

# Material Performances Comparison of Cold-applied Polymeric Tapes

PVC - BITUMEN  
vs.  
PE - BUTYL-RUBBER

5 - 30 sec

10 - 60 sec



# Agenda

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1. Introduction
2. PVC (**P**oly**v**inyl **C**hloride)
3. PE (**P**oly**e**thylene)
4. Bitumen - Complex Mix of Hydrocarbons  
**P**olymer **M**odified **B**itumen (PMB)
5. Butyl-Rubber
6. Conclusions



# 1. Introduction

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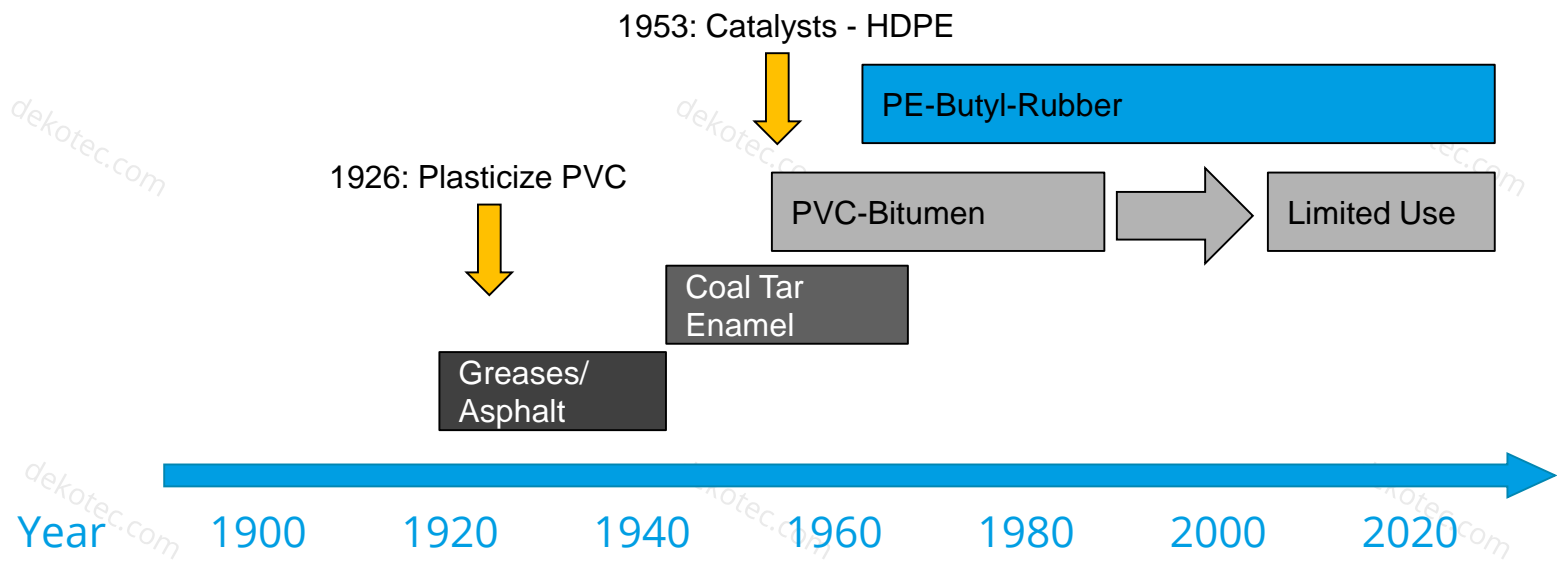
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# Objective of this Presentation

- To understand and to compare the **chemistry and the basic properties** of each material:
  - PVC (**P**oly**v**inyl **C**hloride)
  - PE (**P**oly**e**thylene)
  - Bitumen-Complex Mix of Hydrocarbons/**P**olymer **M**odified **B**itumen (PMB)
  - Butyl-Rubber
- Special focus:  
**Suitability for use in Corrosion Prevention Tapes**

