Primary Properties that make CARILON Polymer a Candidate for the Automotive Fuel System

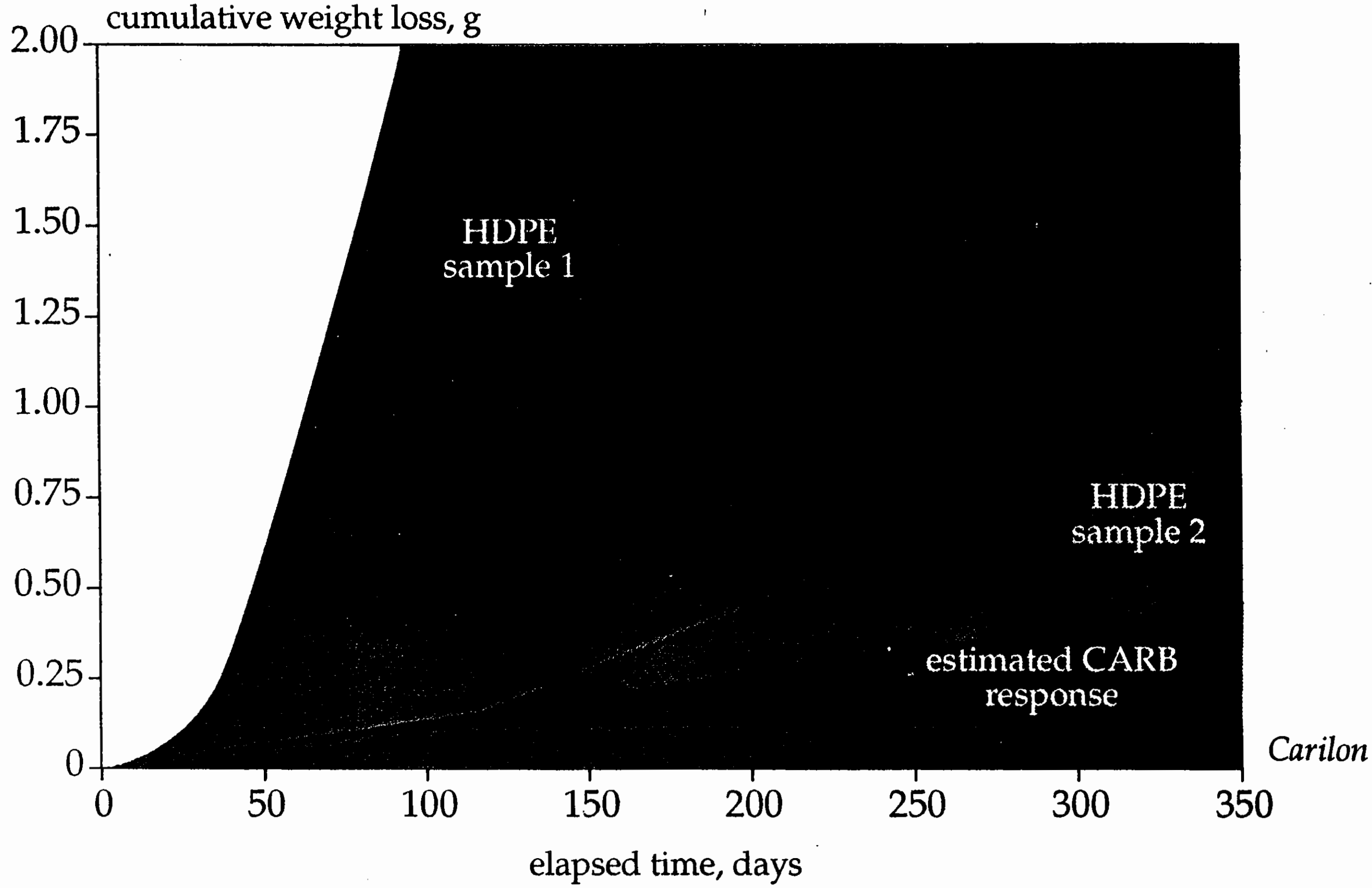
- Barrier Properties
- Chemical Resistance /Compatibility
- Toughness
- Process ability

IFS Automotive Industry Survey

- Industry prefers proven materials & technology
- Extreme pressure from CARB and EPA to reduce emissions.
- Metal best permeation barrier, but subject to leaks at joints.
  - Leaks get worse with time
  - Leakage accounts for more hazardous emissions than permeation.
- Industry MUST find new options for fuel system!

