Carilon

Thermoplastic Polymers

Providing Corrosion Control Solutions for The Oil & Gas Industry

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OUTLINE

- Business Overview
- Carilon Applications
- Technical Introduction
- Liner Handling/Installation Issues
- Conclusion

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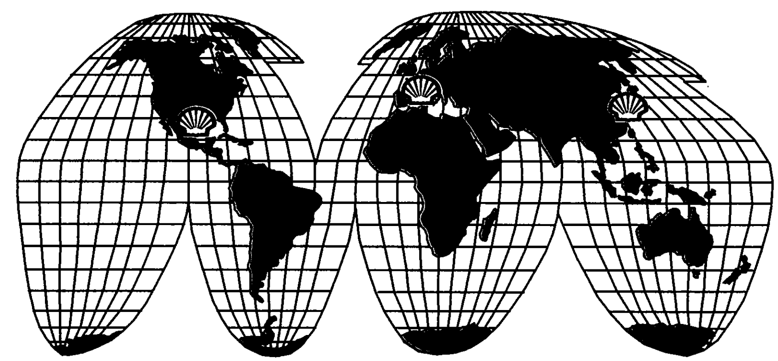
BUSINESS OVERVIEW

Shell Worldwide Chemical Business

- **New global company in place January 1998**
- **Three global regions:**
  Europe/Africa
  Asia Pacific/Middle East
  Americas



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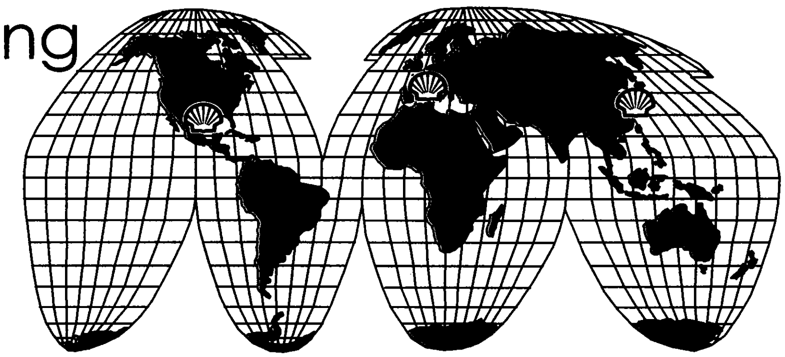
CARILON Worldwide Organization

- **Americas**
  - Sales force in North America
  - R&D, Tech Service, Marketing based in Houston, TX
- **Europe/Africa**
  - Sales force in Europe
  - R&D, Tech Service, Marketing in Belgium, England and Netherlands
- **Asia Pacific/Middle East**
  - Tech Service, Sales in Japan



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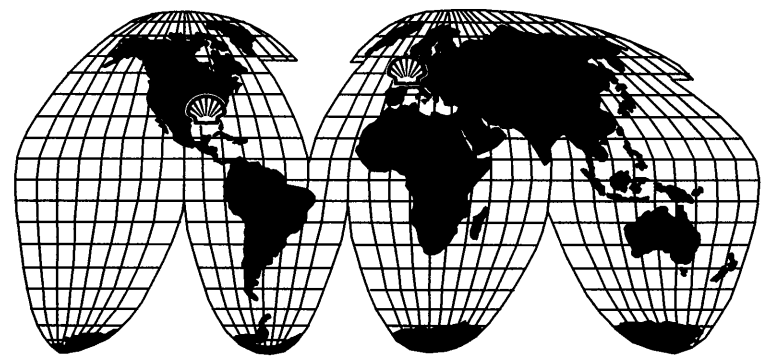
CARILON Worldwide Organization

- **Manufacturing**
  - currently, **20 MM** lb plant in Carrington, England expandable to **40 MM**
  - **55 MM** lb plant in Geismar, LA will be starting up by mid-'99, expandable to **110 MM**



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CARILON Thermoplastic Polymers

The first products in a new family of semicrystalline aliphatic polyketones developed using proprietary Shell technology.

Initial targeted markets:

- Electrical and Electronics
- Automotive
- Appliances
- Industrial

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CARILON Polymers in the Industrial Market

- **Corrosion Control**
  - liner
  - barrier layer
- **Chemical Containment**
  - multilayer hose and pipe
  - blowmolded multilayer container
  - chemical pipe and fittings

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CARILON Polymers in the Industrial Market

FUNCTION	NORTH AMERICA	EUROPE	JAPAN
MARKETING	Cary Veith	Joe Rezell	Makio Wakasawa
TECHNOLOGY	James Kau	Luc Vanderschuren	Fumio Naito
	Carlton Ash	Karin Van Poppel Van	
	Dick Danforth	Cynthia Teniers	
	Pierro Puccini	Jan Van Zomeren	
	Francis Uralil		
	Dennis Krueger		
	Randy Gingrich		
	Dixie Waters		
	Jemei Chang		
	Mark Wednt		
SALES	Guy Antonides	Hans Choufoer	Chikara Iwasaki
	Jim Biederman	Roger Fletcher	Ken Nakamura
	Jim Carver	Hans Kokemueller	
	John Giacalone	Bengt Lindqvist	
	Bob Pilotti	Pierre Yves Mehrenberger	
	Joe Legrand	Paolo Porro	
	Dominic Mammoliti	Harald Seifert	

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OIL & GAS APPLICATIONS

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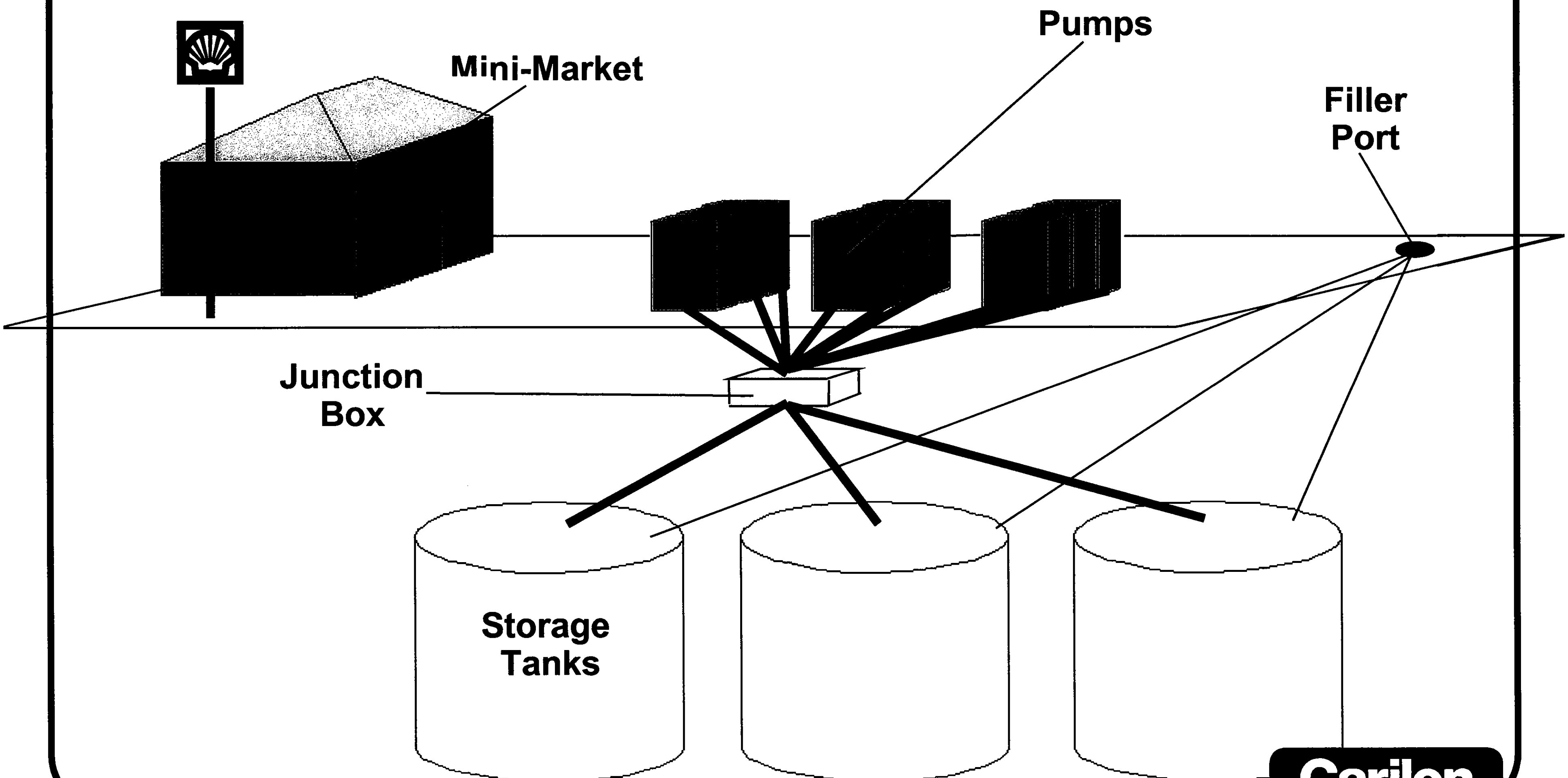
CARILON Polymers in the Retail Applications



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CARILON Polymers in the Retail Applications Value Proposition

PE/PK

Steel	• corrosion - lifetime • easier to install • no traffic disruption (Mini-Market) • higher cost
PE	• permeation resistance • chemical resistance • strength - polymer swell • higher cost
PE/PA11	• lower cost • resistant to more things • worse processing
PE/Other (eg PBT)	• to be addressed

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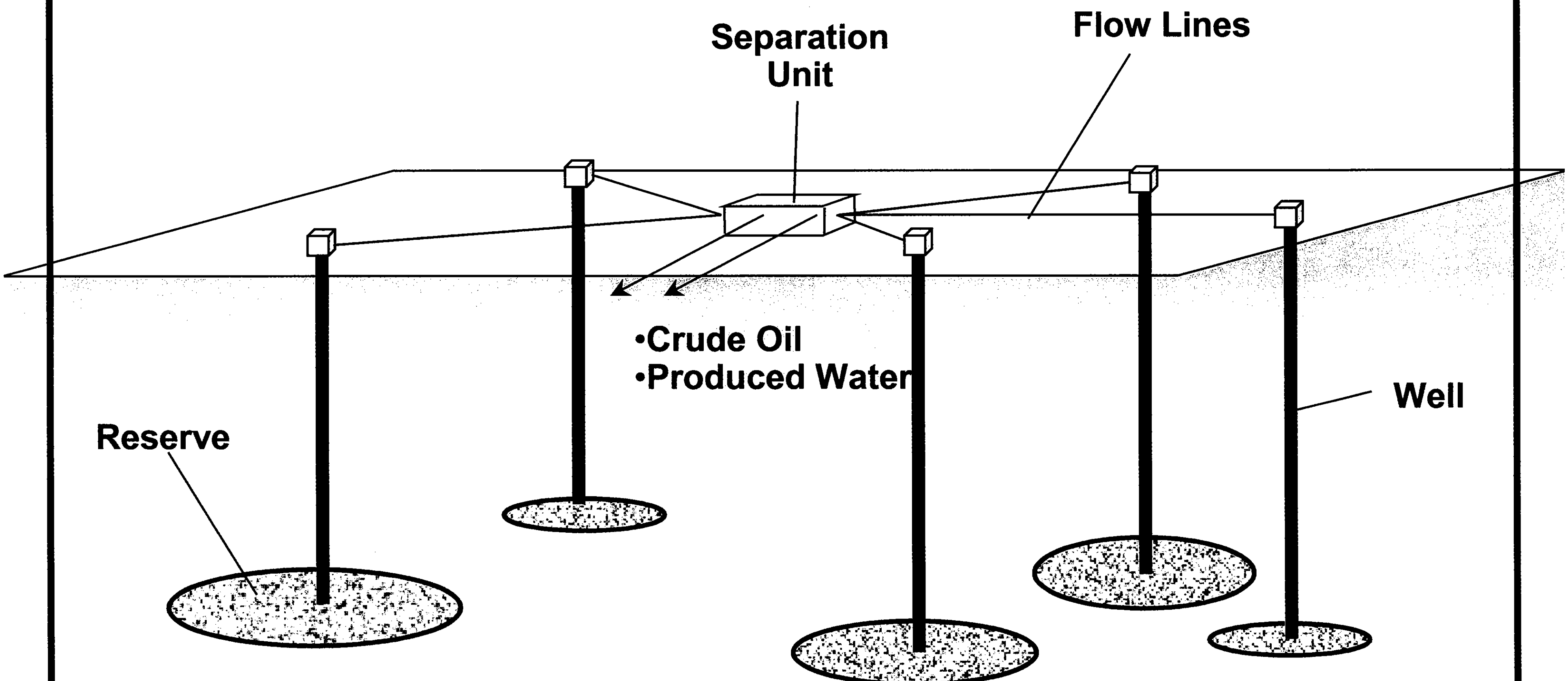
CARILON Polymers in the E & P Onshore Applications



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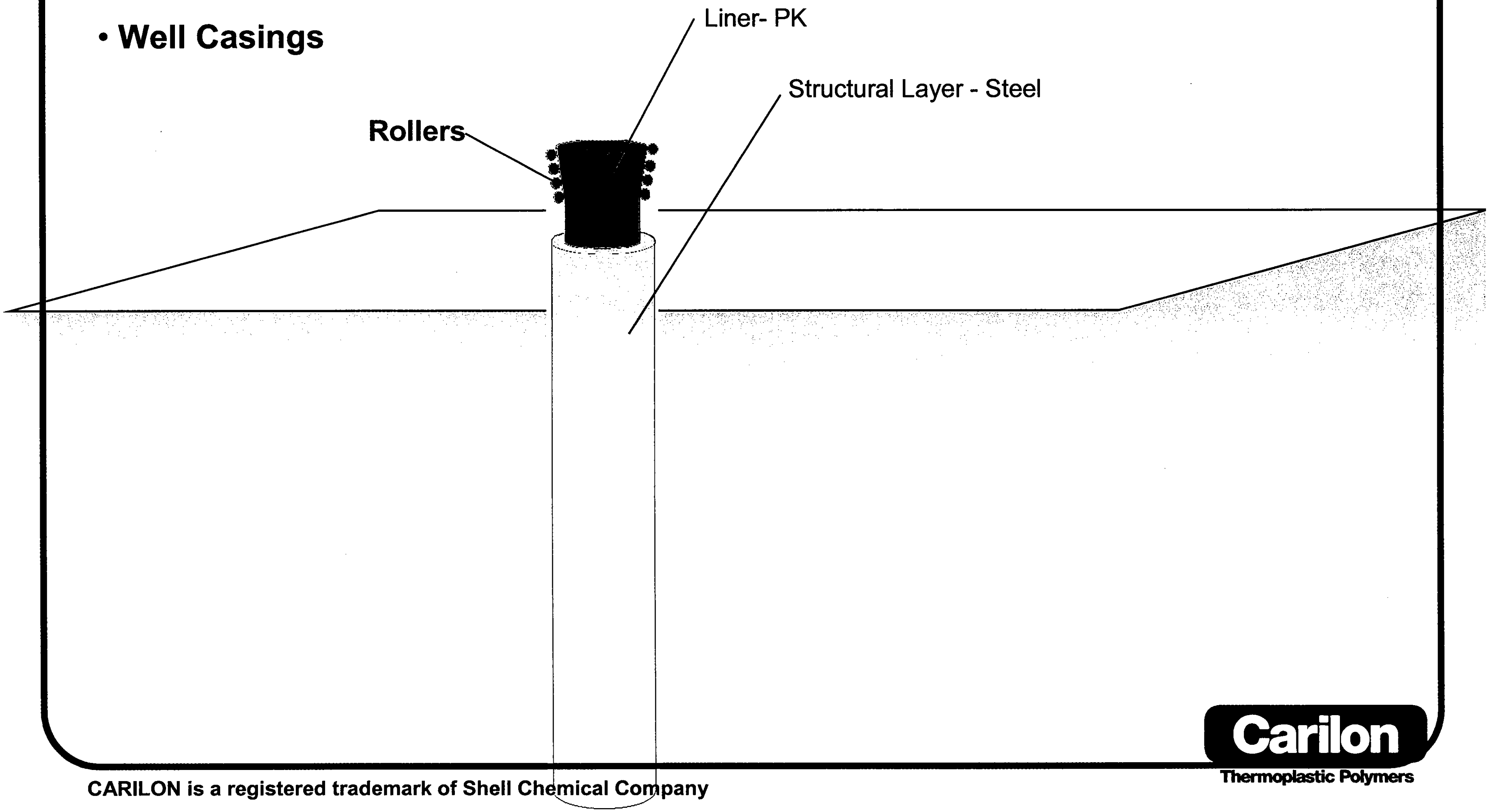
CARILON is a registered trademark of Shell Chemical Company

