Resistance of SAF™ PA11 and PA12 to Automotive Chemicals

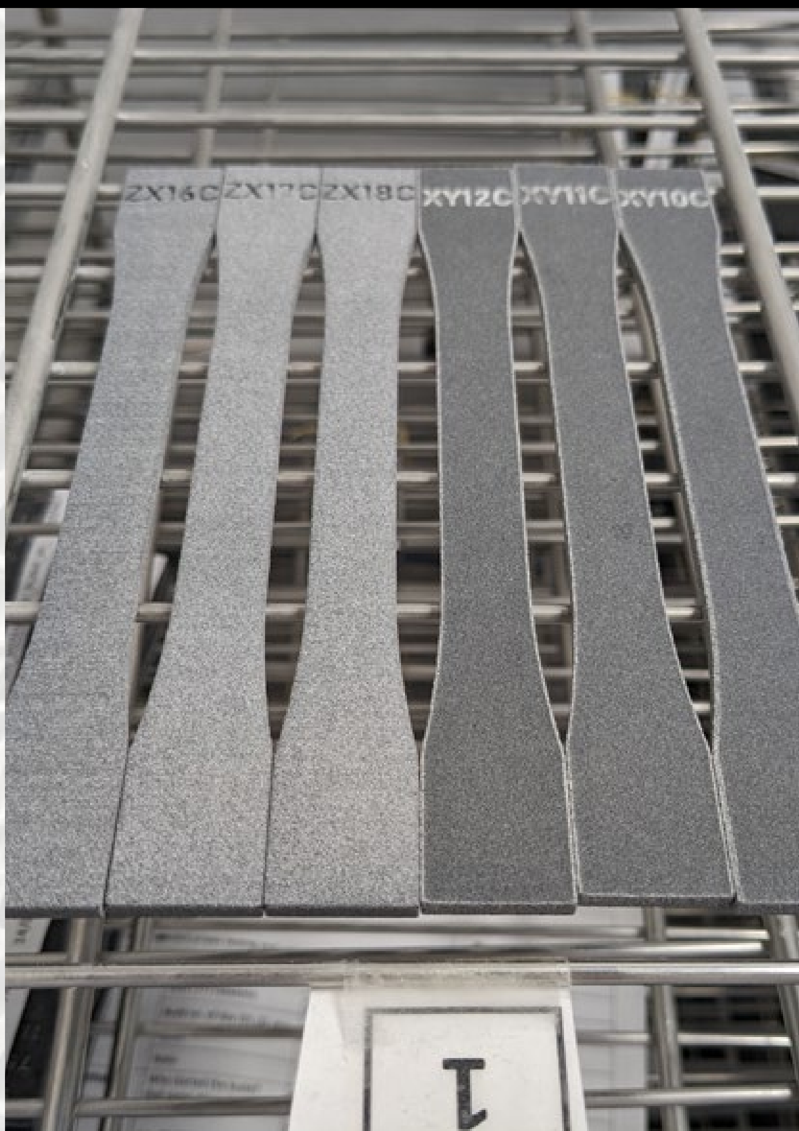
Introduction

From air ducts, seat levers and side mirrors to electrical cable clips, sensor covers and gear shift housing, Stratasys® SAF™ materials are used to create many types of automotive end-use parts. Such parts are subject to a variety of environmental conditions and chemicals. To evaluate the effect of exposure to automotive chemicals, the performance of two SAF materials — Stratasys High Yield PA11 and SAF PA12 — were tested under exposure to several common automotive chemicals.

The reagents tested were:

- Battery acid
- Antifreeze
- Synthetic motor oil
- Silicone grease
- Petroleum grease
- Screen wash
- Distilled water

The results are included in this white paper.



White Paper

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Methodology

The experiment was carried out in accordance with ASTM D543 which defines a standard practice of evaluating the resistance of plastics to chemical reagents.

Specimens were created using Stratasys H350® SAF™ 3D printers, with both vertical (ZX) and horizontal (XY) print orientations tested. The two specimen types used in the test were:

- ASTM D638 Type 1 tensile bars, to evaluate mechanical changes
- 50.80mm x 3.175mm discs, to evaluate dimensional and weight changes

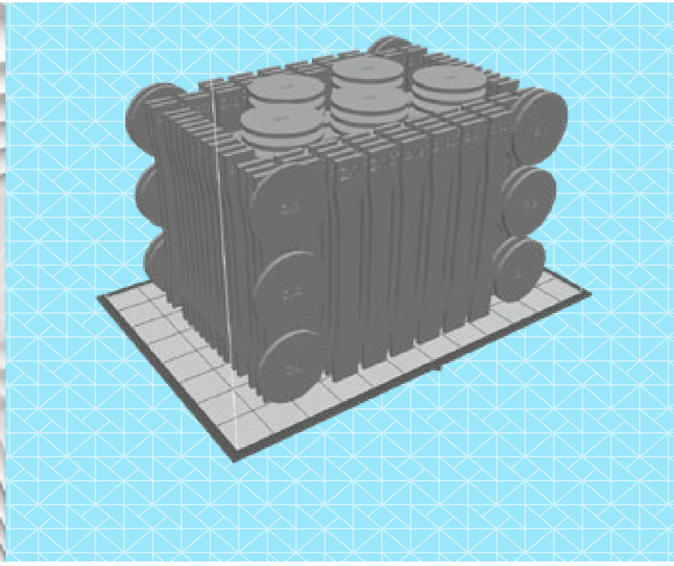

Figure 1. Chemical test parts layout prepared with GrabCAD® Print™ software for printing on the H350.