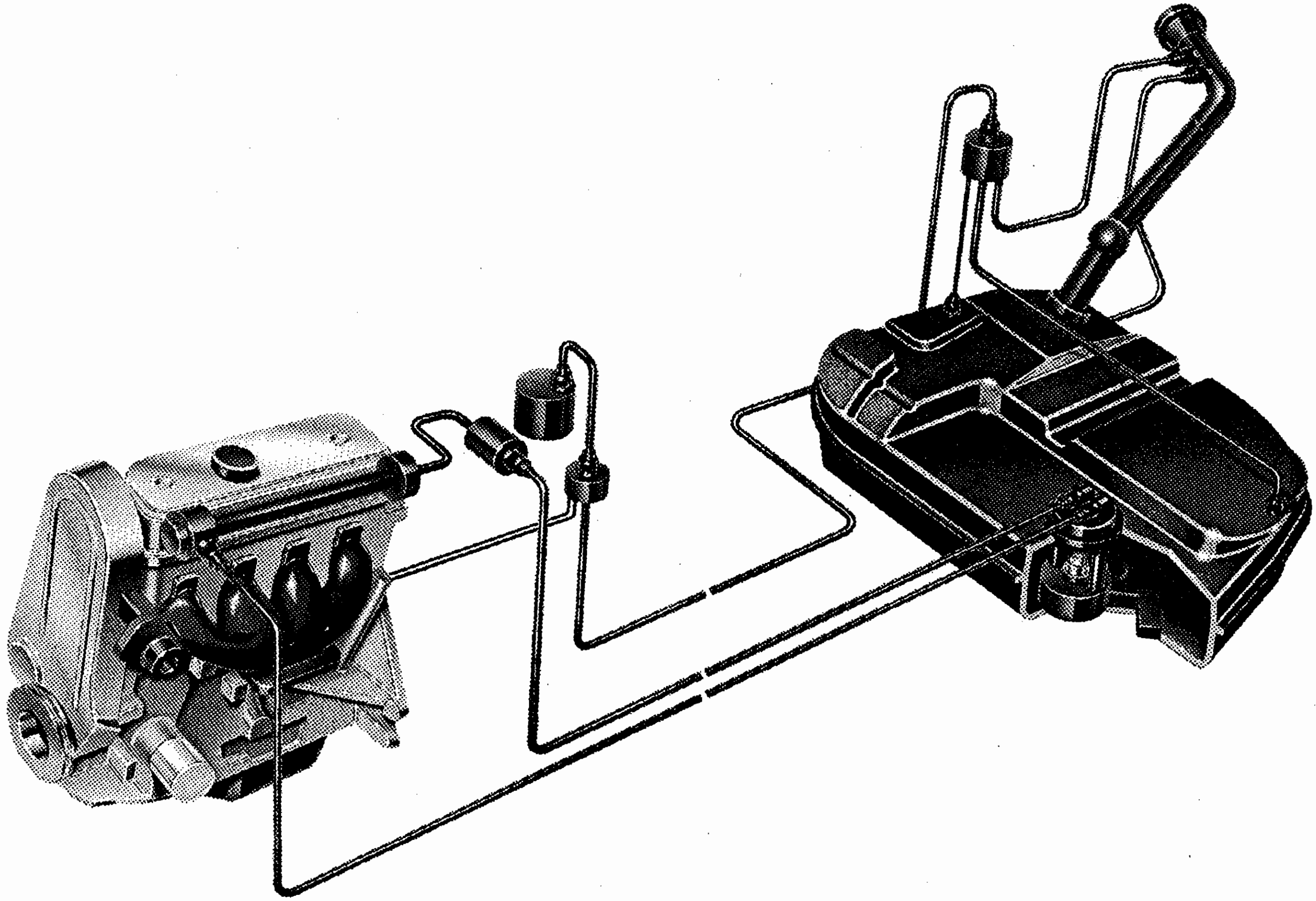
FUEL
SYSTEMS

relative fuel emission



Carilon
Thermoplastic Polymers

FUEL
TANKS

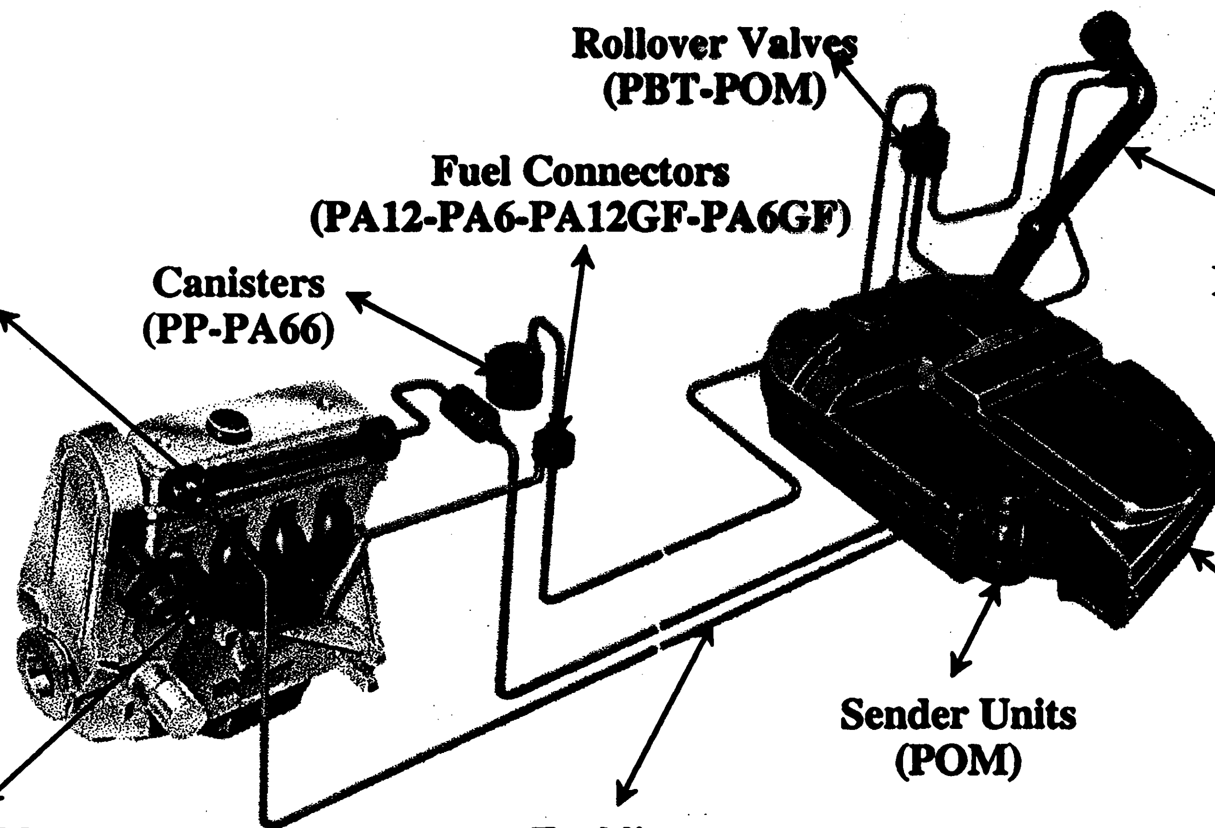


Carilon
Thermoplastic Polymers

Carilon is a Shell Trademark

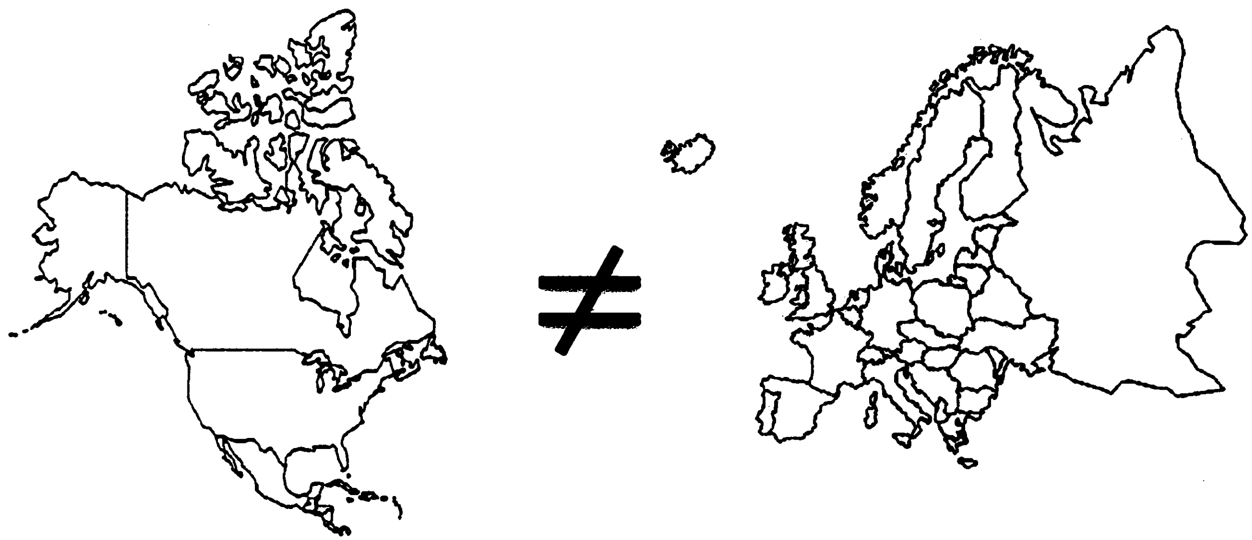
Shell Chemicals

Applications & Developments of CARILON Polymers in the Fuel System



■ Applications ■ Development fields

Carilon
Thermoplastic Polymers



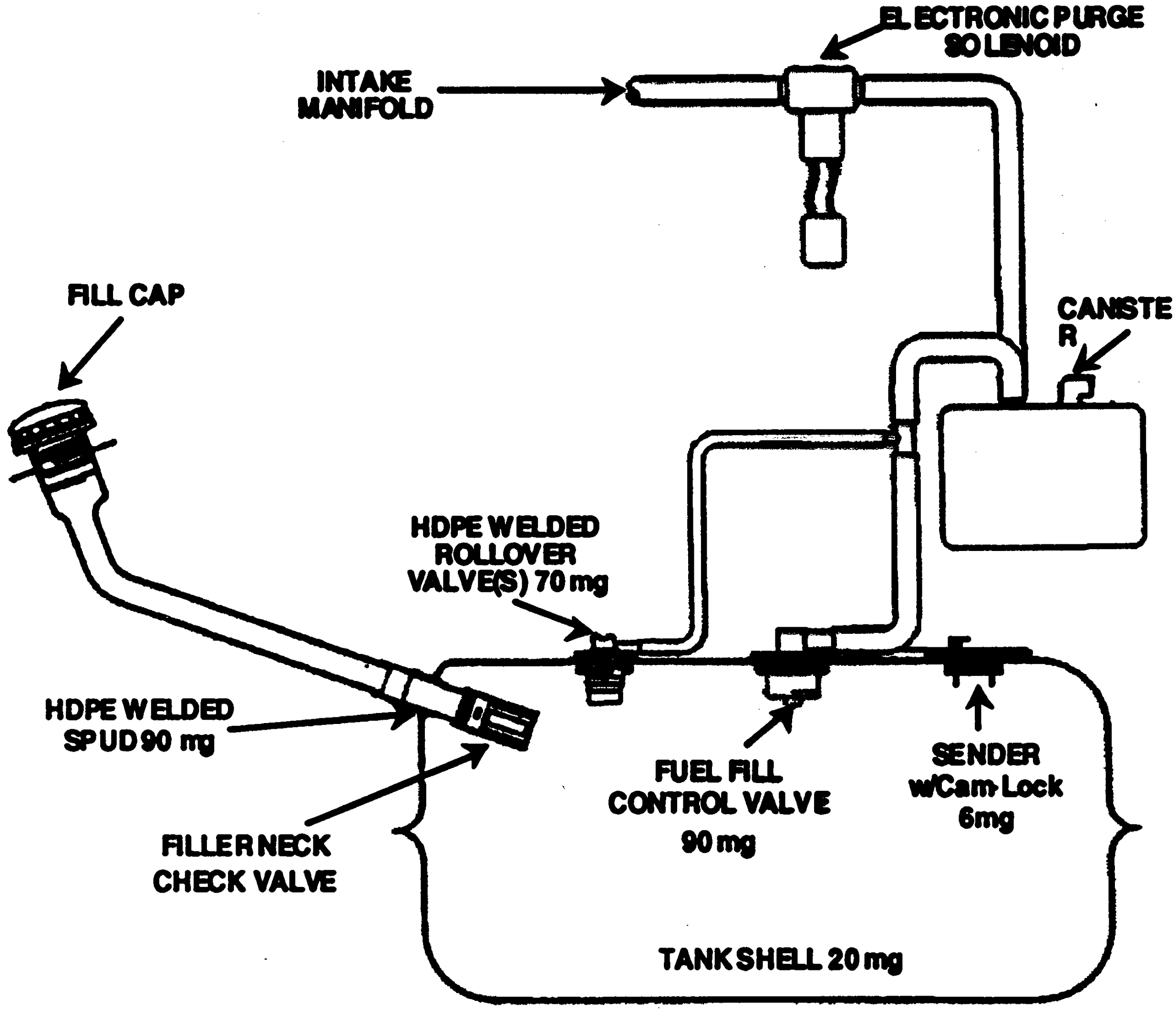
IFS Automotive Industrial Survey

- **CARB and EPA influence growing, European counterparts following.**
- **Laws considered and passed creating standards that may be physically impossible**
  - **Emissions after 150,000 miles same as new car.**
  - **Must certify emissions lower than can be dependably measured.**
  - **Goal is <u>Zero</u> emission Vehicle**

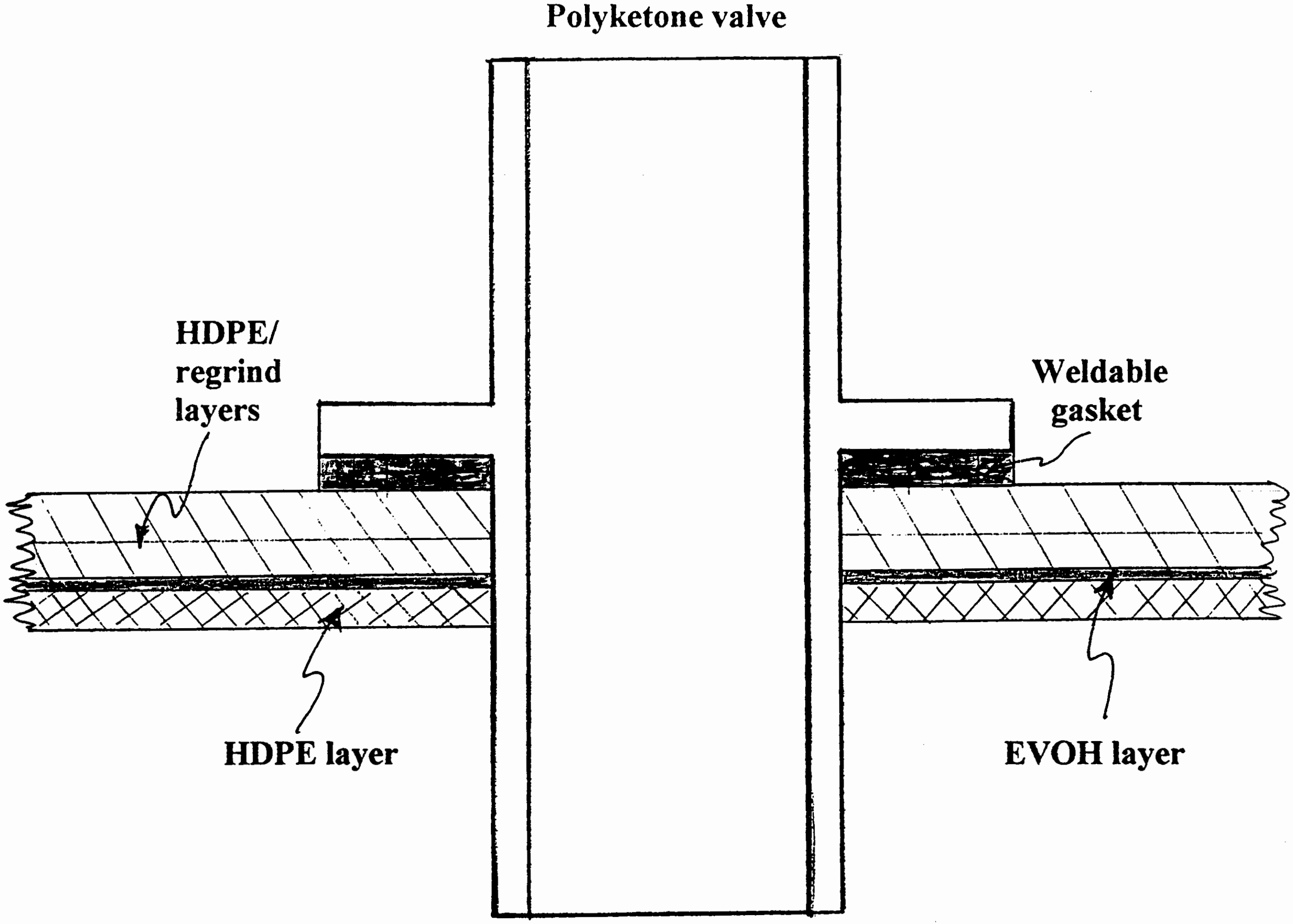
Primary Sources of Evaporative Emissions from the Automotive Fuel System

- Filler neck
- Joints between the fuel tank and any component requiring a hole in the fuel tank
- Joints connecting the fuel and vapor lines to some other component
- Vapor return lines

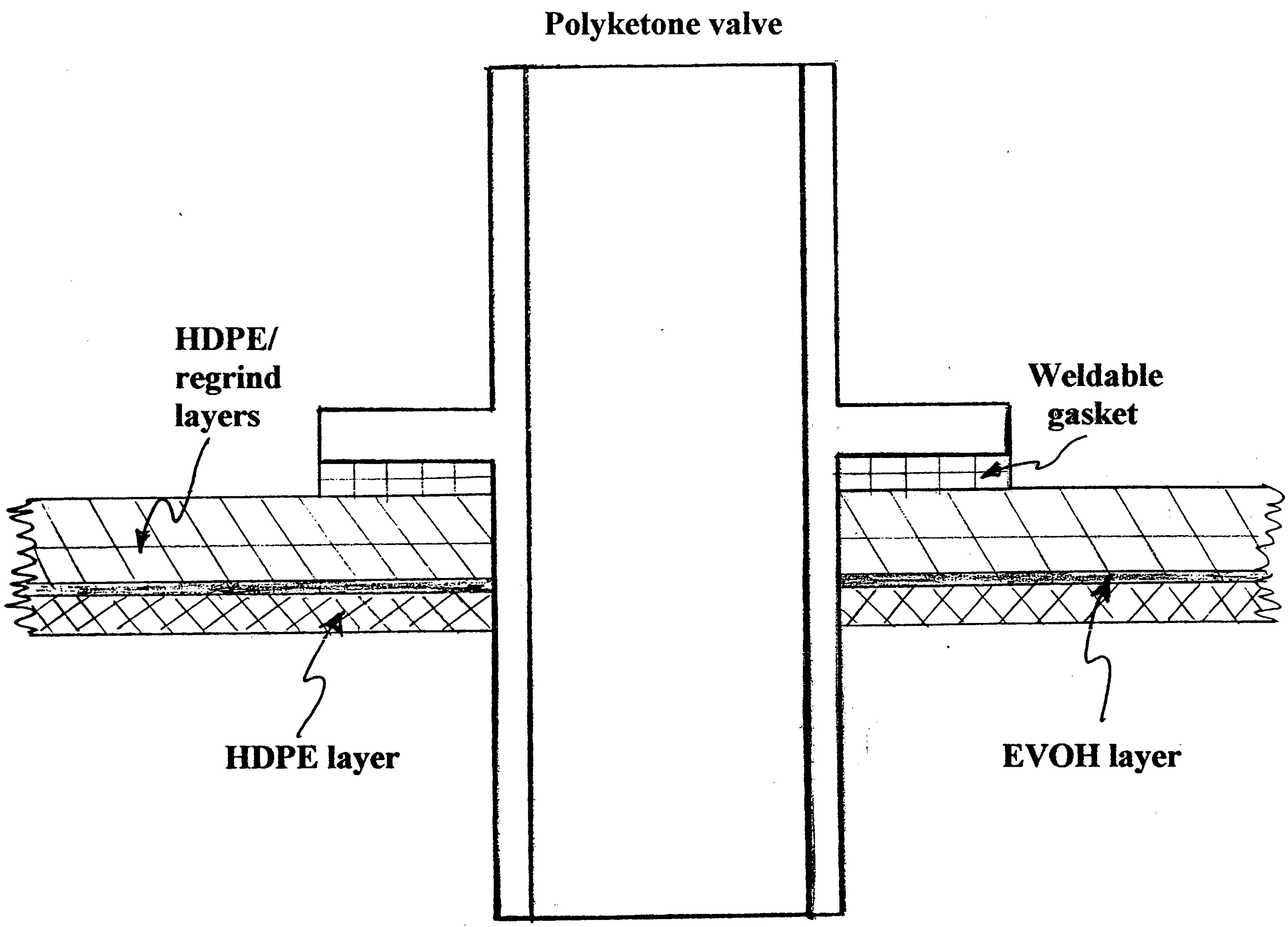
Basic Fuel Tank System



Welded Polyketone Valve Assembly



Welded Polyketone Valve Assembly



Retrofit Fuel Tank Program
Developmental Partners (1)

- Textron Kautex
  - Strong support from partnership at VP level
  - Considered to be an innovative group in North America

- TI Group
  - Full Fuel system involvement since mergers
  - Very fragmented internally
  - Strong follower mentality
  - Wants two way secrecy agreement

Retrofit Fuel Tank Program Developmental Partners (2)

- Delphi
  - Supplier of metal tanks
  - Wants to get into plastic tanks
  - Trying to thermoform tanks

- Visteon
  - Strong player in fuel systems

Retrofit Fuel Tank Program
Developmental Partners (3)

- **Teleflex**
  - Proven track record developing new technology
  - Support at VP level
  - Willing to spend capital money
  - Wants temporary exclusivity

- **Epic Division of Dana**
  - Mixed support for developmental project
  - Has successfully make Carilon Polymer tubing in house

Retrofit Fuel Tank Program
Developmental Partners (4)

- Bundy Corporation
  - Works only with proven technology
- Pilot
  - Not interested in partnership
- ITT
  - Too small
- Mark IV
  - Innovative but very secretive

Shell Chemicals

CTPK/5

Weight loss permeation test

Static permeation of polymer plaques at 40°C

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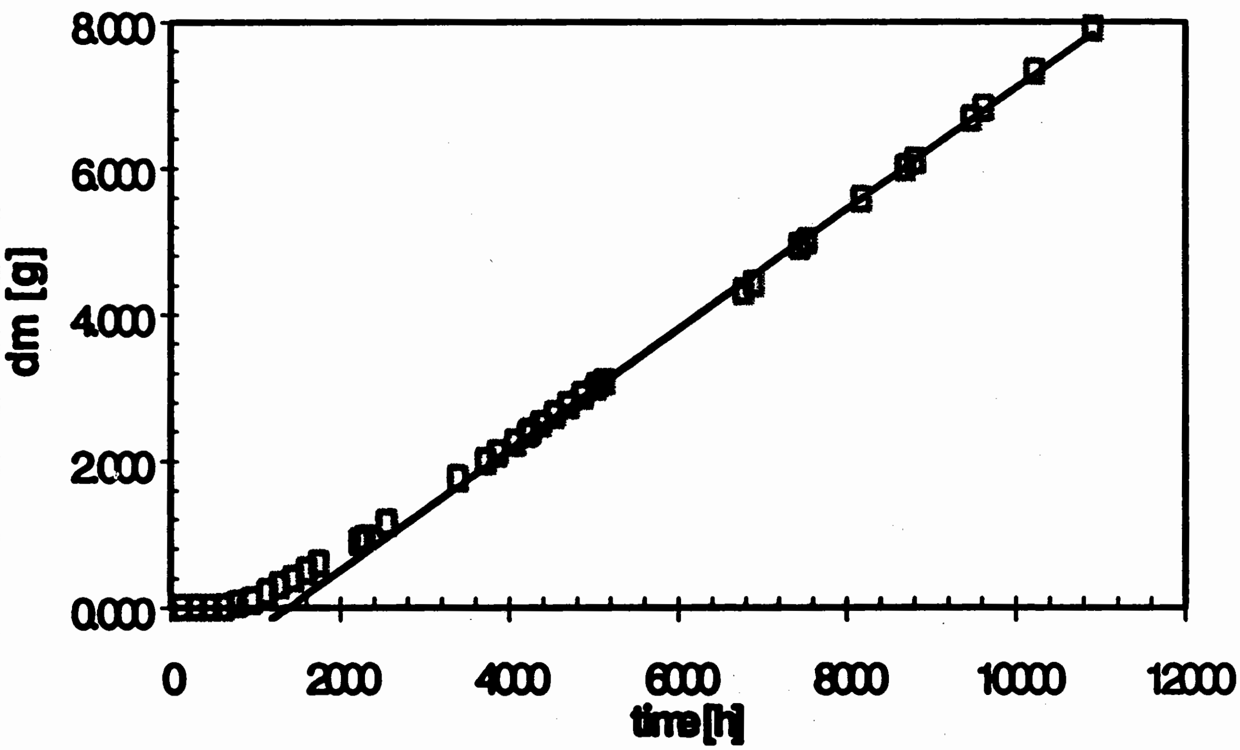
Thermoplastic Polymers