CARILON Polymers in the E & P Downhole Applications

- **Well Casings**



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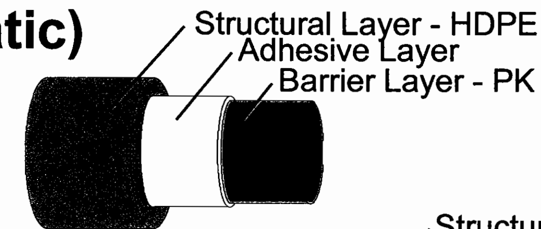
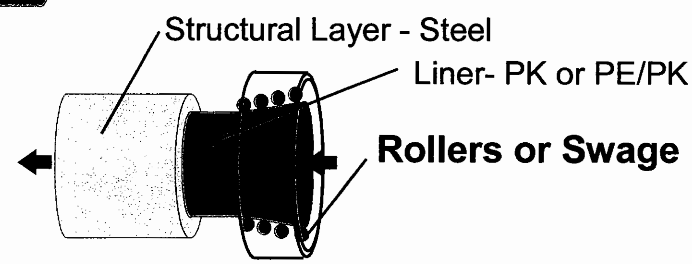
CARILON Polymers in the E & P Market

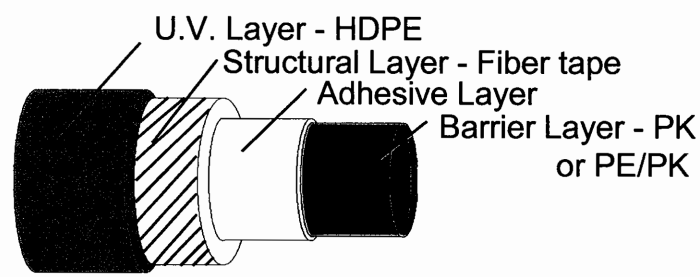
Flow Lines (static)



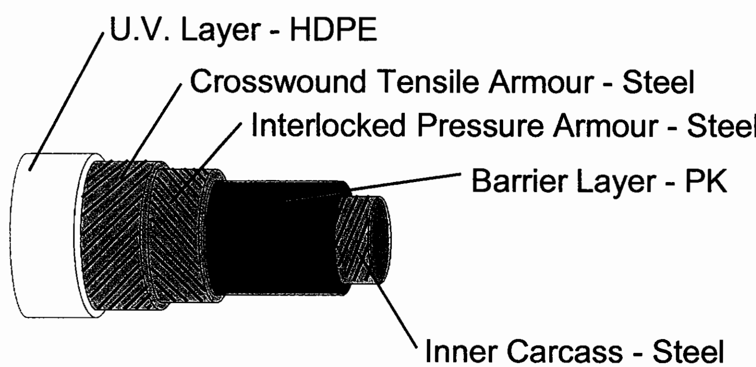
- Free-Standing



- Compression-Fit Liners



- RTP (Reinforced Thermoplastic Pipe)



- Flexibles

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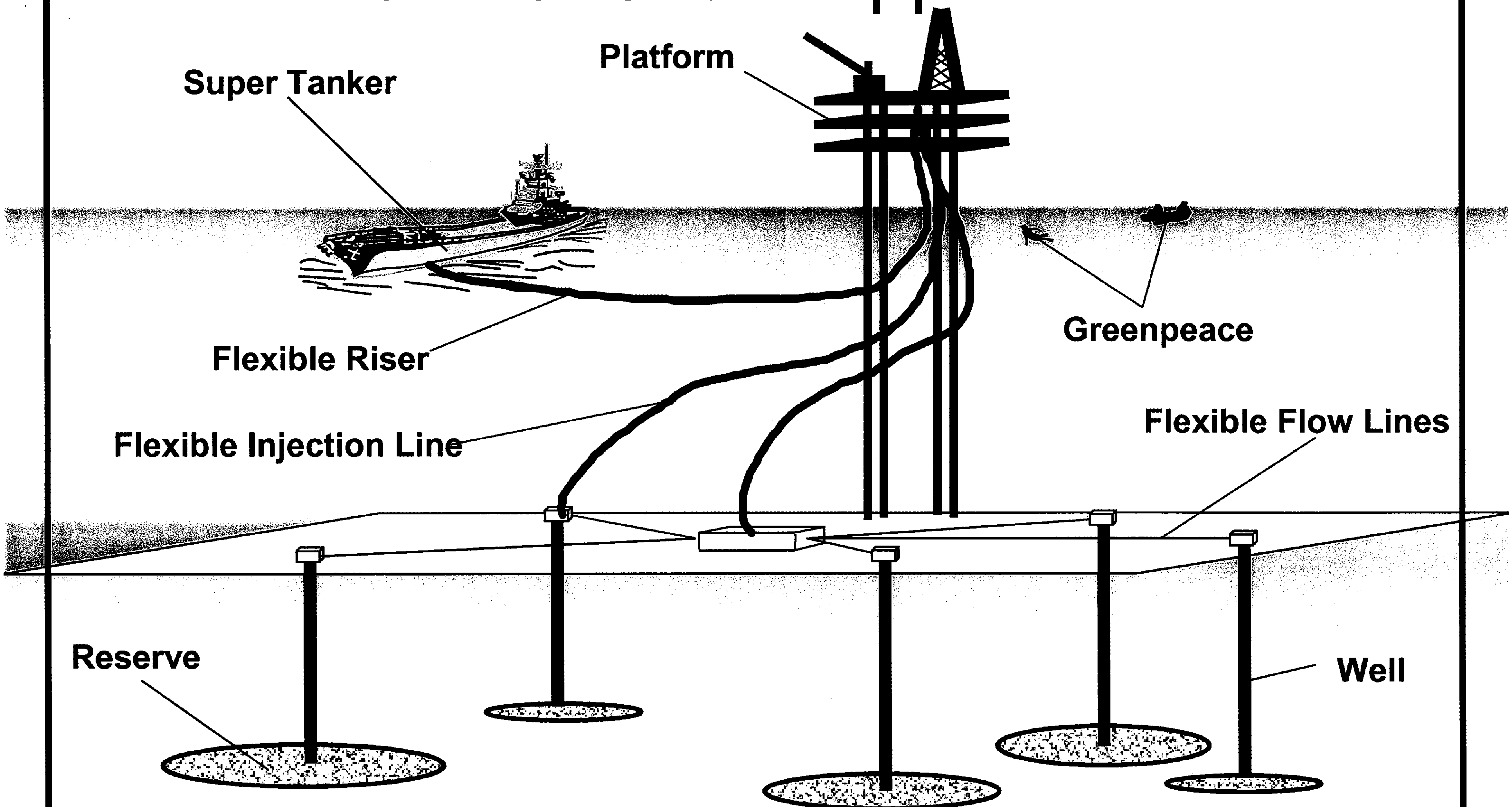
CARILON Polymers in the E & P Offshore Applications



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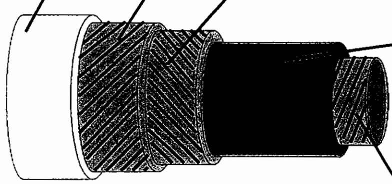
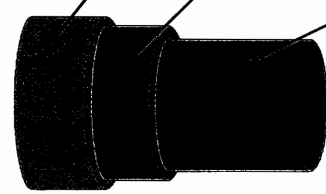
CARILON Polymers in the E & P Offshore Applications

Flexible Risers & Flow Lines (Dynamic)

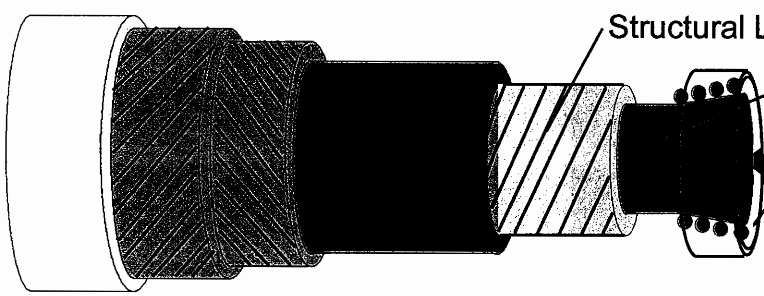
- **Flexibles**



- **Coilable Composites**



- **Injection Rehabilitation**



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CARILON Polymers in the E & P Market Value Proposition

	PE/PK	PK
Steel	• corrosion - lifetime • easier to install • permeation resistance • higher cost	• corrosion - lifetime • easier to install • permeation resistance • higher cost
PE	• permeation resistance • chemical resistance • strength - polymer swell • higher cost • worse processing	• up to 90 deg C temperature • permeation resistance • chemical resistance • strength - polymer swell • strength - longer pulls • worse processing • higher cost
PA11	• lower cost • resistant to more things	• hydrolysis resistance • dimensional stab. (plasticiser) • lower cost • resistant to more things • worse processing
PVdF	• N/A	• lower price and density • dimensional stab. (plasticiser) • compression/recovery • no strong acids/bases • lower temp limit

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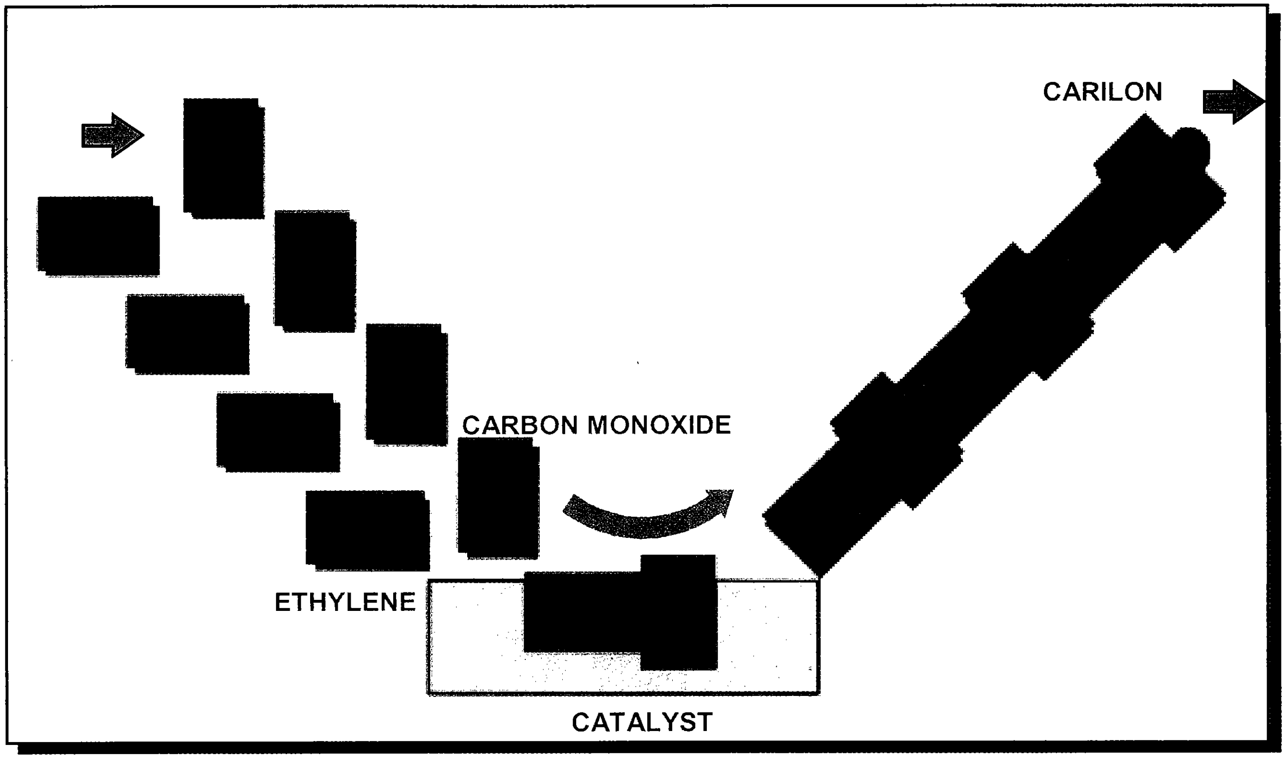
TECHNICAL OVERVIEW



- The discovery
- A NEW generation of polymers
- Tough, semi crystalline

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History of Aliphatic Polyketones

1950 **Du Pont, U.S. Patent 2,495,286**
Free Radical Polymerization Of Ethylene/Carbon Monoxide

1951 **BASF, U.S. Patent 2,577,208**
Ni Catalysis Of Ethylene/Carbon Monoxide Copolymers

1967 **ICI, Eur. Patent Appl. 1,081,304**
Pd Catalysis Of Ethylene/Carbon Monoxide Copolymers

1970 **Union Oil, U.S. Patent 3,530,109**
Other Ligands For Pd Catalysts

1972-1975 **Shell, U.S. Patent 3,689,460, 3,694,412, 3,835,123 & 3,914,391**
Other Pd Based Catalysts

1984-1986 **Shell, Eur. Patent Appl. 0121965, 0181014, 0213671 & 0222454**
Efficient Pd Based Catalysts For Perfectly Alternating Aliphatic Engineering Polyketones

1984 ***Shell, First Pilot Plant For Engineering Polyketones***

1996 ***Shell, First Commercial Plant***

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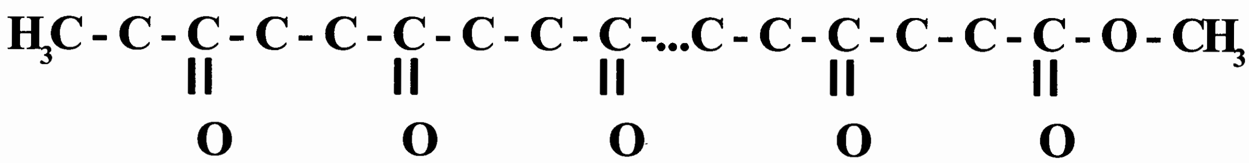
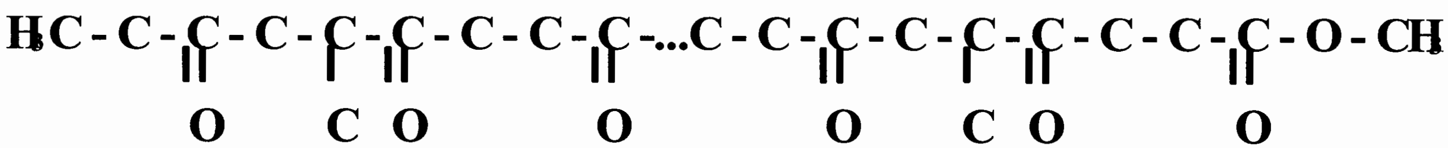
Molecular Structure



Copolymer (E)



Terpolymer (EP)

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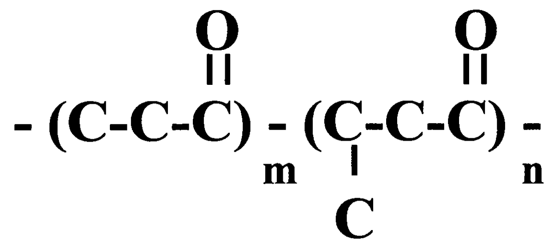
Overview