For each experiment, all parts were preconditioned at 23°C and 50% relative humidity for a minimum of 40 hours before contact with the reagent. Control parts remained on the preconditioning racks for the duration of the experiment (Figure 2), while test parts were submerged in a 4L reagent bath for 168 hours (1 week).

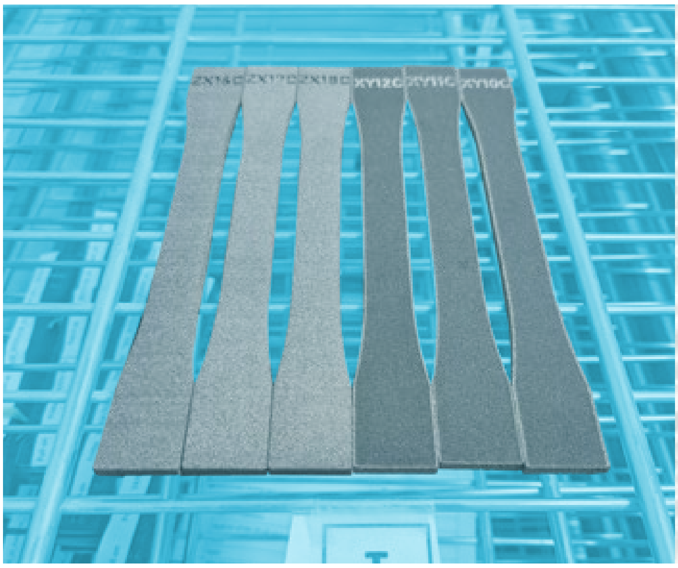

Figure 2. Tensile control parts (marked C with matching pair number) on preconditioning racks.

Frames were fabricated from stainless steel and nichrome wire to hold the specimens in place without touching the container walls or each other during immersion in reagent (Figure 3).

A magnetic stir bar was also placed within the container before sealing the experiment. This was used to agitate the reagent for 30 minutes at six 24-hour intervals before removal of the parts at 168 hours. A digitally timed magnetic stir plate (Figure 4) ensured a consistent stirring time across all experiments.

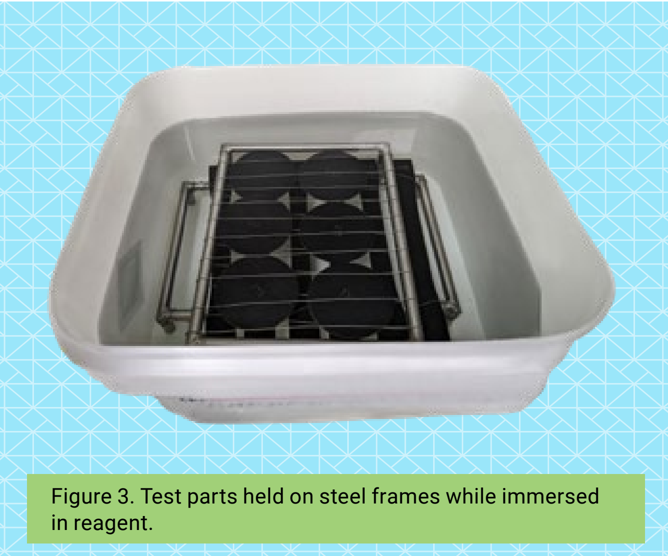

Figure 3. Test parts held on steel frames while immersed in reagent.

Figure 4. Sealed experiment container resting on the digitally timed magnetic stirring plate.

The previously described method would be impractical for silicone and petroleum grease. Instead, a thick spray coating of reagent at the start of each test was opted for, followed by a thin re-application every 24 hours. Parts were checked visually for even coverage on each application.

Tensile Specimens

Tensile tests were carried out on a Tinius Olsen 10ST universal testing setup (Figure 5) in accordance with ASTM D638. These tests were carried out within 30 minutes of removal from the reagent bath.