Shell Chemicals

HDPE/M0 at 40 °C
high weightloss

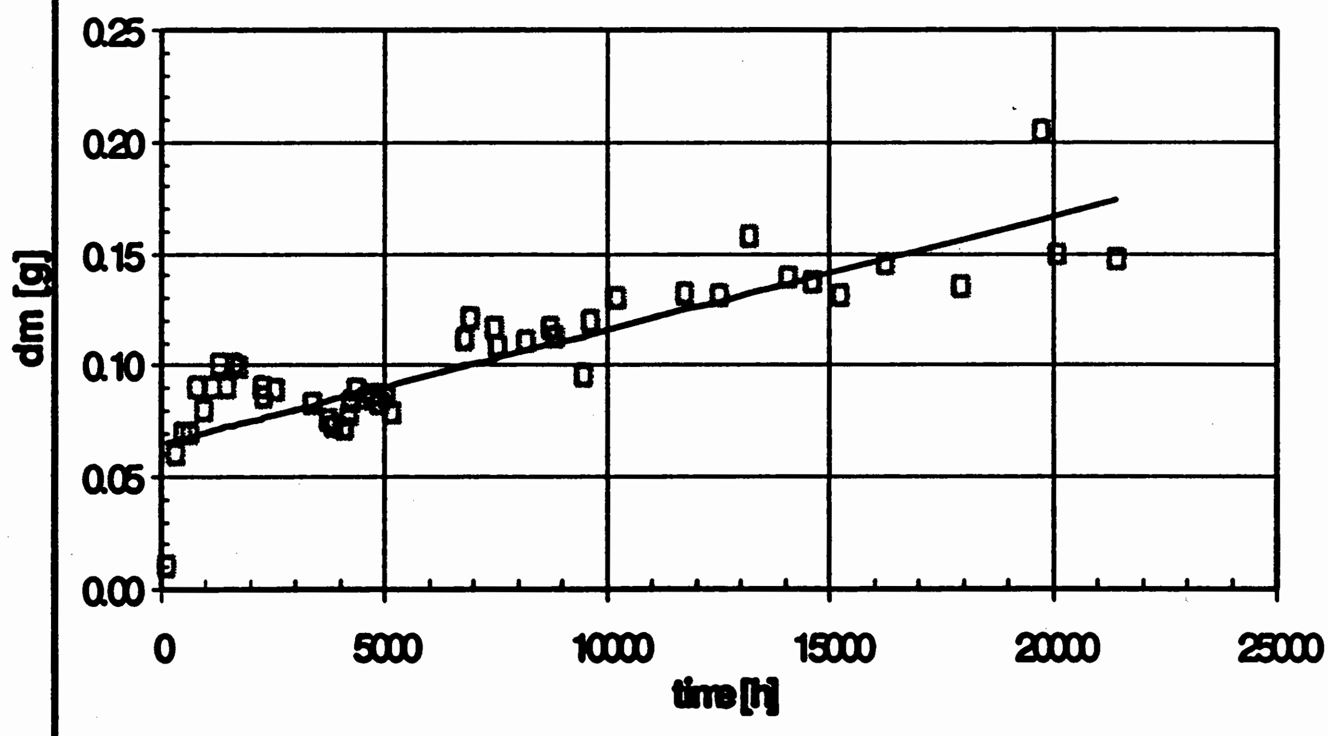


Carilon
Thermoplastic Polymers

CARILON is a Shell trade mark

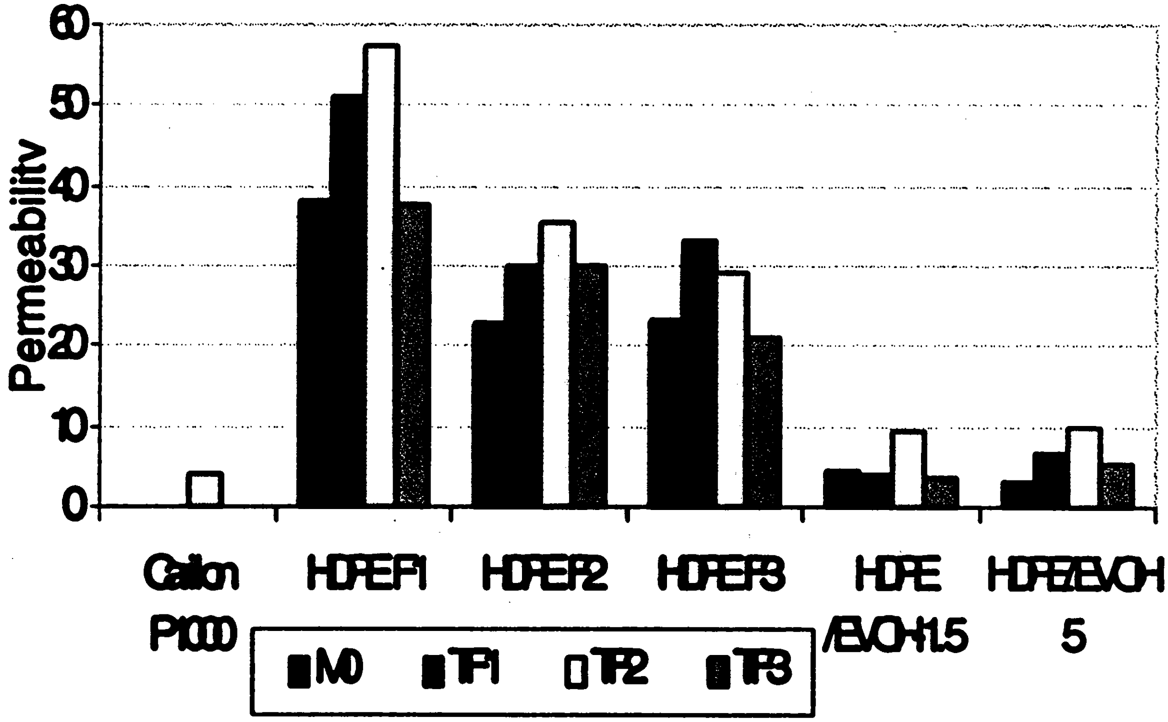
Carilon Polymer/M0 at 40 °C

extremely low weight loss



Shell Chemicals

The permeability (in g.mm/m2.day) of various polymer/fuel combinations



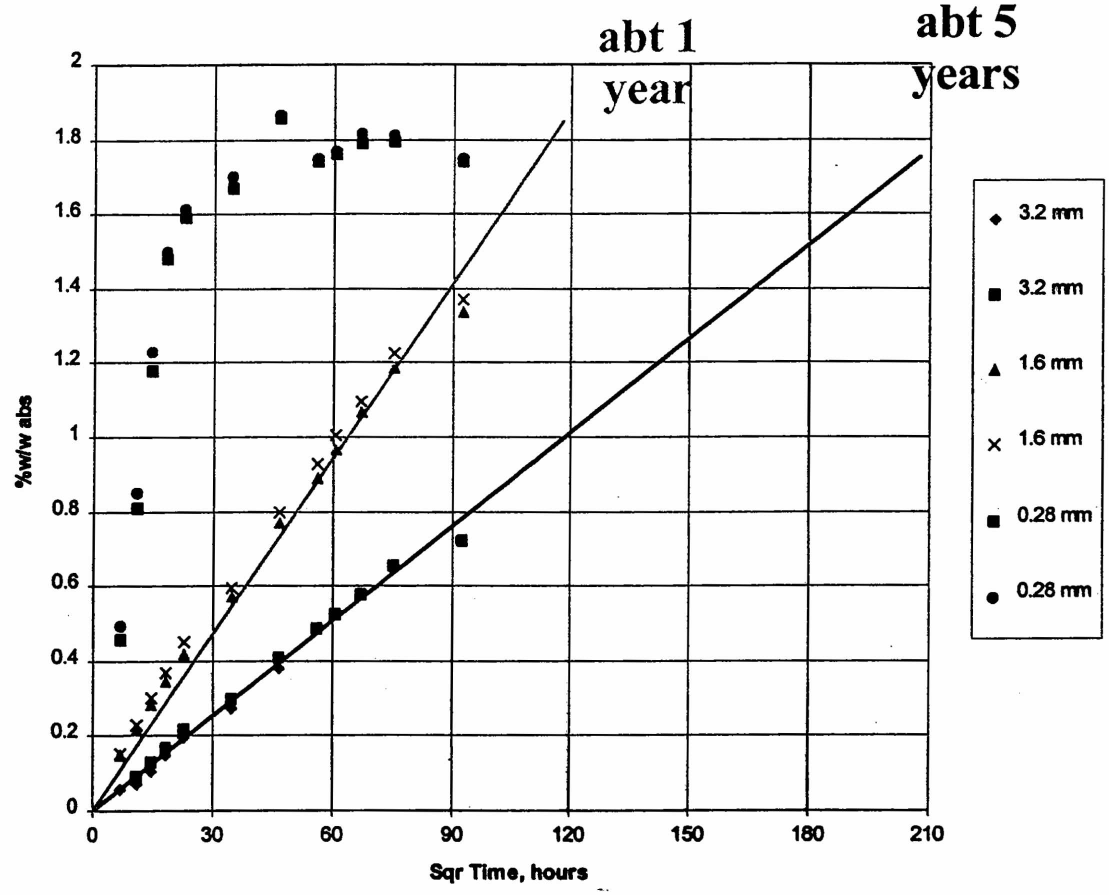
Carilon
Thermoplastic Polymers

CTPK/5

Sorption tests at 40 °C

Shell Chemicals

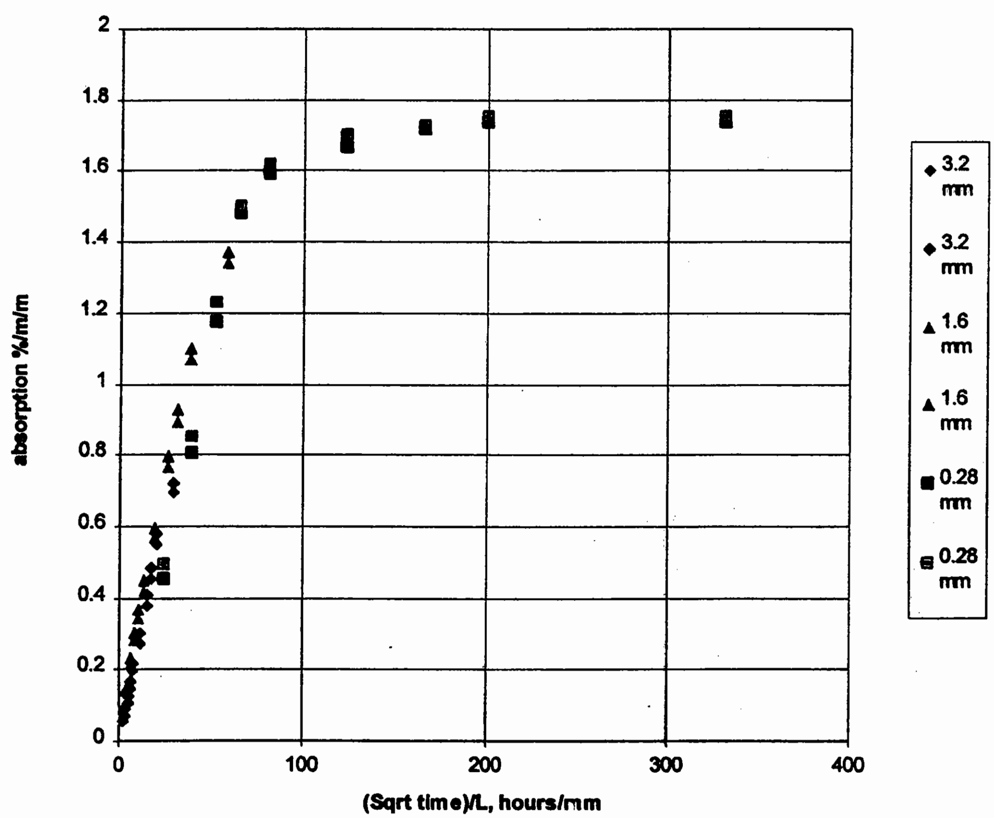
Sorption curves of Carilon Polymer with M0 at 40°C