TERPOLYMER	
MELTING POINT	**220°C (428°F)**
CRYSTALLINITY	**30-40%**
DENSITY	**1.24 g/cc**

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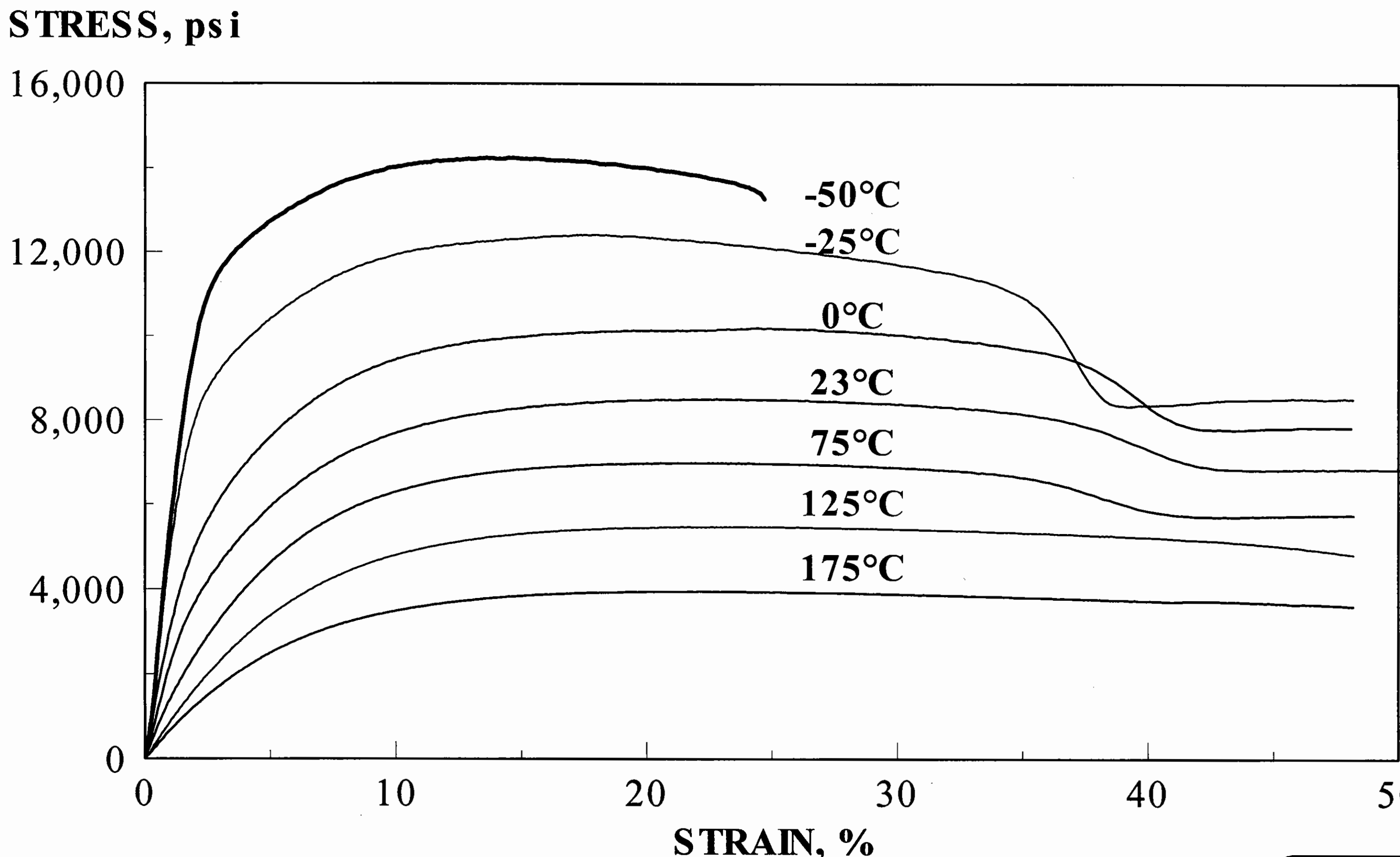
Stress-Strain at Various Temperatures



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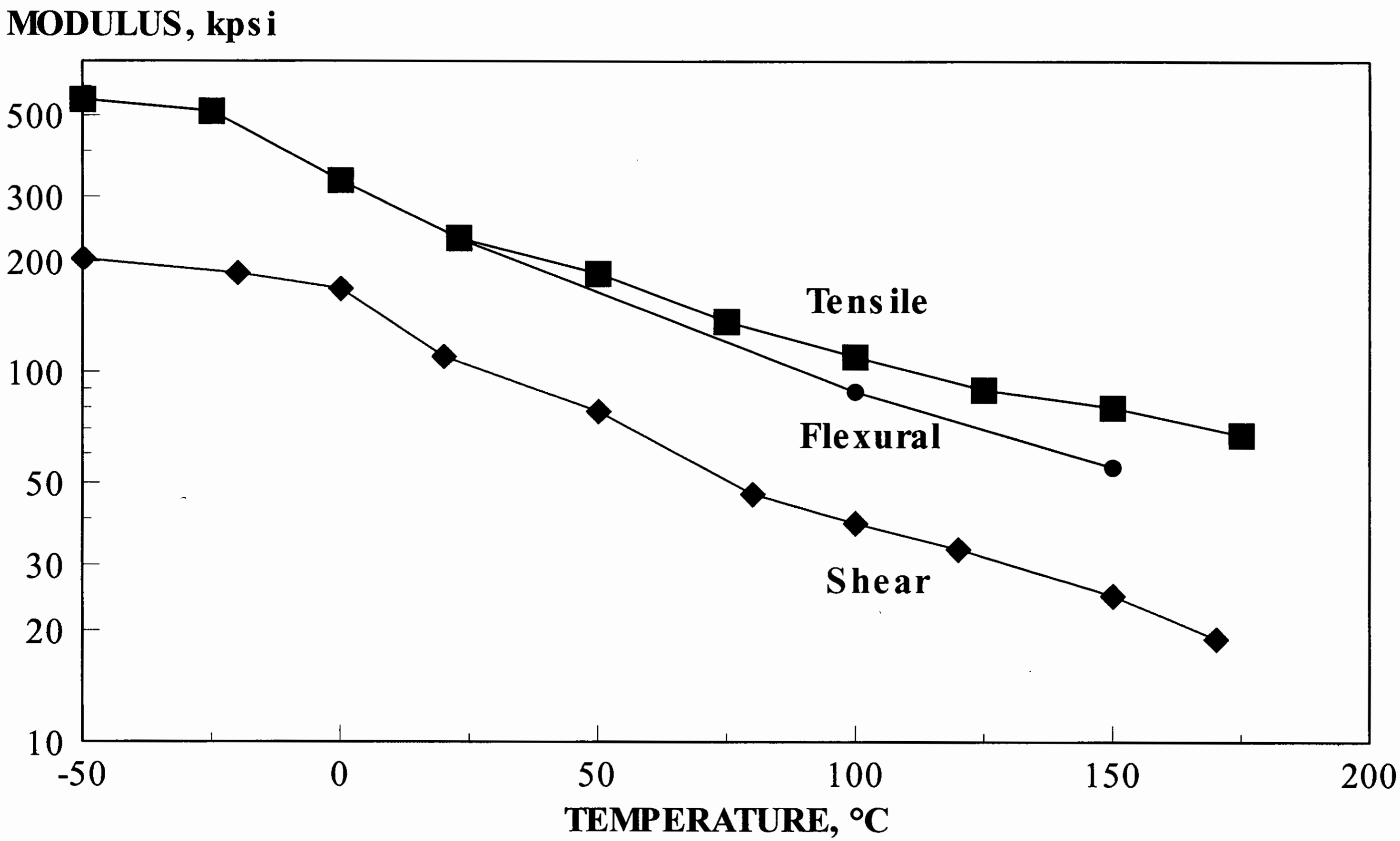
Modulus vs. Temperature



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Typical Properties

Mechanical Properties at 23°C, 50% RH	
Tensile Strength @ Yield, psi (MPa)	8700 (60)
Elongation @ Yield, %	22
Elongation @ Break, %	300
Tensile Modulus, kpsi (GPa)	230 (1.6)
Flexural Modulus, kpsi (GPa)	230 (1.6)
Notched Izod Impact Strength, ft-lb/in (J/m)	4.5 (240)
Unnotched Izod Impact Strength, ft-lb/in (J/m)	No Break
Tensile Impact Strength, ft-lb/in^2 (kJ/m^2)	100 (210)
Gardner Impact Strength, in-lb (J)	>400 (>45)
Physical Properties at 23°C	
Specific Gravity	1.24
Mold Shrinkage, flow direction 1/8" section, in/in	0.020
Water Absorption, 24-hour immersion, %	0.45
Water Absorption, 50% RH saturation, %	0.53
Water Absorption, 100% RH saturation, %	2.1
Thermal Properties	
Melting Point, °C (°F)	220 (428)
Vicat Softening Point, °C (°F)	215 (419)
Heat Deflection Temperature @ 66 psi, °C (°F)	210 (410)
Heat Deflection Temperature @ 264 psi, °C (°F)	105 (220)

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Chemical Resistance

- Resistant To Automotive Fluids
- Resistant To Soaps / Detergents
- Resistant To Hydrocarbon Solvents
- Resistant To Salts
- Resistant To Weak Acids/Bases

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Carilon Attributes Which Provide Chemical Resistance

- Semicrystalline polymer
- Few known solvents
- Polar nature (cohesive energy)
- Nonhydrolyzable backbone
- Low sorption / plasticization

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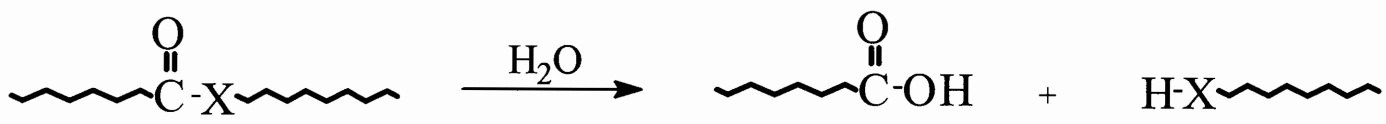
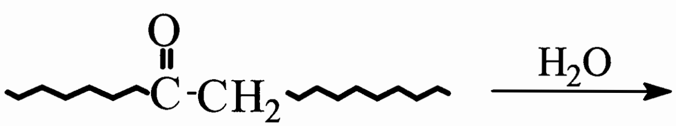
Carilon is Resistant to Hydrolysis



X = -O-, -N(H)-

(PA, PET, PC, PU)

Chain scission



(PK)

No chain scission

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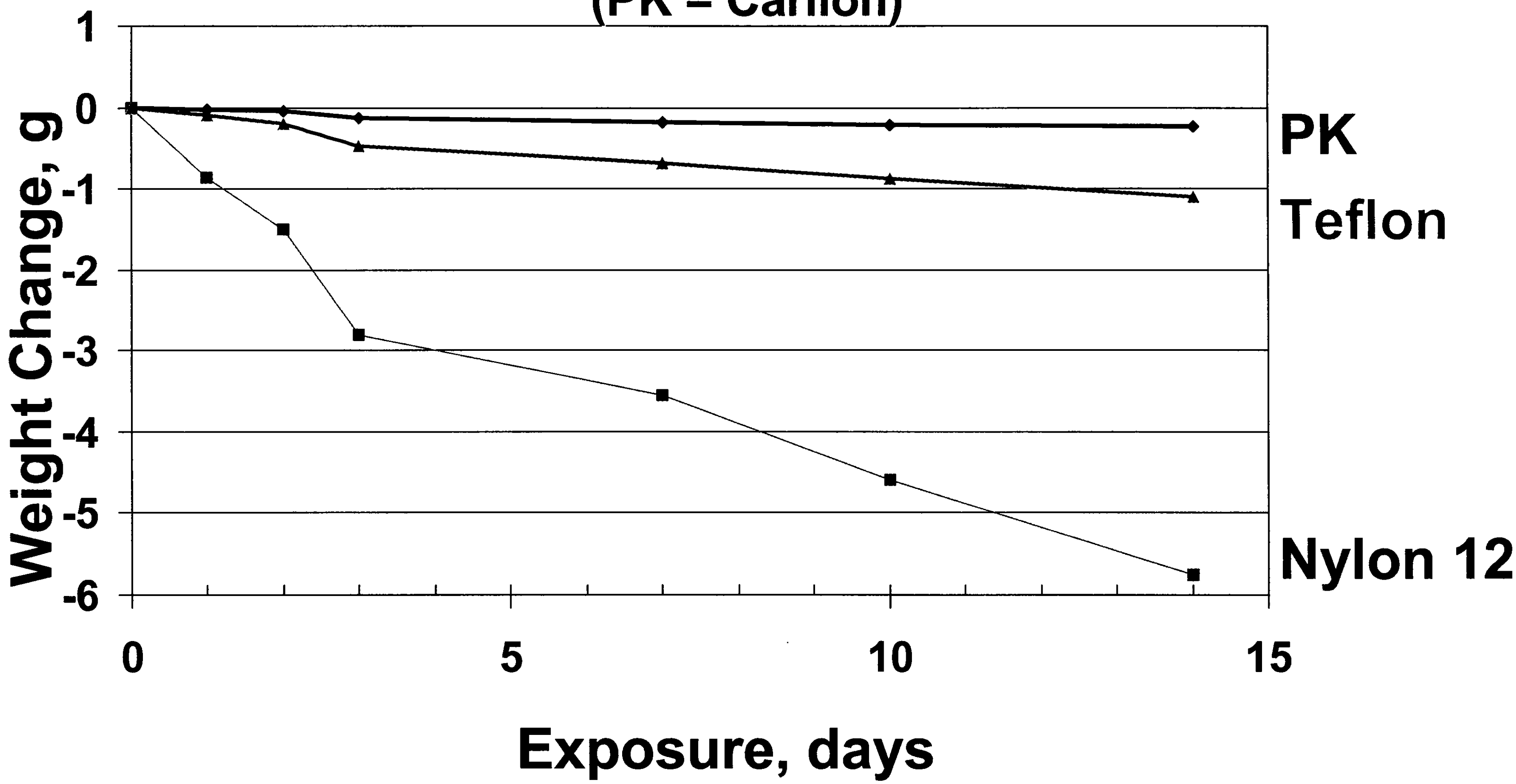
Permeability of Unleaded Gasoline at 93°C

(PK = Carilon)



*Measured according to GM SPEC 9061-P

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Unique Balance of Properties

- **Stiffness/Toughness**
- **Modulus/Temperature**
- **Creep Resistance**
- **Chemical Resistance**
- **Low Permeability**
- **Abrasion/Wear Resistance**
- **Mechanical Resilience**
- **Dimensional Stability at Elevated Temps.**

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Testing of Thermoplastics Used in Liner Applications

	PK (Carilon)	PA11 (BESNO P40TL)	PVDF (Kynar 710)	HDPE (PE 3408)
Physical, Thermal, Mechanical Props.	✓	✓	✓	✓
CH_4, CO_2, H_2S Permeation	✓	✓	✓	✓
ESCR	✓	---	---	---
Explosive Decompression	✓	✓	✓	✓
Oilfield Chemicals Exposure	✓	✓	---	---
Crude Condensate Exposure	✓	---	---	---

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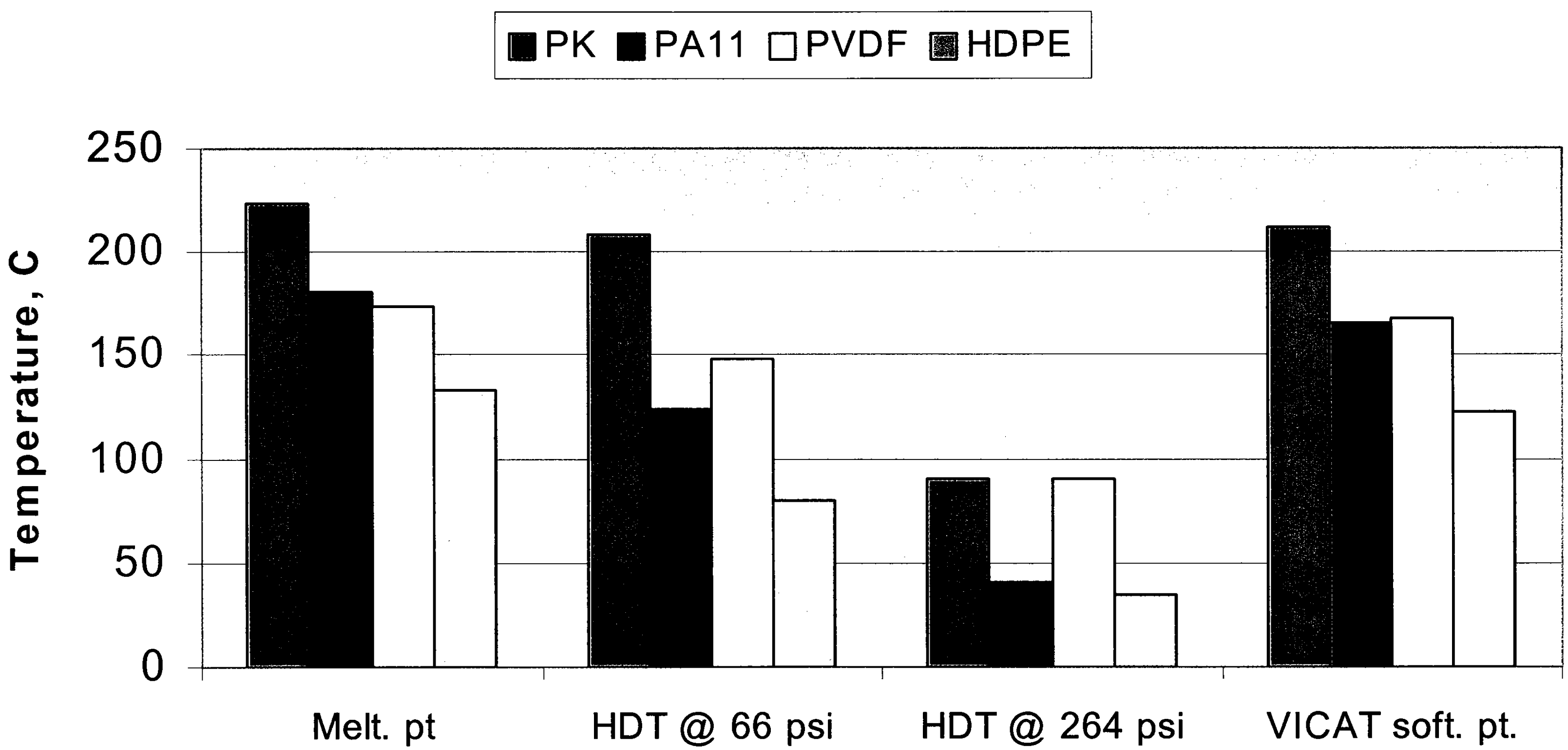
Thermal Properties