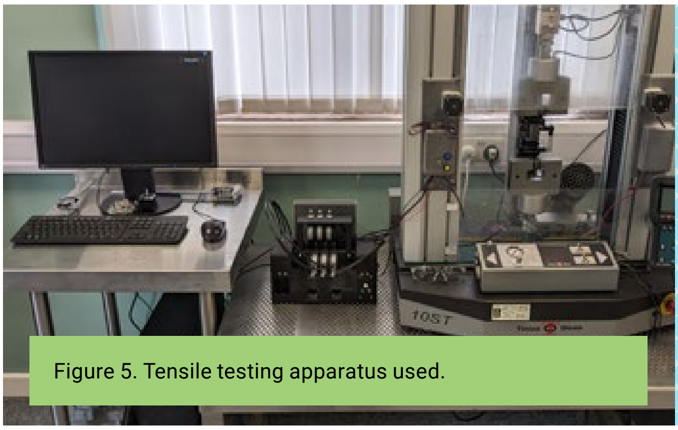

Figure 5. Tensile testing apparatus used.

A total of 12 tensile parts were tested per reagent. This consisted of six parts immersed in reagent, while six parts were held from the same build to provide control values for the test. Control parts were printed adjacent to their respective test parts.

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Weight and Dimension Discs

Weight and dimension tests compared pre- and post-immersion values of disc-shaped specimens (Figure 6). Weights were measured using an A&D HR-100AZ analytical balance. Thickness and diameter values were measured manually using a micrometer and digital callipers, respectively. A total of six weight and dimension parts were tested per reagent.

Figure 6. PA12 weight and dimension specimens after immersion in battery acid.

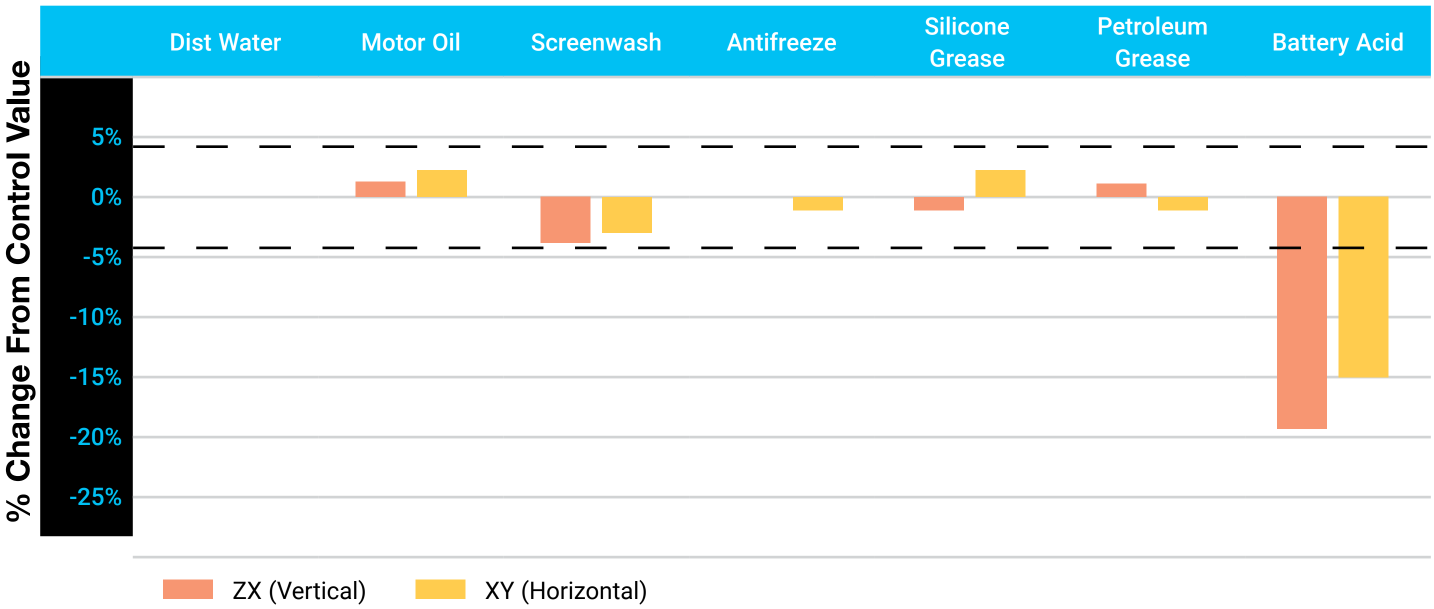
All weight and dimension discs were kept a further 168 hours on preconditioning racks after removal from reagent; then were re-weighed to investigate how parts dry after contact with these chemicals.

Graphs of % Change Per Property

PA11 Results

As a Stratasys preferred material, standard deviation values are available from our High Yield PA11 Datasheet. These are indicated by the black dashed lines.