# History

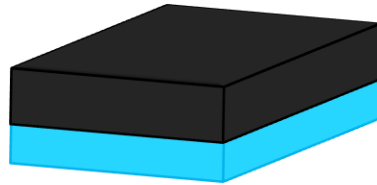


# Structure of Tapes

Cold-applied Polymeric Tapes: ISO 21809-3 – Coating Type 12

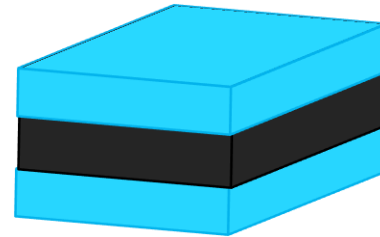
## Carrier Film + Compound

- Carrier Film: PVC or Mesh or PE
- Compound: Bitumen or Butyl-Rubber



### 2-Ply

- |      |                |
|------|----------------|
| PVC  | - Bitumen      |
| Mesh | - Bitumen      |
| PE   | - Butyl-Rubber |



### 3-Ply

PE – Butyl-Rubber

## 2. PVC (Polyvinyl Chloride)

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# PVC - History

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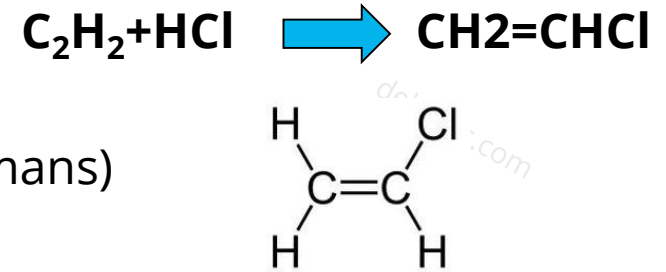
- 1835 (France): *Henri Victor Regnault* accidentally synthesized Vinyl Chloride. With the exposure to UV, a white solid (powder) developed: Polyvinyl Chloride. (*Regnault was not aware of his discovery*).
- 1912 (Germany): *Fritz Klatte* synthesized Vinyl Chloride from Ethine and Hydrogen Chloride and laid the foundation for the production of PVC. (*No products were successfully market at that time*).
- Due to lack of raw materials as a result of World War I, production of PVC started in the USA and Germany.
- 1926 (USA): Plasticize PVC by blending it with various additives –  
**Essential for application of tapes!**



# PVC - Chemical Structure

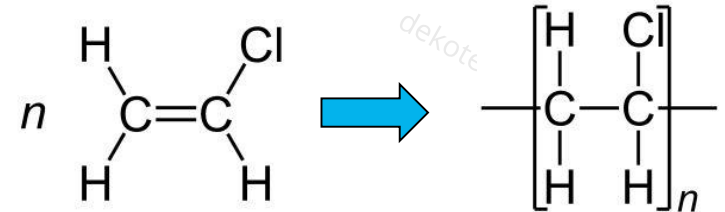
## Vinyl Chloride Monomer

Acetylene + Hydrogen Chloride (gas)  
Using Mercuric Chloride as catalyst (toxic to humans)



## Polymerization of Vinyl Chloride Monomer

Chemical reaction of monomer molecules to form a Polymer chain (=PVC)



# PVC - Additives

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## Various processing aids are needed:

- Impact modifiers - Thermal modifiers
- Fillers
- Biocides
- Pigments
- **Plasticizers**
- **Heat Stabilizers** - UV stabilizers

# PVC - Plasticizers Issue

Plasticizers (up to **40%**) make PVC flexible, but only at -18°C and higher

## Exudation - "Sweating Effect":

Plasticizers are not stable and migrate to:

- Environment: **Groundwater Pollution**
- Adhesive (Bitumen)
  - Backing stiffness embrittlement: **Cracking's**
  - Adhesive plasticizing: Gummy with **poor Lap Shear**



Plasticizers are suspected to cause **Cancer**

# PVC - Stabilizers Issue (Heat Instability)

PVC + Heat (from +70°C) → Dehydrochlorination

**Dehydrochlorination:** Allylic Chloride Structure + HCl

- Allylic Chloride Structure: Thermally unstable in Polymer & Toxic
- HCl + H<sub>2</sub>O (vapor)                      Hydrochloric Acid: **Corrosive & Toxic**