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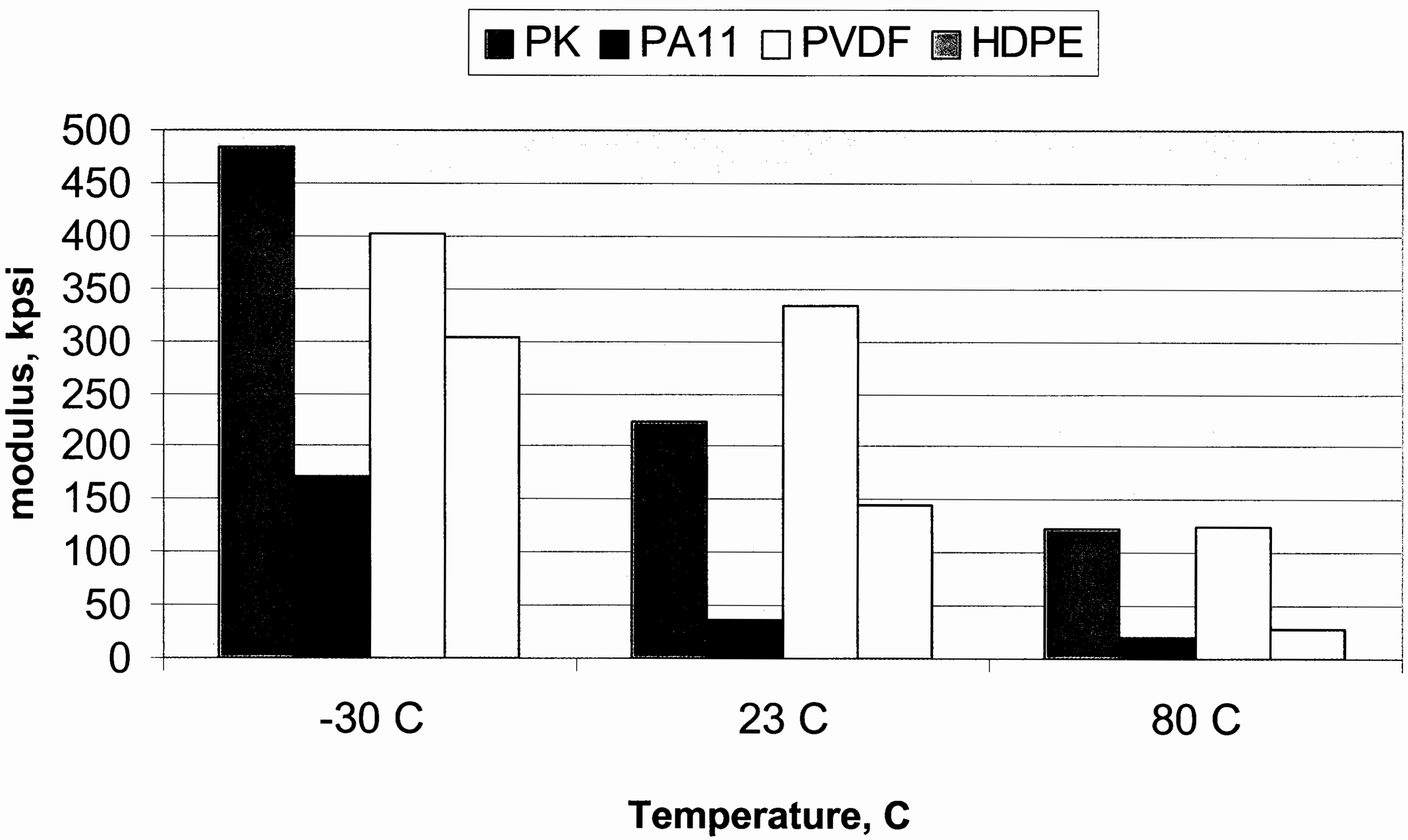
Mechanical Properties - Tensile Modulus



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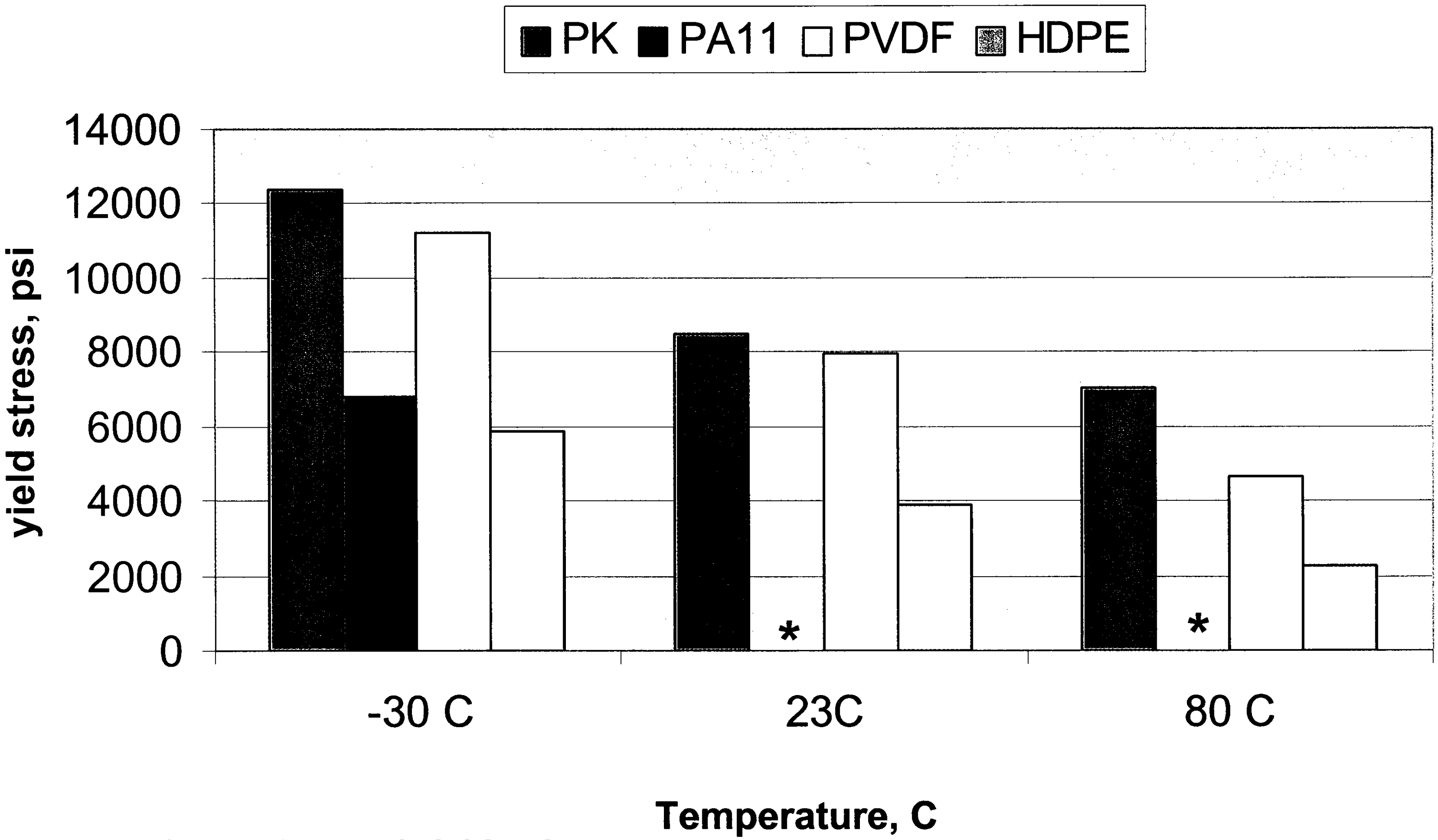
Mechanical Properties - Yield Stress



* : no observed yield point

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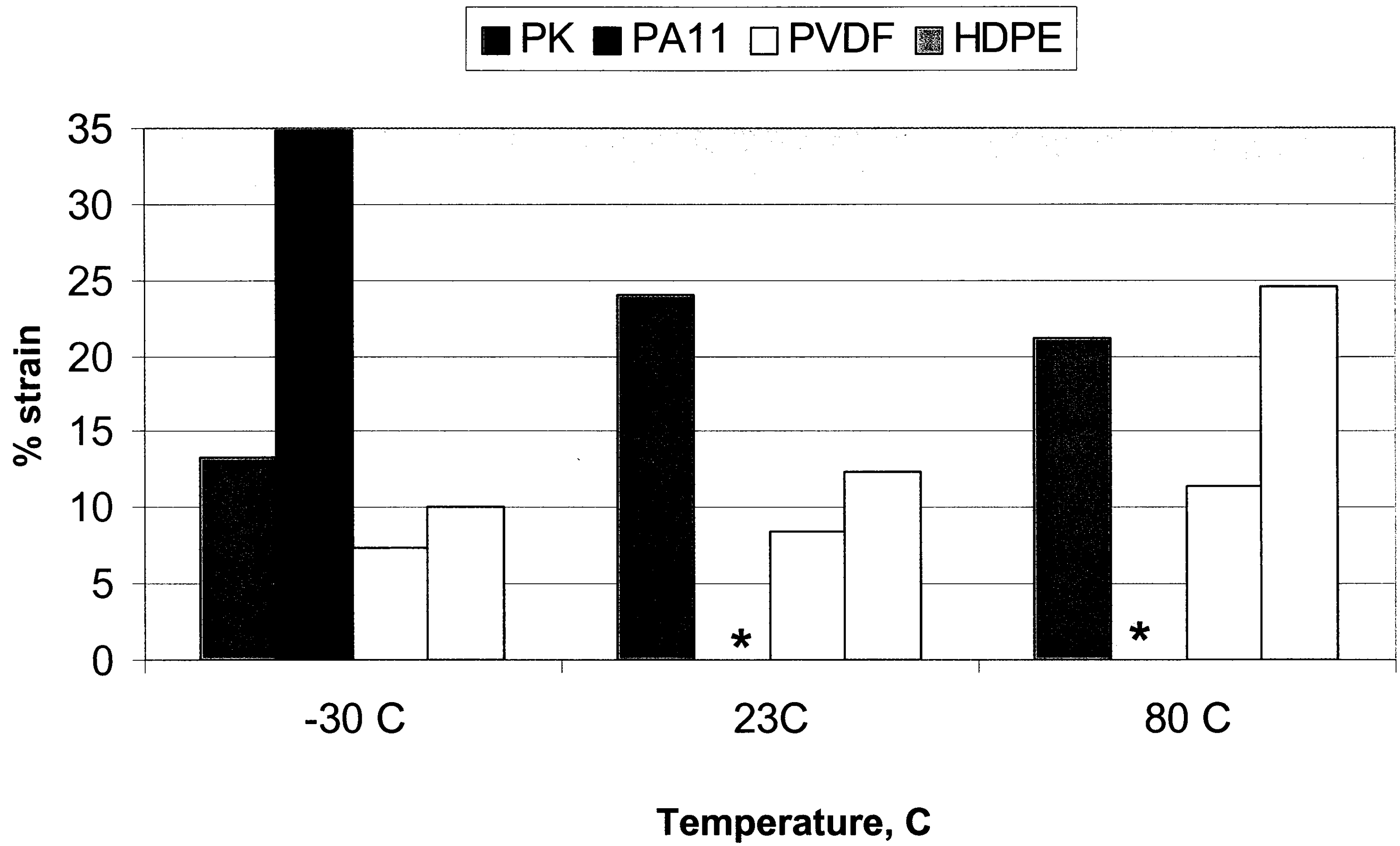
Mechanical Properties - Yield Strain



*** : no observed yield point**

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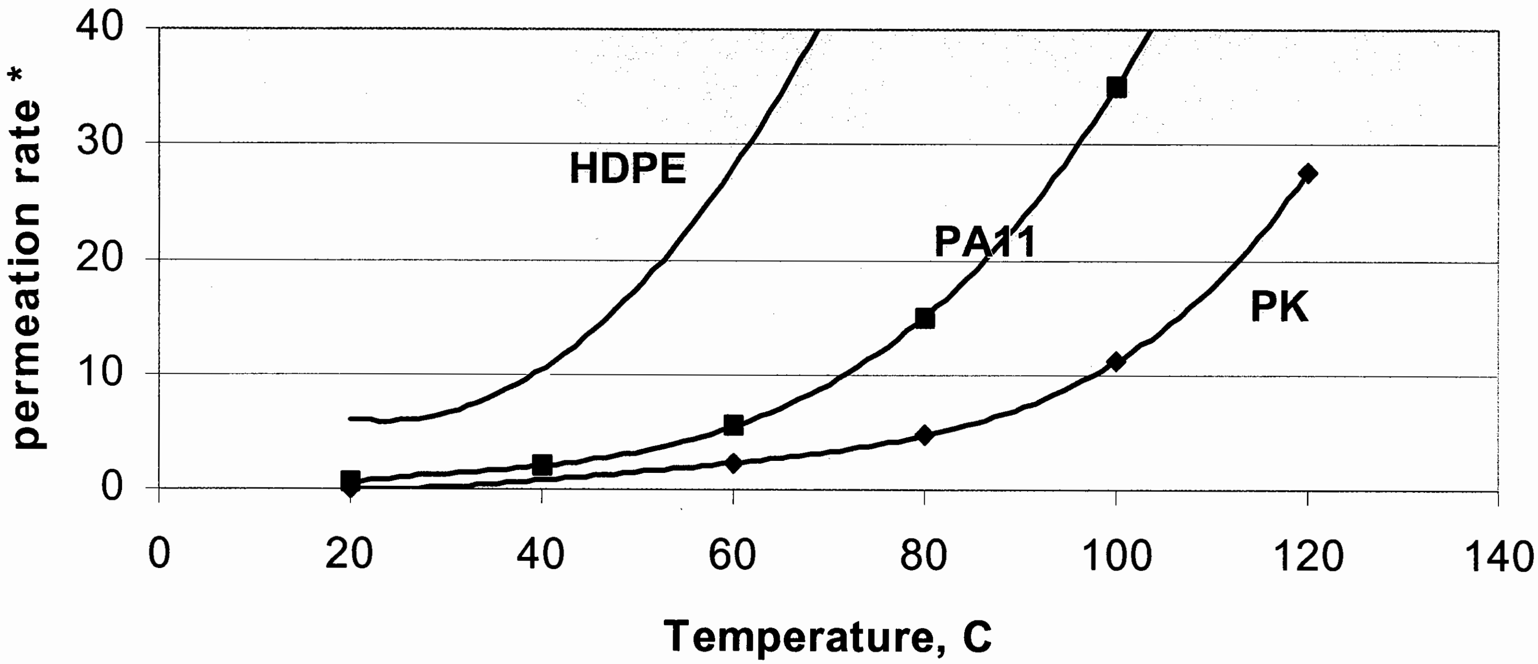
CH_4 Permeation



