Non Metallic Pipe for High Temperature High Pressure (HTHP) Applications & Recent developments in Polyamide 12 UV Resistance

April 2019 | Akshay Ponda

EVONIK
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VESTAMID® NRG PA12 pipelines

Performance & Reliability

Experience

Standards & Safety

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Who we are
Evonik at a glance

15

Billion Euro sales in 2018

176

Sites

>80%

Of turnover gained from leading market positions

>36,000

Employees in over 100 countries

~230

New patent applications

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Our Experience

Specialty chemicals with extensive experience in polymers

EVONIK INDUSTRIES

2007

- ~ 160 years in Specialty Chemicals
- ~ 50 years in specialty long chain polyamides
- ~ 70 years in pipeline operations

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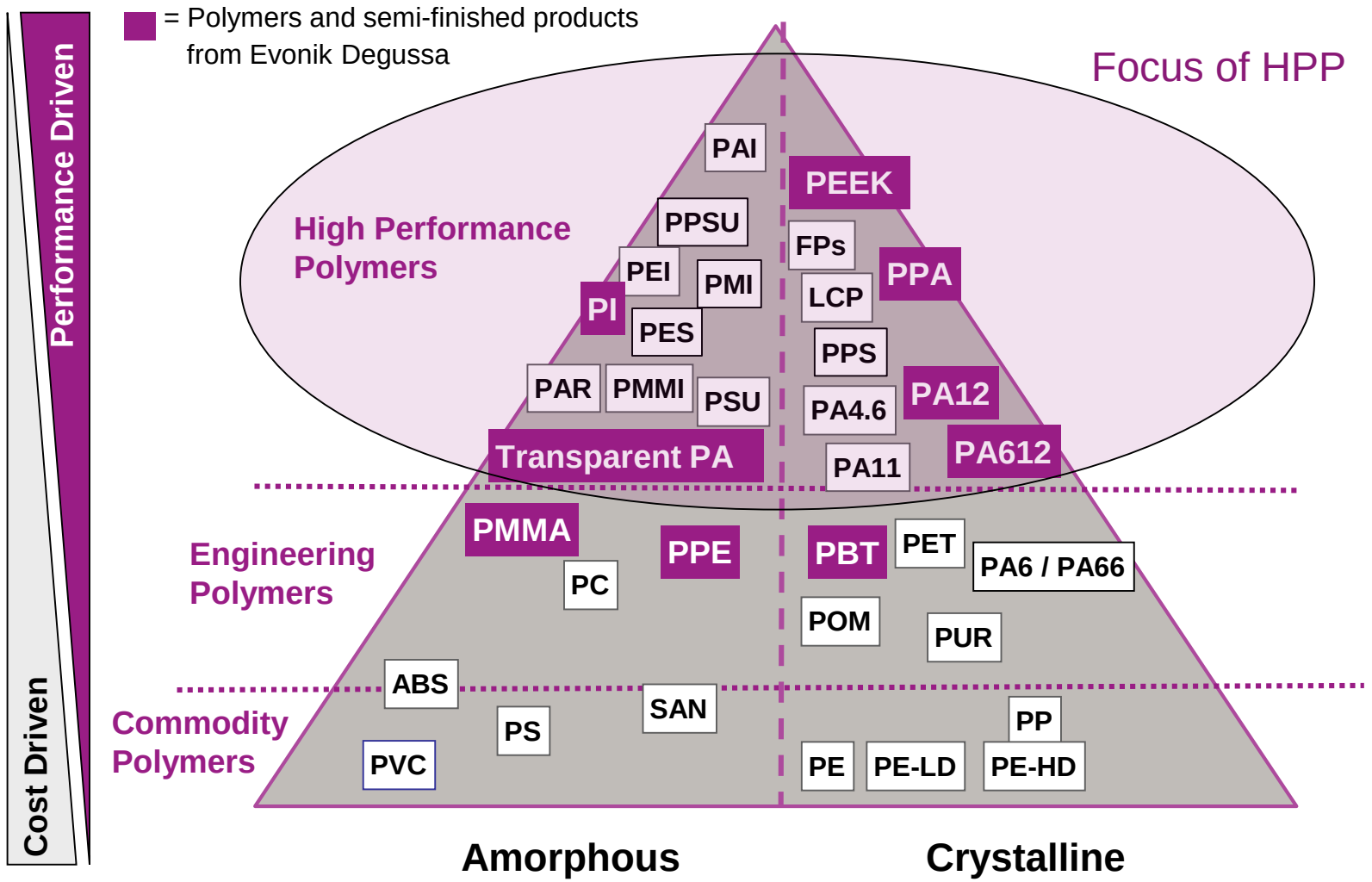
High Performance Polymers Portfolio



Basic

- PA12
- PA1012
- PA612
- PA610
- PA1010
- PEEK
- PPA

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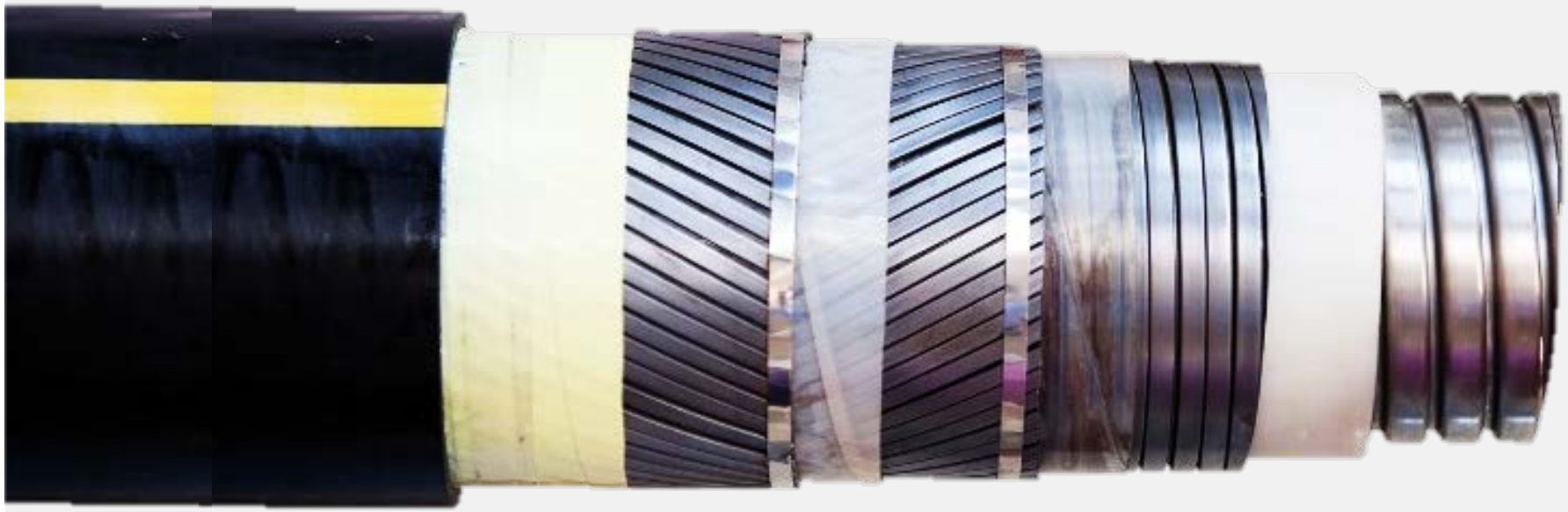
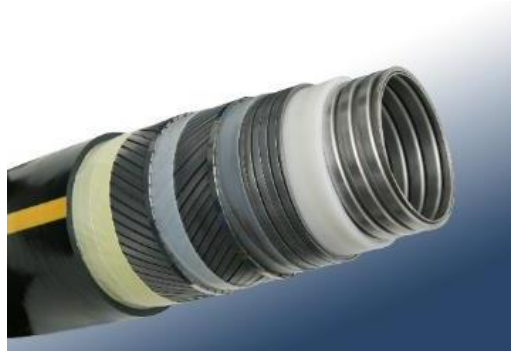
Offshore Experience

VESTAMID® NRG PA 12 is used in flexible pipes

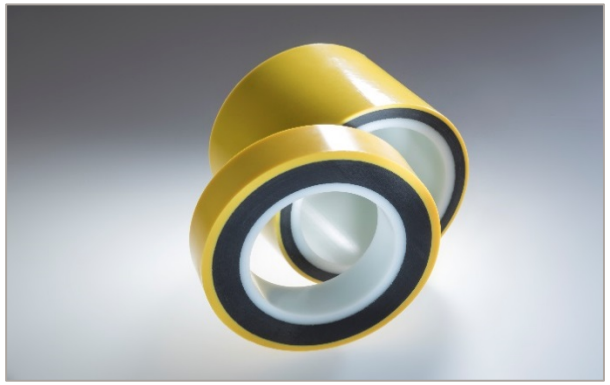


*“Thousands km of flexible pipes containing **VESTAMID® NRG PA12** have been installed since 2006”*

Our portfolio for the pipeline industry



Flexible risers



TCP

Reinforced thermoplastic pipe

PEEK liners

PA 12 Liners

PA 12 Pressure pipe

External steel pipe protection

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VESTAMID® PA12 - Performance

- **VESTAMID® (PA12)** is the material of choice for the **fuel lines** in cars since over **40 years**.
- In 2014 so many automotive lines were produced from **VESTAMID® (PA12)** that the earth could be wrapped six times! (more than 240,000km).

VESTAMID® (PA12)
in fuel lines

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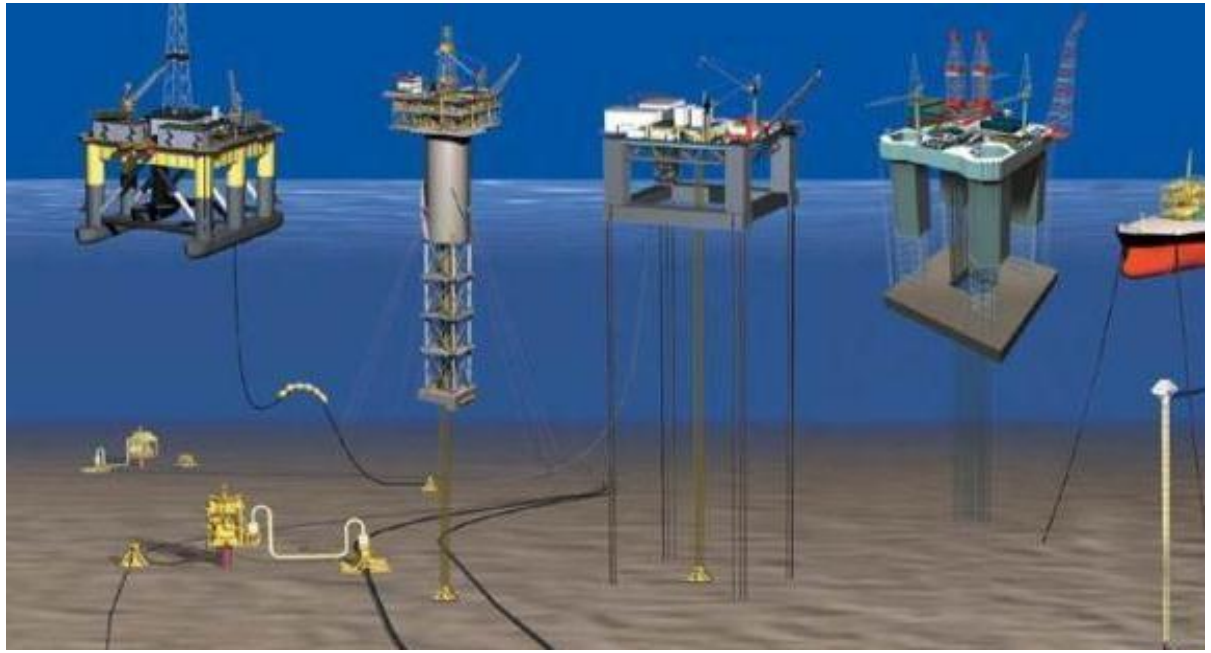
VESTAMID® NRG PA12 - Reliability



VESTAMID®NRG PA12 is used in **flexible pipes** for reliable offshore operations since 2006.

Over 3000km of flexible pipes **VESTAMID® NRG PA12** have been installed since.

