates a maximum allowable volatile content of 0.035% (or 350ppm)

Volatiles (moisture)

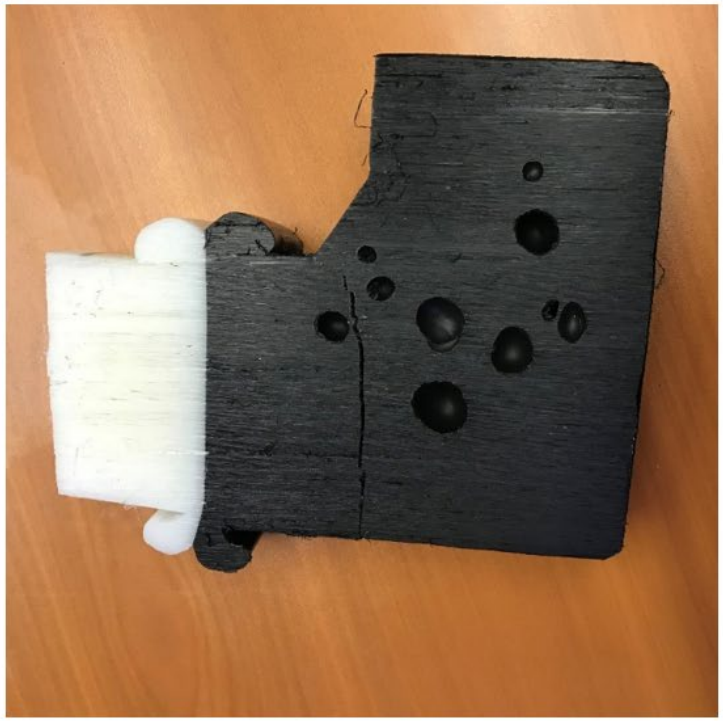
Volatiles of 0.045% - effect on inner and outer surface

450SDR21 pipe – outer surface

450SDR21 pipe – inner surface

Entrapped air/bubbles:

Tiny (and not so tiny) bubbles:



Residual air pockets in a fitting

Bubbles caused by excessive moisture

Post Consumer Waste in Pressure Pipe

Safripol/Qenos recycling study: objectives

- Simulate the major Post Consumer Waste recycling stream consisting of blow moulding resins in South Africa that could be used in pipe applications (*not permitted in terms of SANS and ISO standards*)
- To understand the influence on critical pressure pipe properties (SCG) when blending small part blow moulding type HDPE resins with PE100 pressure pipe resins

Post Consumer Waste in Pressure Pipe

How the recycling study was conducted:

Materials used:

- HDPE Safrene® F7665 (dairy grade HDPE)
- HDPE Safrene® M5010 Natural (pressure pipe HDPE)

Only virgin materials were used:

- Best case scenario (know the starting polymer properties)
- Homogenous blending in laboratory compounders
- No Carbon black added to eliminate variables and dilution
- Post consumer regrind stream ***quality cannot*** be assured
  - Contains Injection moulding & blow moulding resins
  - Contains PP, HDPE, LLDPE and LDPE
  - Contains various pigments, fillers and non pressure pipe quality carbon black
  - Pigment dispersion of all is poor

Post Consumer Waste in Pressure Pipe

Subsequent resistance to cracking:

Baseline of Virgin polymers			
Grade	**Stress (Mpa)**	**Notch Depth (mm)**	**Failure Time (hrs)**
Safrene® F7665 (HIC & Diary)	2.4	3.5	3hrs & 3hrs
Safrene® M5010 Natural	2.4	3.5	Taken off test prior to failure > 2790hrs
iMPACT 100®	2.4	3.5	Taken off test prior to failure > 2790hrs
Safrene® M5010 Natural/Safrene® F7665 Blends			
Blend Composition (M5010/F7665)	**Stress (Mpa)**	**Notch Depth (mm)**	**Failure Time (hrs)**
60/40	2.4	3.5	1.9hrs & 0.9hrs
70/30	2.4	3.5	4.2hrs & 4.2hrs
80/20	2.4	3.5	10hrs
90/10	2.4	3.5	13hrs

Testing conducted by Qenos

Accelerated Pennsylvania Edge-Notch Tensile Test to measure the resistance to Slow Crack Growth (SCG) of polyethylene materials

According to ASTM F1473

Life Expectancy

- Theoretically humans and pressure pipes can easily exceed a lifetime of 100 years…
- But what are the determining factors for life expectancy?

	Humans	PE 100 Pipe
Gene Pool	•Good health •Hormones	• Polymer morphology • Additivation
Environment	•Pollution •Hygienic conditions	• External temperature • UV irradiation • Installation conditions • Processing
Life Style	•Nutrition •Smoking, alcohol, drugs •Sports	• Aggressive media • Pressure, excessive stress • Temperature
Unforeseen	•Accidents •War, violence •Natural disaster	• External damage • Excessive abuse • Natural disaster

Conclusion

- Bimodal polymerization technology and polymer design has led to a vast improvements in Slow Crack Growth (SCG) resistance when compared to first generation materials
- The knowledge of failure mechanisms and the limits under these conditions allows a safe and reliable design of HDPE pressure piping systems for a life expectancy of 100 years *(according to ISO 9080 calculation)*
- Recent polymer and technology development results in improved processability and product properties for:
  - Large bore and thick wall pipes
  - Alternative installation techniques
- All plastics are not equal – PE100 is an engineered material, designed to produce pipe and fittings to last 100 years

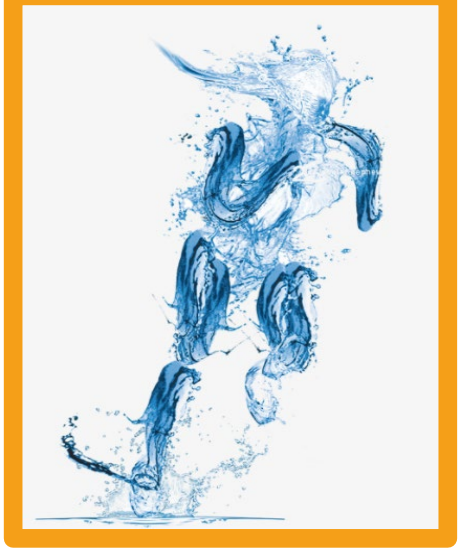
Questions and Answers

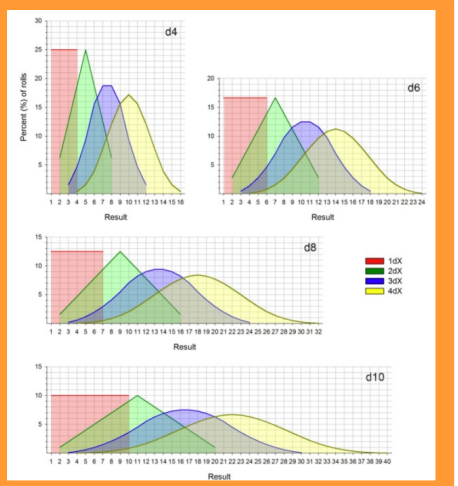
SAFRIPOL
shaping your world, responsibly
Let's plastic responsibly

Contamination introduces a 3de party

3 sided dies

It is only a matter of time before your choices catch up with you





Are you willing to play the game or is the odds stacked up against you?

Participants
Audience
& Organizers

Questions and Answers

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