* unit = 10^9 cm^3 - cm / cm^2 s. bar

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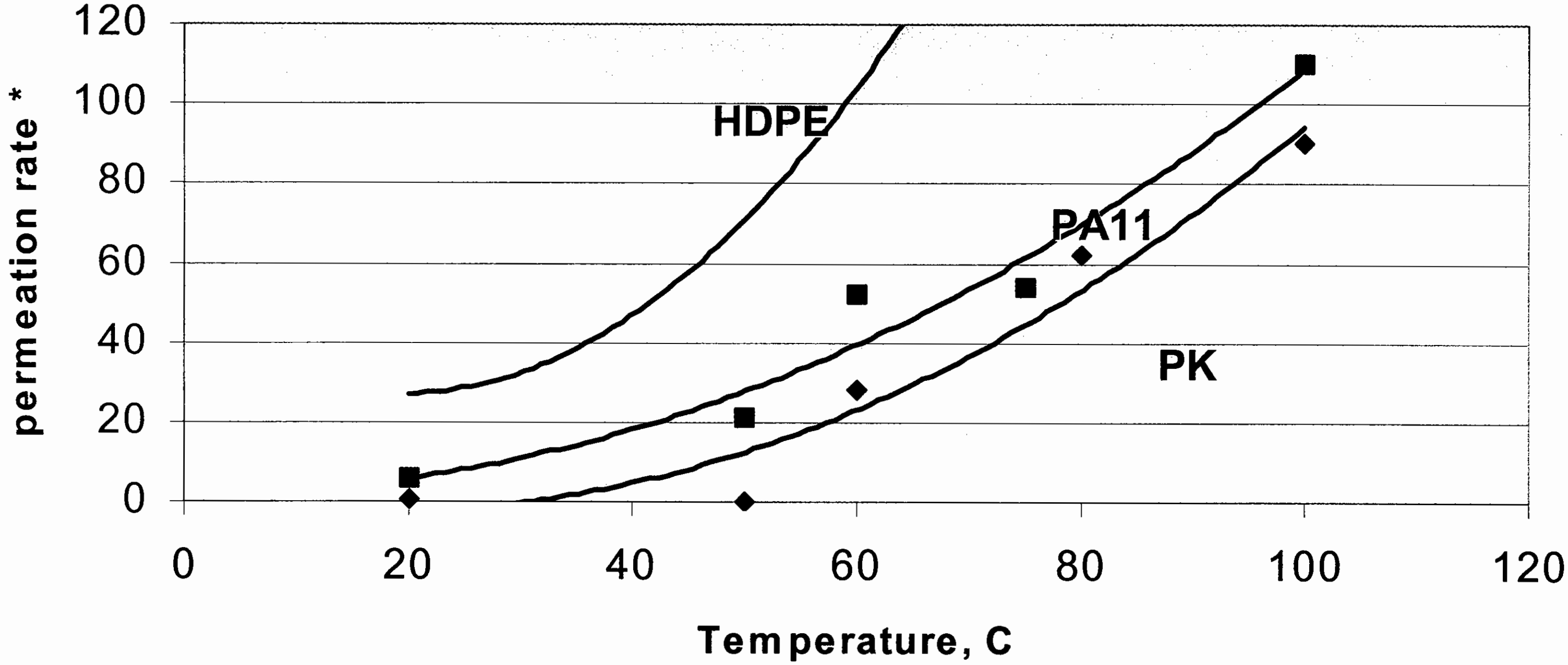
CO_2 Permeation



* unit = 10^9 cm^3 - cm / cm^2 s. bar

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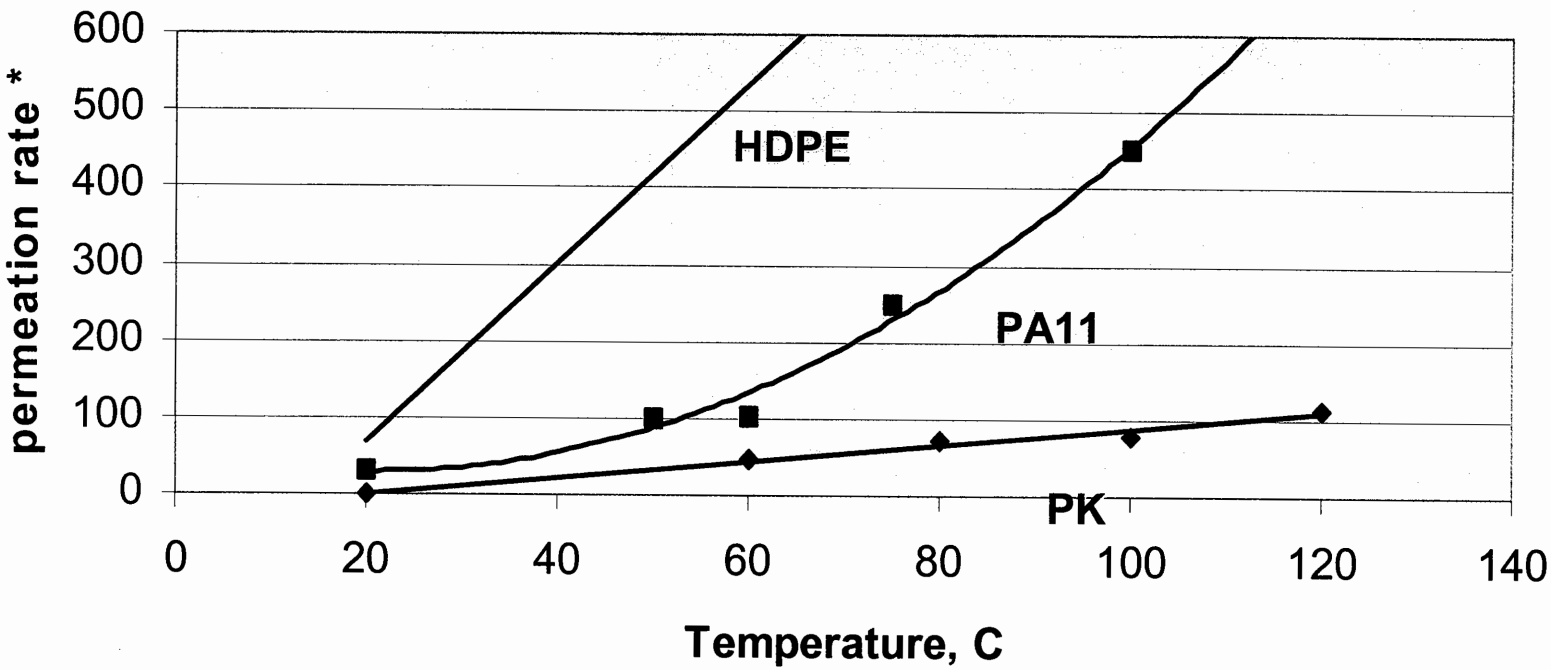
H_2S Permeation



* unit = 10^9 cm^3 - cm / cm^2 s. bar

Environmental Stress Crack Resistance

Environment	Temperature °C	Total time (Hrs)	Number of failures
ASTM -D1693			
Soap solution: Igepal 25%	50	>5000	0
Soap solution: Igepal 100%	50 100	>5000 >2400	0 0
Multicomponent Liquid*	25	>2700	0
Drilling Mud	25 80	>2700 >2400	0 0
Corrosion inhibitor: oil-based polyamine, Tetrolite EC1110A in 3% aq NaCl	25 80	>2700 >2400	0 0
Corrosion inhibitor: water based imidazoline salts, Corexit 6315 in 3% aq NaCl	25 80	>2700 >2400	0 0
Toluene	25 80	>2700 >2000	0 0
Xylene	25	>3000	0
Methyl ethyl ketone	25	>5000	0
1.5%Hf/7.5% HCl	25 80	>2700 >2400	0 0
10% NaOH	25	>2200	0
ASTM -F1248			
Soap solution: Igepal 25%	50	>3600	0
Soap solution: Igepal 100%	50	>3600	0
Multicomponent Liquid	25	>3000	0

*Multicomponent Liquid: Benzene 1%; Toluene 7%; Xylene 11%; Cyclopentenes 6%; Cyclohexanes 6%; C4-C5 17%; C6-C10 42%; C11 10%

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Explosive Decompression Test

I. CO_2 Gas Phase

Test conditions
Sample size: 1"x0.25"x0.25"
Gas phase: CO_2
Temperature: 100 oC
Pressure: 5000 psig
Decompression rate: 2000 psi/minute
Samples examined at cycles after: 72, 144, 264, 456, 600 hours

Material	144 Hours	456 Hours	600 Hours
PK	No damage	No damage	No damage
PA11	No damage	No damage	No damage
PVDF	No damage	No damage	No damage
HDPE	No damage	No damage	Blisters observed

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Explosive Decompression Test

II. CO_2 and Deionized Water

Test conditions
Sample size: 1"x0.25"x0.25"
Gas phase: CO_2
Liquid phase: Deionized water
Temperature: 100 oC
Pressure: 5000 psig
Decompression rate: 2000 psi/minute
Samples were located in both liquid and gas phases.
Samples examined at cycles after :
168,192,216,312,360,480,528,552,624 hours

Material	168 Hours	312 Hours	624 Hours
PK	No damage	No damage	No damage
PA11	Blisters observed on samples exposed in liquid	Blisters observed on samples exposed in gas	
PVDF	No damage	No damage	No damage

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Chemical Exposure Testing

Conditions:

I. Multicomponent Fluid Condensate (done by John Baron, Shell Canada)

- ➔ PK exposed to multicomponent fluid condensate at temp up to 80C: Benzene 1%; Toluene 7%; Xylene 11%; Cyclopentenes 6%; Cyclohexanes 6%; C4-C5 17%; C6-C10 42%; C11 10%.
- ➔ measure mechanical properties after four and eight months at given temps

II. Water Condensate (Nelson Fluid) (done in Shell Amsterdam)

- ➔ PK and PVDF in autoclave testing : 105^{o}C - 150^{o}C, 120 bar, water - condensate : Liquid phase: 6 g benzene, 24 g toluene, 16.2 g xylene, 21.6 g methanol, adjust to 1500 ml with artificial seawater according ASTM 1141-75-6 +10 ppm Naslfloc 1289. Gas phase: 0.2 bar H2S, adjust to 4.0 bar with CO2, adjust to 90 bar with CH4 at aging temperature adjust with CH4 to 120 bar. mechanical properties on exposed samples were measured at room temperature

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Chemical Exposure Testing

Conditions: (cont'd)

III. Oilfield Chemicals (single component fluids)

- **➔ PK, PA11 exposed to oilfield chemicals such as drilling muds, corrosion inhibitors, etc.**
- **➔ measure retention of mechanical properties, weight gain after three months**

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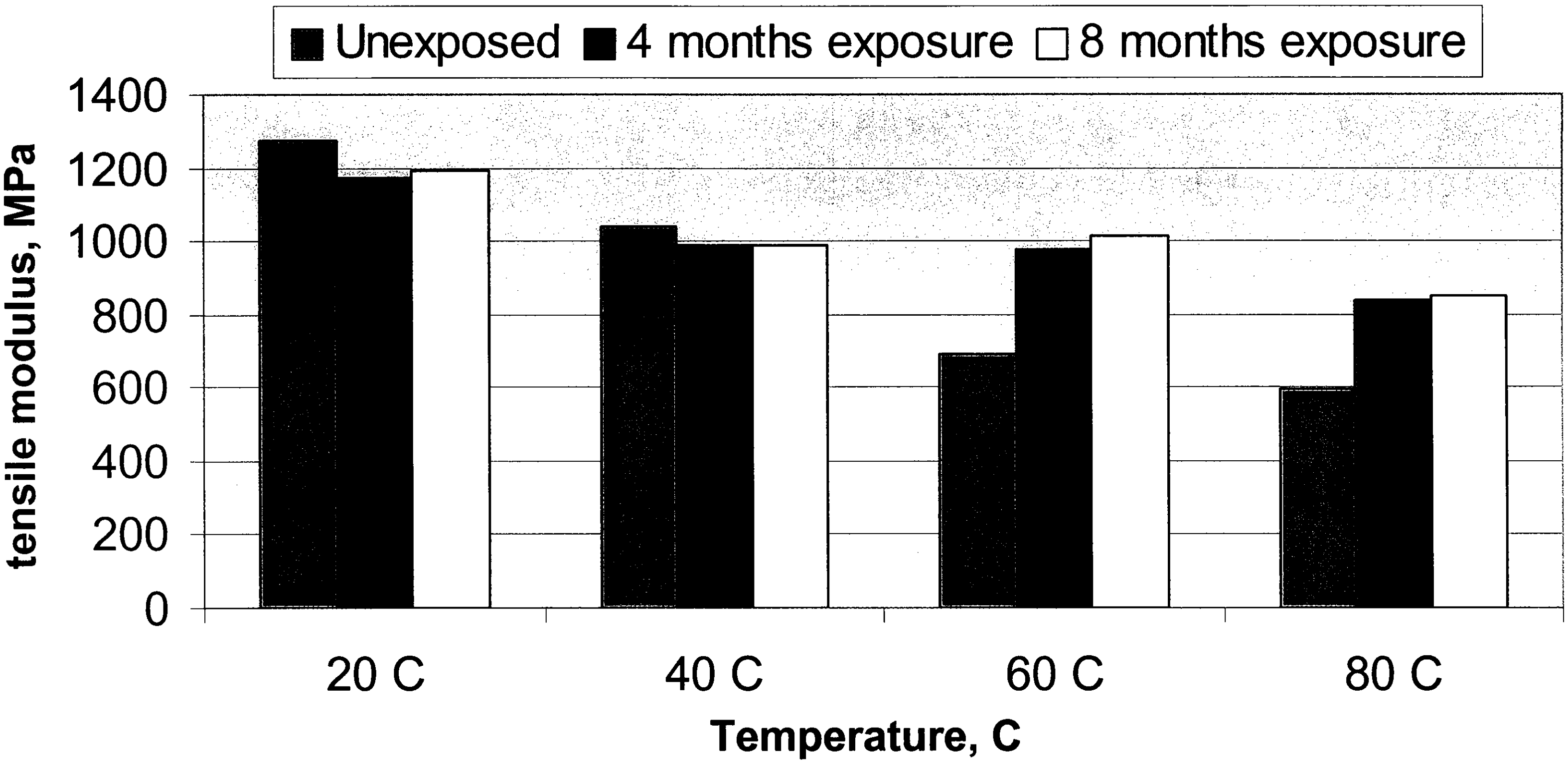
Multicomponent Liquid Testing
(Tensile Modulus)



Multicomp. Liqd.: Benzene 1%; Toluene 7%; Xylene 11%; Cyclopentenes 6%; Cyclohexanes 6%; C4-C5 17%; C6-C10 42%; C11 10%.

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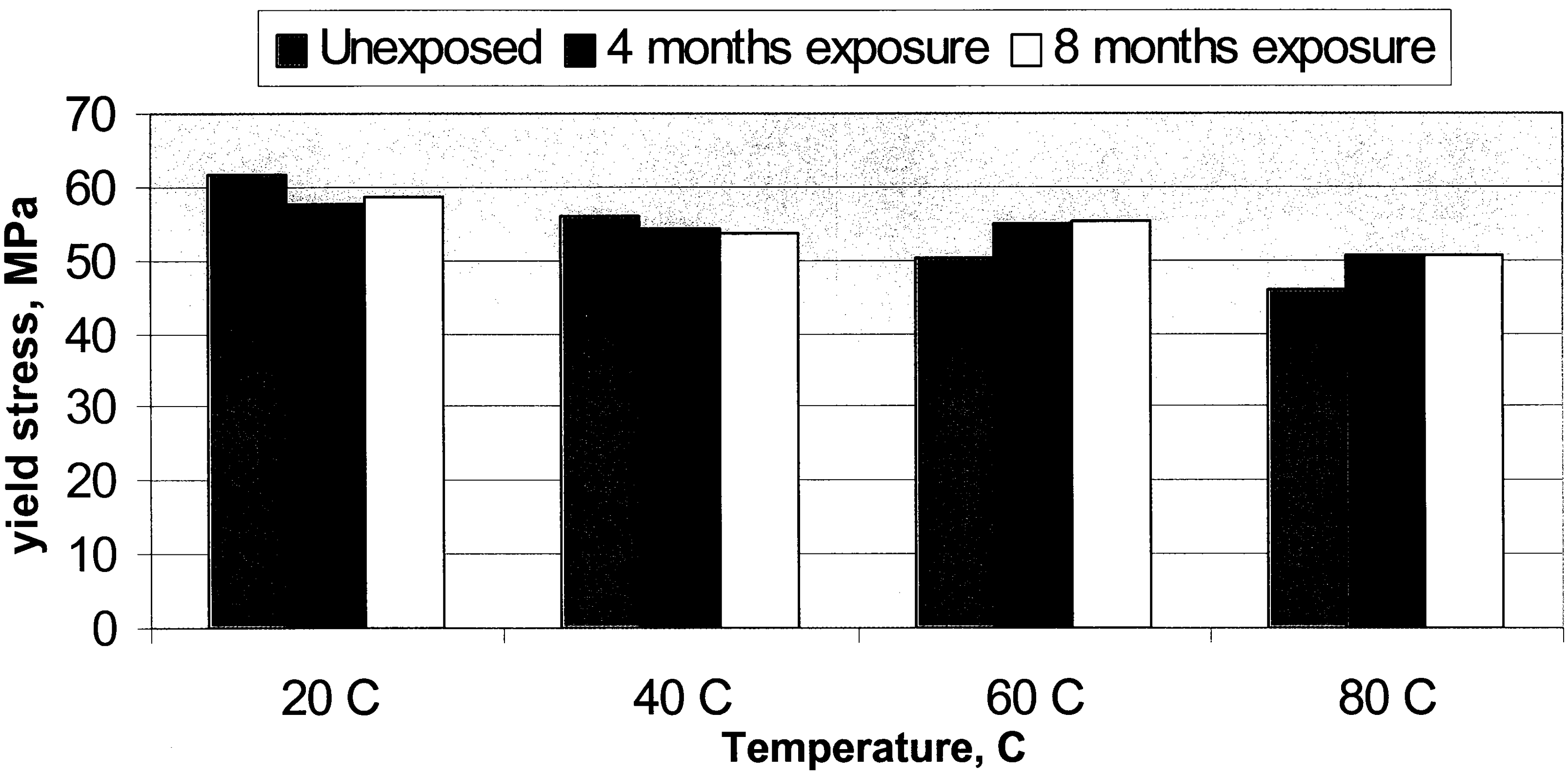
Multicomponent Liquid Testing
(Yield Stress)



Multicomp. Liqd.: Benzene 1%; Toluene 7%; Xylene 11%; Cyclopentenes 6%; Cyclohexanes 6%; C4-C5 17%; C6-C10 42%; C11 10%.