**Stabilizers:** to reduce loss of HCl

**But:** Dehydrochlorination is autocatalytic (“self-dissolution”):

→ Reaction products are catalysts for the same reaction – **Snowball Effect**



# 3. PE (Polyethylene)

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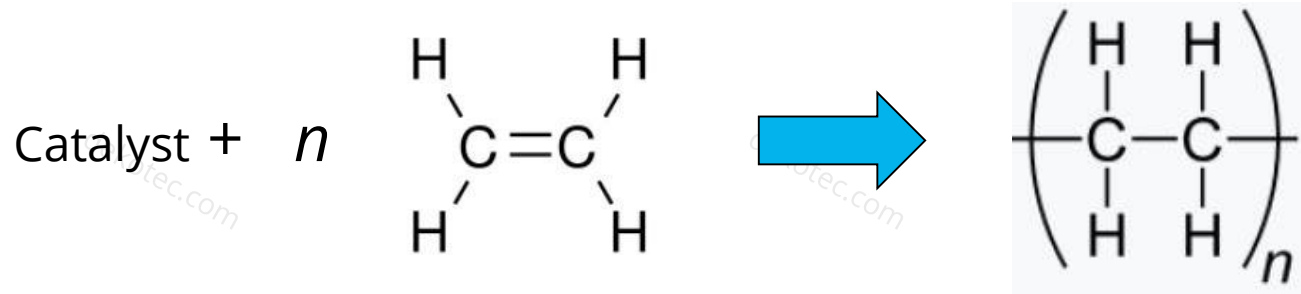
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# PE - History

- 1898 (Germany): White waxy substance was accidentally synthesized by *Hans von Pechmann*. (no practical use at that time)
- 1933 (UK): *Eric Fawcett & Reginald Gibson* “accidentally” synthesized in industrial manner a white, waxy material. Later *Michael Wilcox Perrin* produced in a high-pressure synthesis Polyethylene. ➔ LDPE
- 1944 (USA): Bakelite Corp. & DuPont started commercial production.
- 1951 (USA) and 1953 (Germany):  
Milestone success: catalysts + mild temperature & pressure + Ethylene
  - LDPE (**L**ow **D**ensity **PE**) &
  - HDPE (**H**igh **D**ensity **PE**).

# PE - Polymerization of Ethylene Monomer



Chemical Reaction: Catalyst + monomer molecules to form Polyethylene chains

Monomer molecules: Ethylene (simplest Alkene)

Similar chemical composition as **Candles or Chewing-Gum**

# PE – Basic Mechanical Properties

Rigidity/Flexibility



Flexible **from -40°C**  
**without Plasticizers**

High ductility



Plastic deformations  
before rupture

High impact strength



Absorbs energy and  
deform without fracture



# PE – Basic Mechanical Properties

No Dehydrochlorination → No heat stabilizers

→ Good Thermal stability

Melting Point (HDPE) → 120°C – 180°C

*Melting Point (PVC)* → 77°C – 88°C

# PE - Electrical Resistance & Water Absorption



## Electrical Resistance (EN 12068)

PE	→	$10^{16} \Omega \text{ cm}$
PVC	→	$10^{11} \Omega \text{ cm}$

## Water Absorption (ASTM D570)

PE	→	0.02% - 0.06%
PVC Plasticized	→	0.20% - 1.00%

# PE - Basic Properties (NACE CIP Level II)

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- Temperature resistant close to +100°C.
- Good low temperature flexibility.
- Excellent resistance to chemicals.
- Resistant to creep.
- High impact resistance.
- Excellent tensile strength.

# PE - Basic Properties (NACE CIP Level II)

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- High electrical resistivity.
- Insoluble in organic solvents.
- Does not crack under stress.

 **Perfect for Corrosion Prevention Tapes**

*Note: There is no PVC property mentioned by NACE*

# 4. Bitumen

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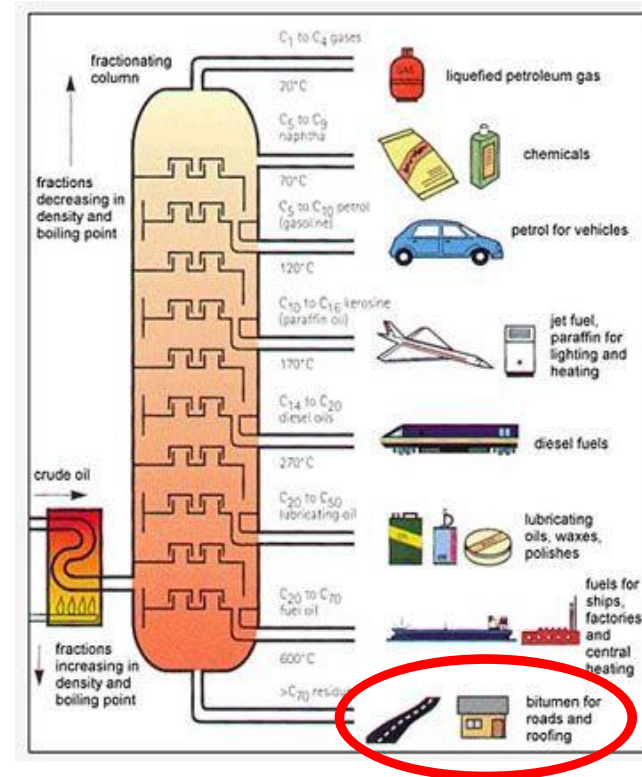
# Bitumen - Asphalt