Carilon
Thermoplastic Polymers

Shell Chemicals

Normalised sorption curves of Carilon Polymer strips with M0 at 40°C



Carilon
Thermoplastic Polymers

PERMEATION

Solubility x Diffusivity

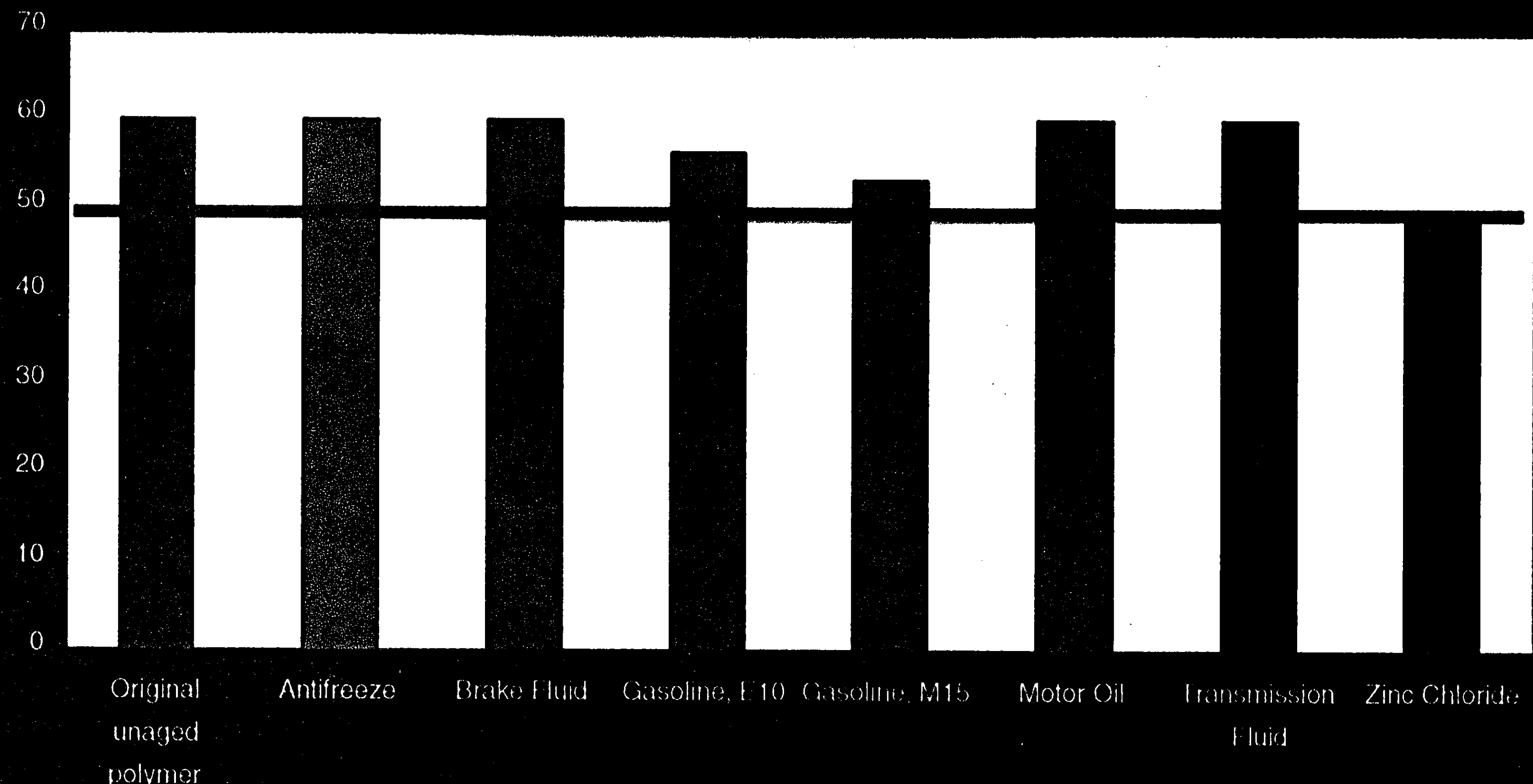
POLYKETONE

25 mg.mm/m^2.day

Shell Chemicals

Long-term Chemical Resistance Data
One Year Aging at 23°C

Tensile Strength at Yield, MPa



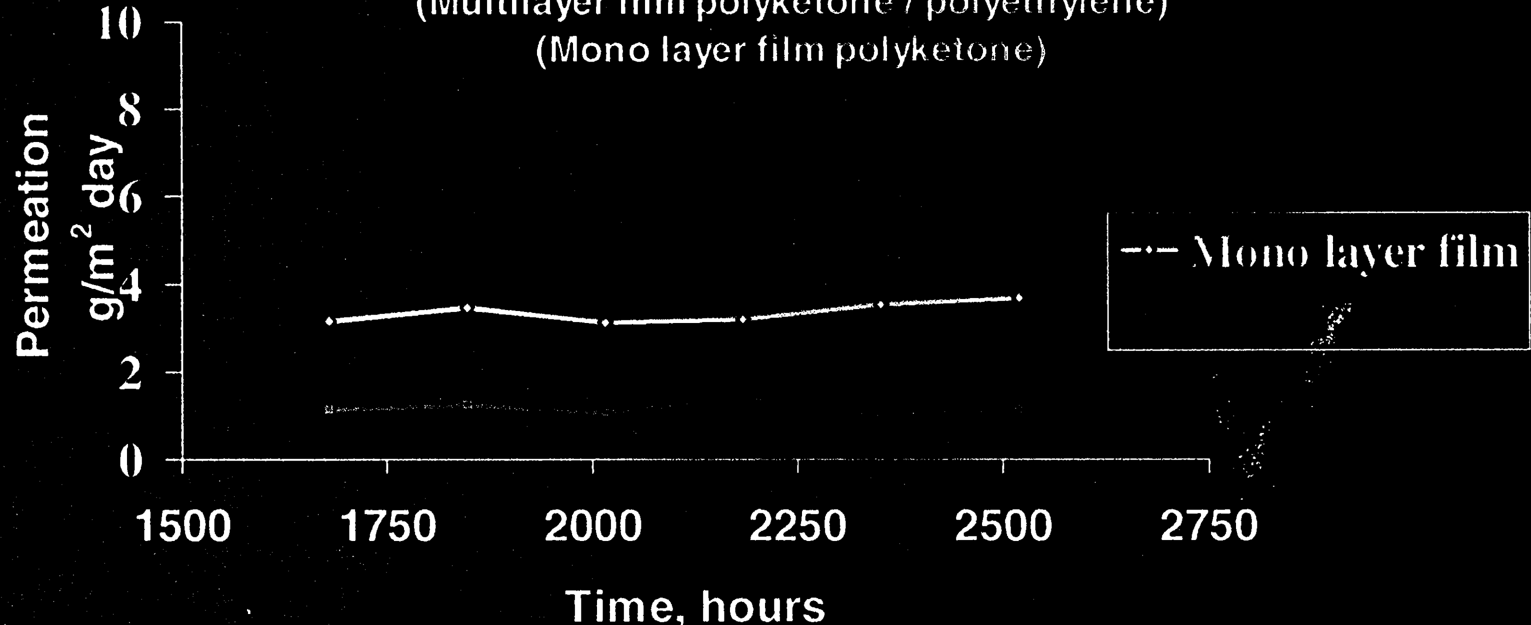
Carilon®
Thermoplastic Polymers

Shell Chemicals

Fuel CM15 EG&G Coupon Testing

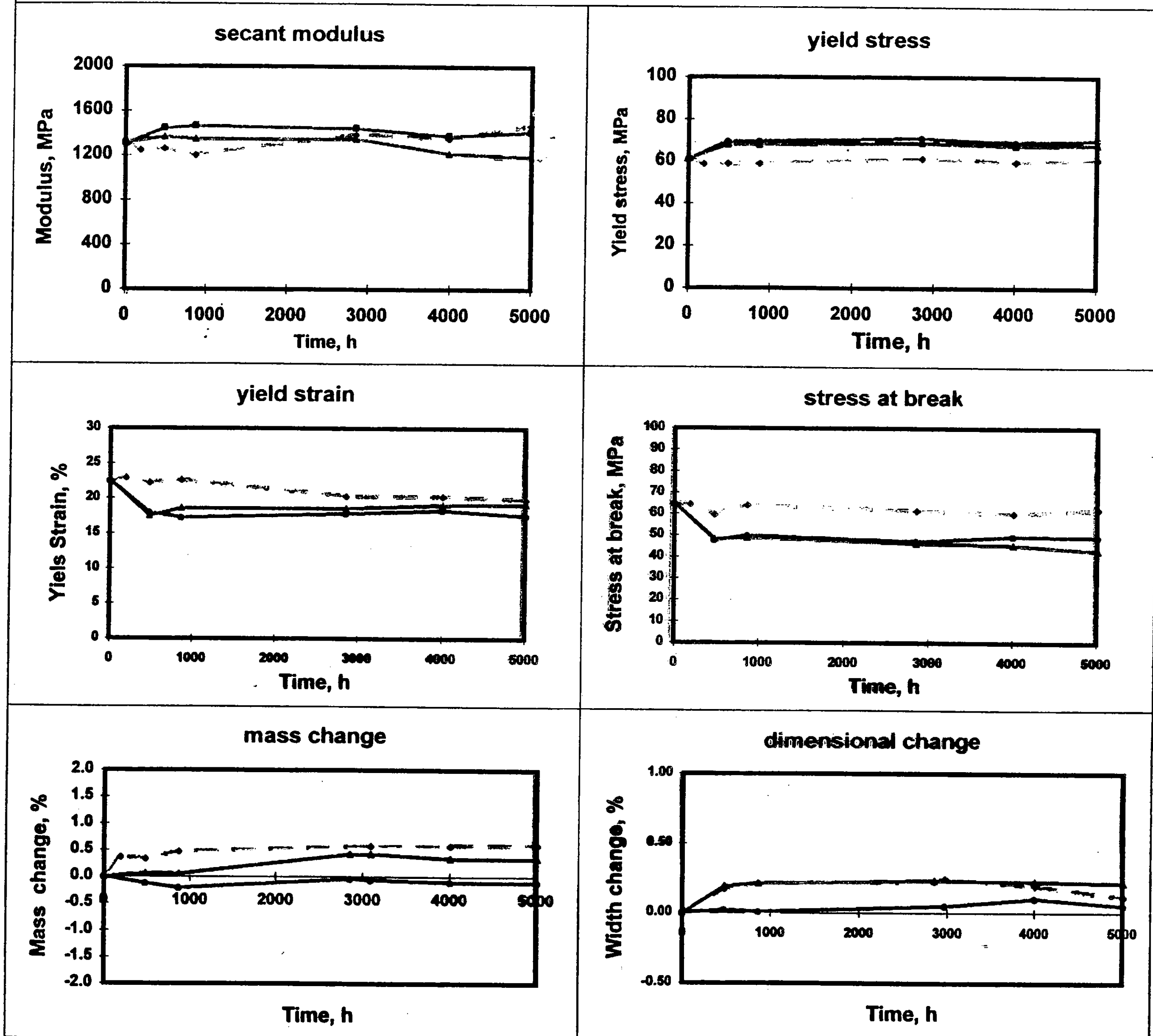
15 mil CARILON Polymer films, 40°C soak

(Multilayer film polyketone / polyethylene)
(Mono layer film polyketone)



Carilon
Thermoplastic Polymers

Effect of RME and RME/diesel on CARILON Polymer, medium flow



Legend:

- — — · air, 23 °C
- ——— diesel/RME, 80 °C
- ——— RME, 80 °C

Key:

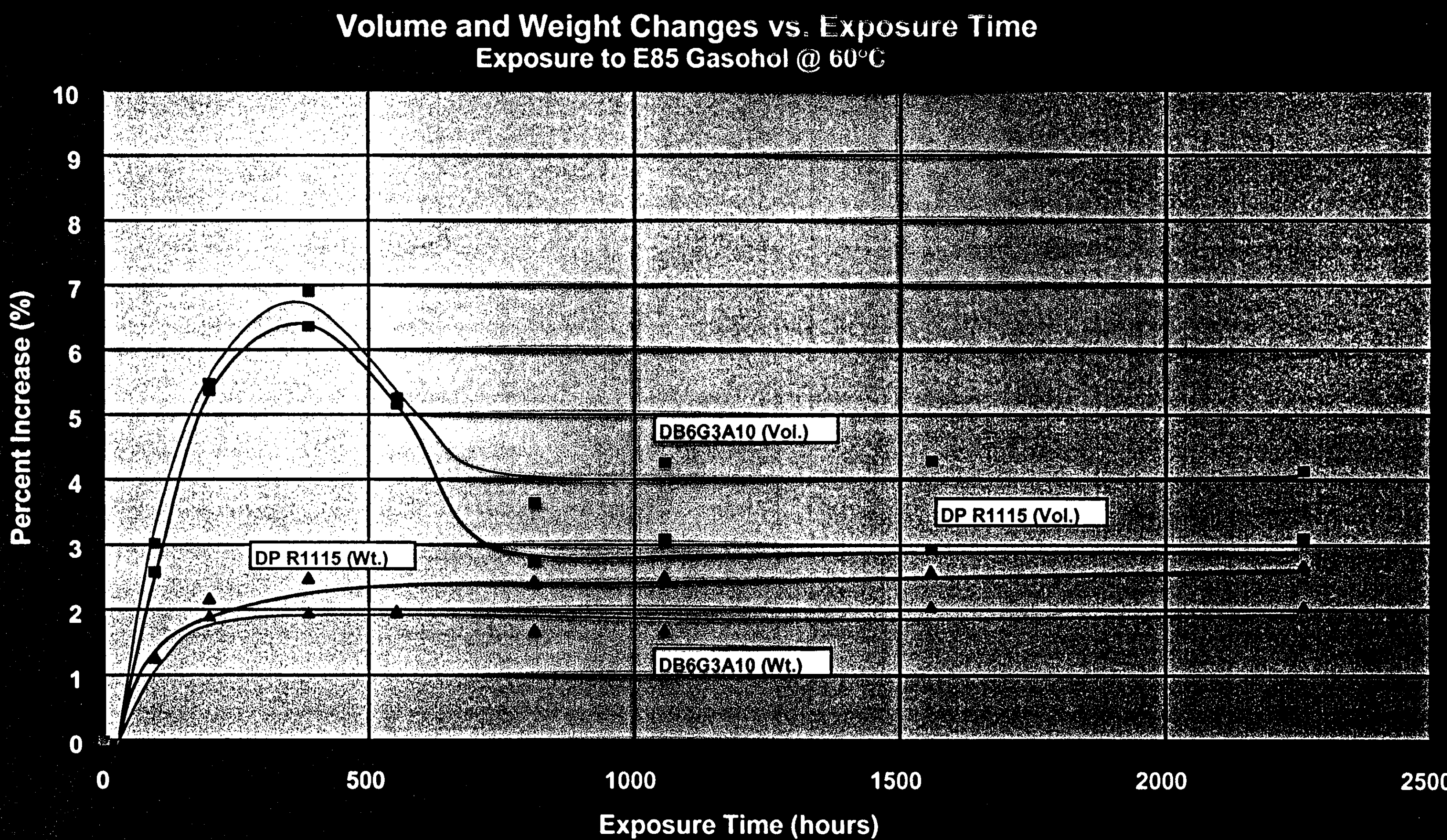
diesel: CEC RF-90-A-92 (ex Haltermann Germany)
RME: rape seed methyl ester (ex Novaol France)
Diesel/RME: volume ratio 85/15
Secant modulus: modulus at 0% - 1 %strain

Shell Chemicals

Carilon®

Thermoplastic Polymers

CARILON Polymer 15% Glass Reinforced Systems



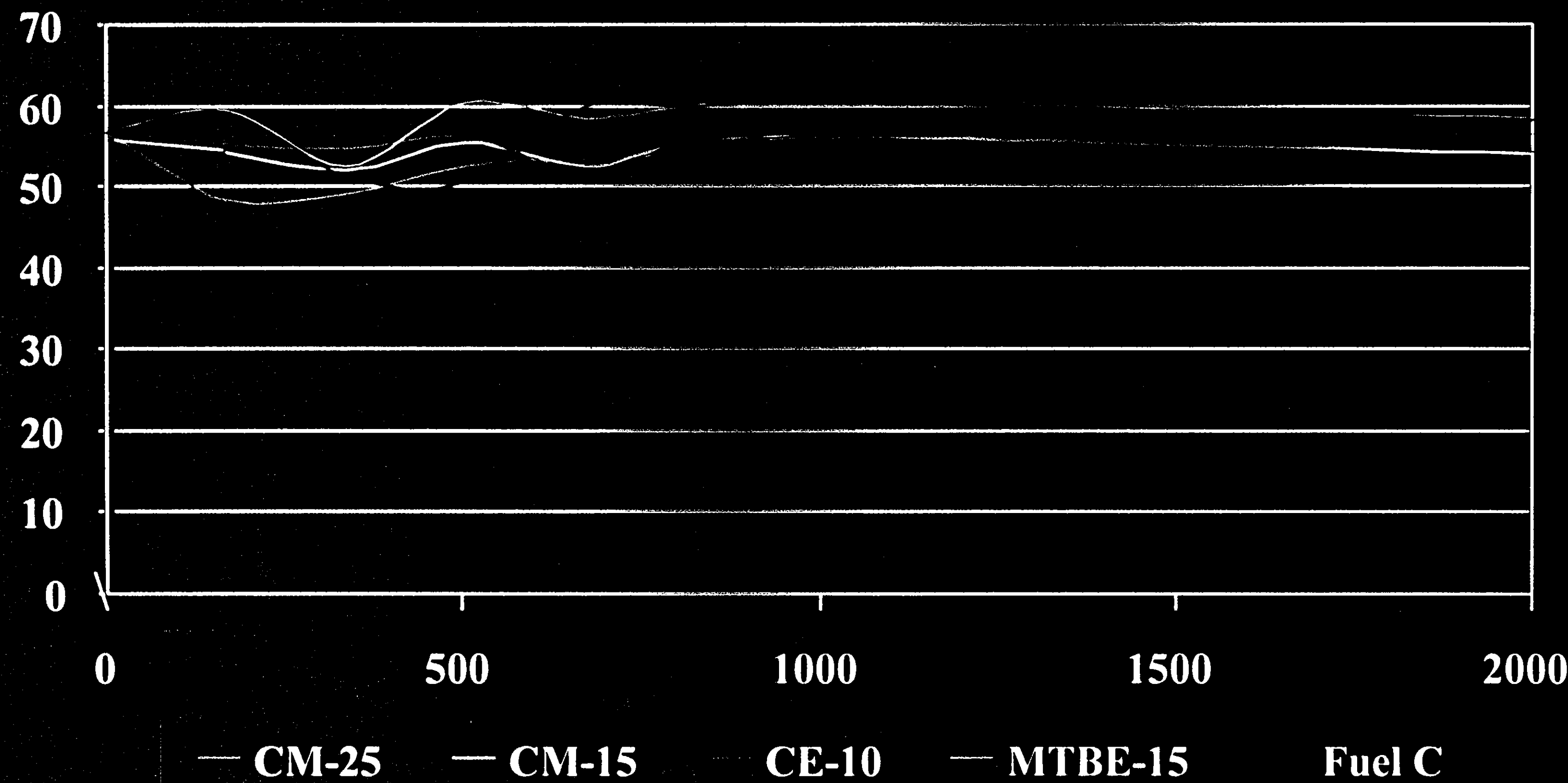
Shell Chemicals refers to the companies of the Royal Dutch/Shell Group which are engaged in the chemical businesses.

