Chevron

- NEW -

Techron® Protection Plus Fuel System Treatment

for Marine and Powersports & Small Engine

A technical, proof of performance competitive benchmarking deck for sales education purposes.

To order, contact:

- Your Chevron sales representative
- Your Chevron Lubrication Marketer
- Chevron Lubricants Business Center at 1 (800) 822-5823

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Contents

- Commercial insights
- *NEW* Techron Protection Plus line
- Market Segments
- Benchmarking data to support our differentiation

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Commercial insights

Consumers

Typically buy what they know, have been using, what their Dad used, what family or friends tell them to use, or perhaps what's on deal.

They may not necessarily know the effectiveness of the products they are using.

Distributors

They want a trusted brand and company that cuts through the myriad of products with questionable efficacy, supported brands and recurring sales to grow their revenue and profit.

Industry / Trade

The National Marine Manufactures Association (NMMA) and Outdoor Power Equipment Institute (OPEI) have been seeking a specific product profile to fill gaps in current product offerings in the market.

< Solution > Chevron's new **Techron Protection Plus** line

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Techron Protection Plus – **Market Needs**

After extensive market analysis, we recognized a clear and compelling need for a more complete solution to protect marine and small engines in the course of everyday and exceptional use. Chevron set out to develop products that would mitigate the three key sources of fuel-related engine issues:

1. **The Type of Fuel Used**: Most gasolines today contain some percentage of ethanol. Ethanol blended fuel can dissolve almost 50x more water than ethanol-free fuel[1]. Water in the fuel can separate out of fuel and will cause rust or corrosion during a long period of non-use. Additionally, drivability and fuel system component failures are possible, particularly in harsh salt water environments.

2. **The Cycles the Engine Performs**: Marine engines and small engines experience wide variations in engine demand cycles, from wide-open-throttle (WOT) to idle. Constant variation and repetition of these cycles can lead to carbon deposits that affect engine performance, fuel economy and increased emissions.

3. **Seasonal Storage**: Seasonal engines can spend much of the year in storage. Long stretches of non-operation can cause idle fuel in tanks to deteriorate and become unstable.

To protect engines against these types of fuel-related issues, Chevron launched the **Techron® Protection Plus** line targeted to the **Marine, Powersports and Small Engine** market segments.

[1] Chevron Products Company, a division of Chevron U.S.A. Inc., "Gasoline and Driving Performance" in Motor Gasolines Technical Review, San Ramon, CA: Chevron Corporation, 2009, ch.4, p.58

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Techron Protection Plus Line – **Market Needs**

Protection from E0 to E85.

E0 = “Pure gas”
E10 = 10% ethanol
E85 = 85% ethanol

E10 accounts for over 96% of the gasoline supplied in the U.S.

The need is real and current market solutions are not complete

July 18, 2017

A new survey by *Boating Industry* magazine says those in the boating industry that manufacture, sell, repair and store recreational vessels are seeing a growing number of problems caused by ethanol-related fuels.

92% said they have seen damage in their business caused by ethanol. Up from 87% last year and 73% in 2015.

That damage can mean bigger repair bills – and more business for the service department – but the long-term effect may be to drive people out of boating, many respondents said.

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Techron Protection Plus Line – **Industry Needs**

The Marine Industry and the Outdoor Power Equipment Industry were seeking a specific product profile to fill gaps in the current offerings:

- Water Impact: – No Alcohol, No Water Uptake, No Emulsifiers
- Oxidation Stability: – Keep Fuel Fresh Longer, stabilize up to 2 Years
- Corrosion Protection: – Protect engine parts from rust, fresh and salt water
- Deposit Control: – Add detergency to clean up, and keep clean
- Compatibility: – Be compatible with system materials

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Introducing….

Techron Protection Plus

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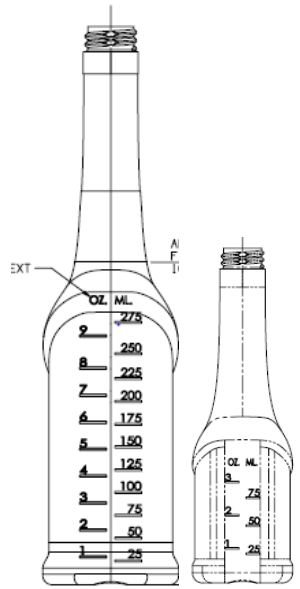
Techron Protection Plus
Marine Fuel System Treatment

1oz treats 10 gallons

Ounce graduations



Product Name	Size	Treats – Gal	Case
Techron® Protection Plus Marine Fuel System Treatment 12/4oz Counter Display	4oz	40	12
Techron® Protection Plus Marine Fuel System Treatment 6/10oz	10oz	100	6
Techron® Protection Plus Marine Fuel System Treatment 4/128oz	128oz	1,280	4

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Neck Tent Graphics

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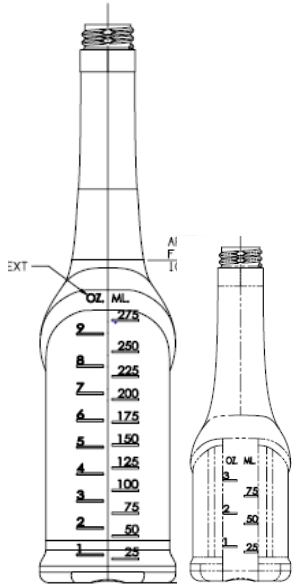
Techron Protection Plus
PowerSports & Small Engine Fuel System Treatment