- Complex Hydrocarbons ( $C_nH_m$ ) Mixture
- Natural:



Natural bitumen from the Dead Sea

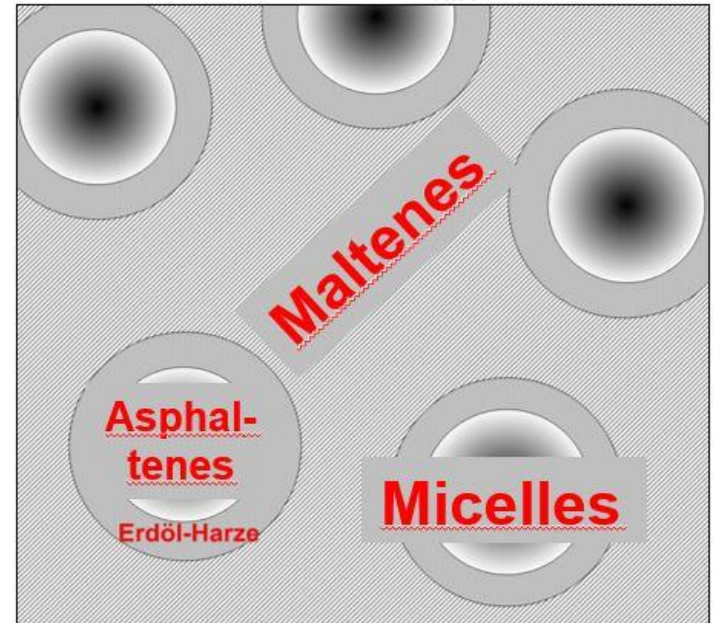
- Refined: Crude Oil Distillation
  - 1500 Crude Oil types, but:
  - only 7% are suitable for qualitative Bitumen
  - Quality issue – No defined composition



# Bitumen - Colloidal Model

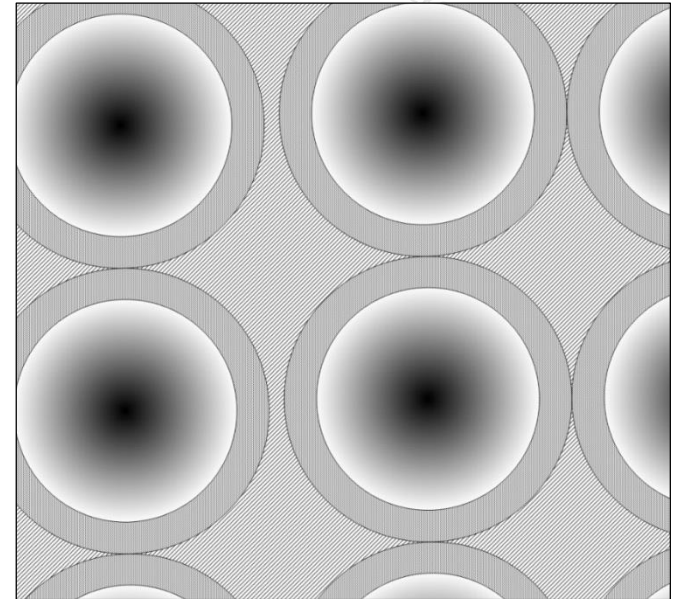
## This model explains the aging behavior of Bitumen

- Non-soluble Solid **Asphaltenes** - radius in nm ( $10^{-9}$  m)
- Asphaltenes are coated by soluble Resins
- Asphaltenes + Resins  
= Solid **Micelles**
- Oily Liquid matrix: **Maltenes**  
Temperature sensitive
- **Sol Type Bitumen**  
Asphaltenes Micelles are fully dispersed & non-interactive