Shell Chemicals

Carilon®
Thermoplastic Polymers

Long-term Chemical Resistance Data
2000 Hour Aging at 60°C

Tensile Stress @ Yield, MPa

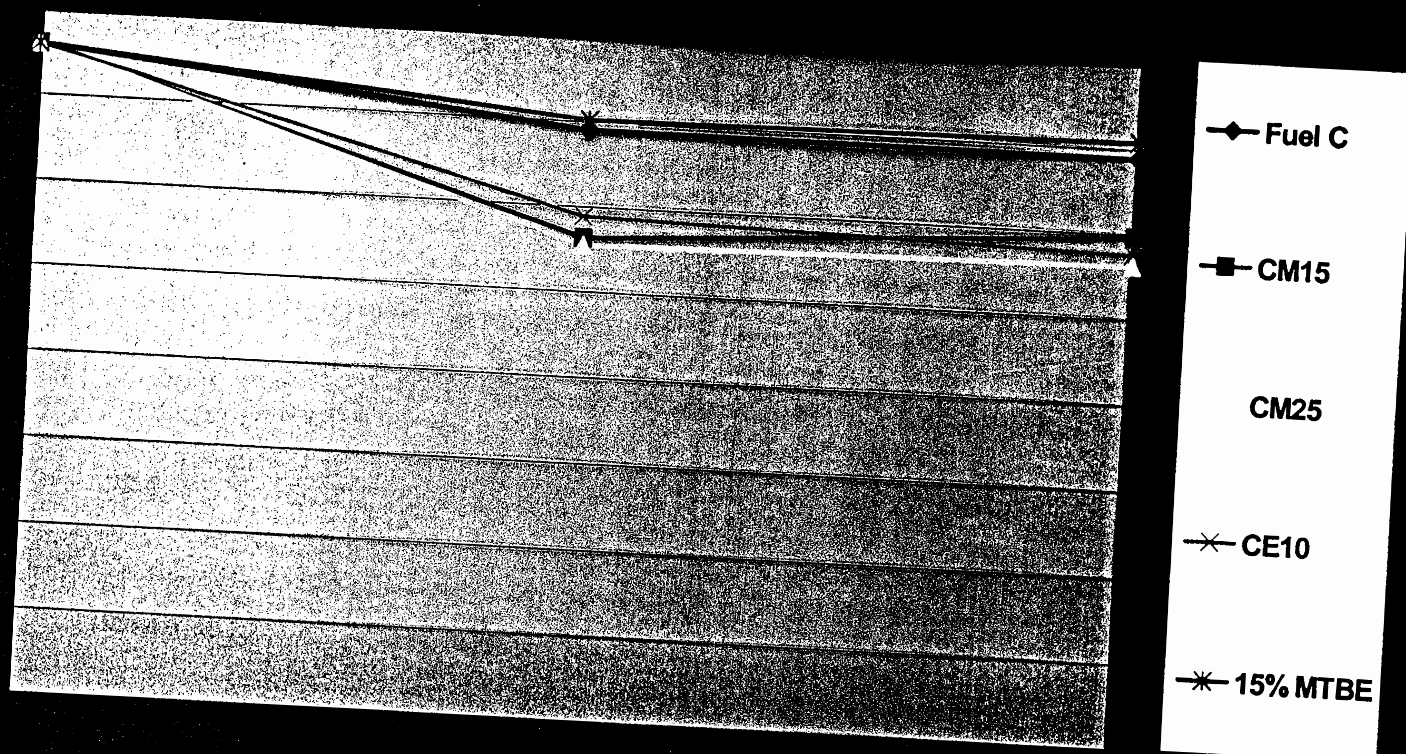


Shell Chemicals refers to the companies of the Royal Dutch/Shell Group which are engaged in the chemical businesses.
CARILON is a registered trademark of Shell Chemical Company

Shell Chemicals

Carilon®
Thermoplastic Polymers

Exposure to Fuels @ 60°C

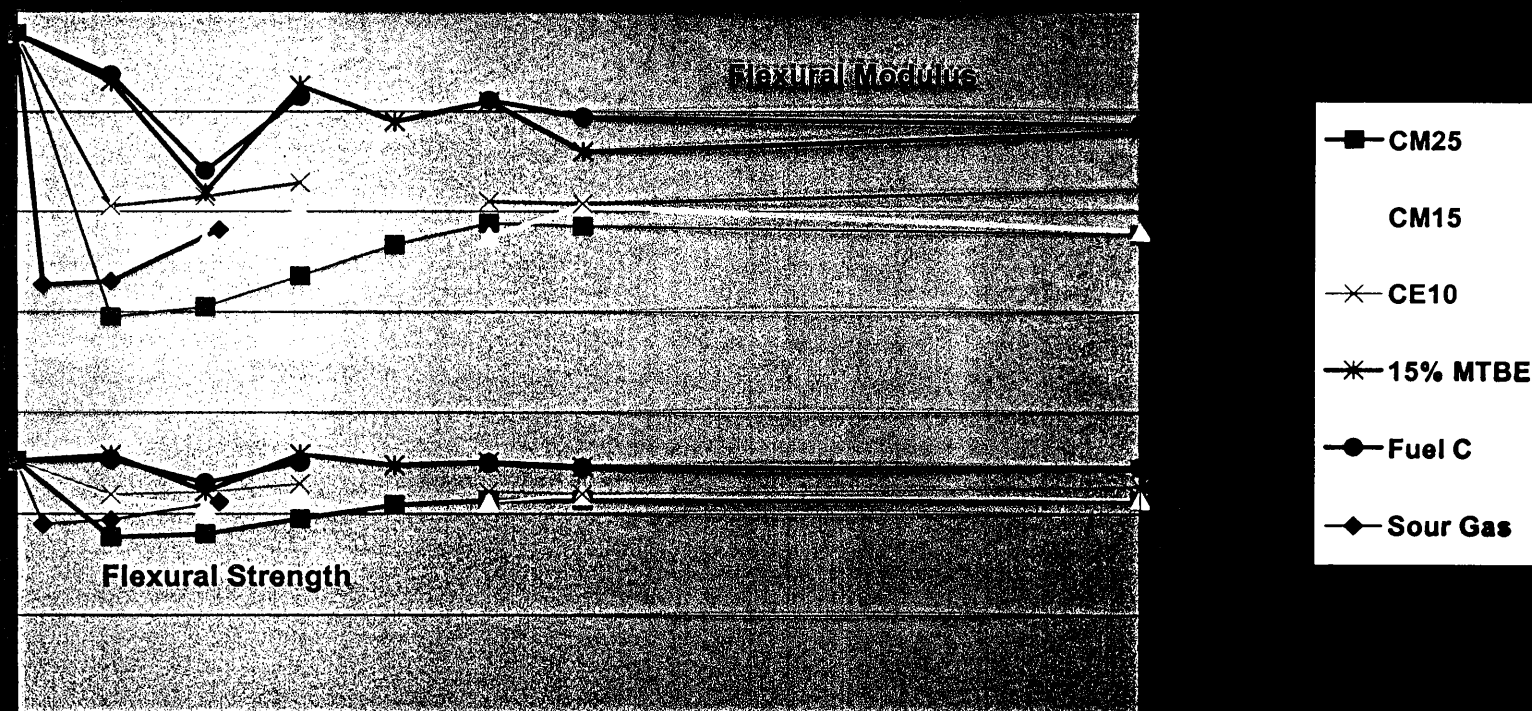


Shell Chemicals

Carilon®

Thermoplastic Polymers

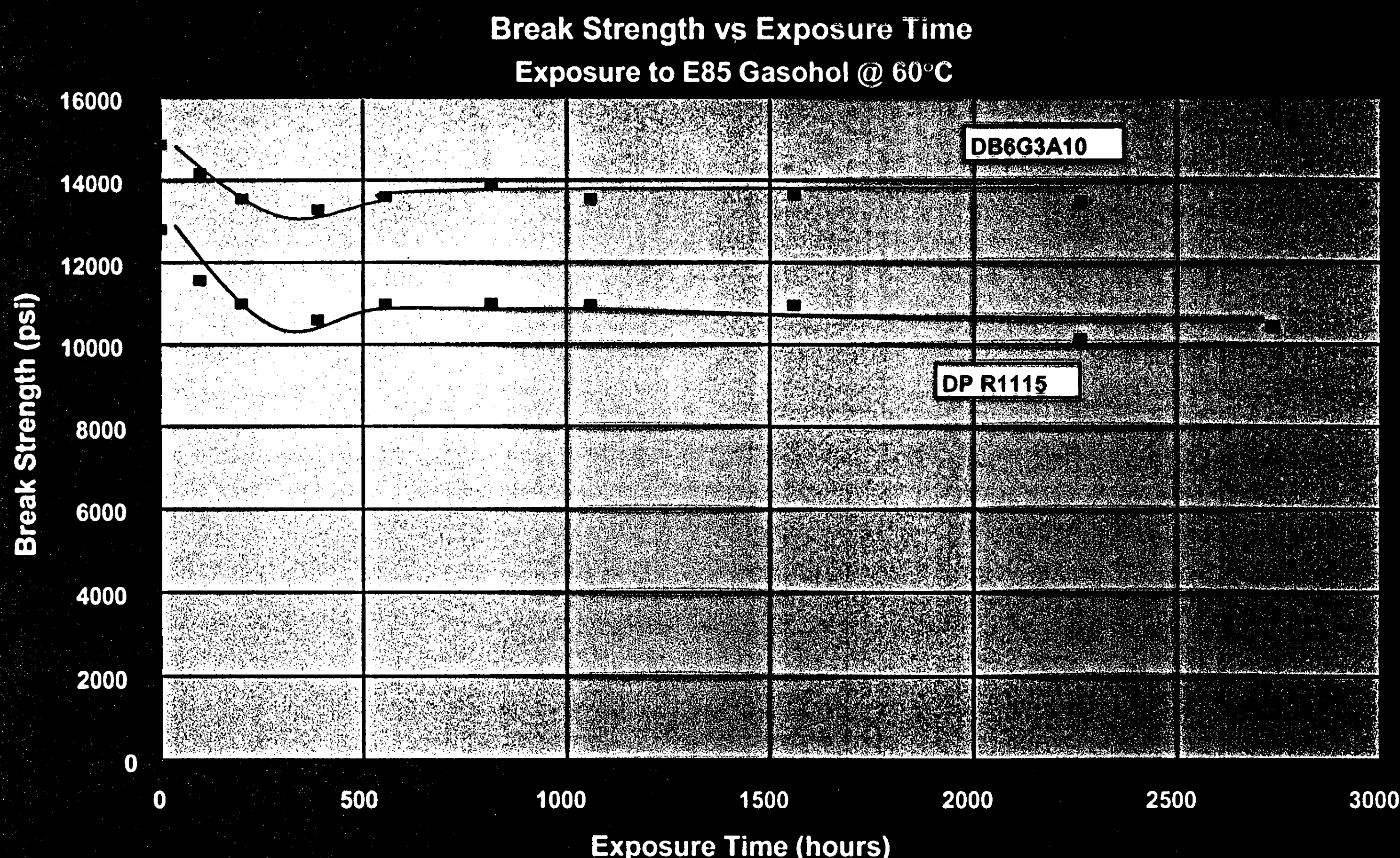
Exposure to Fuels @ 60°C



Shell Chemicals

Carilon®
Thermoplastic Polymers

CARILON Polymer 15% Glass Reinforced Systems



Carilon®

Polymer Fuel Permeation Information Sheets

The task of designing automotive fuel system components has been made more difficult by new tighter emissions standards and uncertainty about the composition of future fuels. A variety of oxygenated fuels may be required to reduce exhaust emissions as mandated in many areas throughout the country. Polymers used in fuel system components must be compatible with these new oxygenated fuels.

CARILON® polymers have excellent barrier properties to gasoline and oxygenated fuels. As the data on the attached pages show, based on the tests performed, CARILON polymers' performance was superior to nylon 12 in all fuels tested and generally equal to polytetrafluoroethylene (PTFE), even at high temperatures.

The testing herein closely followed the procedures outlined by General Motors specification GM 9061-P, "Permeability Test for Fuel Hose and Tubing." The extruded tubing tested had a nominal OD of 8.51 mm (0.34 in.) and a wall thickness of 1.07 mm (0.042 in.). The total effective length of the tubing with both ends plugged was 300 mm (11.8 in.).

Because of the multi-component nature of the new fuel systems, it is difficult to assign a single design permeability coefficient for each of the polymer/fuel systems. However, the relative barrier performances of CARILON polymers, nylon 12, and PTFE in the various fuel systems can be assessed from the attached graphs.

CARILON polymers are strictly developmental products at this time. Although they have been made in commercial scale equipment, only relatively small volumes have been produced to date. Depending on market feedback, CARILON polymers may or may not be scaled up to commercial production. Therefore, Shell reserves the right to modify or discontinue this product without notice.