PA12 pipelines for high pressure natural gas distribution

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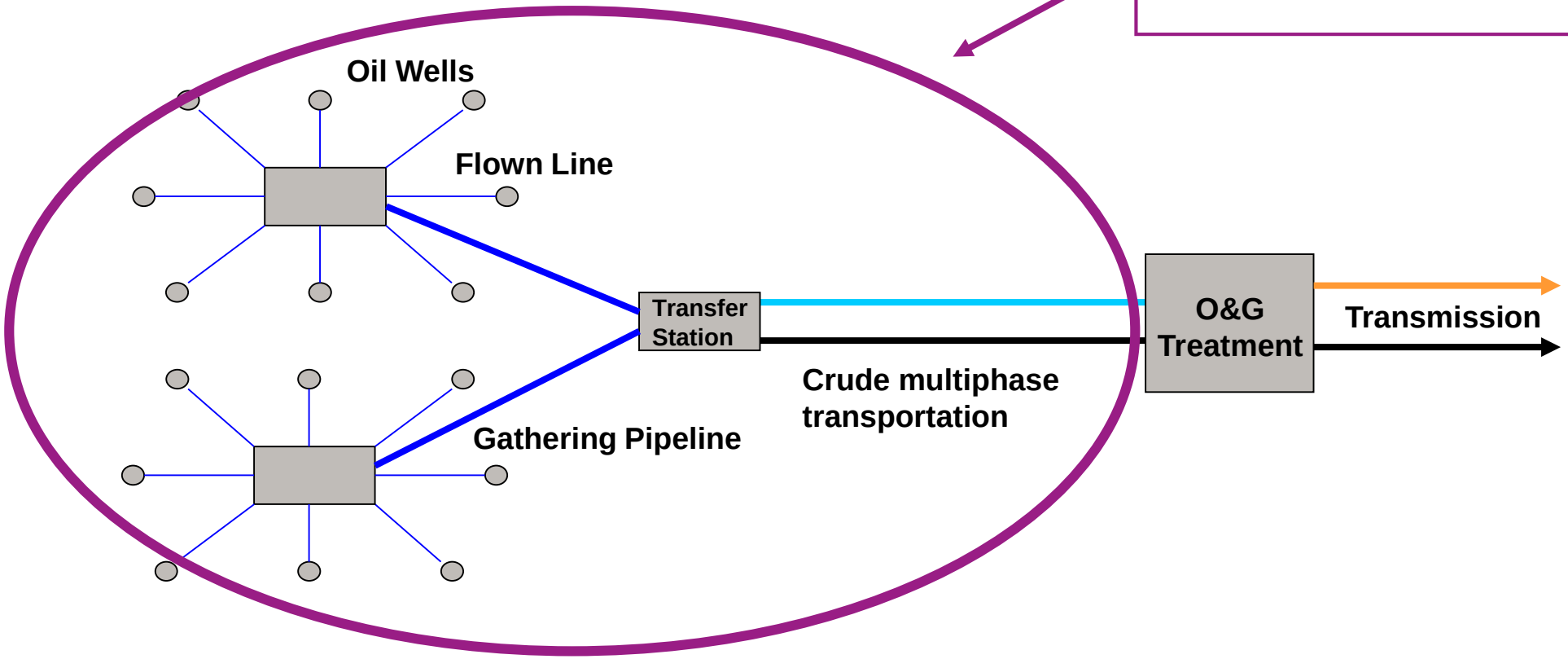
PA12 liner system in Oil & Gas fields

Our main target:
Pipelines operating at high temperature



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Steel = Corrosion !

Old gas pipes prevalent in Ohio

Benjamin Lanka, blanka@centralohio.com 8:52 a.m. EDT September 27, 2014

Danger rises with increasing pipeline leaks, slow fixes

Keith Matheny, Detroit Free Press staff writer 5:41 p.m. EDT September 23, 2014

Alabama Gas Explosion Heightens Concern Over Cast-Iron Pipe Corrosion

By Kala Kachmar, Montgomery Advertiser | September 29, 2014

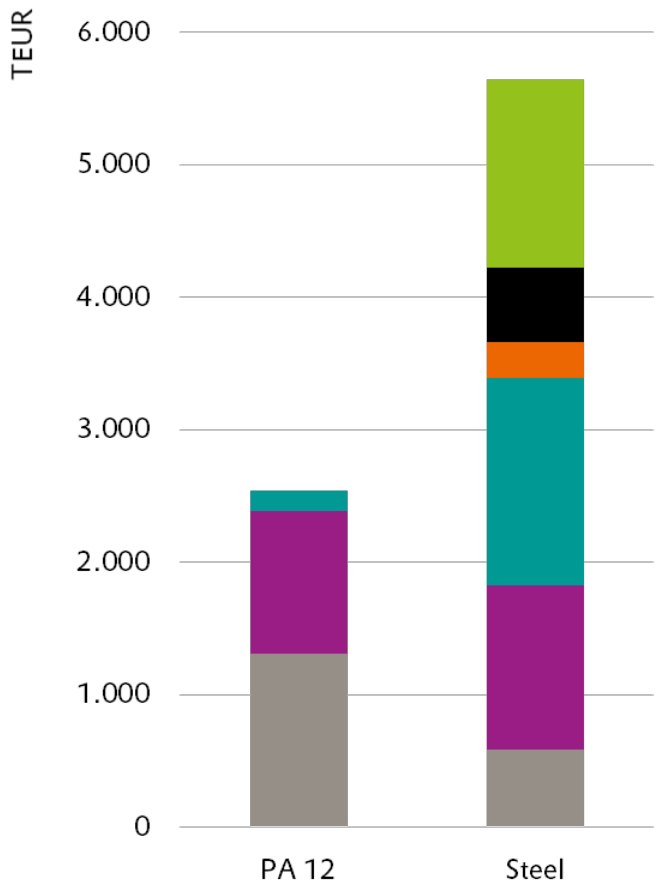
Aging gas pipes pose explosion danger

Daniel P. Finney and Jeffrey C. Kummer, dafinney@dmreg.com 10:40 p.m. CDT September 23, 2014

PA12 saves investment costs:

- Project example:
  - PA12 110mm, SDR11
  - Steel 4” STD.

Corrosion Costs: Total in 50 years	-100 %
Inspection Costs	-100 %
Cathodic Corrosion	-100 %
Installation Costs	-90 %
Construction Costs	-12 %
Pipe & Fittings	+ 122 %



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Installation of PA12 gas pipes is similar to state of the art PE pipe installation

PA12 pipes are coilable

- Reducing welding
- Transport und handling are simplified

PA12 is easy to install

- Fast welding
- Same machines and procedures as PE100
- No need of field joint coating
- No sand bedding
- Ploughing
- HDD

No corrosion

- No Cathodic Corrosion Protection
- No maintenance

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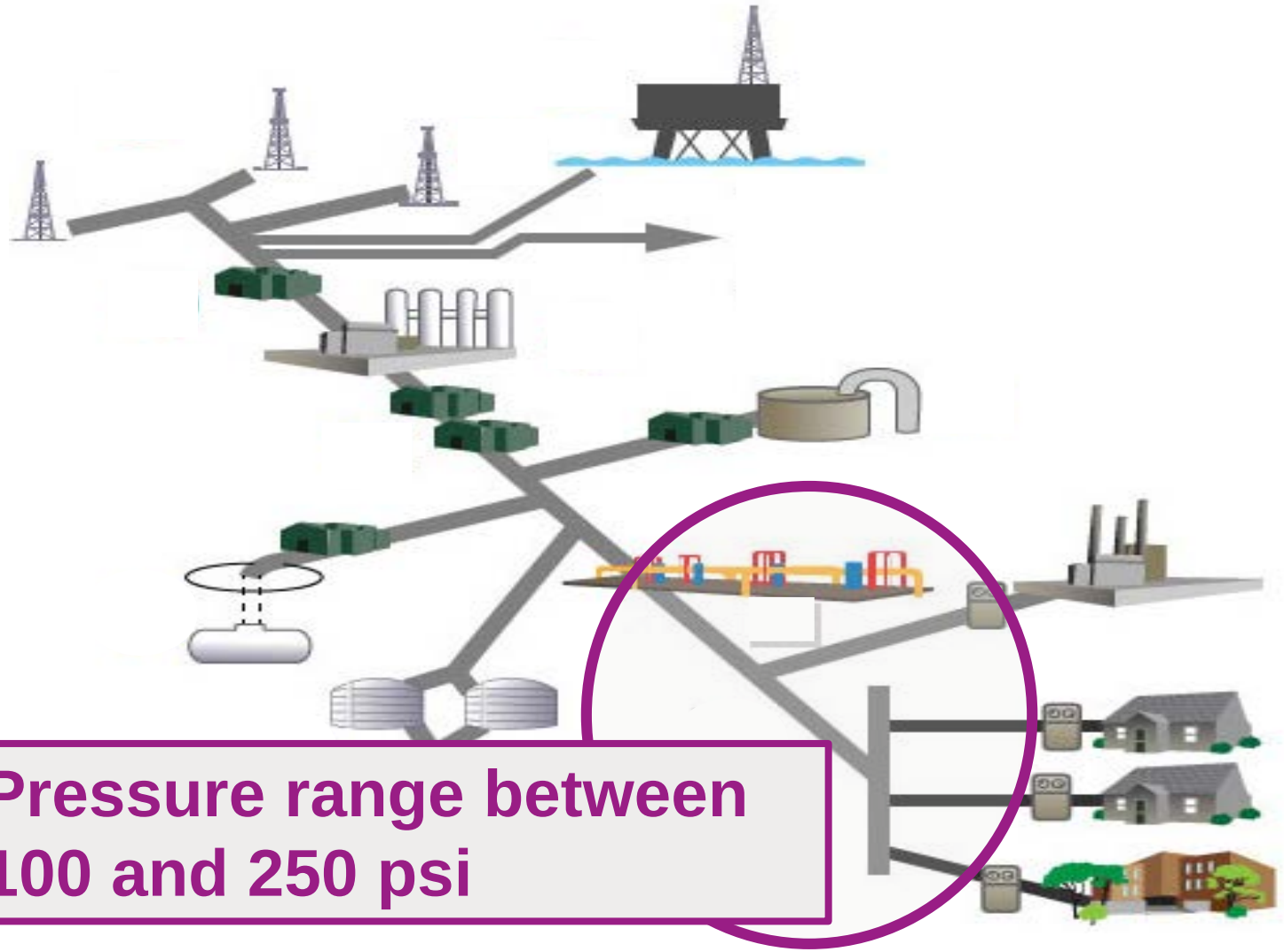
High pressure gas distribution pipelines



Pressure range between 100 and 250 psi

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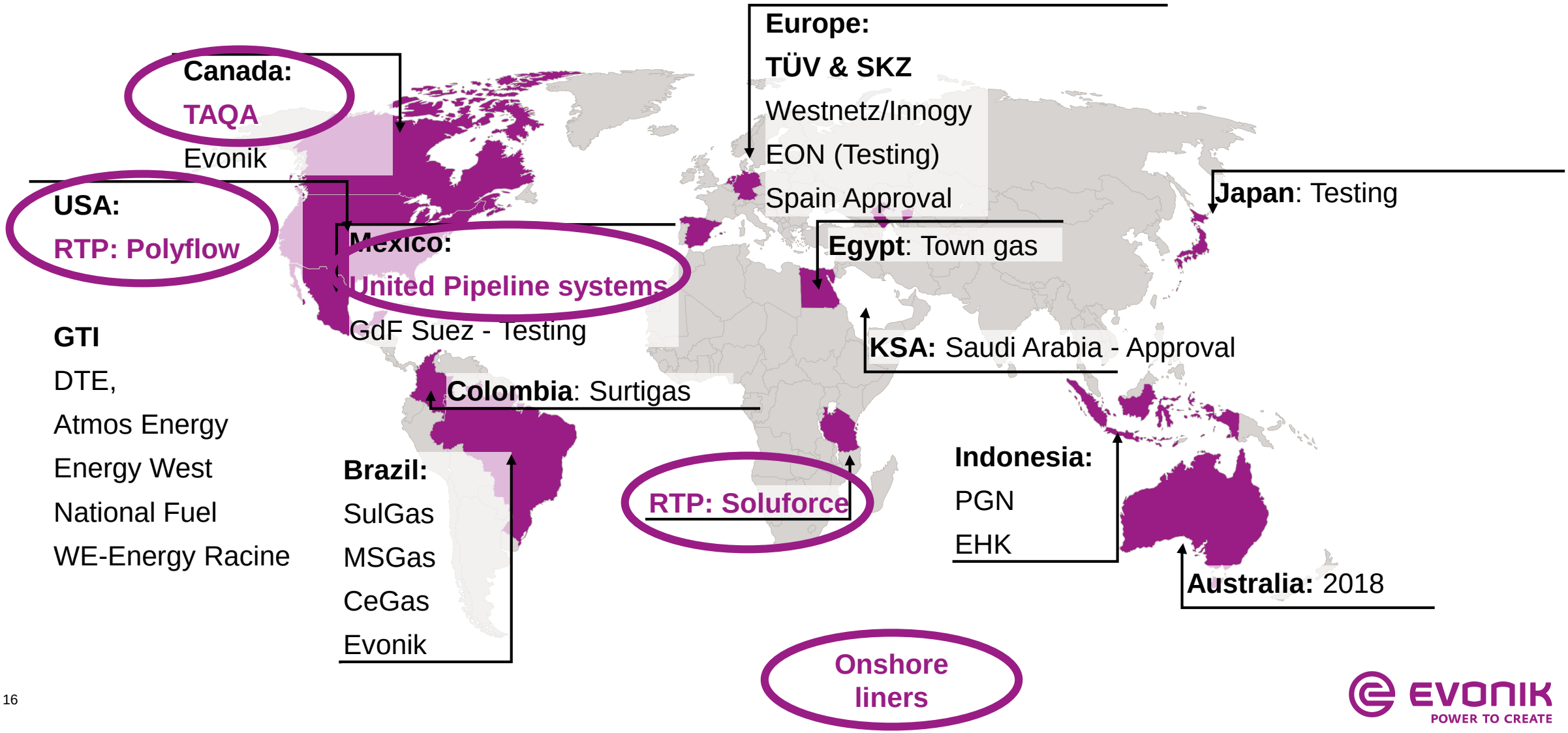
VESTAMID® NRG – Onshore Experience