## When Bitumen ages:

- Asphaltenes are growing (Oxidation) - Micelles are growing
- Maltenes evaporate
- Micelles are clumping & forming chains structures
- **Gel Type Bitumen**  
Ratio: Asphaltenes/Maltenes increases  
Bitumen becomes **hard, brittle & porous!**



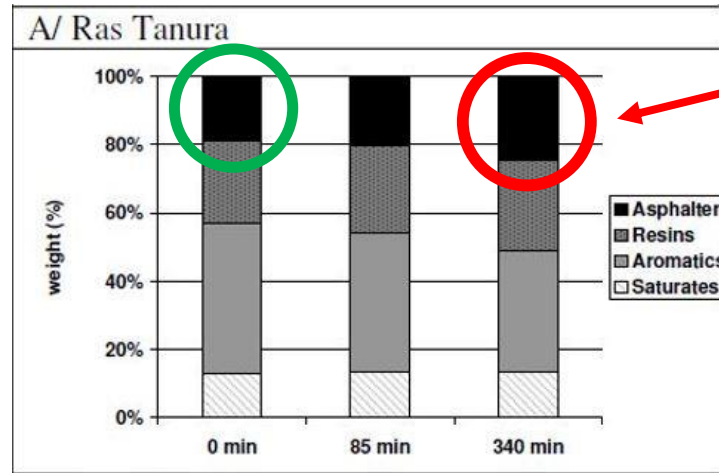


# Bitumen - How to measure ageing?

## Rolling Thin Film Oven Test (RTFOT) – ASTM-D1754 & EN 12607

### Asphaltene expansion rate:

- Depends on Crude Oil origin & temperature
- Is linear with time



The proportion of Asphaltenes is considerably growing after only 340 min.

# Bitumen - Colloidal Model (Structural Ageing)



## **Structural Ageing is the weak point of Bitumen !**

- Oxidation is the most influential factor.
- Ageing is a process that can not be interrupted.

### Ageing speed depends on:

- Crude Oil Origins & temperature
- Bitumen mixture (**Polymers** can only reduce ageing speed).

### Ageing Result:

Bitumen becomes **hard, brittle & porous!**



# Bitumen - Pipeline Coatings (Ageing Issue)

Bitumen becomes  
**hard, brittle & porous**

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# Bitumen - Pipelines Coatings

## Polymer Modified Bitumen (PMB)

Polymers (ex: SBS, SBE, EVA, EBA) are added:

- ...to make the mixture sticky (adhesion).
- ...to increase plasticity window temperatures (breaking-softening).

### BUT:

- Cheap Polymers don't reduce ageing speed.
- Non-homogeneous mixture (Polymer chains are not broken during mixing) .
- Ex: Problems with **storage conditions!**

# Bitumen - Pipeline Coatings (Storage Issues)



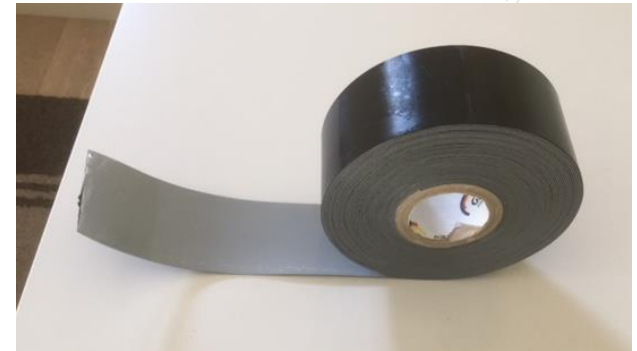
Storage at **Room Temperature** (+23°C) for 5 months:

**PVC-Bitumen:**



**Can no longer be used**

**PE-Butyl Rubber**  
(3-ply coextruded):



**Still in perfect condition**

# Bitumen - Pipeline Coatings (Ageing Testing)



**100 days ( $T_{\max}+20^{\circ}\text{C}$ ) aging tests - EN 12068 & ISO 21809-3:**

Requirement Peel Strength to steel surface:  $A_{100}/A_o \geq 0.75$

- Mesh-Bitumen Tape (2-ply laminated):  $A_{100}/A_o \pm 0.60$
- PE-Butyl-Rubber Tape (3-ply coextruded):  $A_{100}/A_o \geq 0.90$