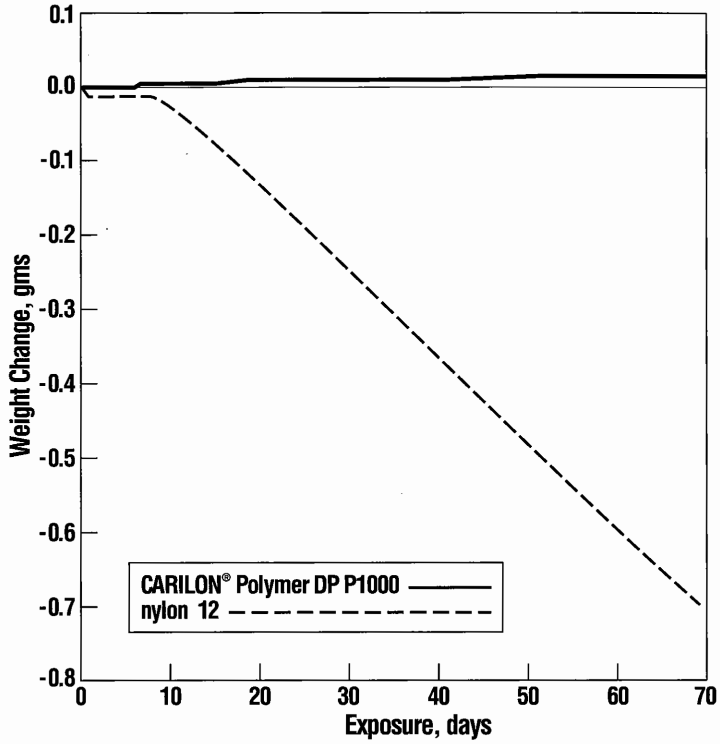
Shell Chemical Company

Never underestimate what we can do together.℠

PERMEABILITY OF CARILON® THERMOPLASTIC POLYMER VERSUS OTHER ENGINEERING PLASTICS IN UNLEADED GASOLINE

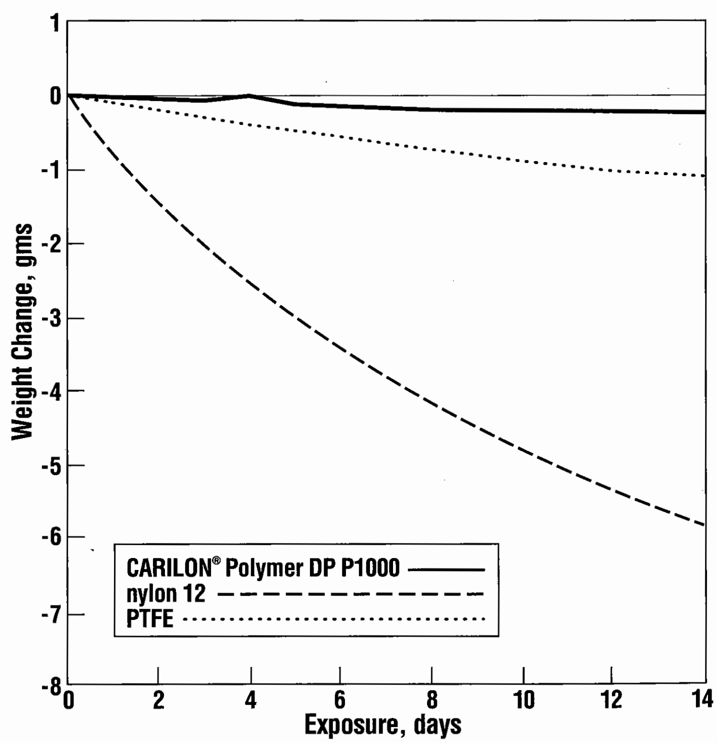
Unleaded Gasoline at 23 °C (73 °F)

Exposure, days	Weight Change, gms	
	CARILON® Polymer DP P1000	nylon 12
1	0.00	-0.01
7	0.00	-0.01
14	0.00	-0.07
21	0.01	-0.15
35	0.01	-0.31
70	0.01	-0.69



Unleaded Gasoline at 93 °C (200 °F)

Exposure, days	Weight Change, gms		
	CARILON® Polymer DP P1000	nylon 12	PTFE
1	-0.03	-0.85	-0.10
2	-0.05	-1.50	-0.20
5	-0.13	-2.80	-0.48
7	-0.18	-3.55	-0.68
10	-0.21	-4.60	-0.88
14	-0.24	-5.76	-1.10



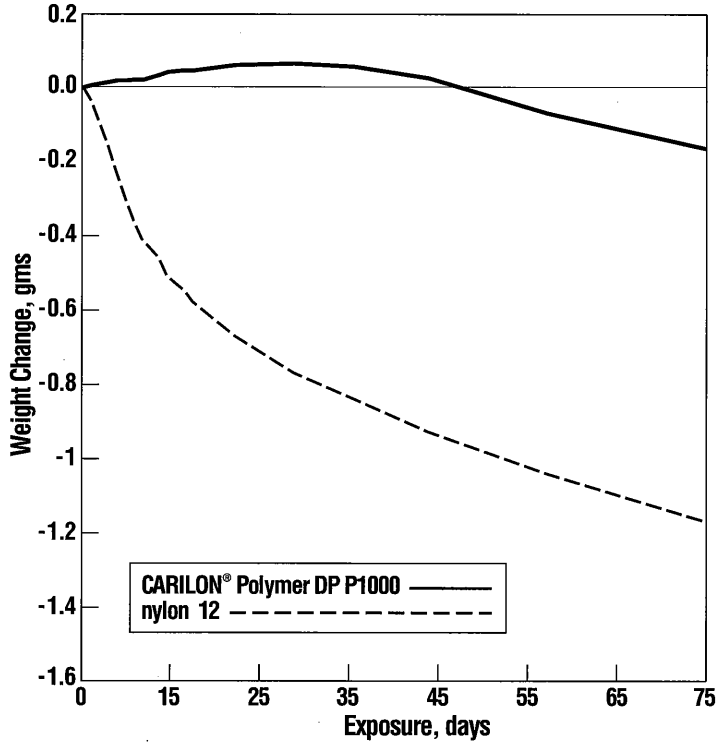
Note: Measured under conditions outlined in GM SPEC 9061-P.

PERMEABILITY OF CARILON® THERMOPLASTIC POLYMER VERSUS OTHER ENGINEERING PLASTICS IN TEST FUEL

(3% Methanol, 5% Ethanol in Unleaded Gasoline)

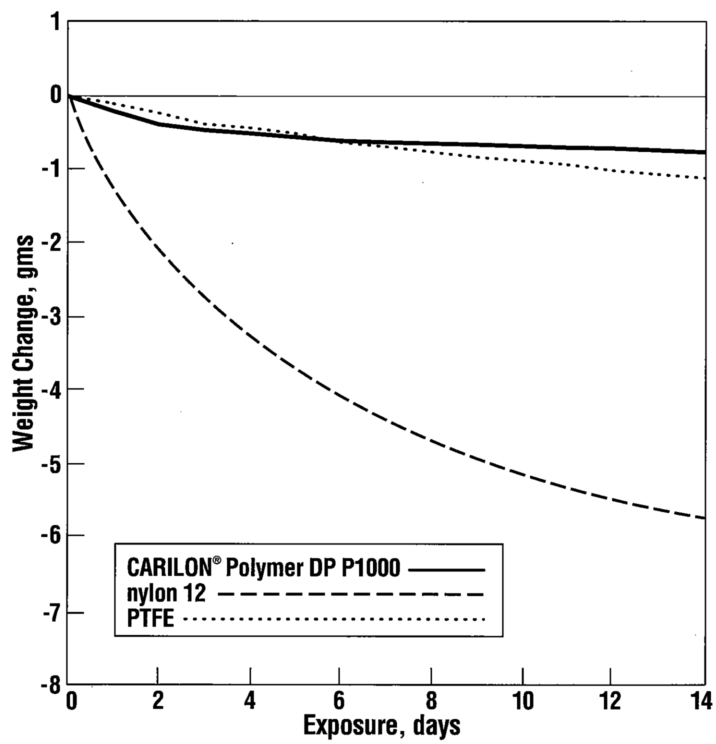
Test Fuel at 23 °C (73 °F)

Exposure, days	Weight Change, gms	
	CARILON® Polymer DP P1000	nylon 12
1	0.00	-0.03
7	0.02	-0.41
14	0.05	-0.60
21	0.06	-0.70
35	0.05	-0.85
70	-0.15	-1.15



Test Fuel at 93 °C (200 °F)

Exposure, days	Weight Change, gms		
	CARILON® Polymer DP P1000	nylon 12	PTFE
1	-0.20	-1.50	-0.10
2	-0.38	-2.10	-0.23
5	-0.55	-3.50	-0.50
7	-0.62	-4.40	-0.68
10	-0.67	-5.20	-0.87
14	-0.75	-5.70	-1.10



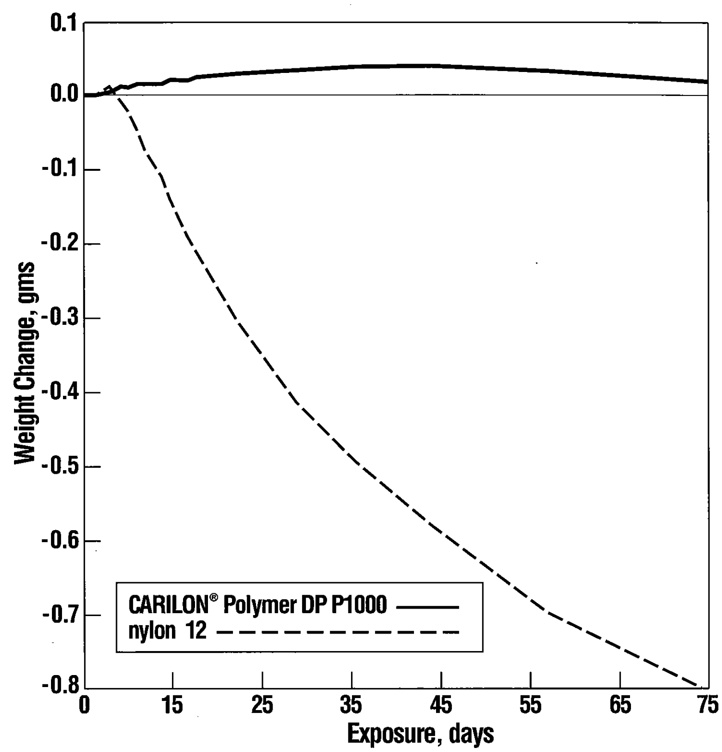
Note: Measured under conditions outlined in GM SPEC 9061-P.

PERMEABILITY OF CARILON® THERMOPLASTIC POLYMER VERSUS OTHER ENGINEERING PLASTICS IN GASOHOL/OXYGENATED FUEL BLEND

(5% Ethanol, 7.5% MTBE in Unleaded Gasoline)

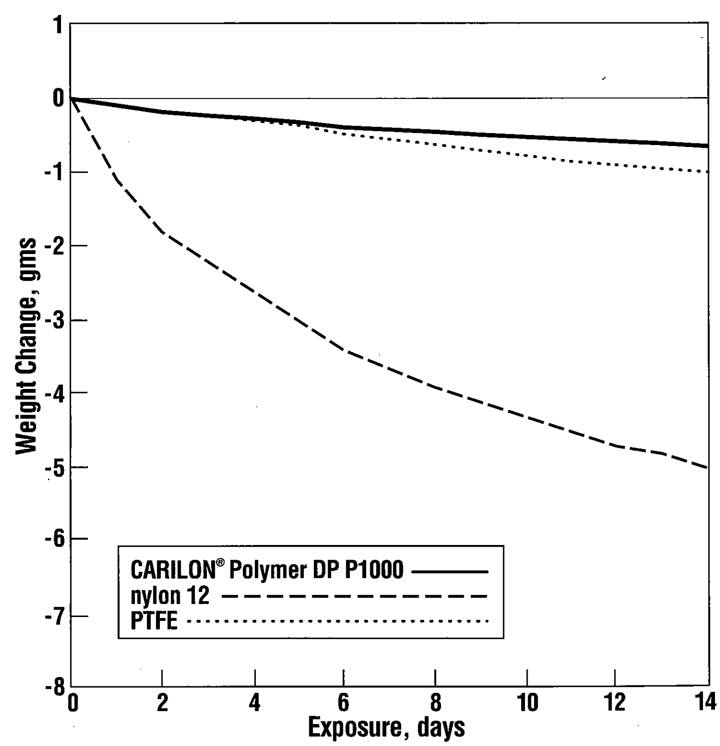
Gasohol/Oxygenated Fuel Blend at 23 °C (73 °F)

Exposure, days	Weight Change, gms	
	CARILON® Polymer DP P1000	nylon 12
1	0.00	0.00
7	0.01	-0.08
14	0.03	-0.21
21	0.03	-0.35
35	0.04	-0.52
70	0.02	-0.80



Gasohol/Oxygenated Fuel Blend at 93 °C (200 °F)

Exposure, days	Weight Change, gms		
	CARILON® Polymer DP P1000	nylon 12	PTFE
1	0.09	-1.10	-0.09
2	-0.18	-1.80	-0.18
5	-0.32	-3.00	-0.36
7	-0.42	-3.65	-0.55
10	-0.52	-4.30	-0.77
14	-0.65	-5.00	-1.00

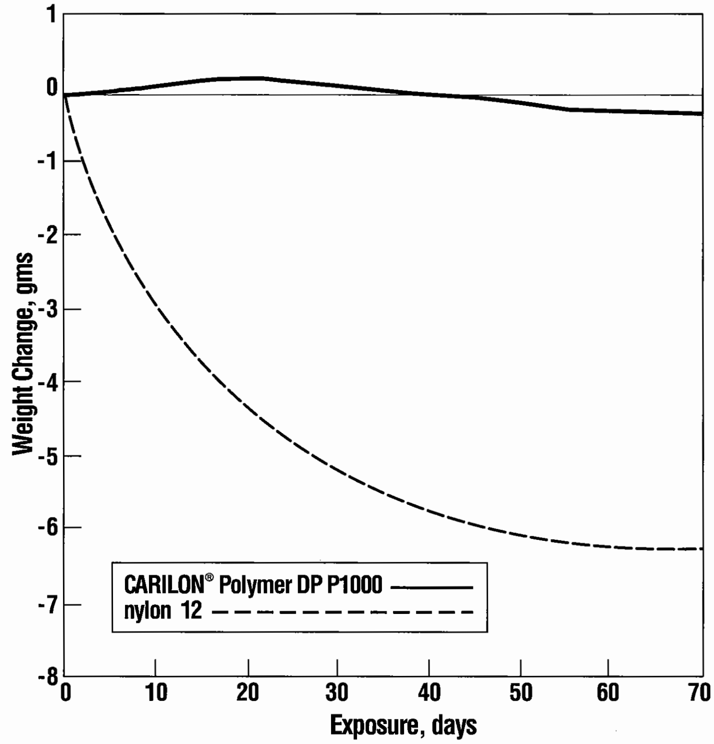


Note: Measured under conditions outlined in GM SPEC 9061-P.