PA11 UTS% Change from Nominal



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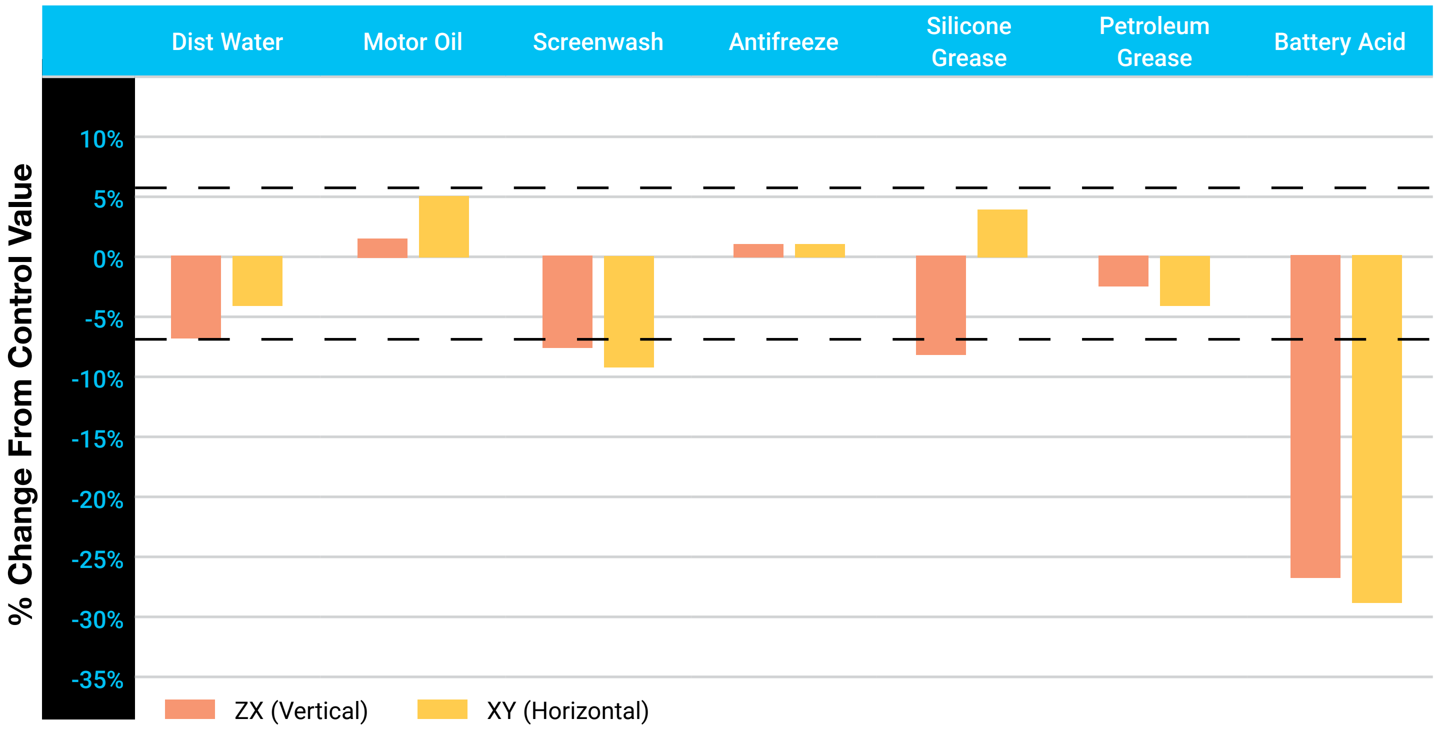
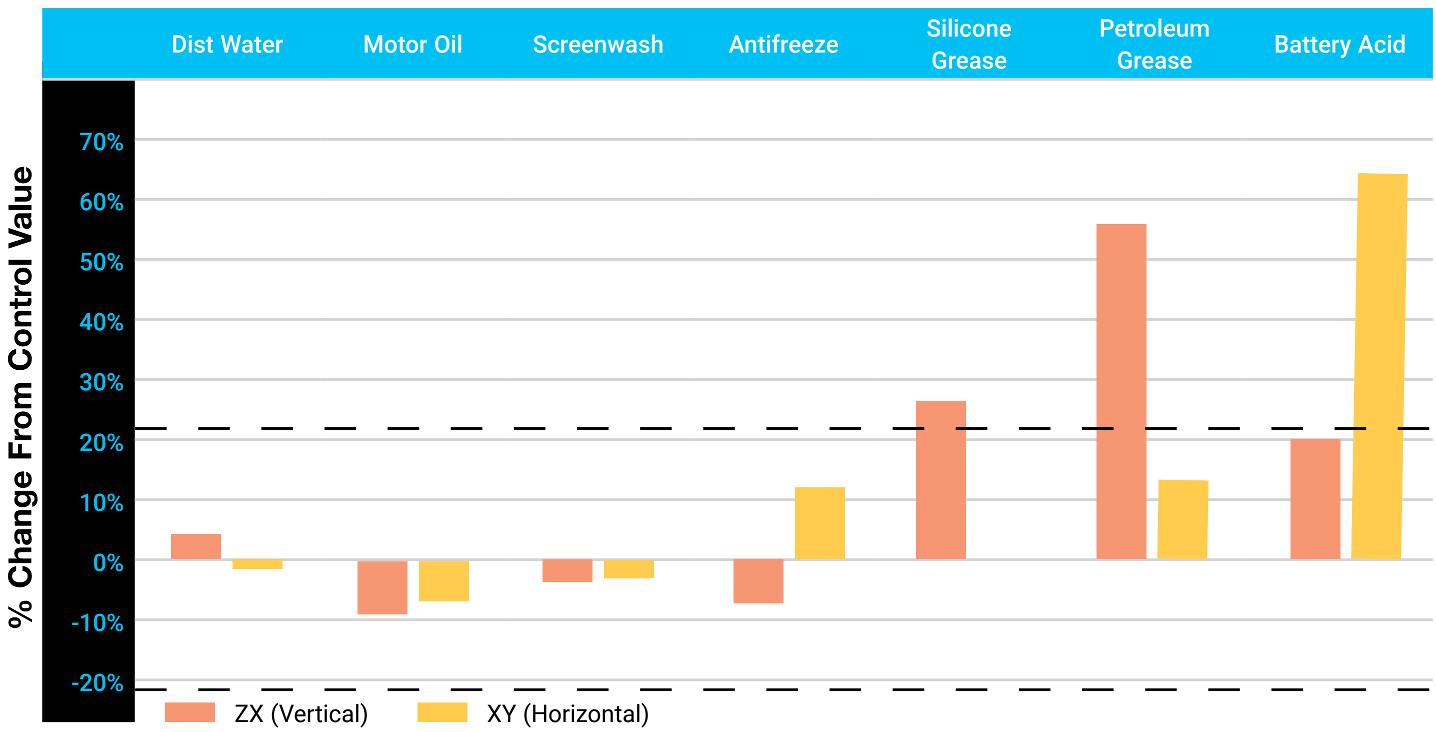
PA11 Results