# Bitumen - Pipeline Coatings (Ageing Testing)



## Hot Water Immersion (HWI) Tests – ISO 21809-3:

Requirement Peel Strength to steel surface:  $\geq 1 \text{ N/mm}$

Requirement Peel Strength to steel surface after 28 days HWI:  $\geq 0.4 \text{ N/mm}$

	<u>Initial</u>	<u>After HWI</u>
■ Mesh-Bitumen Tape (2-ply laminated):	$> 1.0 \text{ N/mm}$	– <b>0.2</b> - $0.4 \text{ N/mm}$
■ PE-Butyl-Rubber Tape (3-ply coextruded):	$> 3.0 \text{ N/mm}$	– $> 3.0 \text{ N/mm}$

# Bitumen - Pipeline Coatings (Porosity Issue)

**High Porosity = high Cathodic Protection (CP) current demand**

**ISO 15589-1:2015** – Cathodic Protection onshore Pipelines.  
§ 8.4. Cathodic Protection Current Demand

## § 8.4.2 - Coating Breakdown Factors ( $f_f$ )

$$I_{\text{tot}} = \pi D \times L \times k \times j \times f_f$$

$I_{\text{tot}}$ : total current demand

$k$ : contingency factor - non uniform distribution ( $\geq 1.25$ )

$j$ : design current density (100mA/m<sup>2</sup> - 1A/m<sup>2</sup>)

$f_f$ : High Coating Breakdown Factor = High CP current demand



# Bitumen - Pipeline Coatings (Porosity Issue)

$$f_f = f_i + (\Delta f \times t_{dl})$$

$f_i$ : initial  $f_f$

$\Delta f$ : Avg yearly increase of  $f_f$

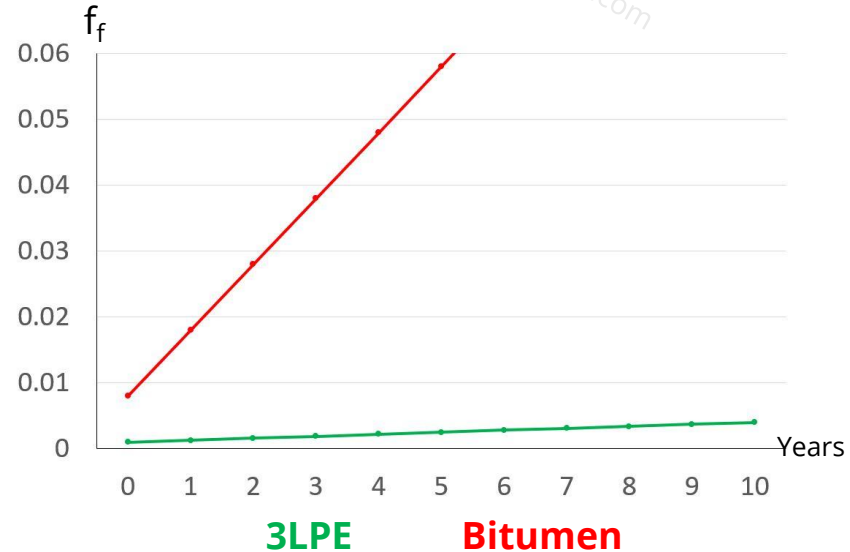
$t_{dl}$ : design life (years)

Table 2 — Typical design coating breakdown factors

Pipeline coating	$f_i$	$\Delta f$
FBE	0,005	0,002
3LPE	0,001	0,000 3
3LPP	0,001	0,000 3
Liquid epoxy	0,008	0,01
Coal tar urethane	0,008	0,01

Coal Tar and Bitumen are very similar materials with comparable properties

## Coating Breakdown Factors after 10 years



# Bitumen - Pipeline Coatings (Porosity Issue)

## § 8.4.3 - Current density

$$I_{\text{tot}} = \pi D \times L \times k \times j \times J_c$$

k: contingency factor - non uniform distribution ( $\geq 1.25$ )

$j_c$ : design current density (Table 3)

**Table 3 — Typical design current density values for coated pipeline**

Type of coating	Current density for optimized design mA/m <sup>2</sup>	Current density for conservative design mA/m <sup>2</sup>
3LPE or 3LPP	0,001 to 0,02	0,05 to 0,2
FBE	0,02 to 0,2	0,4 to 0,7
Coal tar or bituminous coating	0,2 to 0,3	0,3 to 0,8

NOTE These values are given for pipelines built with respect to standards mentioned in [7.5.2](#) and [7.5.3](#).