PERMEABILITY OF CARILON® THERMOPLASTIC POLYMER VERSUS OTHER ENGINEERING PLASTICS IN M85
(85% Methanol and 15% Unleaded Gasoline)

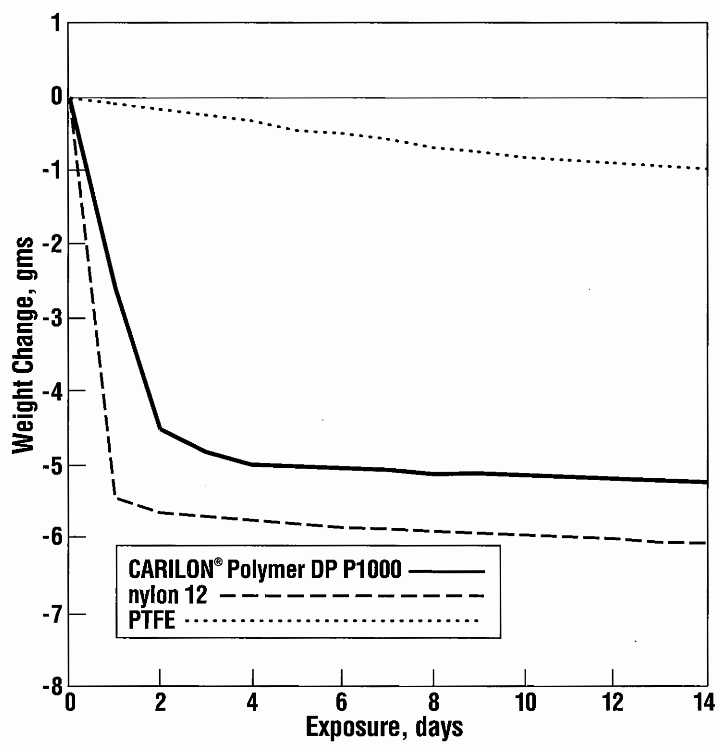
M85 at 23 °C (73 °F)

Exposure, days	Weight Change, gms	
	CARILON® Polymer DP P1000	nylon 12
1	0.01	-0.50
7	0.08	-2.60
14	0.18	-3.80
21	0.17	-4.54
35	-0.20	-5.60
70	-0.25	-6.67



M85 at 93 °C (200 °F)

Exposure, days	Weight Change, gms		
	CARILON® Polymer DP P1000	nylon 12	PTFE
1	-2.57	-5.40	-0.08
2	-4.47	-5.60	-0.15
5	-4.97	-5.75	-0.44
7	-5.03	-5.83	-0.56
10	-5.09	-5.95	-0.80
14	-5.19	-6.01	-0.96



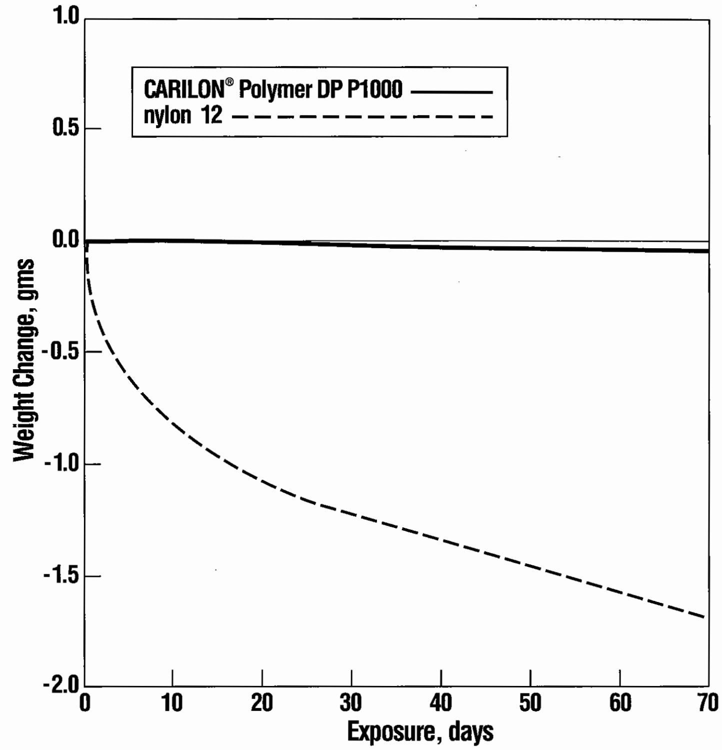
Note: Measured under conditions outlined in GM SPEC 9061-P.

PERMEABILITY OF CARILON® THERMOPLASTIC POLYMER VERSUS OTHER ENGINEERING PLASTICS IN M15

(15% Methanol and 85% Unleaded Gasoline)

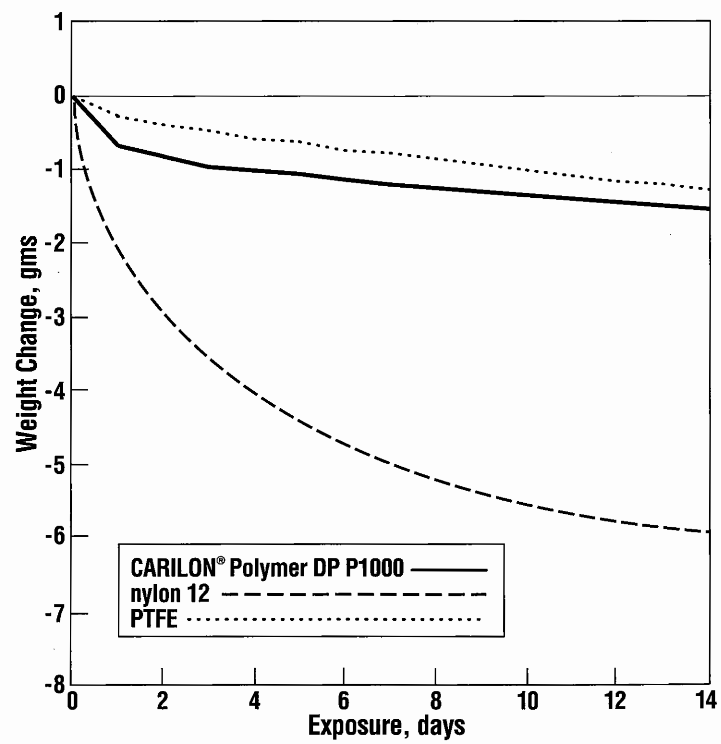
M15 at 23 °C (73 °F)

Exposure, days	Weight Change, gms	
	CARILON® Polymer DP P1000	nylon 12
1	0.00	-0.24
7	0.04	-0.77
14	0.00	-0.97
21	-0.06	-1.07
35	-0.22	-1.34
70	-0.42	-1.70



M15 at 93 °C (200 °F)

Exposure, days	Weight Change, gms		
	CARILON® Polymer DP P1000	nylon 12	PTFE
1	-0.67	-2.30	-0.27
2	-0.81	-3.00	-0.38
5	-1.05	-4.40	-0.61
7	-1.19	-5.00	-0.77
10	-1.33	-5.40	-0.99
14	-1.52	-5.90	-1.26



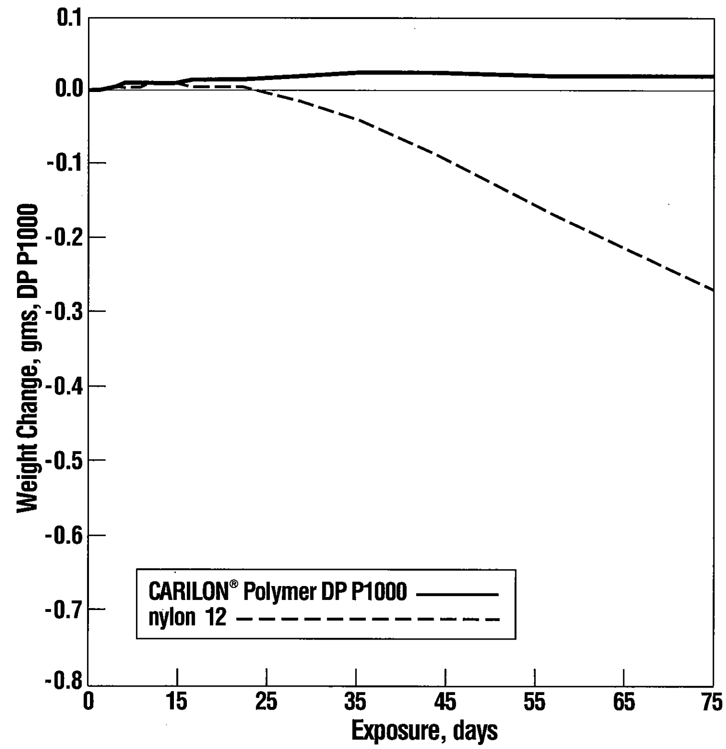
Note: Measured under conditions outlined in GM SPEC 9061-P.

PERMEABILITY OF CARILON® THERMOPLASTIC POLYMER VERSUS OTHER ENGINEERING PLASTICS IN UNLEADED GASOLINE WITH MTBE

(15% MTBE and 85% Unleaded Gasoline)

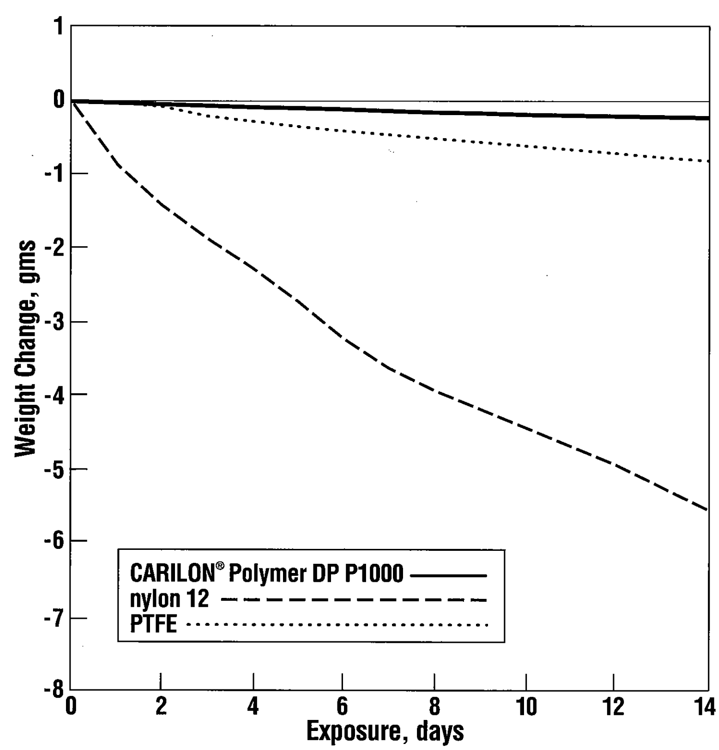
Unleaded Gasoline with 15% MTBE at 23 °C (73 °F)

Exposure, days	Weight Change, gms	
	CARILON® Polymer DP P1000	nylon 12
1	0.00	0.00
7	0.01	0.01
14	0.01	0.01
21	0.02	-0.01
35	0.03	-0.06
70	0.02	-0.27



Unleaded Gasoline with 15% MTBE at 93 °C (200 °F)

Exposure, days	Weight Change, gms		
	CARILON® Polymer DP P1000	nylon 12	PTFE
1	-0.02	-0.85	-0.02
2	-0.04	-1.40	-0.07
5	-0.09	-2.70	-0.34
7	-0.13	-3.60	-0.45
10	-0.18	-4.40	-0.60
14	-0.22	-5.50	-0.80



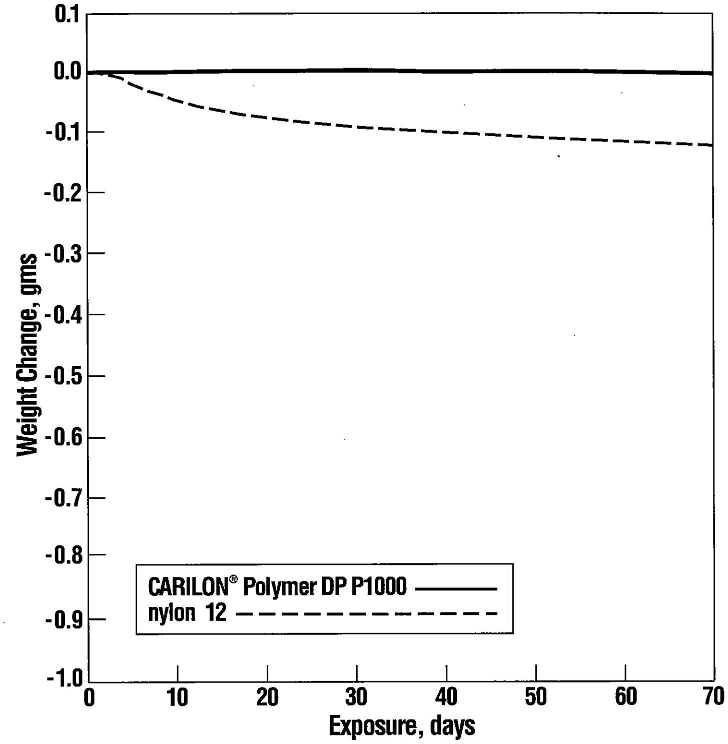
Note: Measured under conditions outlined in GM SPEC 9061-P.

PERMEABILITY OF CARILON® THERMOPLASTIC POLYMER VERSUS OTHER ENGINEERING PLASTICS IN GASOHOL

(10% Ethanol and 90% Unleaded Gasoline)

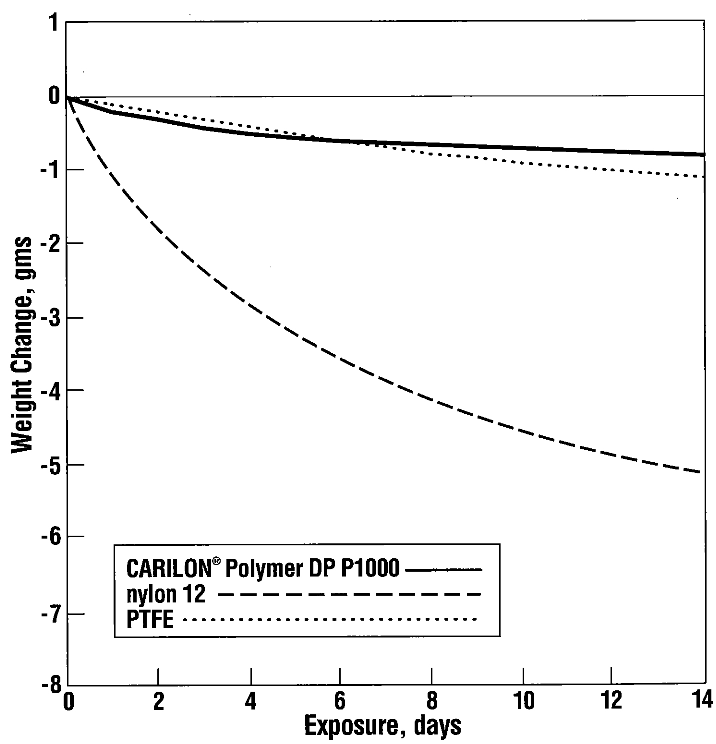
Gasohol at 23 °C (73 °F)

Exposure, days	Weight Change, gms	
	CARILON® Polymer DP P1000	nylon 12
1	0.00	0.00
7	0.00	-0.31
14	0.02	-0.60
21	0.03	-0.80
35	0.04	-0.95
70	-0.01	-1.20



Gasohol at 93 °C (200 °F)

Exposure, days	Weight Change, gms		
	CARILON® Polymer DP P1000	nylon 12	PTFE
1	-0.20	-1.20	-0.10
2	-0.30	-2.00	-0.20
5	-0.55	-3.20	-0.50
7	-0.62	-3.80	-0.67
10	-0.70	-4.50	-0.90
14	-0.80	-5.10	-1.10



Note: Measured under conditions outlined in GM SPEC 9061-P.