PA11 Youngs Modulus % Change from Nominal



PA11 Elongation at Break % Change from Nominal



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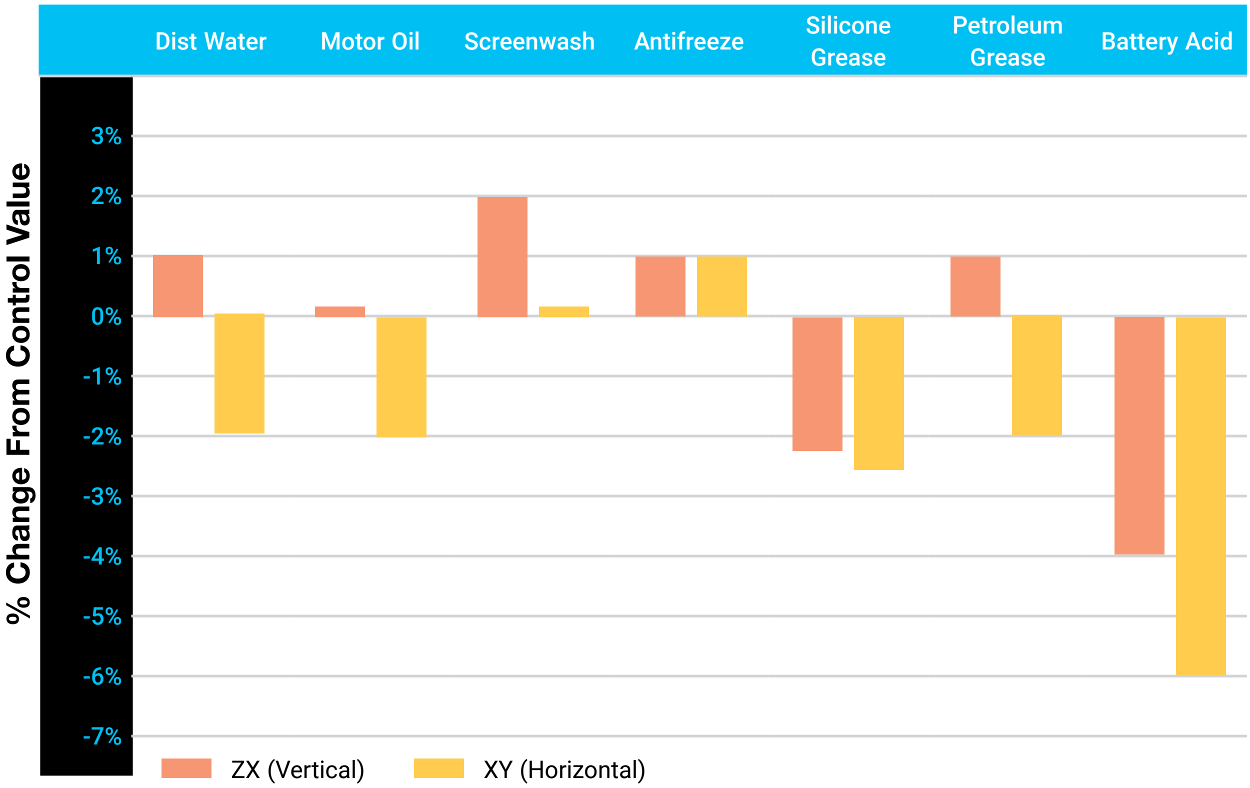
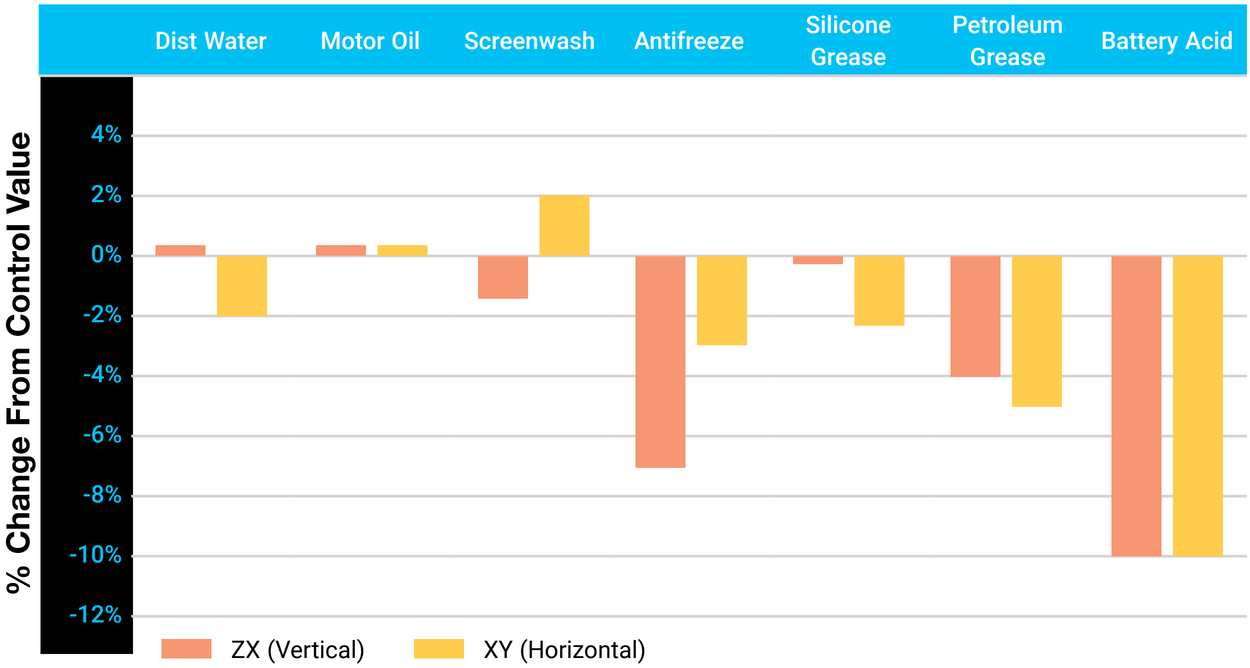