# 5. Butyl-Rubber

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# Butyl-Rubber - History

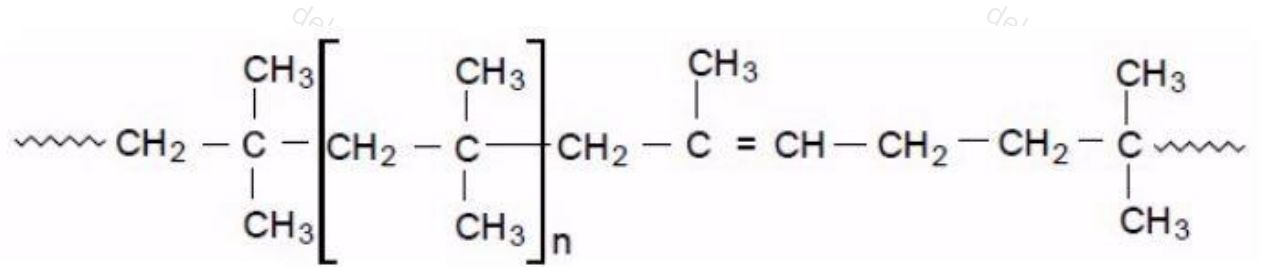
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- 1825 (UK): *Michael Faraday* (better known for discovery of electromagnetic induction, diamagnetism and electrolysis) discovered Isobutylene.
- 1931 (Germany): BASF developed Polyisobutylene (PIB), which was sold under the trade name *Oppanol B*.
- 1937 (USA): Development into Butyl-Rubber by Standard Oil laboratory.
- Today, the majority of the global supply of Butyl-Rubber is produced by:
  - **ExxonMobil** (USA), one of the descendant of Standard Oil (USA).
  - **LANXESS AG** (Germany), Bayer AG bought Polysar Rubber (Canada) in 1990.

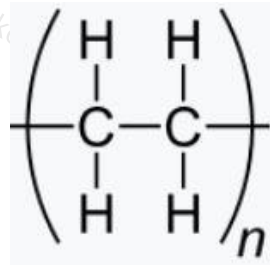
# Butyl-Rubber

Isobutylene Isoprene Rubber (IIR) is polymerization of:

- 98% Poly-Isobutylene (PIB)
- 2% Isoprene



Chemical structure close to PE



# Isobutylene Isoprene Rubber (IRR)

## Basic Properties

- Low permeability to air, gases & moisture (tire profile and tubes).
- Glass transition temperature:  $-67^{\circ}\text{C}$ .
- Maximum temperature:  $+100^{\circ}\text{C}$  ( $+150^{\circ}\text{C}$  if vulcanized with sulfur).
- Resistant to ageing & weathering (stable).
- Hardness & tensile strength properties.
- Low filler content.
- Safe (chewing-gum effect).



**Perfect for Corrosion Prevention Tapes**

# Butyl-Rubber (NACE CIP Level II)

- Temperatures resistant close to +100°C.
- Pliable and moldable material.
- Typical use: mastics, adhesives, sealants.
- Excellent resistance to acids.

 **Perfect for Corrosion Prevention Tapes**

*Note: No Bitumen property is mentioned by NACE*

# Butyl-Rubber: properties are stable over time



PE-Butyl-Rubber Tape **after 40 years of operation**  
exceeds current requirements





# 6. Conclusions

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# PVC-Bitumen vs. PE-Butyl-Rubber

Properties	PVC	Bitumen	PE	Butyl-Rubber
Low Temperature	-18°C	-50°C	-40°C	-67°C
Melting Point Temp.	+77°C	+80°C	+120°C	+100°C
Electrical Resistance	10 <sup>11</sup> Ω cm		10 <sup>16</sup> Ω cm	
Water absorption	0.2% - 1.0%		0.02% - 0.06%	
Ageing	<b>Poor</b>	<b>Poor</b>	<b>Stable</b>	<b>Stable</b>
	<b>Cracks</b>	<b>Porous</b>	<b>HWI &amp; Ageing tests</b>	

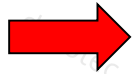


# PVC-Bitumen vs. PE-Butyl-Rubber

## PVC-Bitumen

**From their intrinsic material properties**, PVC & Bitumen are **unsuitable** as base material for Polymeric Tapes.

- PVC **needs Plasticizers and Stabilizers** which evaporate with ageing.
- Bitumen shows **Structural Ageing**: it becomes **hard, brittle and porous**.