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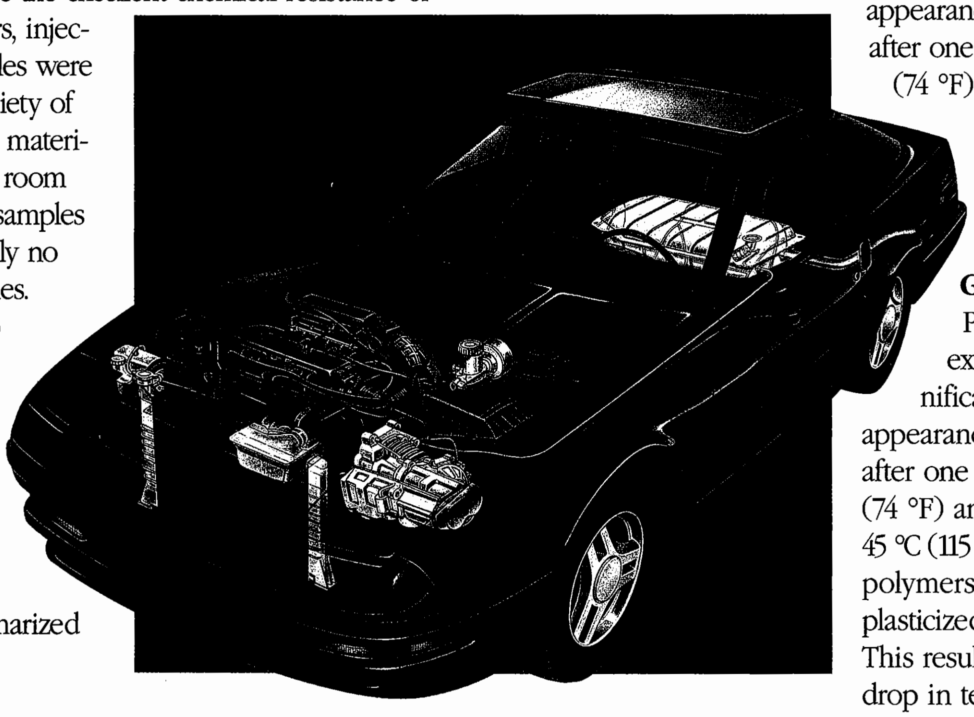
500 12/94

Resistance of CARILON® Polymers to Automotive Fluids

CARILON® polymers and compounds have outstanding chemical resistance. They can be exposed to a wide variety of industrial, automotive, and consumer chemicals with minimal effect on appearance and mechanical properties.

CARILON polymers are especially well suited for use in contact with automotive fluids and chemical environments. They exhibit excellent retention of appearance and properties when in contact with the automotive related materials listed below, both at room temperature and relevant elevated temperatures.

To demonstrate the excellent chemical resistance of CARILON polymers, injection molded samples were immersed in a variety of automotive related materials for one year at room temperature. The samples displayed essentially no change in properties. Samples were also tested in these same materials at elevated temperatures, again showing satisfactory results. The results of this test program are summarized in this bulletin.



Gasoline	**Power Steering Fluid**
Oxygenated Gasoline	**Antifreeze Solutions**
Diesel Fuel	**Brake Fluid**
Motor Oil	**Zinc Chloride**
Lubricants	**Calcium Chloride**
Automatic Transmission Fluid	**Most Cleaning Compounds**

Chemical Resistance of CARILON® Polymers

The performance of CARILON polymers when exposed to specific automotive fuels, lubricants, and other fluids is discussed below. In addition to the automotive related products discussed, CARILON polymers have excellent resistance to hydrocarbon solvents, alcohols, aldehydes, ketones, esters, ethers, and most weak acids and bases.

FUELS

Non-Lead Gasoline

Performance is excellent; no significant effect on appearance or properties after one year at 23 °C (74 °F) and one year at 45 °C (115 °F).

Oxygenated Gasolines

Gasohol

Performance is excellent; no significant changes in appearance or properties after one year at 23 °C (74 °F) and one year at 45 °C (115 °F). CARILON polymers are slightly plasticized by alcohol. This results in a slight drop in tensile strength and modulus, but is reversible, and original properties are obtained if the product is dried.

MTBE Modified

Performance is excellent; no changes in appearance or properties after one year at 23 °C (74 °F) and one year at 45 °C (115 °F). CARILON polymers show the same outstanding resistance to 100% MTBE under similar conditions.

LUBRICANTS

Motor Oil

Excellent performance for one year at 23 °C (74 °F) and 90 days at 120 °C (250 °F).

Chassis Lube

Excellent performance for one year at 23 °C (74 °F) and very good performance after 90 days at 120 °C (250 °F).

Automatic Transmission Fluid

Excellent performance for one year at 23 °C (74 °F). Fair performance after 90 days at 120 °C (250 °F).

SALTS

Zinc Chloride

Unlike many engineering thermoplastics, CARILON polymers are specifically suggested for use in contact with zinc chloride. No significant changes are seen after full immersion in zinc chloride solution for one year at 23 °C (74 °F).

Calcium Chloride

CARILON polymers are unaffected by exposure to calcium chloride for one year at room temperature. They would also be expected to perform well in contact with any other salt solution.

OTHER AUTOMOTIVE FLUIDS

Brake Fluid

Excellent performance. No significant changes in mechanical properties after one year of immersion at 23 °C (74 °F). A slight brown discoloration is noted after one-half year of exposure.

Antifreeze

Excellent performance after one year at 23 °C (74 °F). No changes noted. A good performance when exposed to antifreeze for 90 days at 120 °C (250 °F).

Reagent	Exposure °C (°F)	Time	Tensile Strength at Yield % Change	Surface Appearance	Weight Change %	Volume Change %
Fuels						
Gasoline Unleaded	23 (74)	1 Year	No Change	Slightly Yellow	0	0
		2 Years	No Change	Slightly Yellow	0	0
	45 (115)	1 Year	No Change	Slightly Yellow	1	3
Gasohol 10% Ethanol	23 (74)	90 Days	No Change	No Change	0	0
		180 Days	No Change	No Change	0	0
		1 Year	- 6	Slightly Yellow	1	0
		2 Years	- 8	Slightly Yellow	2	3
	45 (115)	60 Days	No Change	No Change	1	1
		180 Days	- 8	Yellow	3	5
		1 Year	- 8	Yellow	3	5
Gasohol M-15 (Unleaded Gasoline 85%, Methanol 15%)	23 (74)	30 Days	No Change	No Change	1	0
		60 Days	- 8	No Change	2	1
		90 Days	- 11	Slightly Yellow	2	2
		1 Year	- 11	Slightly Yellow	5	3
Gasohol M-85 (Unleaded Gasoline 15%, Methanol 85%)	23 (74)	30 Days	- 4	No Change	1	1
		60 Days	- 9	No Change	2	2
		1 Year	- 13	No Change	3	4
Methanol	23 (74)	30 Days	- 5	No Change	2	1
		60 Days	- 9	No Change	2	2
		1 Year	- 11	No Change	2	3
Jet Fuel A	23 (74)	1 Year	No Change	No Change	0	0
		2 Years	No Change	No Change	0	0
	45 (115)	1 Year	No Change	No Change	1	2
MTBE	23 (74)	1 Year	No Change	No Change	1	1

Reagent	Exposure °C (°F)	Exposure Time	Tensile Strength at Yield % Change	Surface Appearance	Weight Change %	Volume Change %
Lubricants						
Motor Oil 10W - 40	23 (74)	1 Year	No Change	Yellow	0	0
		2 Years	No Change	Dark Yellow	0	0
	45 (115)	60 Days	No Change	Yellow	0	0
		180 Days	+ 10	Yellow	0	0
		1 Year	+ 15	Dark Yellow	0	0
	120 (248)	90 Days	No Change	Brown	0	0
		180 Days	+ 6	Black	0	- 1
Chassis Lube	23 (74)	1 Year	No Change	Slightly Yellow	0	0
		2 Years	No Change	Yellow	0	0
	45 (115)	90 Days	No Change	Dark Yellow	0	0
		1 Year	+ 10	Brown	0	0
	120 (248)	180 Days	No Change	Black	- 1	- 1
Automatic Transmission Fluid	23 (74)	1 Year	No Change	Yellow	0	0
		2 Years	No Change	Yellow	0	0
	45 (115)	60 Days	No Change	No Change	0	0
		1 Year	+ 9	Slightly Yellow	0	0
		60 Days	No Change	Dark Brown	0	0
	120 (248)	90 Days	- 50	Black	- 1	- 1
		180 Days	- 60	Black	- 1	- 1
Brake Fluid	23 (74)	1 Year	No Change	Brown	0	0
		2 Years	No Change	Brown	0	0
	45 (115)	80 Days	No Change	Dark Yellow	0	0
		1 Year	+ 8	Light Brown	0	0
		90 Days	No Change	Black	5	5
	120 (248)	180 Days	10	Black	5	5
Skydrol 500 B	23 (74)	1 Year	No Change	No Change	0	0
		2 Years	No Change	No Change	0	0
	45 (115)	60 Days	No Change	No Change	0	0
		90 Days	+ 7	No Change	0	0
		1 Year	+ 11	No Change	0	0
	120 (248)	30 Days	+ 6	Brown	1	1
		60 Days	+ 8	Brown	2	2
		180 Days	- 66	Black, Blisteral	2	2
Other Fluids						
Antifreeze 100%	23 (74)	1 Year	No Change	No Change	0	0
		2 Years	No Change	No Change	0	0
	45 (115)	1 Year	No Change	Slightly Yellow	2	2
	120 (248)	60 Days	- 10	Brown	5	4
		90 Days	- 10	Dark Brown	5	4
Antifreeze 50% Water 50%	23 (74)	1 Year	No Change	No Change	0	0
		2 Years	No Change	No Change	0	0
	45 (115)	90 Days	No Change	No Change	1	1
		1 Year	+ 8	Yellow	1	1
Zinc Chloride 10% Volume	23 (74)	1 Year	- 4	Yellow	2	3
Calcium Chloride 30% Volume	23 (74)	1 Year	No Change	No Change	0	0

Note: In the samples exposed to Methanol or fuels containing Methanol or Ethanol, the slight loss in tensile strength is not a sign of degradation. In these cases, it is a result of plasticization by the alcohol. Vacuum drying the samples prior to testing returns the tensile strength to its original value. No change in surface hardness was noted in any case.

Solvent Exposure Procedures

Testing under no strain at room temperature and elevated temperature

Tensile bars are totally immersed in the solvent in a carefully controlled temperature environment. The specimens are periodically removed and the following steps taken:

- The sample surface is inspected for signs of pitting, cracking, or crazing.
- Color change is recorded.
- Samples are weighed and measured to determine swelling and dimensional distortion.
- Samples are tested for physical deterioration by determining tensile properties, tensile strength, at yield and elongation.

Health & Safety Considerations

Shell strongly suggests that all those who will come in contact with CARILON polymers and compounds read and follow all information presented in the Material Safety Data Sheet (MSDS) for this product. Also refer to all safety information provided with processing equipment.

MODERN PLASTICS

AUTOMOTIVE

Aliphatic polyketones win broad role in fuel systems

Aliphatic polyketones from Shell Chemical Co. are replacing established engineering resins in the automotive market. In Europe and the U.S., this new polymer class is forging a role as a contender in fuel systems due to superior chemical resistance, barrier properties, and low gas permeation.

Most notable is the first fuel line made of Carilon, a polyketone (PK) slated for introduction by a European car maker this month. Other successes include fuel-pump reservoirs and flanges, fuel connectors, fuel-pump housings, and onboard refueling vapor recovery (ORVR) valves. In most cases, nylon and acetal are being replaced due to PK's impact and permeation resistance, and shorter molding cycles. "Most molders are impressed when they see how well the material processes and the cycle-time reductions that can be realized," says Nicolas Betin, Shell automotive manager in Amsterdam.

Shell has laid out an ambitious game plan for its PK polymers, said to offer a properties spectrum broader than competing engineering thermoplastics. These semi-crystalline resins combine strength, stiffness, and impact resistance with good wear and friction-resistance. PK polymers retain performance over a range of temperatures.

Paul Sykes, Shell automotive manager in Houston, foresees strong potential from the "gas tank cap, through the fuel system to the manifold." Considering the characteristically long lead times in gaining material qualification, Shell has made solid progress since introducing Carilon at K'95 and unveiling it in late 1996 in the U.S. Only a handful of commercial auto applications were secured in 1997, but the supplier expects to announce several new fuel-system parts this year. Meanwhile, to meet anticipated demand, Shell will open its first U.S. facility (25,000 tons/yr) at Geismar, LA, in 1999.

In the U.S., ORVR valves designed by GT Products, Ann Arbor, MI, are molded of neat PK, replacing acetal because of improved strength and fuel resistance. The ORVRs, which mount on the fuel tank, significantly reduce hydrocarbon emissions in refueling and meet U.S. Environmental Protection Agency regulations that go into effect this year.

PK is also claimed to facilitate assembly through a snap-fit design and to provide better dimensional stability. The part, used mostly on GM vehicles, has a projected annual volume of 3 million. Sykes says developments are underway to extend the technology to other car makers.

Fuel-line connectors under the chassis are slated for commercialization at GM and Ford in the first quarter. Shell's unfilled Carilon D26HM100 grade is being employed as a replacement for nylon 12. The material is said to provide better pull-off strength at elevated temperatures and offers 15% to 20% cycle-time reductions.

In Europe, the first fuel lines of extruded PK are slated for commercialization this month, says Betin. As a replacement for nylon 11, the underhood, rubber-coated PK fuel line is said to provide better permeation properties and meets Euro 2000 emissions regulations at a comparable cost. Shell is also working on monolayer PK fuel lines, which are less costly than monolayer nylon 11, and comparable in cost to multilayer nylon 6 and 12.

Major efforts are also focused on diesel engines and the replacement of acetal in fuel system parts. Betin says European auto makers are implementing direct injection, common fuel-rail technology to improve fuel efficiency and reduce emissions. However, this technology results in higher temperatures which, combined with new diesel additives, can depolymerize acetal, according to Betin. PK is claimed to provide the necessary chemical resistance at elevated temperatures (90°C to 120°C).

Carilon is used for the fuel pump reservoir on the 1997 BMW5 U.S. export series. In that application acetal cracked. Meanwhile, in the second quarter, two car makers will introduce models sporting fuel-pump reservoirs and flanges injection molded of Carilon.

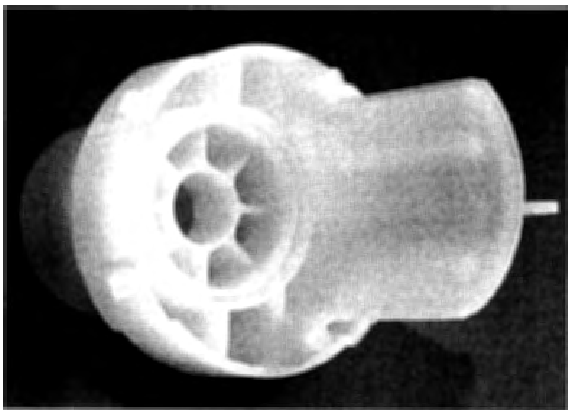
Glass-filled Carilon is targeted for fuel connectors in the first half, replacing glass-filled nylon 12 at a 20% cost reduction.

In the U.S., another development project is fuel-pump housings made of mineral-filled PK for improved dimensional stability. In the tight-tolerance application, acetal can take almost 48 h to crystallize, compared to 30 min for Carilon. Longer-term, polyketone is being considered as a barrier material in multilayer fuel tanks. Sykes says that the Carilon polyketone can withstand fuel exposure using a four-layer coextrusion with HDPE. *–Joseph A. Grande*

How polyketone compares with competitive resins

	PBT	POM (copolymer)	PK[a]
Specific gravity	1.31	1.41	1.24
Flexural modulus, psi	340,000	375,000	230,000
Izod impact, ft/lb	1.2	1.3	4.0
Heat deflection temp., 264 psi, °F	130	230	221
Stress yield, psi	8000	8800	8600

a: Carilon D26HM100
Source: Shell Chemical



Polyketone is challenging other engineering resins in fuel system parts like vapor recovery valves. [Photo, Shell]