PA12 Results

PA12 UTS % Change from Nominal



PA12 Youngs Modulus% Change from Nominal



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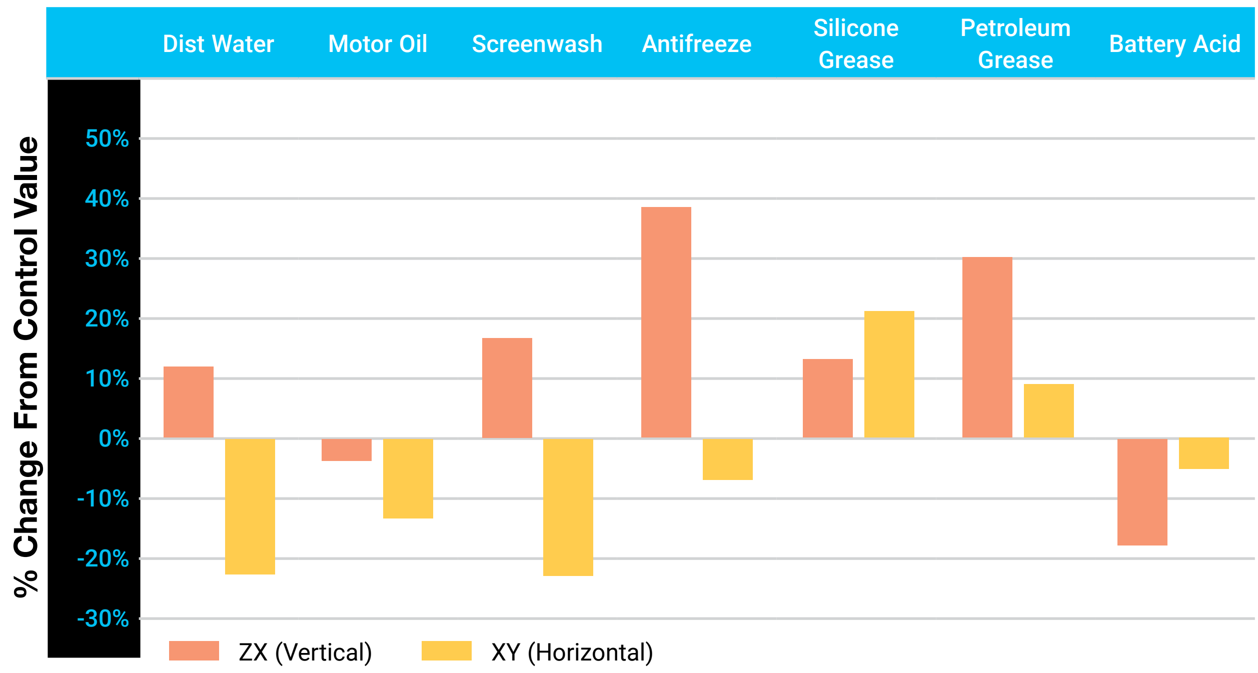
PA12 Results