***PVC-Bitumen Tapes show poor performance on long terms***

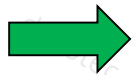


# PVC-Bitumen vs. PE-Butyl-Rubber

## PE-Butyl-Rubber

**According to their material properties**, Polyethylene (PE) & Butyl-Rubber are **well suited** for Polymeric Tapes

- Polyethylene doesn't need Plasticizers or Stabilizers: **excellent thermal stability**.
- Butyl-Rubber: **stable & strong** sealing compound.



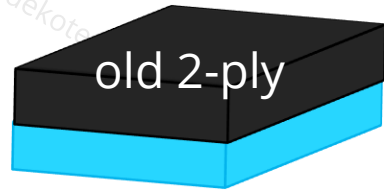
***PE-Butyl-Rubber Tapes show excellent performance on long terms***



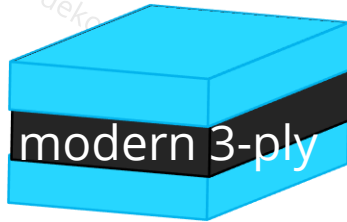
*Best as 3-ply real-coextruded tapes*

# PVC-Bitumen vs. PE-Butyl-Rubber

**PVC-Bitumen:** old fashioned technology with some storage issues and significant **long-term risks**



**PE-Butyl-Rubber:** modern technology allowing modern product design (3-ply) with proven outstanding performance and unique track record.





Thank you for your attention!

If you have any further questions  
please contact us!



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# ANNEX

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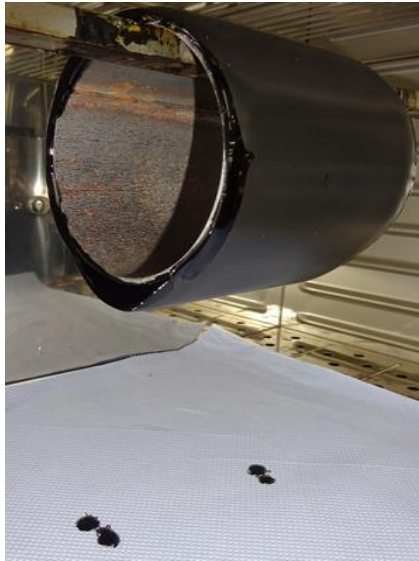
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# PVC-Bitumen vs. PE-Butyl-Rubber (Ageing)

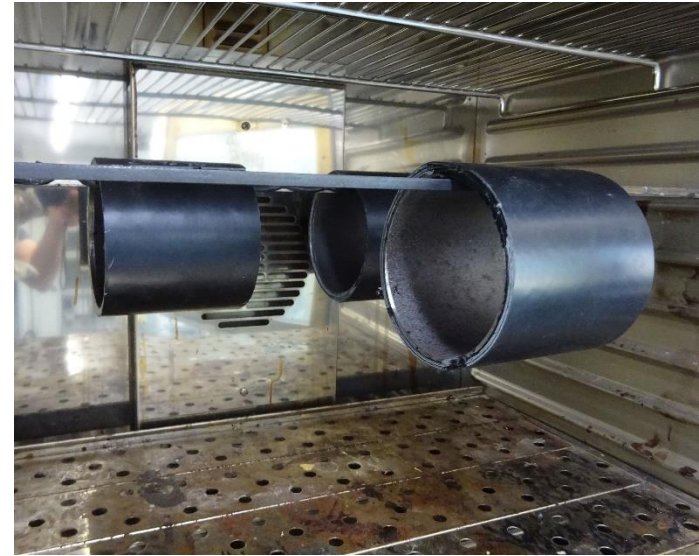


24 hours @ 75°C

**PVC-Bitumen Tape**



36 hours @ 75°C



100 days @ 70°C

**PE-Butyl-Rubber Tape**



Peel strength  $\geq 2.75\text{N/mm}$