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PA 12- Experience

Location	Date	Characteristics	Pressure
Energy West, Montana, USA	Jul. 09	4” SDR 13.5	175 psig
Energy West, Montana, USA	Aug. 12	4” SDR 13.5	150 psig

PA 12 - Experience

Location	Date	Characteristics	Pressure
MSGAS, Campo Grande, Brazil	Oct. 12	90 mm SDR 11	17 bar
MSGAS, Campo Grande, Brazil	Nov. 15	160 mm SDR 11	16 bar

MSGÁS
COMPANHIA DE GÁS DO ESTADO DE MATO GROSSO DO SUL

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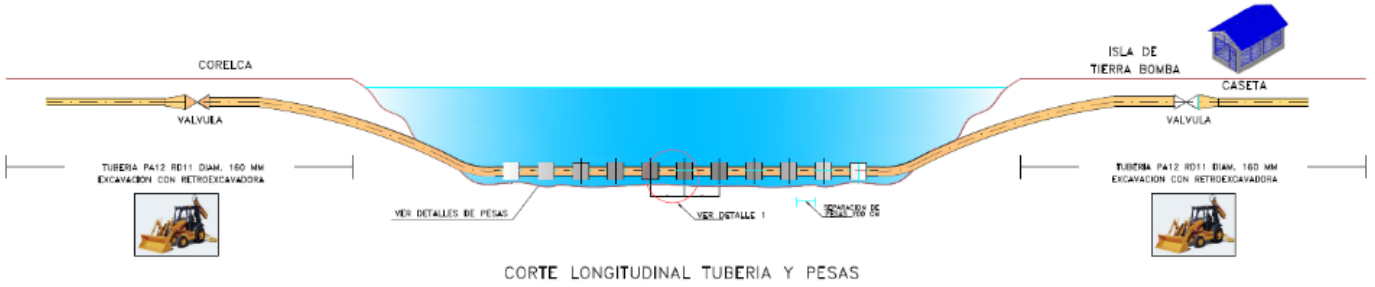
VESTAMID® NRG PA12 has a long track record

Location	Date	Characteristics	Pressure
Surtigas, Cartagena, Colombia	Jun. 16	160mm SDR 11	16 bar



CORTE LONGITUDINAL TUBERIA Y PESAS

surtigas℠

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VESTAMID® NRG - Experience

Location	Date	Characteristics	Pressure
Indonesia	Dec. 16	110 mm SDR 11	16 bar

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Squeezed-off PA 12 pipe after 3 years service

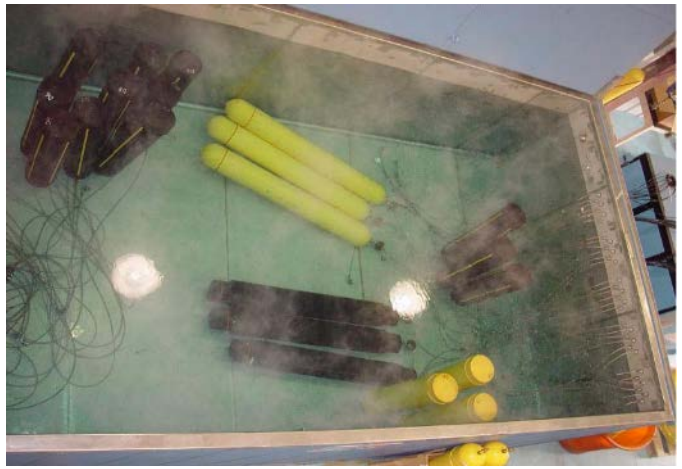
Location: Gas Technology Institute, USA

Pipe Dimension: 4 inches, SDR 13.5

Pressure: 16 bar

Performance	ASTM Specification	LHTS of 3-year Service Squeeze-off pipe at 2800 psi hoop stress
Hours exposed	>1000	2761 hours without failure of pipe

Squeeze-off Pipe



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Squeeze-off of PA12 tested by E.ON, SKZ, KIWA and DBI

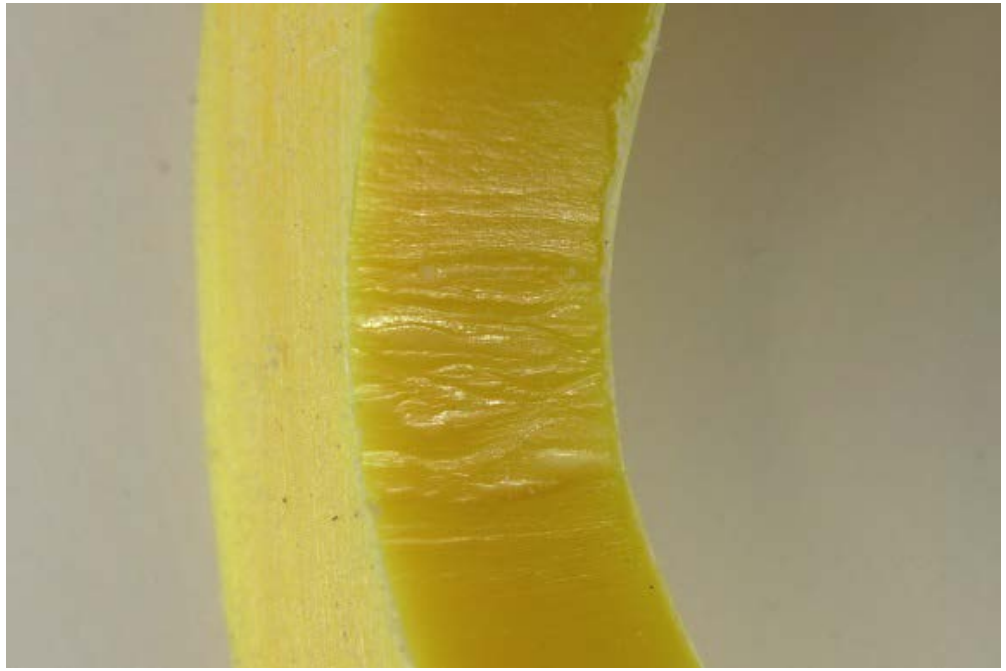
OD 110 & 160mm SDR 11 squeezed off at 5°C.

1. Technically tight.

2. No cracks on surfaces of squeezed off pipe. Only wrinkles with a depth of less than 1mm.

3. Squeezed off pipe tested under very sharp hydrostatic strength test. Similar results as non-squeezed-off pipe.

4. Pipe recovery is enough so that re-rounding might not be necessary.



kiwa
Partner for progress

e·on

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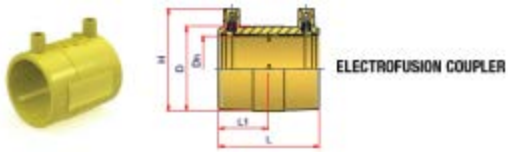
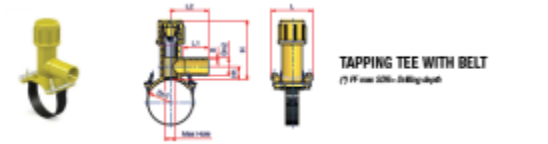
Complete set of fittings is available in PA12



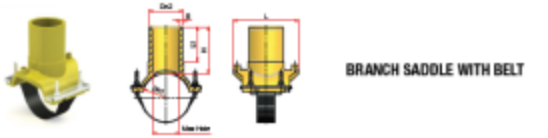
OD: 32, 63, 90, 110, 160mm; SDR 11

63-32, 90-32, 90-63, 110-32, 160-32; SDR 11

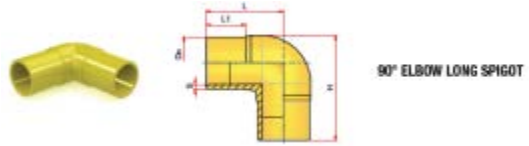


110-63, 160-63; SDR 11

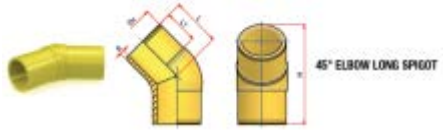
63-32, 90-32, 63-63, 90-63, 110-63; SDR 11



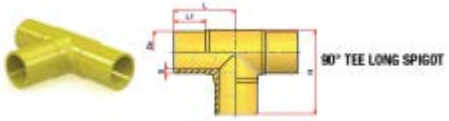
160-63; SDR 11



OD: 32, 63, 90, 110, 160mm; SDR 11

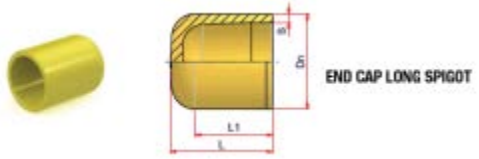


OD: 32, 63, 90, 110, 160mm; SDR 11

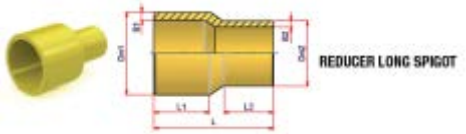


OD: 32, 63, 90, 110, 160mm; SDR 11

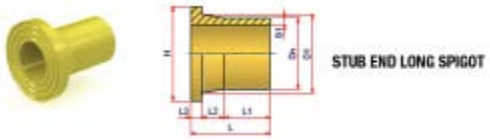
90-63, 110-63, 110-90, 160-110; SDR 11



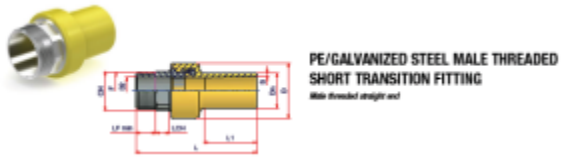
OD: 32, 63, 90, 110, 160mm; SDR 11



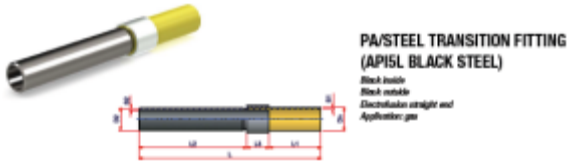
63-32, 90-63, 110-63, 160-110; SDR 11



OD: 32, 63, 90, 110, 160mm; SDR 11



32*1“, 63*2“, 90*3“, 110*4“



32*25, 63*50, 90*80, 110*100, 160*150

60 different parts !!

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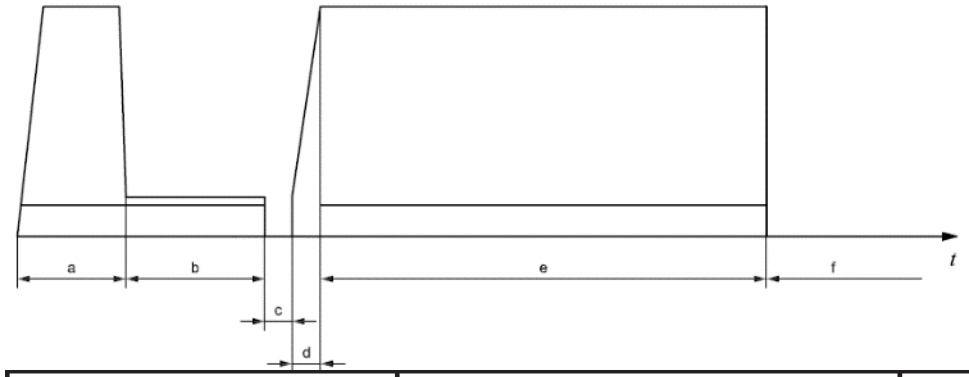
Butt and Electro Fusion of PA12 pipe is verified and standardized



Parameters		Values	Units
Heater-plate temperature, T		240 ± 20	°C
Phase 1	Pressure, p_1[a]	0,3 ± 0,1	MPa
	Time, t_1	Measured as the time until B_1 is reached	s
	Bead width, B_1	See Table A.3	mm
Phase 2	Pressure, p_2[a]	0,03 ± 0,02	MPa
	Time, t_2	See Table A.3	s
Phase 3	Time, t_3	See Table A.3	s
Phase 4	Time, t_4	See Table A.3	s
Phase 5	Pressure, p_5[a]	0,3 ± 0,1	MPa
	Time, t_5	See Table A.3	min
Phase 6	Time, t_6	Minimum value: $1{,}5e_n$	min
		Maximum value: 20	min

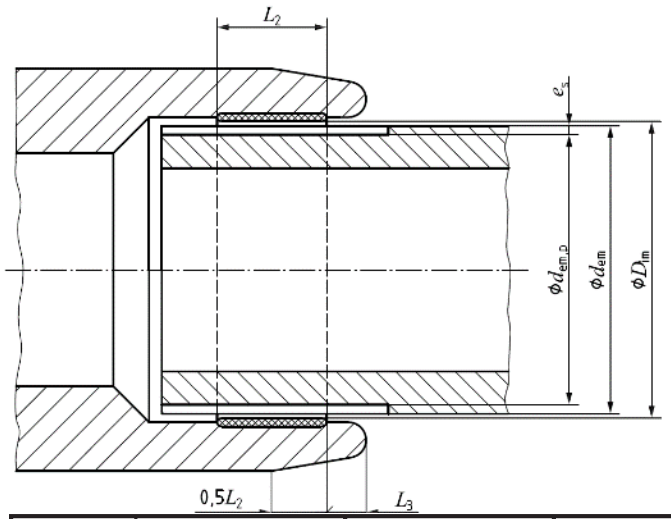
[a] This pressure is the interface pressure and is related to d_n, e_n and the butt fusion equipment used.