PA12 Elongation at Break % Change from Nominal



Resistance of SAF™ PA11 and PA12 to Automotive Chemicals

Tables of Final Results

PA11 Change in Mechanical Properties - 168hr Exposure (ASTM D543)

	Reagent	ZX % Change	XY % Change
UTS (MPa)	Dist Water	0%	0%
	Motor Oil (Synth)	1%	2%
	Screenwash	-4%	-3%
	Antifreeze	0%	-1%
	Silicone Grease	-1%	2%
	Petro Grease	1%	-1%
	Battery Acid	-19%	-15%
Modulus (MPa)	Dist Water	-7%	-4%
	Motor Oil (Synth)	2%	5%
	Screenwash	-8%	-9%
	Antifreeze	1%	1%
	Silicone Grease	-8%	4%
	Petro Grease	-3%	-4%
	Battery Acid	-27%	-29%
EaB (%)	Dist Water	+5%	-1%
	Motor Oil (Synth)	-9%	-7%
	Screenwash	-4%	-3%
	Antifreeze	-7%	+12%
	Silicone Grease	+27%	0%
	Petro Grease	+55%	+13%
	Battery Acid	+20%	+64%

High Yield PA11 Reference Values

Property (Orientation)	Mean Value
Tensile Strength (ZX)	47 MPa
Tensile Strength (XZ, YX)	51 MPa
Elongation at Break (ZX)	11 %
Elongation at Break (XZ, YX)	30 %
Tensile Modulus (ZX)	1609 MPa
Tensile Modulus (XZ, YX)	1529 MPa

Resistance of SAF™ PA11 and PA12 to Automotive Chemicals

Tables of Final Results

PA12 Change in Mechanical Properties - 168hr Exposure (ASTM D543)

	Reagent	ZX % Change	XY % Change
UTS (MPa)	Dist Water	+1%	-2%
	Motor Oil (Synth)	0%	-2%
	Screenwash	+2%	0%
	Antifreeze	+1%	+1%
	Silicone Grease	-2%	-3%
	Petro Grease	+1%	-2%
	Battery Acid	-4%	-6%
Modulus (MPa)	Dist Water	0%	-2%
	Motor Oil (Synth)	0%	0%
	Screenwash	-1%	2%
	Antifreeze	-7%	-3%
	Silicone Grease	0%	-2%
	Petro Grease	-4%	-5%
	Battery Acid	-10%	-10%
EaB (%)	Dist Water	+12%	-23%
	Motor Oil (Synth)	-4%	-13%
	Screenwash	+16%	-23%
	Antifreeze	+39%	-7%
	Silicone Grease	+14%	+22%
	Petro Grease	+30%	+9%
	Battery Acid	-17%	-5%

SAF PA12 Reference Values

Property (Orientation)	Mean Value
Tensile Strength (ZX)	46 MPa
Tensile Strength (XZ, YX)	47 MPa
Elongation at Break (ZX)	5 %
Elongation at Break (XZ, YX)	11 %
Tensile Modulus (ZX)	1700 MPa
Tensile Modulus (XZ, YX)	1750 MPa

Note: small elongation values are due to the rigidity of PA12. As a result, this test is more susceptible to noise and may see large percentage changes over this limited sample size.