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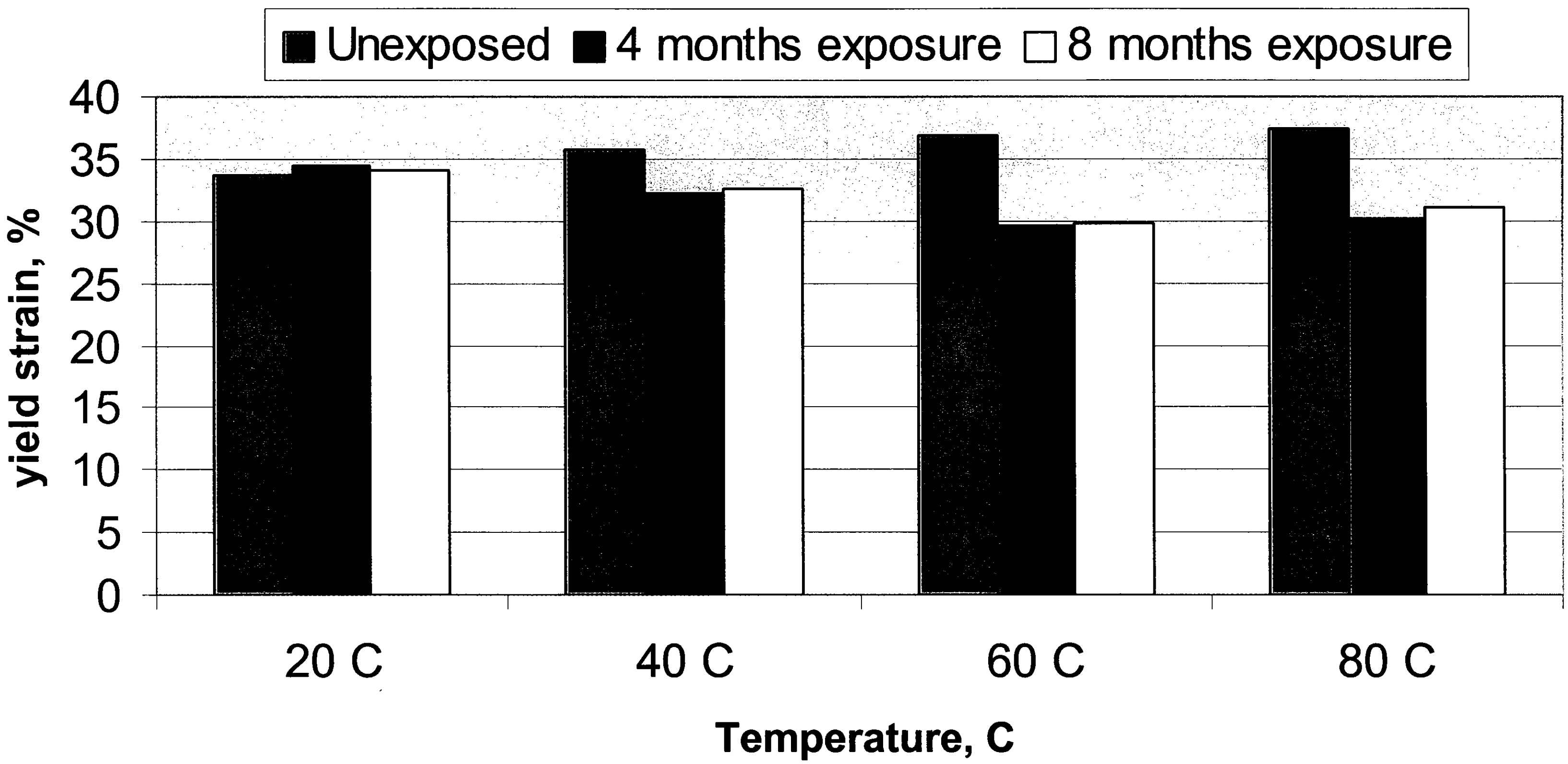
Multicomponent Liquid Testing
(Yeild Strain)



Multicomp. Liqd.: Benzene 1%; Toluene 7%; Xylene 11%; Cyclopentenes 6%; Cyclohexanes 6%; C4-C5 17%; C6-C10 42%; C11 10%.

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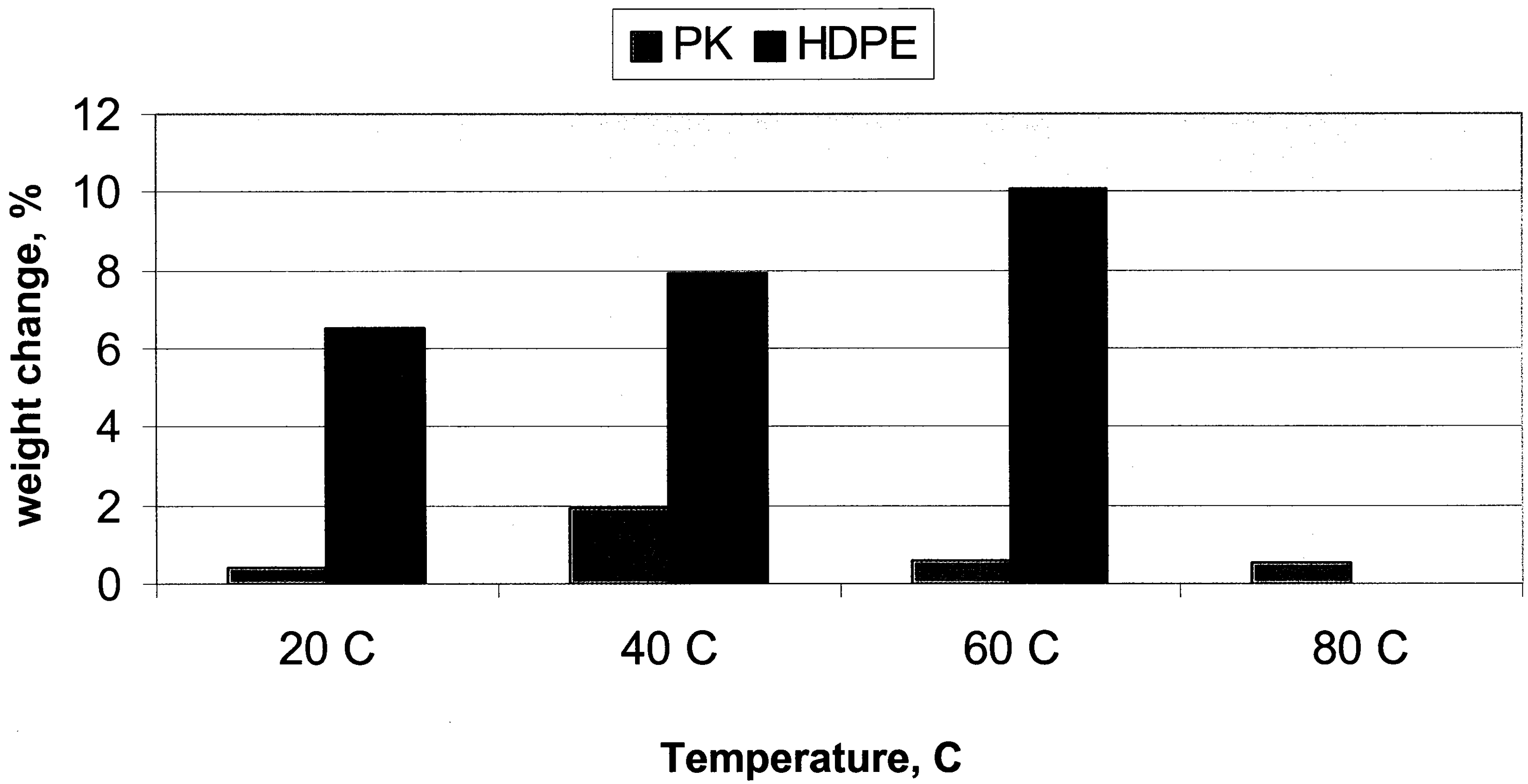
Multicomponent Liquid Testing

(Weight Change after 8 Months Exposure)



Multicomp. Liqd.: Benzene 1%; Toluene 7%; Xylene 11%; Cyclopentenes 6%; Cyclohexanes 6%; C4-C5 17%; C6-C10 42%; C11 10%.

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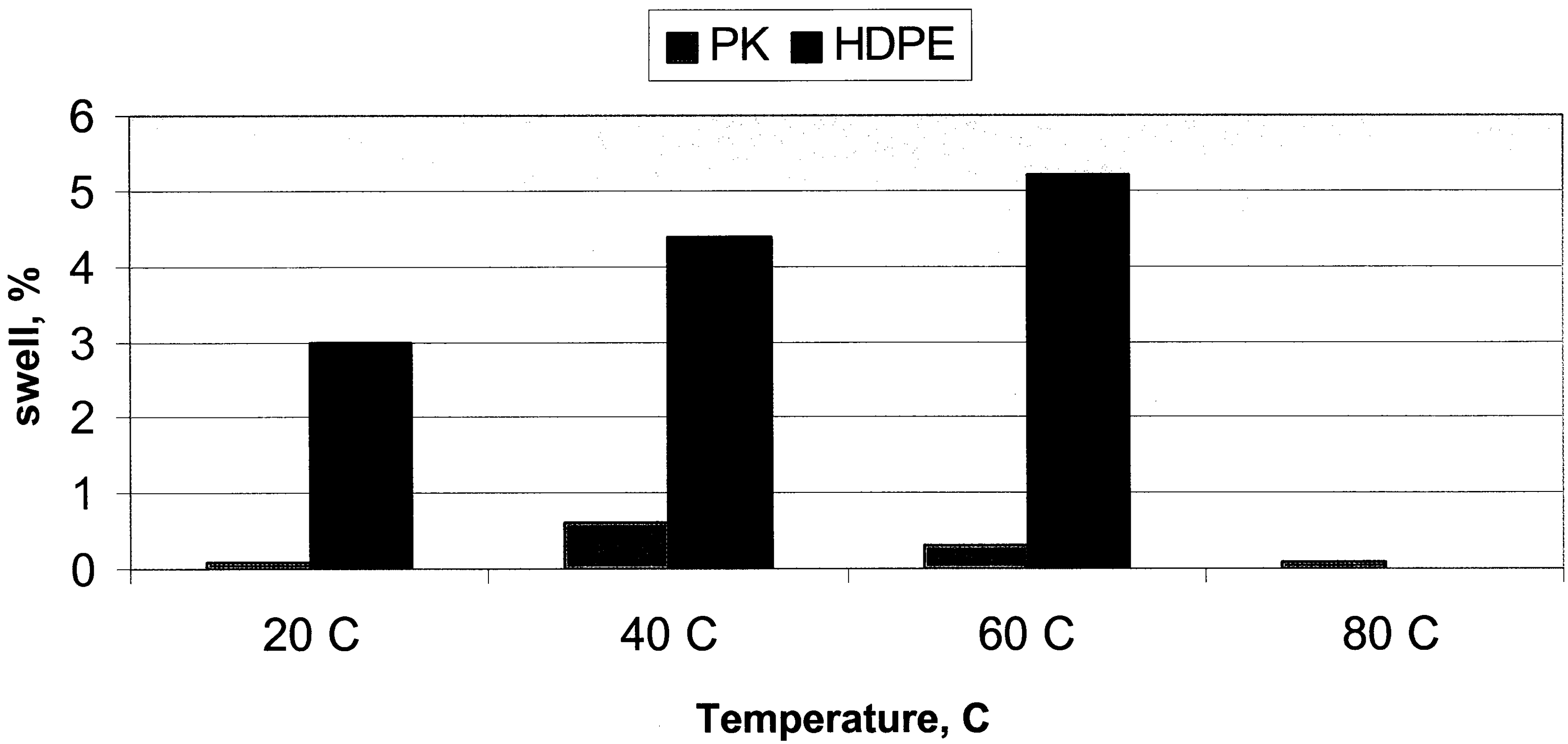
Multicomponent Liquid Testing

(Swell after 8 Months Exposure)



Multicomp. Liqd.: Benzene 1%; Toluene 7%; Xylene 11%; Cyclopentenes 6%; Cyclohexanes 6%; C4-C5 17%; C6-C10 42%; C11 10%.

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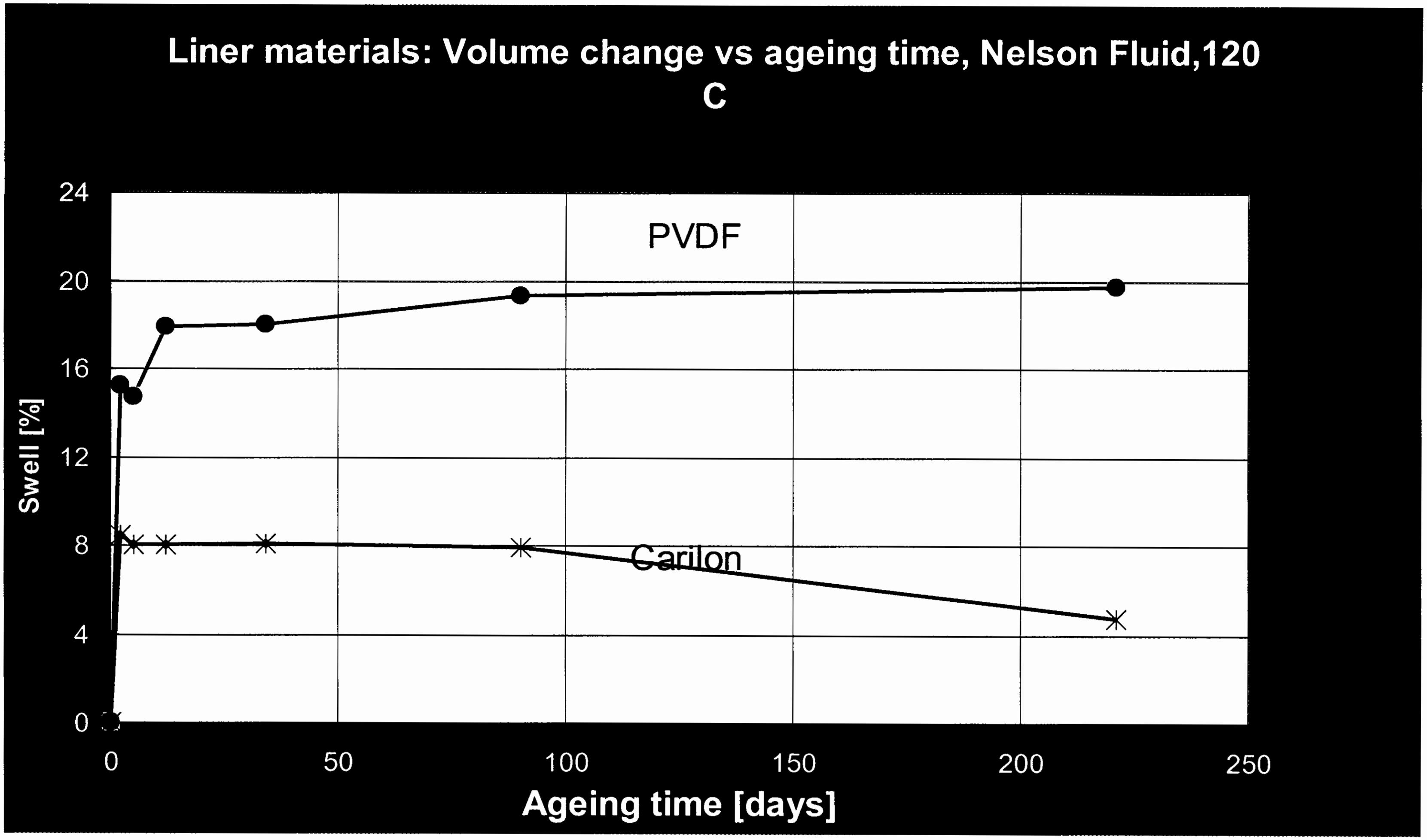
Autoclave aging in Nelson Fluid (120 C, 120 bar)