ISO 16486 defines procedure and inspection criteria

Same procedure and machine as PE pipe.

EVONIK POWER TO CREATE

Electrofusion of VESTAMID® NRG pipe is verified and standardized



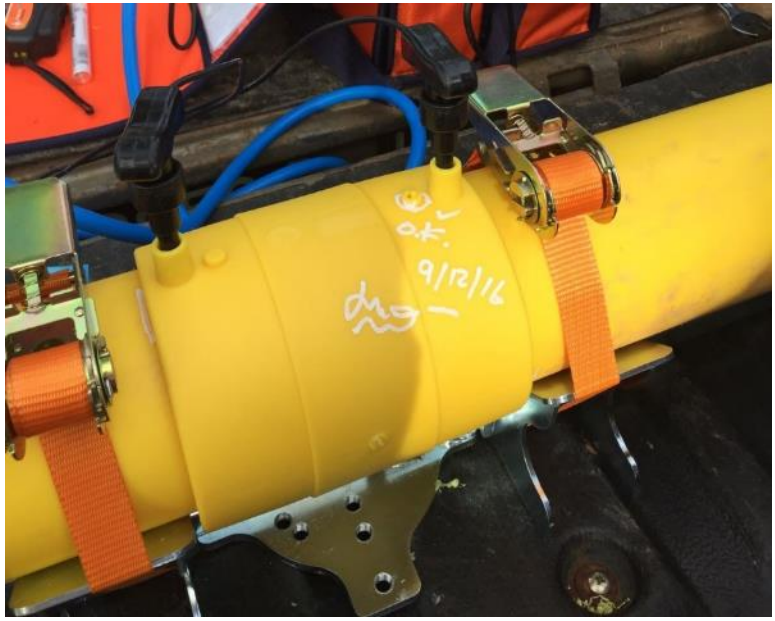
Set of conditions	Ambient temperature, T_a	Pipe configuration	Clearance[a]	Energy	Assembly load[b]
1	T_R	Coiled or straight pipe as supplied	C_2	reference	usual
2.1	T_{min}	Straight pipe	C_4	nominal	usual
2.2	T_{min}	Straight pipe	C_4	minimum	minimum
3.1	T_{max}	Straight pipe	C_2	nominal	usual
3.2	T_{max}	Straight pipe	C_2	maximum	maximum
4	T_{max}	Straight pipe	C_4	minimum	minimum
5	T_{min}	Coiled or straight pipe as supplied	C_2	maximum	maximum

NOTE Sets of conditions 1 to 5 are applicable to the energy profiles illustrated in Figures B.2 and B.3.

[a] In the case of saddles, the clearance shall be considered to be zero.

[b] Applicable to joints with saddles, where the load can be controlled.

ISO 16486 defines procedure and inspection criteria



Same procedure and machine as PE pipe.

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DOT: VESTAMID® NRG
Pipe survives hitting test

PA12 HDPE

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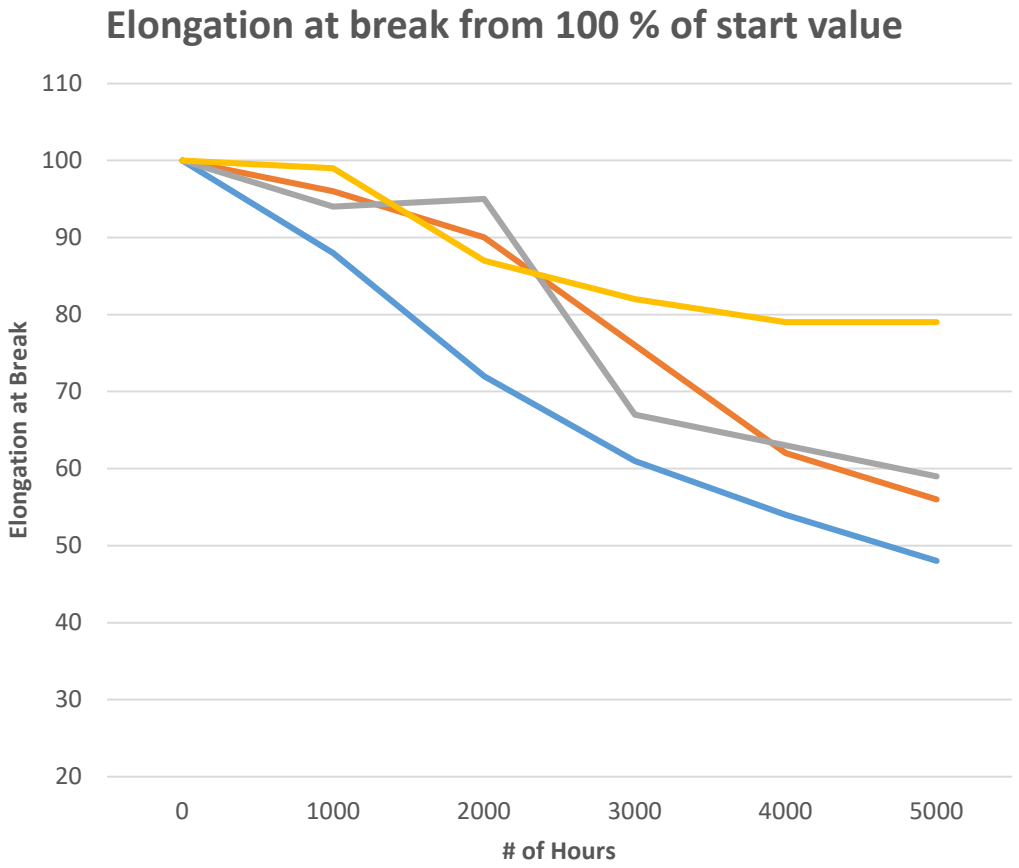
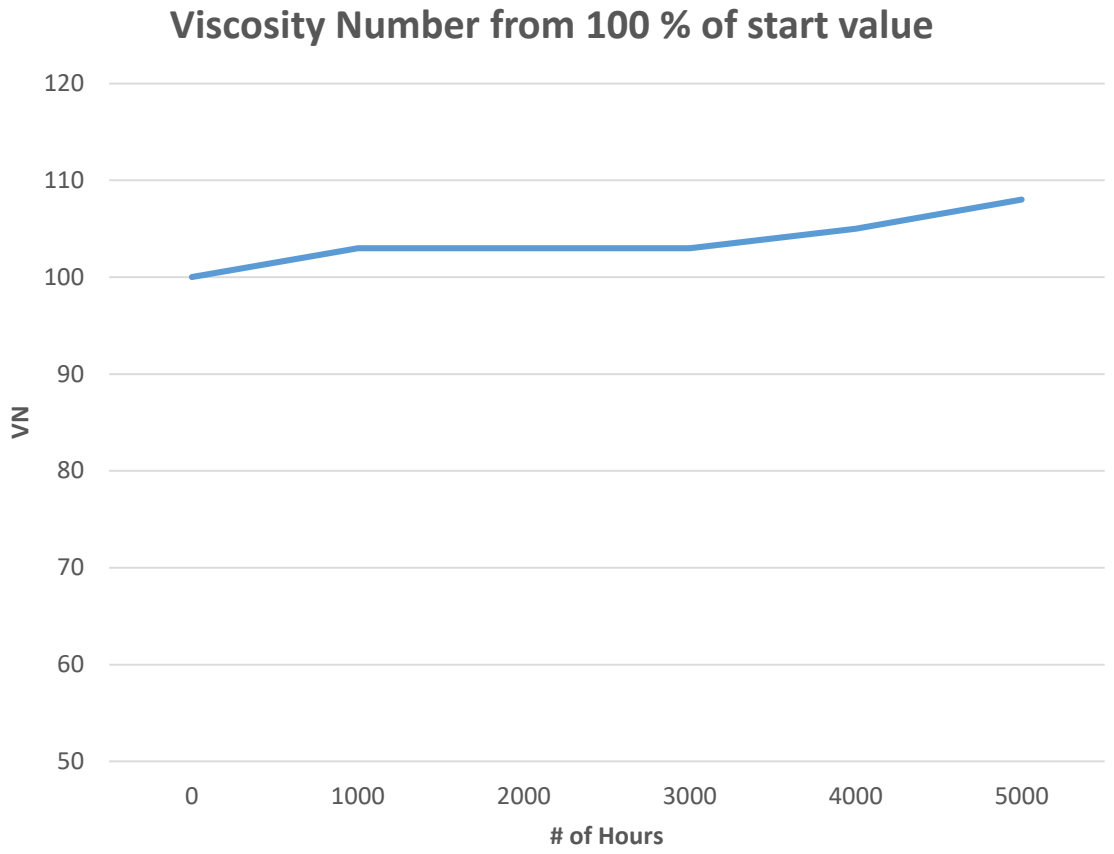
Latest UV Resistance Data on PA12





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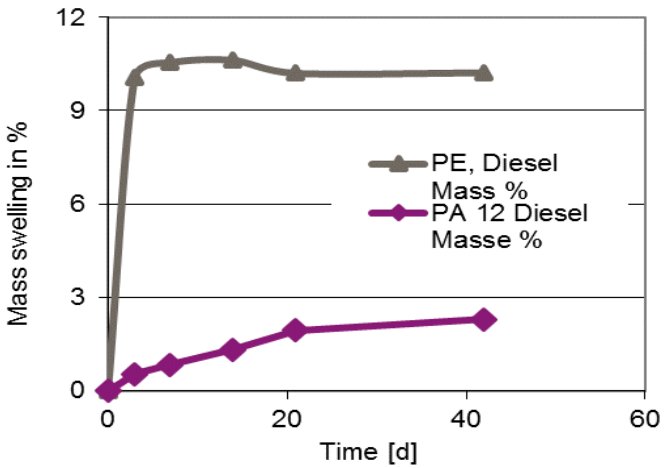
VESTAMID® NRG PA12 Liners – trouble free corrosion protection
Case study:

Application

- Sour gas & condensate service
- High H2S concentration ca. 25 Vol.%
- Operating temperature ca. 50°C

Key issues solved

- Previous HDPE–liner experienced collapse due to **Permeation** and **Swelling.**
  - PA12: Lower permeation of gases
  - PA12: Very low swelling in hydrocarbons
  - PA12: No loss of mechanical strength in hydrocarbons



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Multilayer liner with PE external layer and PA12 barrier layer

Combination of PE100 with VESRTAMID® NRG.