Resistance of SAF™ PA11 and PA12 to Automotive Chemicals

Tables of Final Results

PA11 Change in Dimensions and Weight - 168hr Exposure (ASTM D453)

	Reagent	ZX % Change	XY % Change
Diameter	Dist Water	0.0%	0.0%
	Motor Oil (Synth)	0.0%	0.0%
	Screenwash	0.0%	0.0%
	Antifreeze	0.1%	-0.1%
	Silicone Grease	0.0%	0.0%
	Petro Grease	0.0%	0.0%
	Battery Acid	0.4%	0.4%
Thickness	Dist Water	0.2%	0.7%
	Motor Oil (Synth)	0.0%	-0.5%
	Screenwash	0.2%	1.0%
	Antifreeze	0.0%	0.1%
	Silicone Grease	-0.4%	-0.2%
	Petro Grease	0.1%	0.3%
	Battery Acid	7.0%	6.6%
Weight	Dist Water	1.0%	0.6%
	Motor Oil (Synth)	1.0%	0.4%
	Screenwash	0.3%	0.3%
	Antifreeze	0.9%	0.4%
	Silicone Grease	1.0%	0.6%
	Petro Grease	1.8%	1.0%
	Battery Acid	13.3%	13.0%
Weight (168hrs Dried)	Dist Water	0.2%	0.2%
	Motor Oil (Synth)	1.0%	0.5%
	Screenwash	0.3%	0.4%
	Antifreeze	PA	0.2%
	Silicone Grease	0.2%	0.2%
	Petro Grease	1.6%	0.9%
	Battery Acid	11.5%	10.9%

Resistance of SAF™ PA11 and PA12 to Automotive Chemicals

Tables of Final Results

PA12 Change in Dimensions and Weight - 168hr Exposure (ASTM D453)

	Reagent	ZX % Change	XY % Change
Diameter	Dist Water	0.1%	0.1%
	Motor Oil (Synth)	0.0%	0.0%
	Screenwash	0.0%	0.0%
	Antifreeze	0.0%	0.0%
	Silicone Grease	0.0%	0.0%
	Petro Grease	0.0%	0.0%
	Battery Acid	0.1%	0.1%
Thickness	Dist Water	0.1%	0.1%
	Motor Oil (Synth)	-0.4%	-0.1%
	Screenwash	-0.1%	0.0%
	Antifreeze	-0.4%	0.1%
	Silicone Grease	0.1%	0.2%
	Petro Grease	2.4%	0.6%
	Battery Acid	1.1%	1.3%
Weight	Dist Water	-2.1%	-1.0%
	Motor Oil (Synth)	1.0%	0.7%
	Screenwash	0.7%	0.5%
	Antifreeze	1.4%	1.1%
	Silicone Grease	1.0%	0.5%
	Petro Grease	1.8%	1.2%
	Battery Acid	3.9%	3.8%
Weight (168hrs Dried)	Dist Water	2.3%	-2.1%
	Motor Oil (Synth)	1.3%	1.0%
	Screenwash	0.4%	0.4%
	Antifreeze	0.2%	1.5%
	Silicone Grease	0.3%	0.6%
	Petro Grease	1.8%	1.3%
	Battery Acid	3.0%	3.2%

Resistance of SAF™ PA11 and PA12 to Automotive Chemicals

PA11 Conclusions

Reagent	Weight & Dimension Stability	Mechanical Stability
Distilled Water	Excellent	Excellent
Synthetic Motor Oil	Excellent	Excellent
Screenwash	Excellent	Excellent
Antifreeze	Excellent	Excellent
Silicone Grease	Excellent	Excellent
Petroleum Grease	Excellent	Excellent
Battery Acid	Limited Chemical Resistance	Limited Chemical Resistance

High Yield PA11 demonstrated good chemical resistance properties to six of the seven reagents tested. The effects of distilled water, synthetic motor oil, screen wash, antifreeze coolant, silicone grease, and petroleum grease on the material were observed to be negligible. Battery acid, as predicted, caused mechanical strength reductions averaging -17% with a subsequent increase in elasticity due to softening of the material.

While dimensional changes across all reagents were negligible, a notable gain in weight was observed in PA11 when immersed in battery acid. A permanent change in coloration from light gray to dark blue was also observed (Figure 7), the only test to undergo such a change.

Figure 7. Parts from PA11 battery acid test displaying color change after 168 hours drying.

Resistance of SAF™ PA11 and PA12 to Automotive Chemicals

PA12 Conclusions

Reagent	Weight & Dimension Stability	Mechanical Stability
Distilled Water	Excellent	Excellent
Synthetic Motor Oil	Excellent	Excellent
Screenwash	Excellent	Excellent
Antifreeze	Excellent	Excellent
Silicone Grease	Excellent	Excellent
Petroleum Grease	Excellent	Excellent
Battery Acid	Good Chemical Resistance	Good Chemical Resistance

SAF PA12 displayed good chemical resistance properties to six of the seven reagents, and withstood battery acid better than PA11. The effects of distilled water, synthetic motor oil, screen wash, antifreeze coolant, and petroleum grease were observed to be insignificant.

Performance of PA12 exposed to battery acid was better than predicted, only experiencing mild reductions in part strength alongside a slight decrease in stiffness.

All dimensional changes were negligible during this test. This material also displayed minimal increase in weight when exposed to battery acid, performing better than PA11 in this regard.

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White Paper

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