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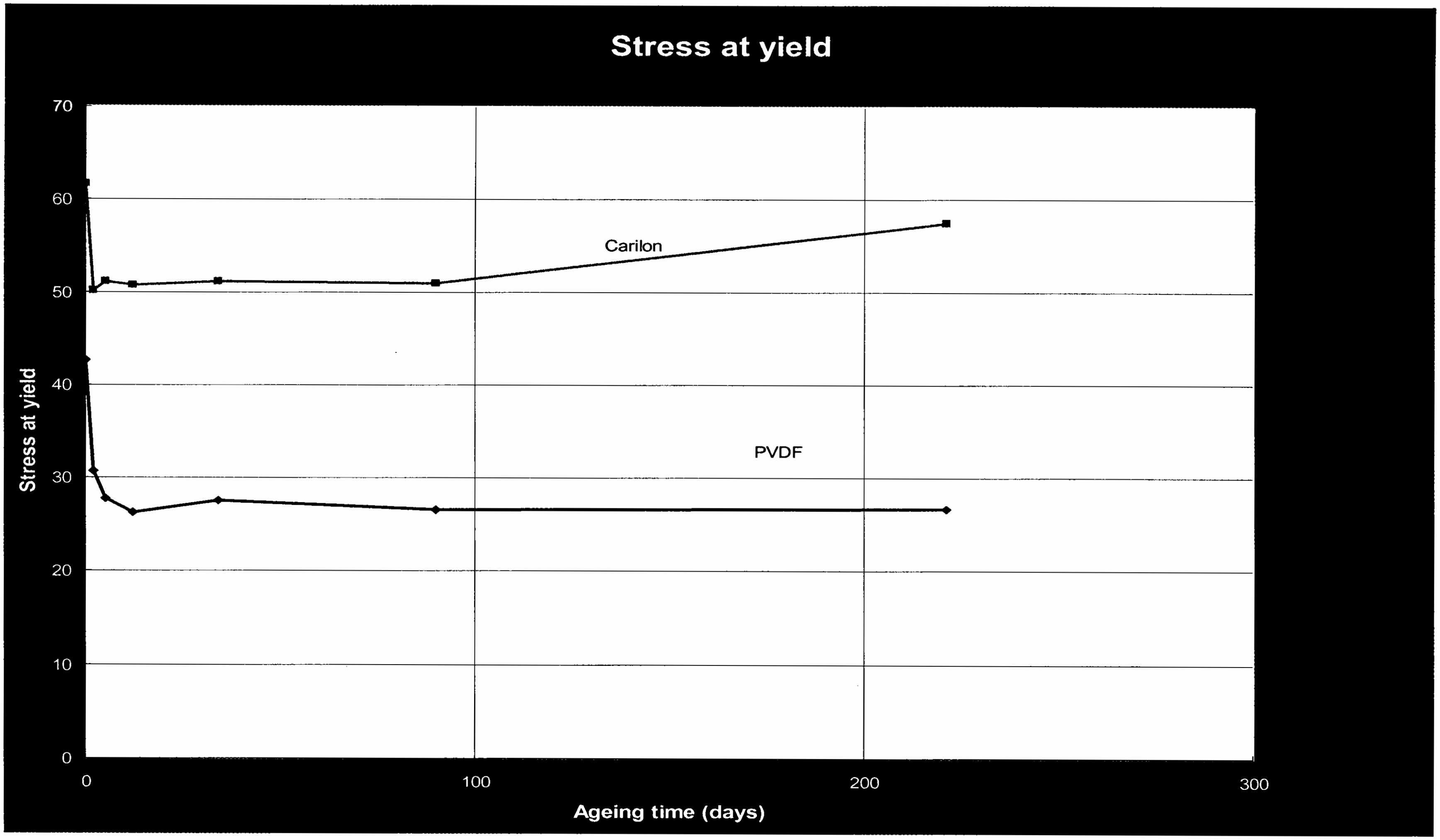
Autoclave aging in Nelson Fluid (120 C, 120 bar)



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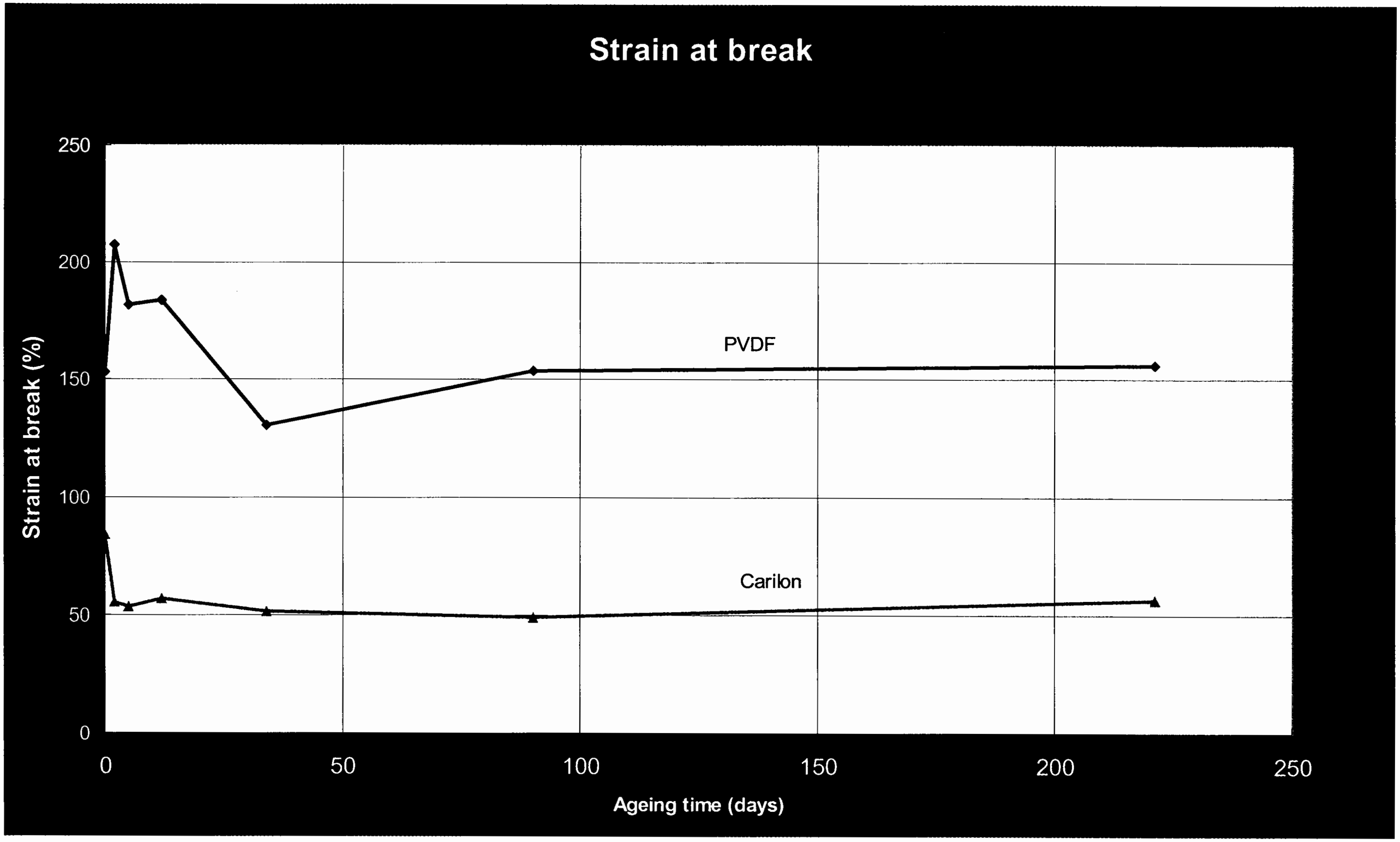
CARILON is a registered trademark of Shell Chemical Company

Autoclave aging in Nelson Fluid (120 C, 120 bar)



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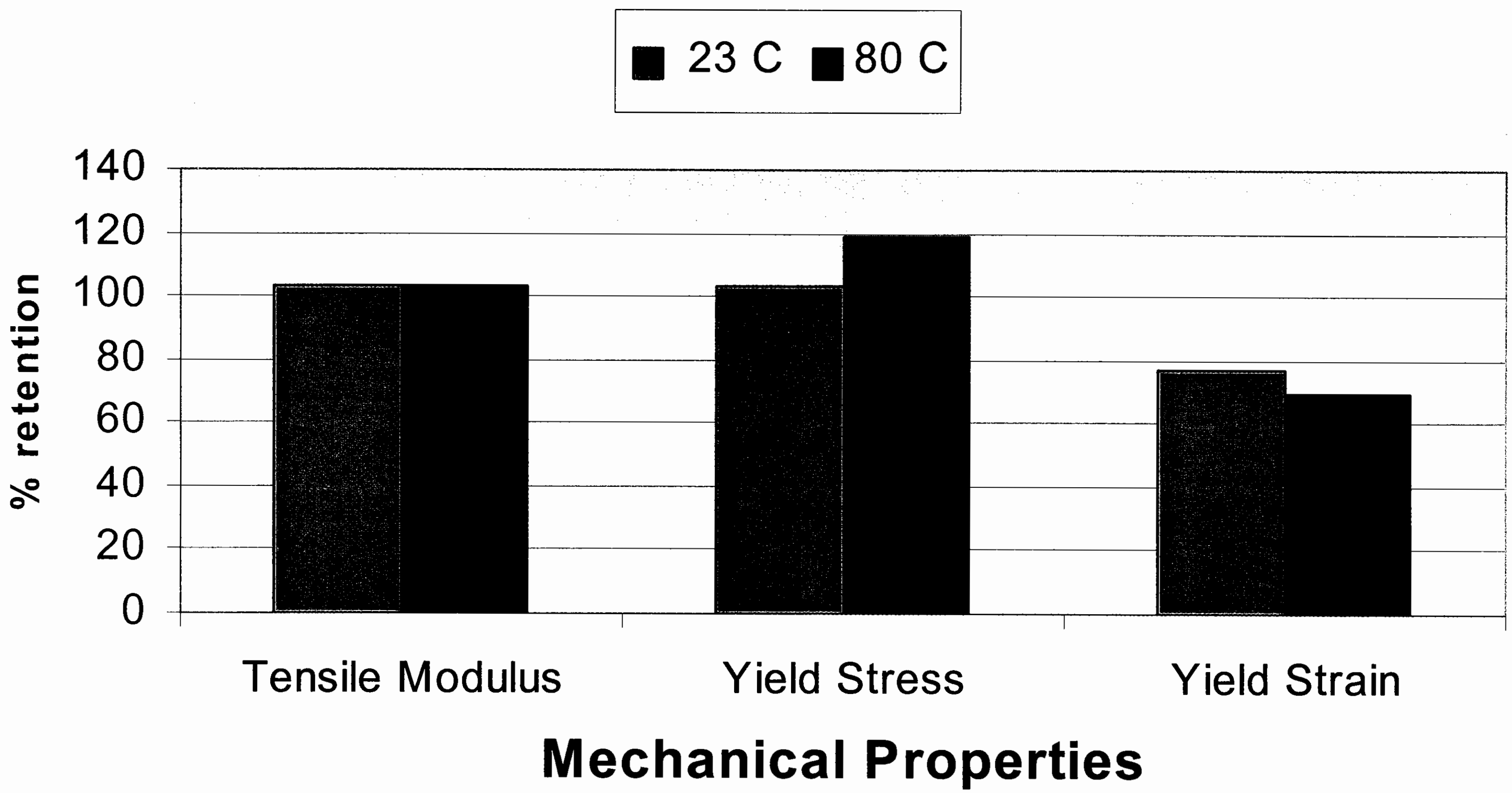
Oilfield Chemical Exposure

(9 months exposure in drilling mud*)



* Baroid, Petrofree Drilling Mud 22.2 lb/gallon

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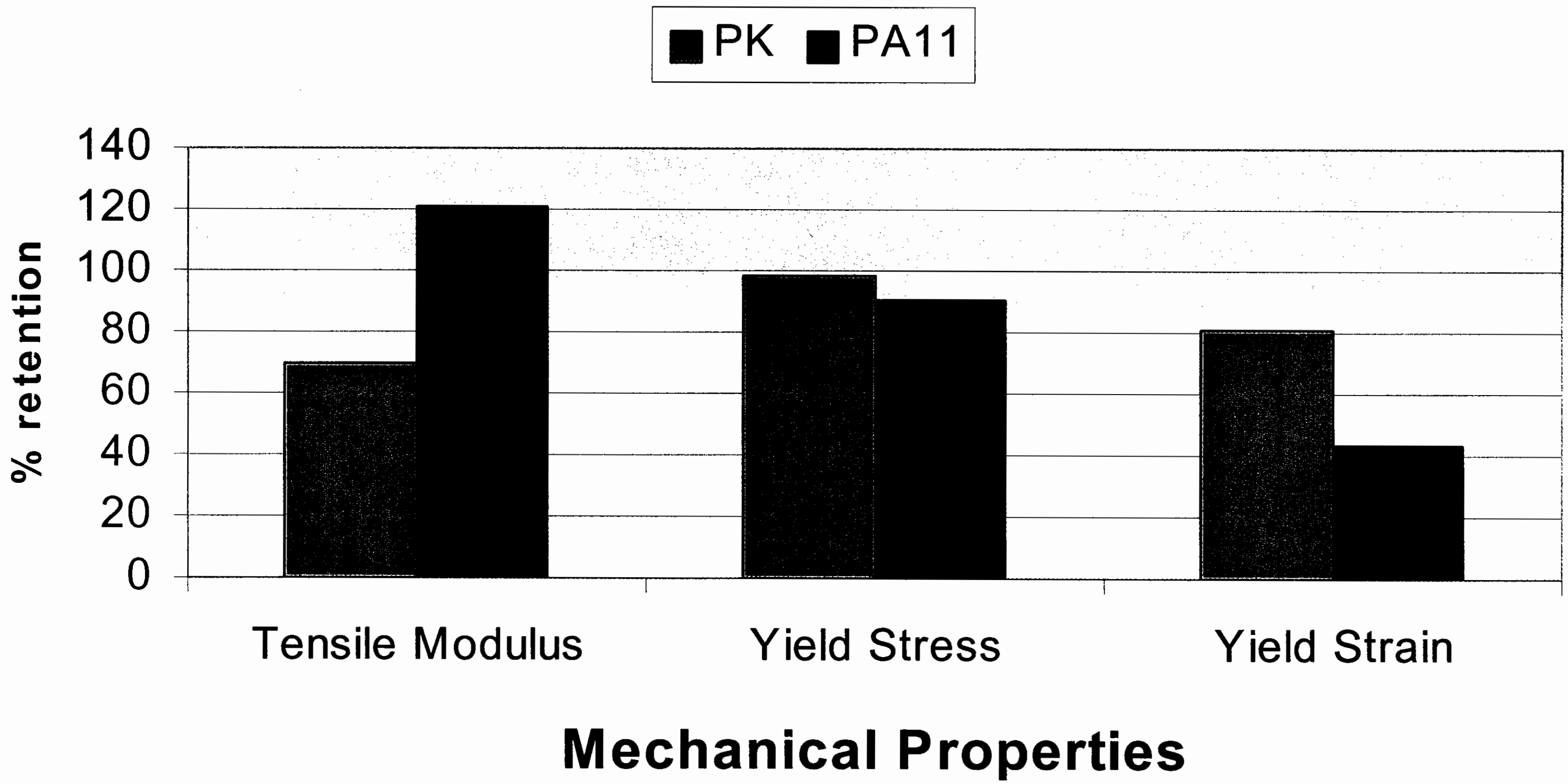
Oilfield Chemical Exposure @ 80° C

(9 months exposure in Corrosion Inhibitor: 1% COREXIT 6315 in 3% Aq. NaCl)



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LINER INSTALLATION ISSUES

Hot Plate Fusion of Carilon

Quick Burst Hoop Stress of 2” OD, SDR15 pipe with Butt-welding at Room Temperature

Sample	Hoop Stress, psi
Laboratory pipe with no welding	**7300+/-200**
Laboratory pipe with welding	**7430+/-440**
Commercial pipe with no welding	**7750+/-380**
Commercial pipe with welding	**7380+/-400**

Tensile Property for Butt Welded 4.2” OD SDR17 Pipe

Tensile Sample	Yield Strain, %	Break Stress, psi	Break Elongation, %
Control	18.1 +/- 1.9	9070 +/- 276	191 +/- 23.4
Butt Welded	18.8 +/- 1.18	9293 +/- 151	93.2 +/- 44