Case 1:

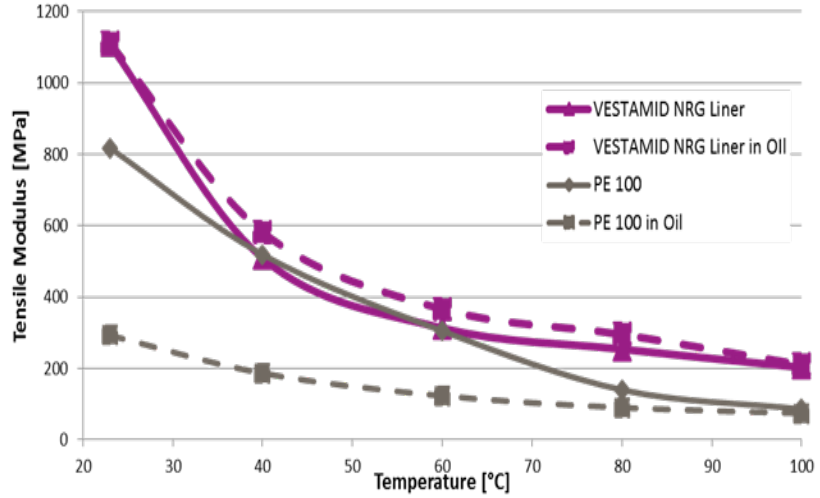
- Outer Layer : PE-RT
- Adhesive layer: grafted adhesive
- Inner Layer : VESTAMID® NRG
- Circumferential bonding strength = 221N/cm
- Longitudinal bonding strength = 217 N/cm

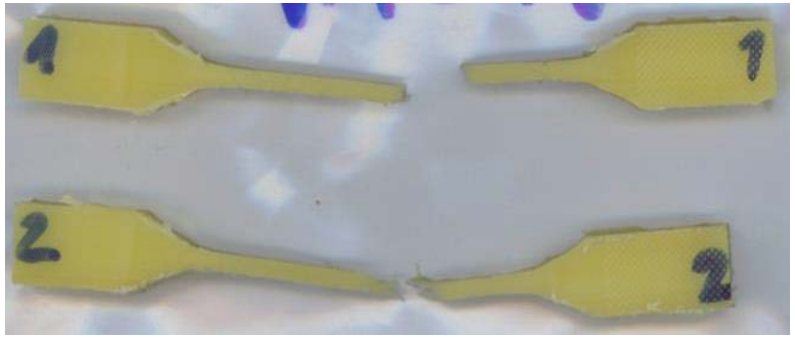
Case 2:

- Outer Layer : PE100
- Adhesive layer: grafted adhesive
- Inner Layer : VESTAMID® NRG
- OD = 110 mm

Case study – Canada:
No degradation after 12 months in highly sour conditions

Property	Units	Material	After 12 months
Tensile Modulus (at 1mm/min)	MPa	709	488
Tensile Stress at Yield (10 mm/min)	MPa	36	31
Tensile Elongation at Yield (10 mm/min)	%	12	17
Stress at Break (10 mm/min)	**MPa**	**37**	**36**
Corrected Inherent Viscosity	**dl/g**	**1.829 ± 0.02**	**1.812 ± 0.02**





AEGION Stronger. Safer. Infrastructure. | united | EVONIK POWER TO CREATE

VESTAKEEP for O&G Pipe Applications

Akshay Ponda, Evonik USA

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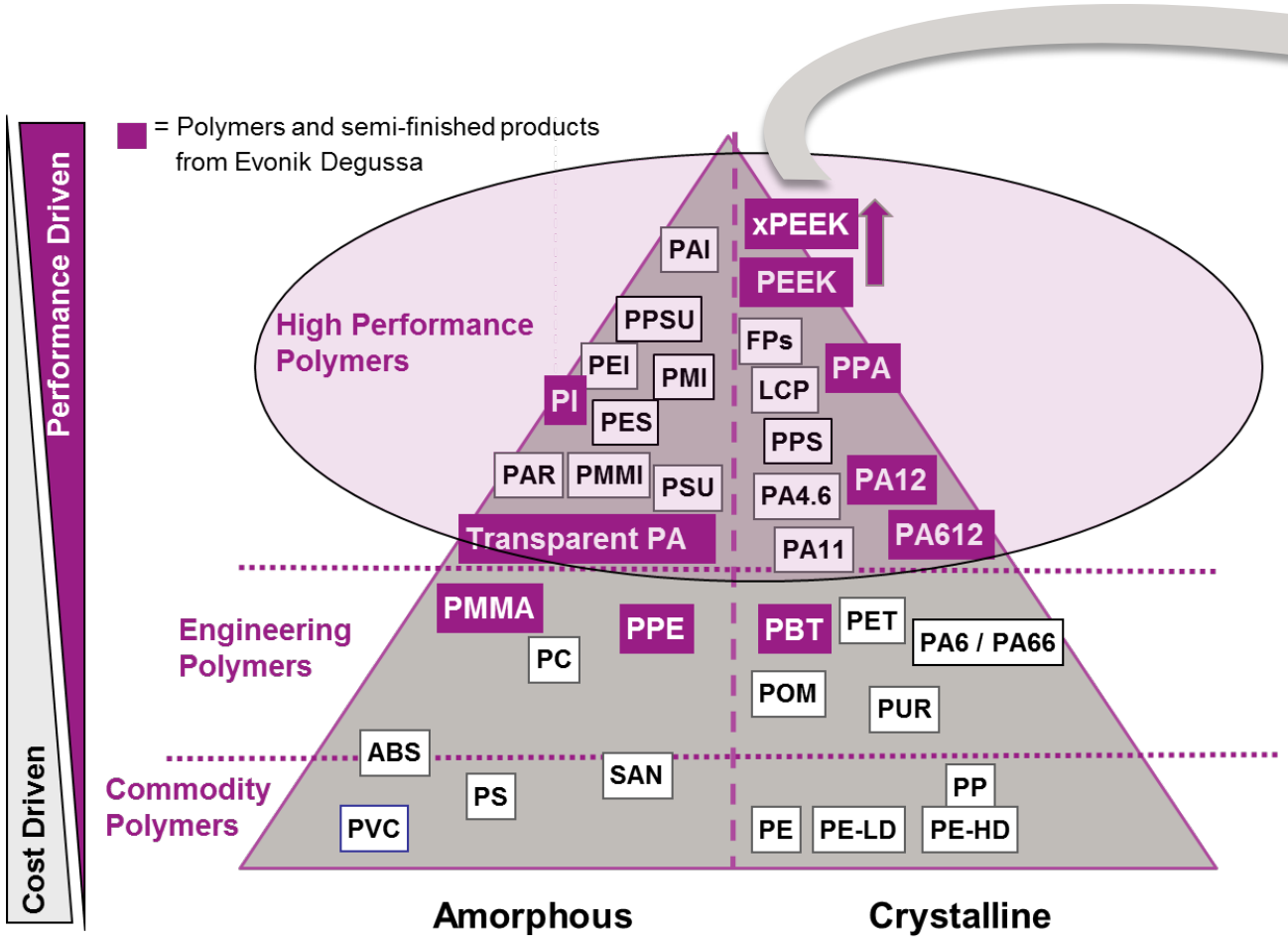
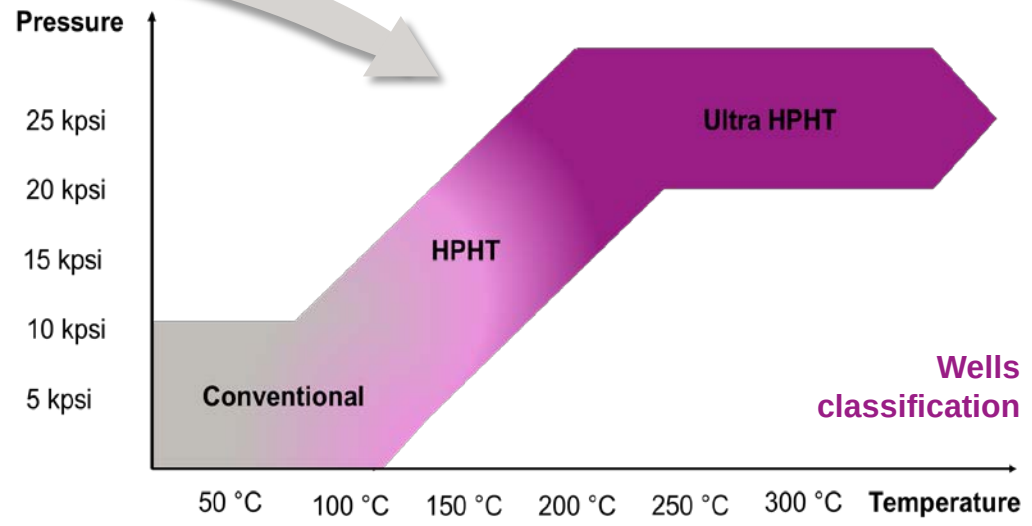
Polymers for Oil & Gas
PEEK & xPEEK for HPHT applications





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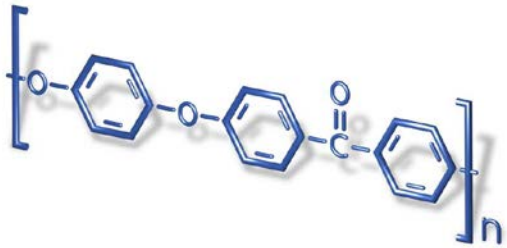
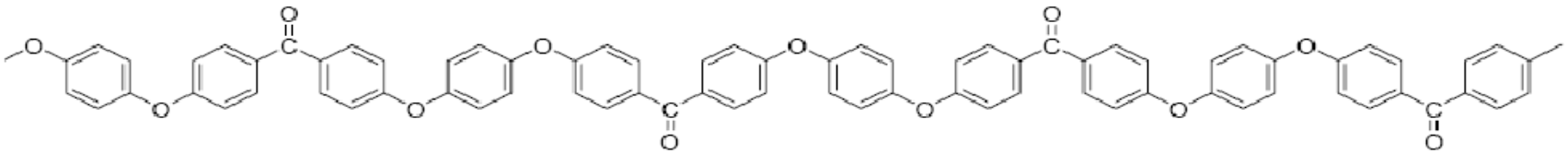
PEEK – Basic Properties

- High Glass Transition Temp (Tg) → ~143 - 152 °C
- High Melting Point (Tm) → ~ 340 °C
- Continuous service temperature → ~ 250 °C
- Hydrolysis, hot water and hot steam resistance up to 250 ° C
- High mechanical strength and rigidity
- Excellent resistance to chemicals.
- Outstanding wear and tribological behaviour.
- Inherent flame resistant (UL-V0, wall thickness independent)
- Good radiation resistance / highest gamma radiation resistance of all plastics
- Stress crack resistant very good friction and wear properties





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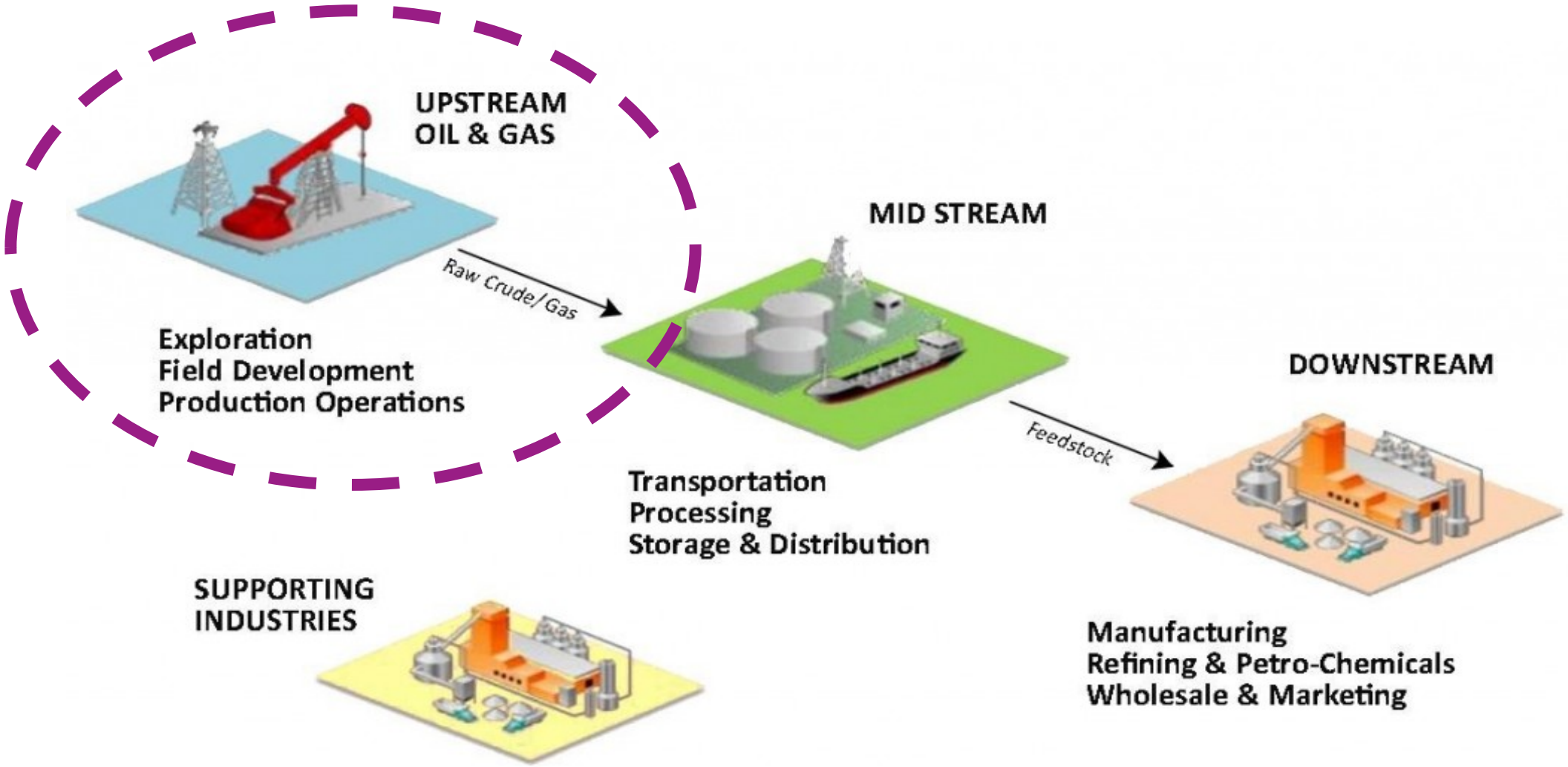
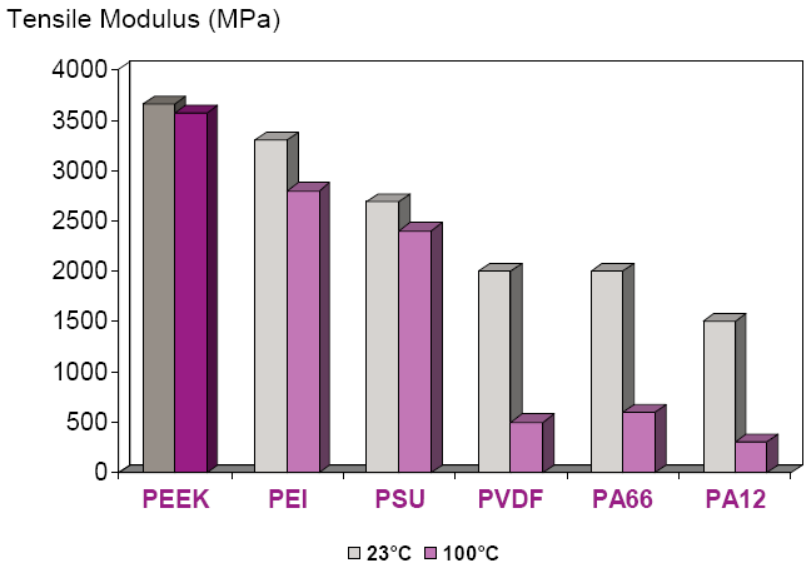
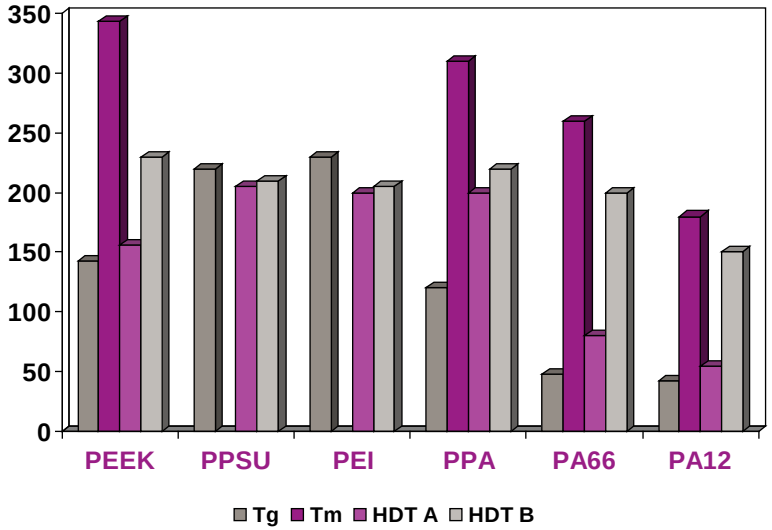
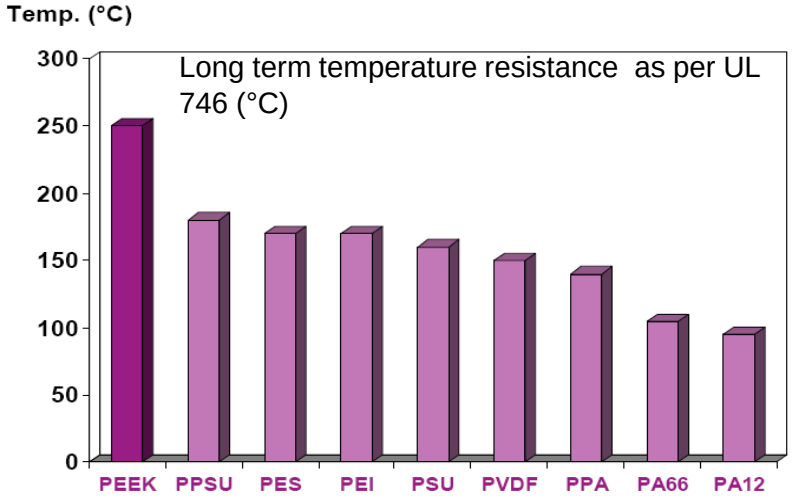
Oil and Gas Application Overview

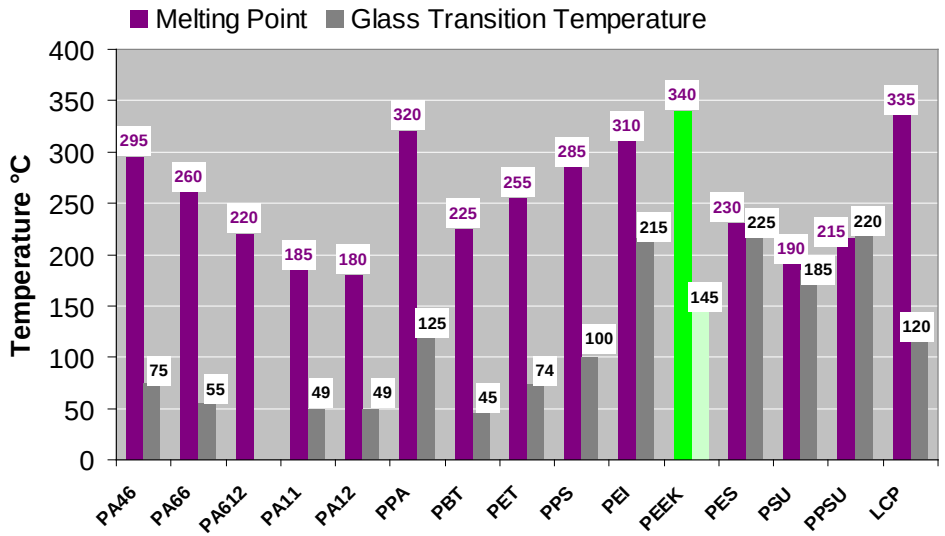


Relative Properties of PEEK Polymer









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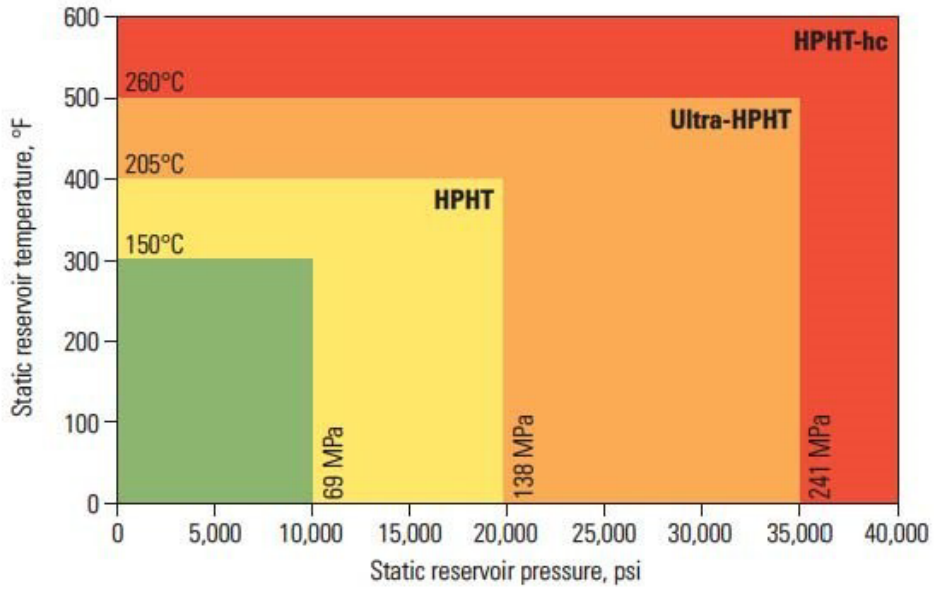
PEEK is ideal for demanding upstream applications

Current Applications:

- Seal Packs – Back-up rings, face seals, etc
- Electrical Connectors, W&C Jacketing
- Anti wear tapes, Subsea Pipes and Liners
- Corrosion resistant coatings
- Parts for compressors, pumps, valves, etc.
- Tools, Subsea components
- Many more…



^ HPHT classification system. The classification boundaries represent stability limits of common well-service-tool components—elastomeric seals and electronic devices.

*Ref for above Chart : Schlumberger's website. www.slb.com

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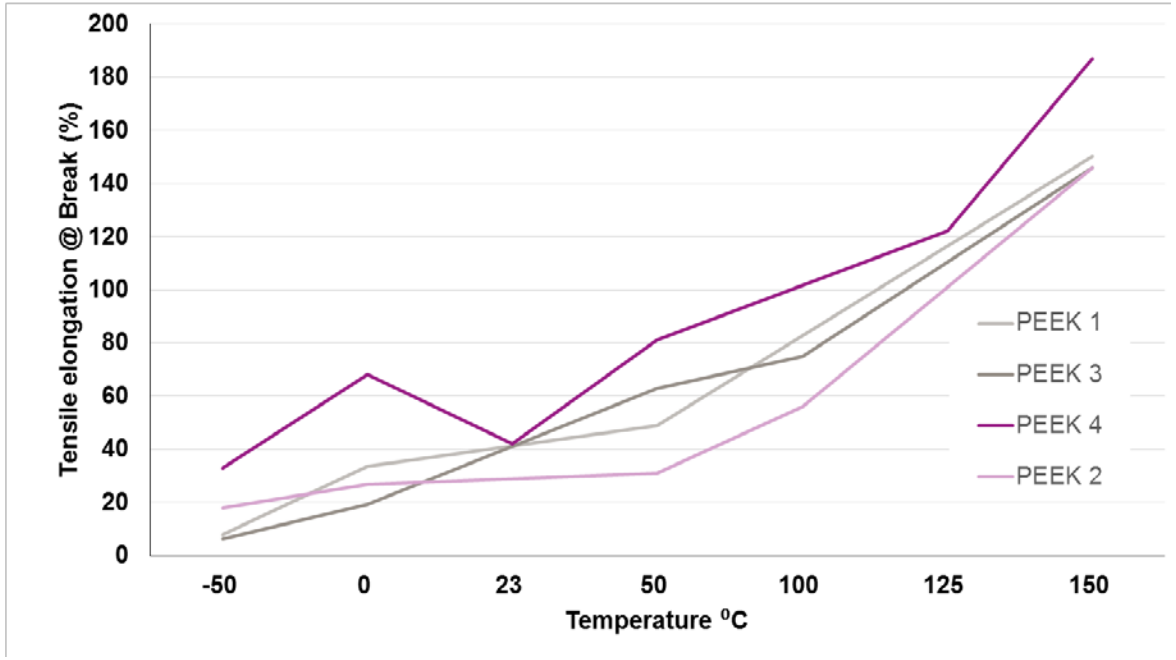
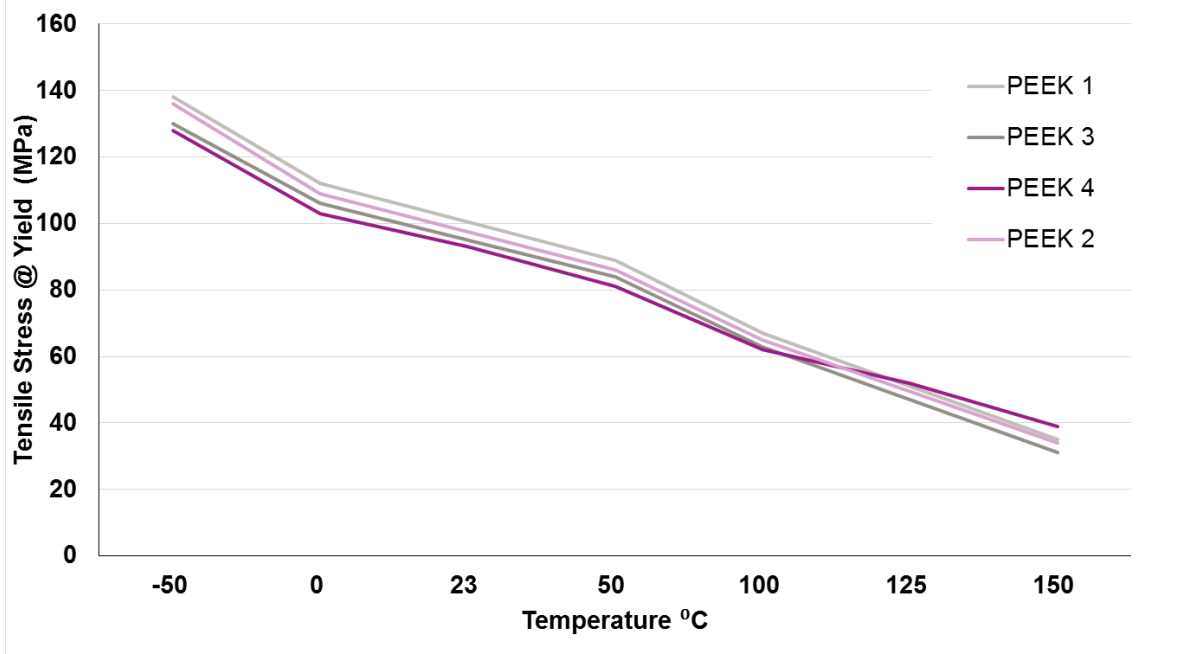
Tensile Test Data: PEEK Grades in Comparison