Test conducted at 2 inch/min strain rate and room temperature

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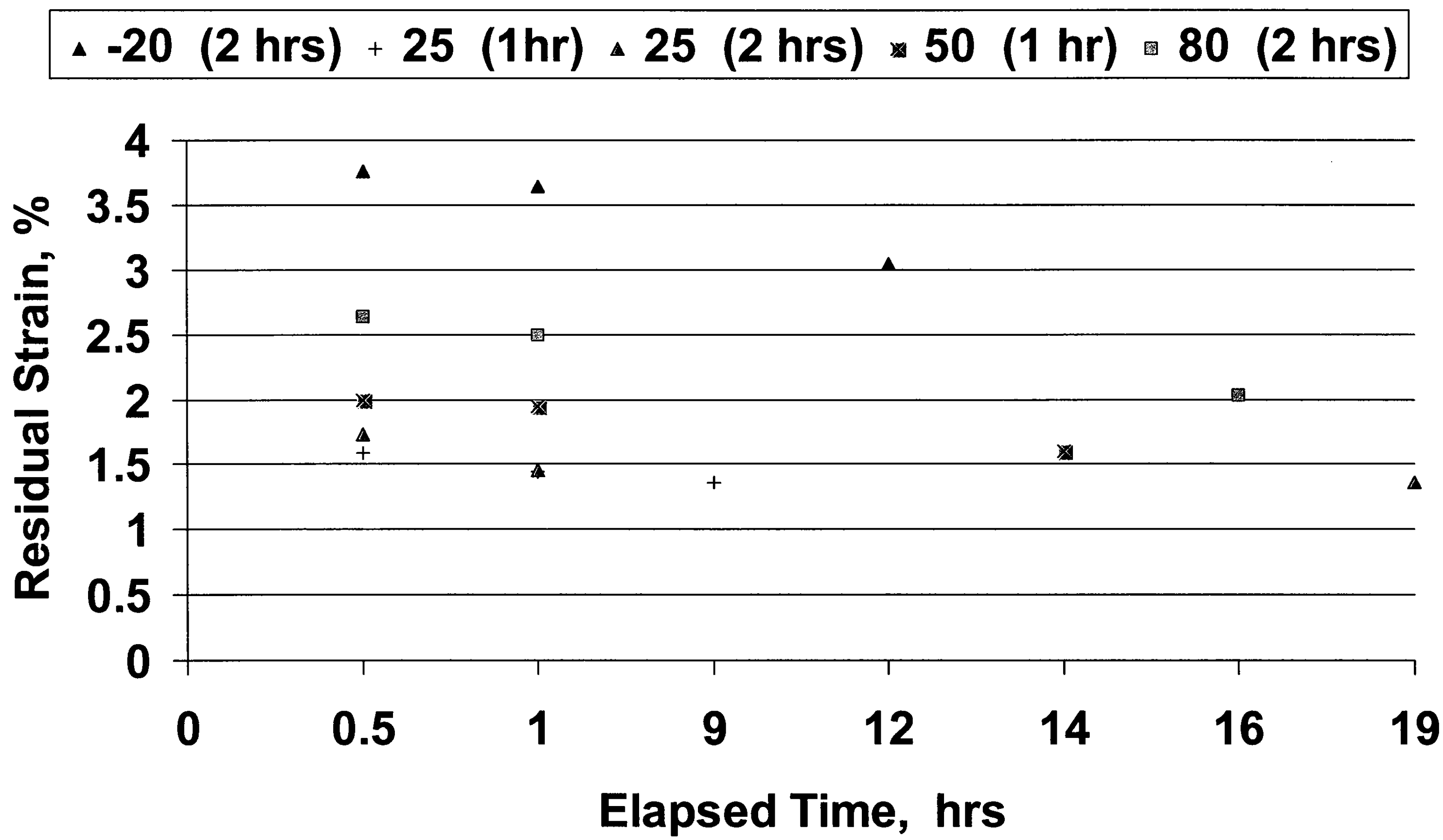
Strain Relaxation of Carilon Liner

Conditions:

- ➔ **tensile bars cut from pipe in axial direction**
- ➔ **stretch to 8% elongation and hold for a given period of time and at a given temperature**
- ➔ **remove stress and measure residual strain after certain time intervals**

Strain Relaxation of Carilon Liner

(Effect of Holding Time and Temperature)



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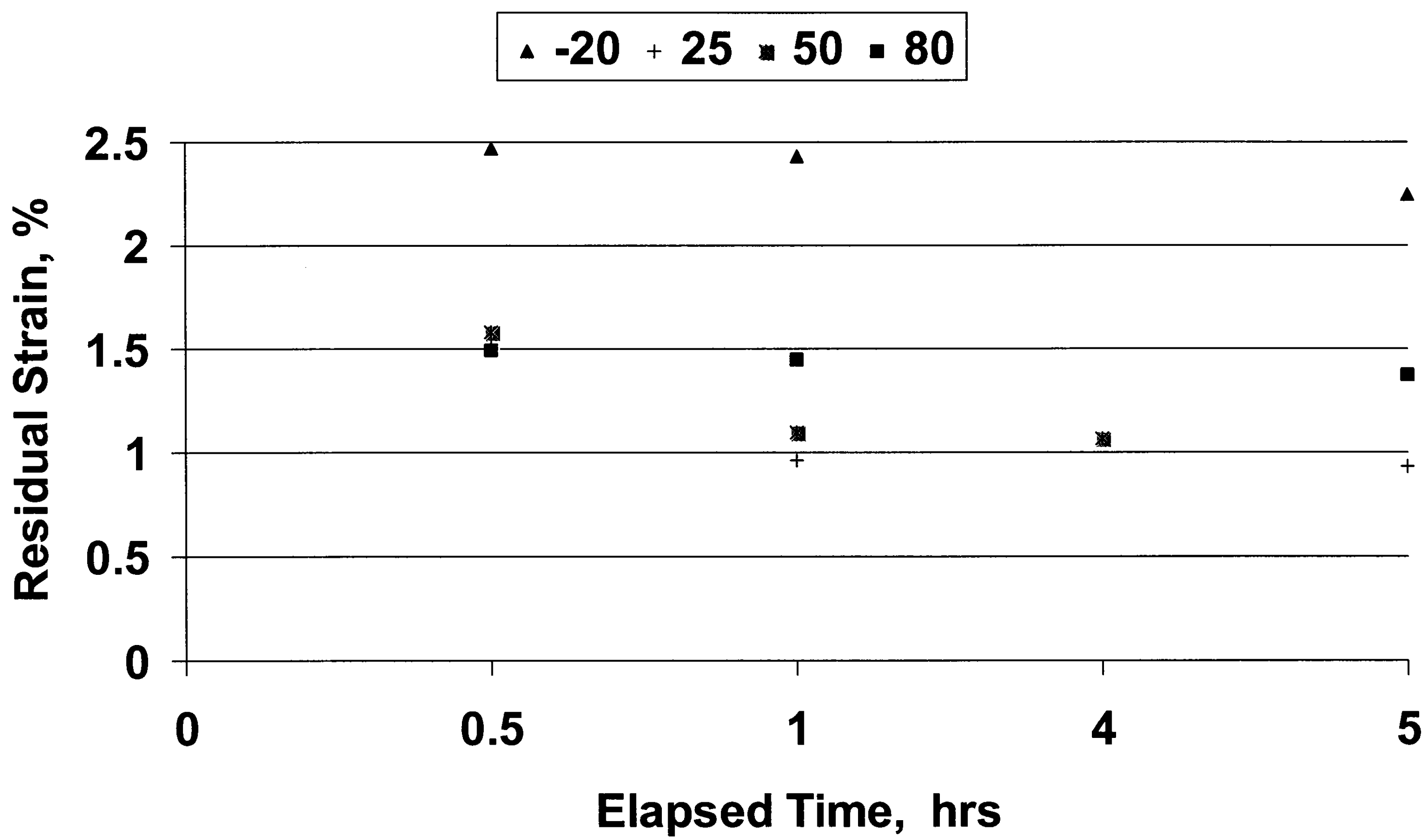
Strain Relaxation of Carilon Liner

(Constant Holding Time (30 Seconds) - Effect of Temperature)



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Minimum Bend Radius Ratio of Liner

INTRODUCTION

When considering the bending-radius ratio for liner there appears to be two different failure modes dependent on liner thickness; 1) a yield-driven failure-mode for liner with SDRs < 20 and 2) a buckling-driven failure-mode for liners with SDRs ≥ 20. Analysis will be covered in this technical discussion for both liner with SDRs < 20 (yield-driven) and SDRs ≥ 20 (buckling-driven).

FAILURE OF LINER w/ SDRs < 20 (YIELD DRIVEN)

TABLE 1. MINIMUM BEND RADIUS RATIO (SDR < 20)

LINER MATERIAL	E psi	σ_y psi	MIN. BEND RADIUS RATIO (R / d)
HDPE	136,000	3,500	23.5
PK	230,000	8,700	16.5

FAILURE OF LINER w/ SDRs ≥ 20 (BUCKLING DRIVEN)

TABLE 2. MINIMUM BEND RADIUS RATIO (SDR ≥ 20)

LINER MATERIAL	POISSON'S RATIO (ν)	SDR 21	SDR 26	SDR 32.5
HDPE	.40	25.4	32.1	40.7
PK	.44	24.4	30.8	39.1

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CONCLUSION

Carilon Features in Oil & Gas Applications

Elevated Temperature Mechanical Props.

Good CH_4, CO_2, H_2S Permeation Resistance

Resistant to Stress Cracking/Blistering

Good Retention of Mechanical Properties When Exposed to Oilfield Chemicals and Condensates

Installation Processes Characterized: OD reduction 13.5%, weld line strength, and coilability

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Carilon Forward Plan in Oil & Gas Applications

Retail - Forecourt Market

- continue to expand sales into co-extruded hose and pipe

E&P - Onshore

- Free-Standing PK/PE co-extruded pipe flow line field trial in 1998
- RTP to be produced with PK/PE co-extruded base tube in 1998
- Horizontal compression fit liner flow line field trial in 1998
- Vertical compression fit liner well casing field trial in 1998

E&P - Offshore

- Flexible production trial in 1998

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BACKUP SLIDES TO FOLLOW

Mechanical Properties

at Room Temperature

Tensile Property (ASTM D638)	PK	PA11 BESNO P40TL	PVDF Kynar 710	PVDF Solef 1010	HDPE PE3408
Modulus, Kpsi	223	35.8	322	333	158
Yield Stress, psi	8740	--	8000	7970	3900
Yield strain, %	24.5	--	7.92	8.42	12.4
Break Stress, psi	11900	5920	6180	5750	3350

at Room Temperature

Flexural Property (ASTM D790)	PK	PA11 BESNO P40TL	PVDF Kynar 710	PVDF Solef 1010	HDPE PE3408
Modulus, Kpsi	210	37.6	276	278	113
Peak Stress, psi	7710	1680	1030	1020	3310

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Mechanical Properties, cont.

at - 30 °C

Tensile Property (ASTM D638)	PK	PA11 BESNO P40TL	PVDF Kynar 710	PVDF Solef 1010	HDPE PE3408
Modulus, kpsi	484.6	170.7	368.4	402.4	303.6
Yield Stress, psi	12380	6815	11320	11210	5889
Yield Strain, %	13.3	34.8	6.98	7.27	10.1

at 120 °C

Tensile Property (ASTM D638)	PK	PA11 BESNO P40TL	PVDF Kynar 710	PVDF Solef 1010	HDPE PE3408
Modulus, kpsi	86.00	19.13	76.16	76.20	15.99
Yield Stress, psi	5600	--	2934	3064	--
Yield Strain, %	22.97	--	12.3	12.8	--

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Gas Permeability

CH_4

Temperature, °C	Relative Humidity %	Permeability, 10^9 *cm^3 / cm^2 * s * bar		
		Polyketone	PA11 (Rilsan BESNO P40TL)	HDPE
20	0		0.60	
40	0		2.00	
60	0		5.50	
80	0	4.70	15.0	
100	0	11.1	35.0	
120	0	27.6		

PK data measured at IFP
PA data cited from Rilsan BESNO P40TL data sheet

CO_2

Temperature, °C	Relative Humidity %	Permeability, 10^9 *cm^3 / cm^2 * s * bar		
		Polyketone	PA11 (Rilsan BESNO P40TL)	HDPE
20	0	2.4	7.1 (6.0)*	27.4
50	0		(21)	
60	0 50	5.4 6.9	52.4 58.9	104 106
75	0		(54)	
100	0		(110)	

data measured on commercial sheet (0.5mm thick) at Mocon
*( ): PA data cited from Rilson BESNO P40TL data sheet

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Multicomponent Liquid Exposure

Carilon samples (tensile bars taken from extruded liner) exposed at various temperatures for 4 months

Exposure Temp., °C	Young's Modulus, Mpa (kpsi)		Yield Stress, Mpa (psi)		Elongation at Yield, %	
	Control	exposed	control	exposed	control	exposed
-20	3237 (466)		96.3 (13856)		20.1	
0	2322 (334)		77.8 (1119)		24.9	
20	1274 (183)	1173 (169)	61.6 (8863)	57.6 (8288)	33.8	34.4
40	1042 (150)	989 (142)	56.0 (8057)	54.4 (7827)	35.7	32.2
60	693 (100)	978 (141)	50.4 (7252)	54.8 (7885)	36.8	29.6
80	593 (85)	837 (120)	45.8 (6590)	50.7 (7295)	37.4	30.2
100	505 (72.7)	664 (95)	41.0 (5899)	40.2 (5784)	38.3	20.3
120	413 (59)	525 (75)	36.4 (5237)	30.3 (4360)	34.9	15.2

*Multicomponent Liquid: Benzene 1%; Toluene 7%; Xylene 11%; Cyclopentenes 6%; Cyclohexanes 6%; C4-C5 17%; C6-C10 42%; C11 10%.

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Oilfield Chemical Exposure

(PK exposed for 3 months at 23° and 80° C)

Exposure at 23° C for 3 months

	PERCENT RETENTION			
	Drill Mud	1% EC110A*	1% Corexit*	1.5% HF and 7.5% HCL
Modulus	104 %	80 %	82 %	
Yield Stress	100 %	95 %	96 %	
Yield Strain	98 %	104 %	101 %	
Break Stress	99 %	98 %	97 %	
Break Elongation	70 %	72 %	58 %	

Exposure at 80° C for 3 months

	PERCENT RETENTION			
	Drill Mud	1% EC110A*	1% Corexit*	1.5% HF and 7.5% HCL
Modulus	103 %	59 %	60 %	66 %
Yield Stress	115 %	101 %	100 %	109 %
Yield Strain	68 %	103 %	102 %	91 %
Break Stress	118 %	101 %	99 %	120 %
Break Elongation	48 %	51 %	88 %	36 %

* Corrosion inhibitors: 1% EC110A in 3% NaCl
1% Corexit 6315 in 3% NaCl

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Oilfield Chemical Exposure

PA11 Exposed for 3 Months at 80° C

	PERCENT RETENTION			
	Drill Mud	1% EC110A*	1% Corexit*	1.5% HF and 7.5% HCL
Modulus		70 %	70 %	
Yield Stress		101 %	98 %	
Yield Strain		88 %	87 %	
Break Stress		97 %	94 %	
Break Elongation		48 %	48 %	

* Corrosion inhibitors: 1% EC110A in 3% NaCl
1% Corexit 6315 in 3% NaCl

Weight Changes for PK and PA11 Exposures

	Weight Changes, %			
	Drill Mud	1% EC110A	1% Corexit	HF & HCL
PK at 23 °C	0	0.7	1.8	1.8
PK at 80 °C	0.4	4.8	4.9	5.6
PA11 at 80 °C		-4.7	-3.8	

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Strain Relaxation of Carilon Pipe

Axial Strain Recovery of Carilon Pipe from 8% Initial Elongation

Temperature °C	Time Held	% Strain after 0.5 hr	% Strain after 1.0 hr	% Strain at elapsed time
-20	30sec 2 hours	2.47 3.76	2.43 3.64	2.25, 5 hrs 3.05, 12 hrs
Room Temperature	30 sec 1 hour 2 hours	1.52 1.59 1.73	0.96 1.45 1.46	0.93, 5 hrs 1.36, 9 hrs 1.36, 19 hrs
50	30 sec 1 hour	1.58 2.00	1.10 1.95	1.07, 4 hrs 1.60, 14 hrs
80	30 sec 2 hours	1.49 2.64	1.45 2.50	1.37, 5 hrs 2.03, 16 hrs

tensile bars cut from pipe were held at 8% elongation at given temperature & time

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