Very high molecular weight PEEK exhibits higher strain at break at all temps…

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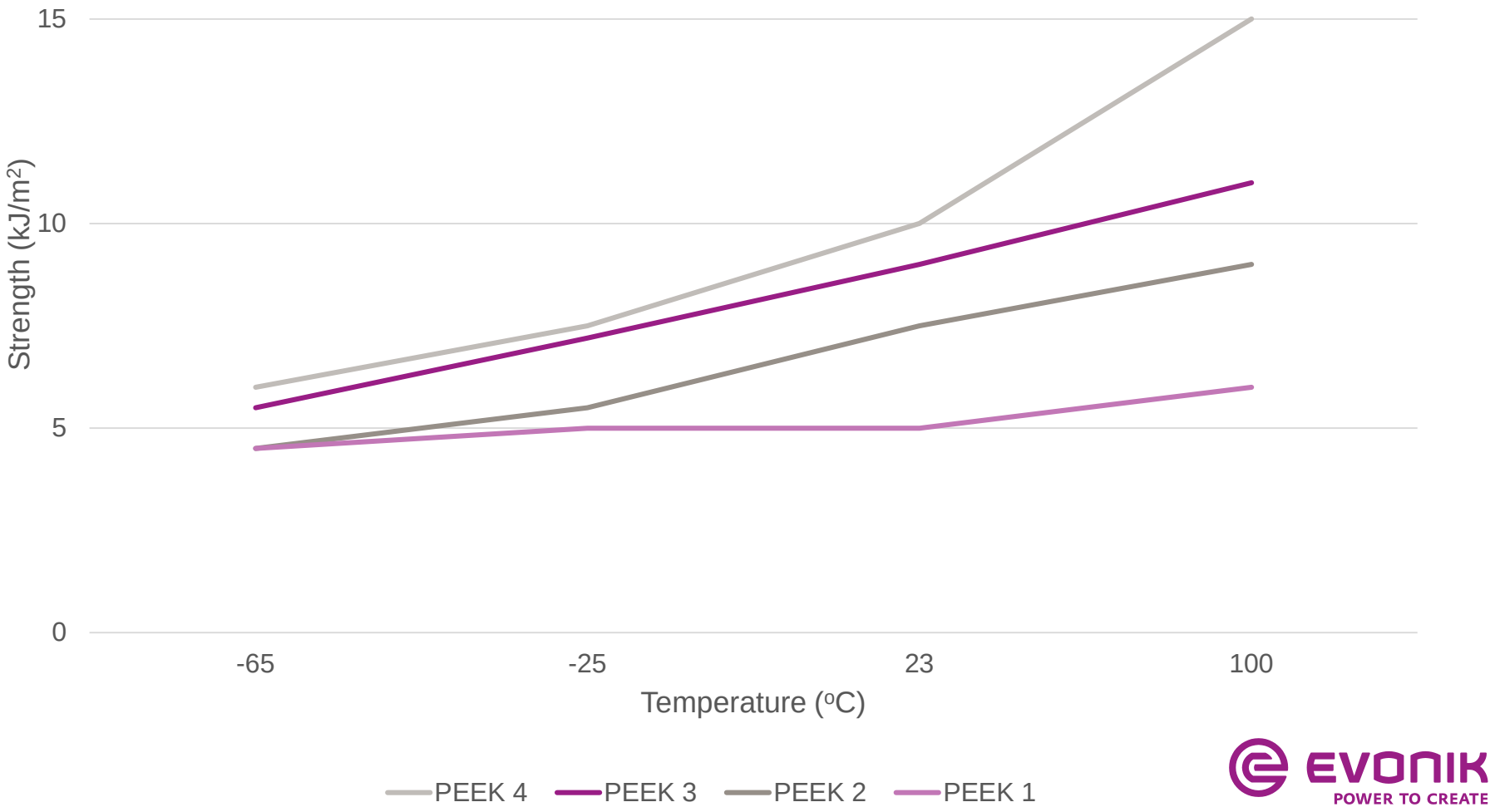
Notched Impact Strength @ -65 to 100°C

- Higher the Molecular weight, better is the Impact resistance



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Sour Fluid Resistance at Elevated Temperatures

- **NORSOK M710 Rev 2 testing:**
  - Test Temps – 195ºC, 215ºC, 225ºC.
  - Exposure time – Up to 32 days

Exposure fluid composition and distribution

Volume (%)	Composition
30	10 (2) / 5 / 85 mol% H2S/CO2/CH4
10	Distilled Water
60	70 % heptane, 20% cyclohexane, 10% tolune

Results:

Vestakeep® 4000G and 5000G meet NORSOK Acceptance Criteria in terms of:

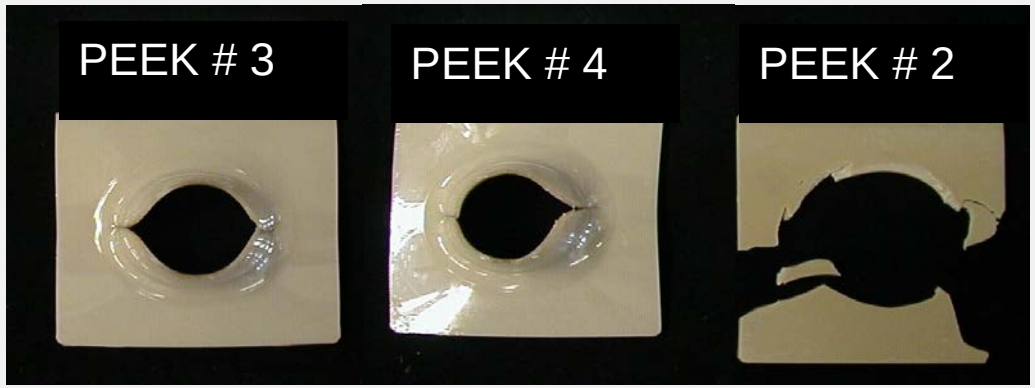
- Swell
- Tensile Properties – Changes in modulus, strength and elongation at break.

Ongoing work to test Vestakeep ® grades under extreme conditions of exposure in temperature, chemical (very high % H2S / salt water) and time…

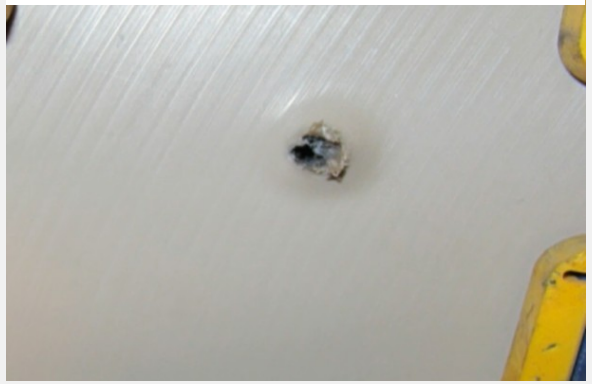
High Speed Impact Testing

- **High speed penetration testing:**
  - Piston is pushed through sample plate
  - Speed 1 m/s - 10 m/s
  - Force and elongation of sample recorded

@ 23°C	PEEK 3	PEEK 4	PEEK 2
1m/s	D	D	D
4.4m/s	D	D	D
10m/s	D	D	**B**



PEEK # 4



PEEK # 2

- PEEK 4 – shows **ductile fracture** behavior due to a higher energy absorption
- High molecular weight PEEK also shows much **less brittleness** and thus does not fail in brittle mode…..

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Summary: Molecular Weight Matters…

- **<u>Very High Molecular Weight PEEK exhibits:</u>**
  - Similar Mechanical Properties to other grades
  - Similar Chemical compatibility / resistance behavior
  - <u>Higher Viscosity</u>
  - <u>Much less sensitivity to cracking (less brittle)</u>
  - Potentially have an effect on overall long term performance and ultimate failure mode.


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Regional standards for PA-U 12 180 are developing globally

USA

ISO

Germany

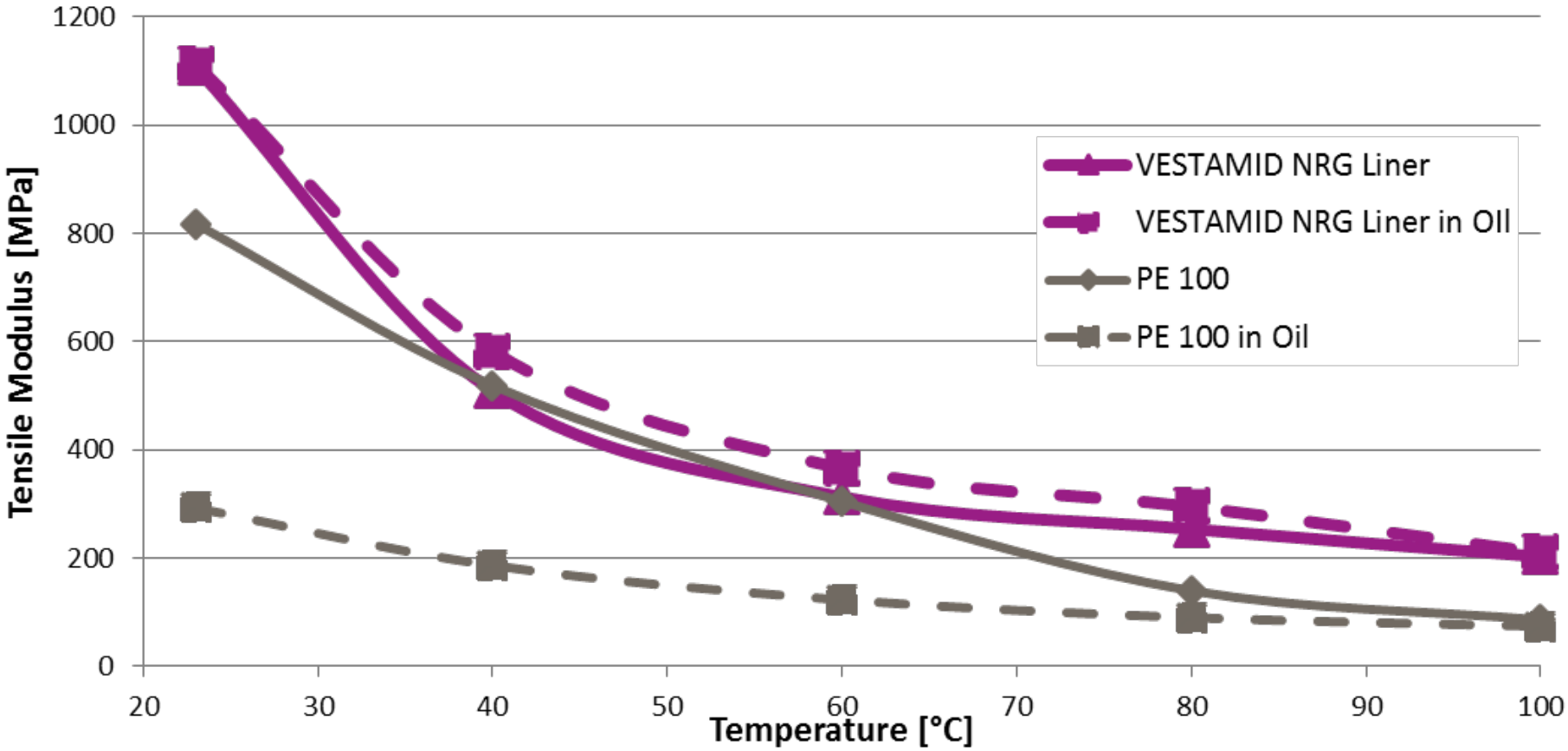
Mexico

Brazil

Colombia
Federal code

DVS
Technical Code
DVS 2207-16

VESTAMID® NRG PA12 improves the reliability of liners:
- High mechanical strength in Hydrocarbons



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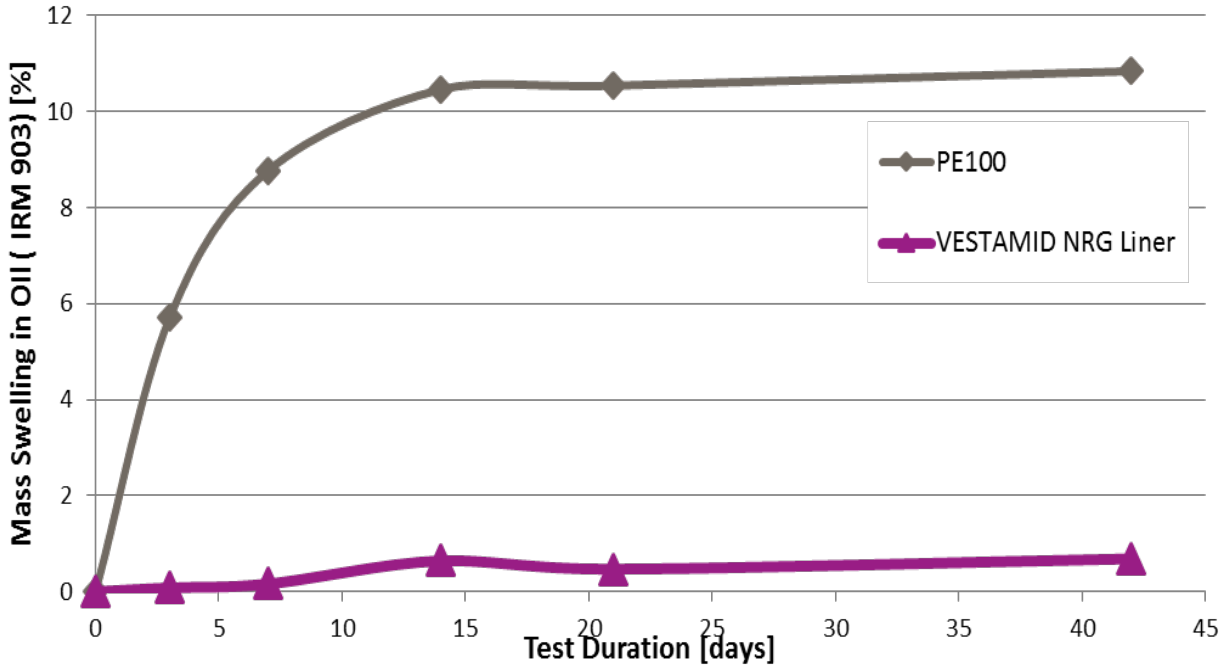
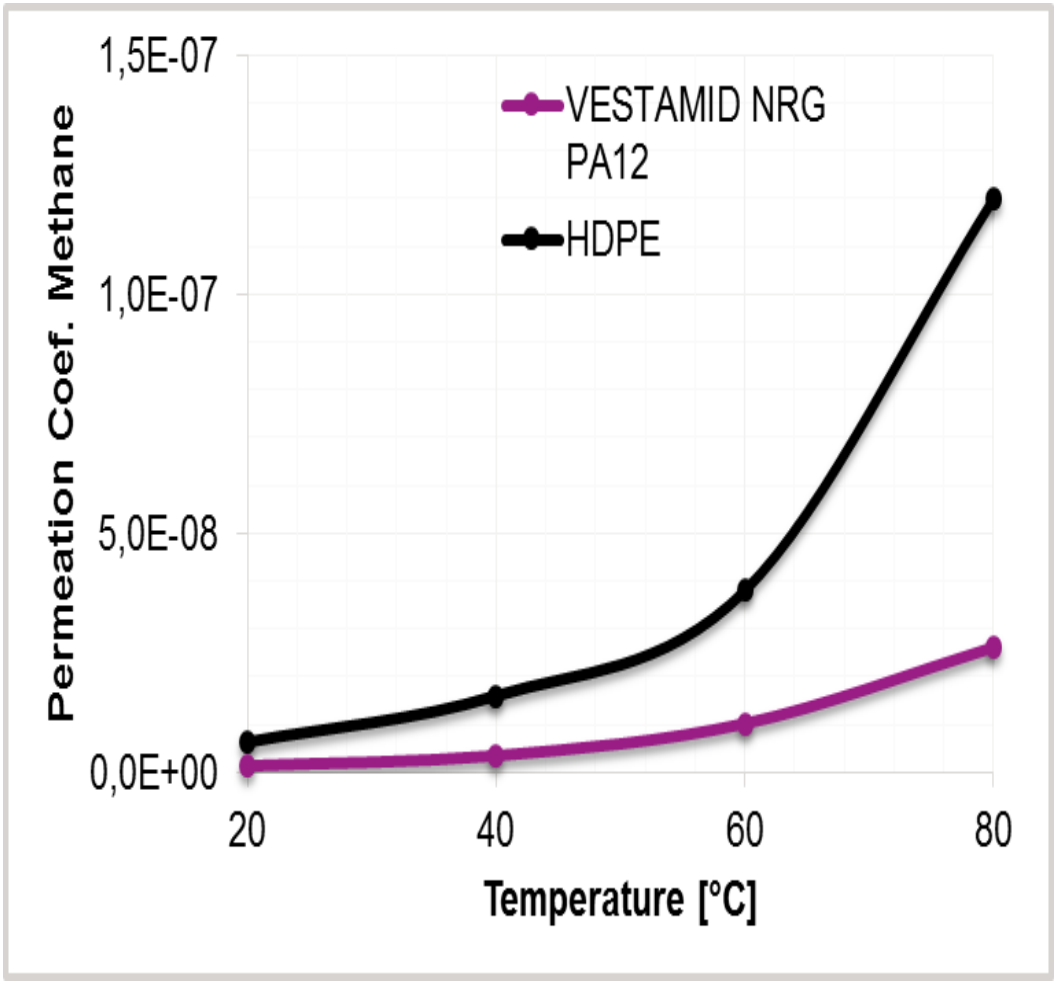
VESTAMID® NRG PA12 improves the reliability of liners:
- Low swelling in Hydrocarbons





- Better corrosion protection
- Pipeline venting frequency reduced ➔ OPEX savings
- Improved collapse resistance

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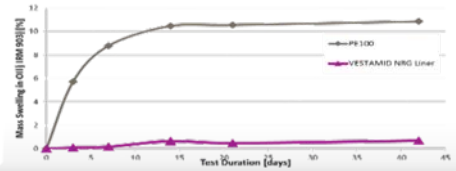
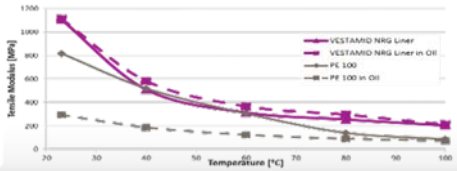
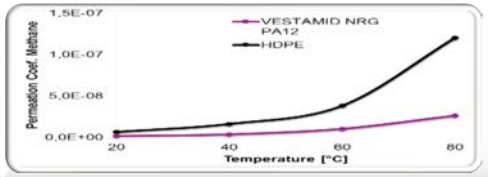
VESTAMID® NRG PA12 – reliable liners in harsh conditions



Low swelling in oil



No loss of mechanical strength after saturation in oil



Low gas permeation

Improved collapse resistance

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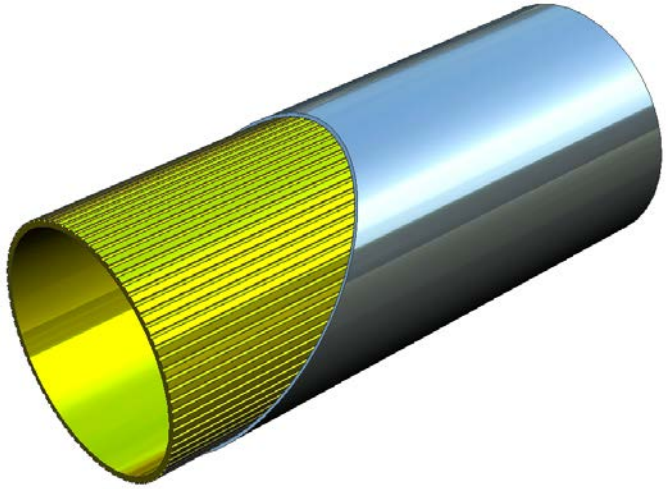
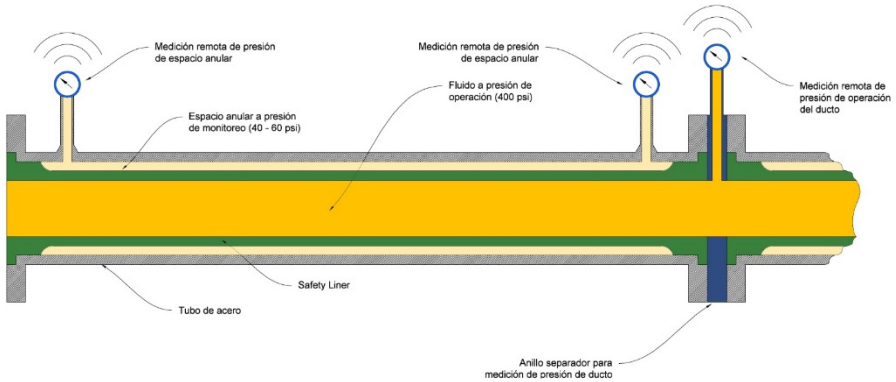
Grooved liner: active liner monitoring and leak detection system

1. The liner pipe was designed so that it could carry an annular space fluid used as a means for detecting damage to the steel without an actual leak developing.

2. A series of annular grooves were incorporated to the liner surface which carry air pressurized at 10 to 15 psi and monitored continuously.

3. In case a pinhole leak develops, the annular space pressure will drop indicating damage to the steel pipe while the liner bridges the hole and a possible leak.





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Hydrolysis protection

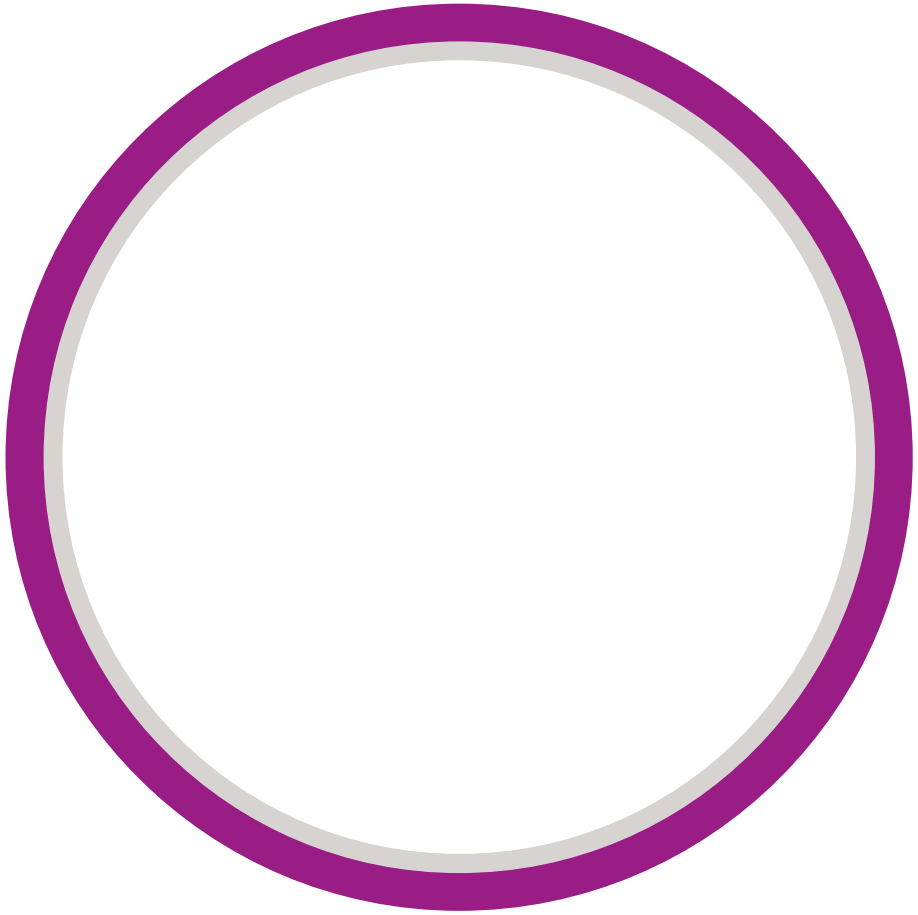
2 layer system:

- **Inner layer:** modified PVDF (optimized bonding to PVDF).

  Provides chemical protection for PA12 layer (permeation, chemical resistance).

- **Outer layer:** PA12.

  Provides mechanical protection for PVDF layer (fatigue, ductility, creep).



VESTAMID® NRG PA12 Liners – trouble free corrosion protection
Case study:

24 Months operation

- No change in chemical properties of liner
- No loss in mechanical properties of the liner
- No swelling
- No venting of gases required

Value proposition of VESTAMID® NRG PA12

- Trouble free liner for corrosion protection in harsh conditions
- Collapse resistant liner with a design of more than 20 years