1oz treats 4 gallons

Ounce graduations



Product Name	Size	Treats - Gal	Case
Techron® Protection Plus Powersports & Small Engine Fuel System Treatment 12/4oz Counter Display	4oz	16	12
Techron® Protection Plus Powersports & Small Engine Fuel System Treatment 6/10oz	10oz	40	6
Techron® Protection Plus Powersports & Small Engine Fuel System Treatment 4/128oz	128oz	512	4

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Techron Technology Serves Many Markets

Complete Fuel System Treatment	Fuel Injector Cleaner	Fuel System Cleaner	Fuel System Treatment		OEM Relationships	
TECHRON CFSC	TECHRON FIC	TECHRON DIESEL	TECHRON Marine	TECHRON PowerSports SE	OEM In-Tank	Induction Cleaners

12oz 20oz 32oz 12oz 20oz 20oz 4oz 10oz 128oz 4oz 10oz 128oz

BMW
Ford
GM
Honda
Infinity
Jaguar
Mazda
Toyota
Hyundai
Mercedes Benz
Mini Cooper
Mitsubishi
Nissan
Porsche
Rolls-Royce
Saab
Chrysler / Dodge / Fiat
Yamaha
VW/Audi

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Market Segments

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Target Market Segments

MARINE (fresh & salt water)	POWERSPORTS & SMALL ENGINE
Recreational Boating	Motorcycle, motocross
Sport/recreational Fishing	ATV/UTV
Recreational Marine Powersport	Dealerships, repair/maintenance shops
Marinas	Landscaping – Commercial/residential
Marine Dealerships - Branded	Forestry
Independent Marine Powersports Dealers	Construction
	Grounds Maintenance
	Portable Power
	Snowmobile
	Snow Removal

retailers | distributors | brokers | dealerships | repair | online

CONSUMERS

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The biggest volume opportunity is in Motorcycles?

Motorcycles can be used with some consistency or used infrequently. Either way, the fuel pump and fuel system need protection from corrosion and assistance keeping the fuel fresh as long as possible. All Motorcycles are a key market. Here are some examples.

Performance/Sport

Cruising

Touring

Classic

Scooter

Motocross

What are Powersports?

Powersports are a subset of the generalized category motorsports. Defining features of any Powersport is the use of an engine, in one form or another, the use of handlebars to control movement and the mounting of the rider "on" the machine, exposed to the elements.

Powersports are the most common vehicles in the X-games.

ATVs

Watercraft

Snowmobiles

UTVs

Scooter

Dune Buggies

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What is the difference between ATV and UTV?

ATVs are (All Terrain Vehicles). They're smaller than a UTV (Utility Task Vehicle) and are usually meant for a single rider. They're recreational and are often used for racing/sports because they're nimble and handle well.

UTVs/side by sides are off-road vehicles that can seat between 2 and 4 people and they're designed for rougher terrain, hauling, and more work horse sort of tasks.

ATVs you straddle like a saddle to ride. UTVs you sit in bench or bucket seats. ATVs steer using a handlebar system. UTVs have a steering wheel similar to a car or truck.

Also:

ORV – Off Road Vehicle

ROV – Recreational Off-Highway Vehicle

OHV – Off-Highway Vehicle

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What is a Small Engine? Outdoor Power Equipment?

A small engine is the general term for a wide range of small-displacement, low-powered (less than 25 hp) internal combustion engines used to power lawn mowers, generators, concrete mixers and many other machines that require independent power sources.

The term outdoor power equipment refers to the types of equipment that are powered by small gasoline engines and that are generally used outdoors. Many different companies manufacture outdoor power equipment.

8.5MM in use

75MM in use

4.0MM in use

1.2MM in use

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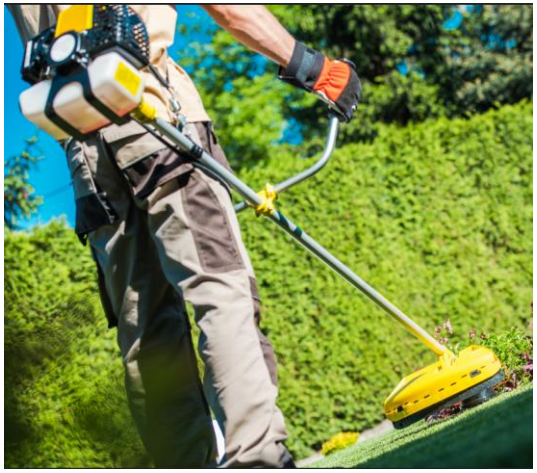
Outdoor Power Equipment



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Outdoor Power Equipment

- Compact Equipment
- Generators
- Pressure Washers
- Pumps
- Trenchers

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Competitive Benchmarking

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Benchmarking Our Performance

Brands

Sta-bil
Lucas Oil
Starbrite
Yamalube
Briggs & Stratton
Biobor EB
Mercury

Measures & Metrics

Performance Criteria	Test Method
Fuel Stability	ASTM D525
Fresh Water Corrosion Resistance	ASTM D665A
Salt Water Corrosion Resistance	ASTM D665B
Amount of Detergent	Evaporative Loss Analysis combined with Nitrogen content measurement (ASTM D5762)
Base Fuel	E10 Pump Fuel

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Benchmark Testing - Methodology

Oxidative Stability

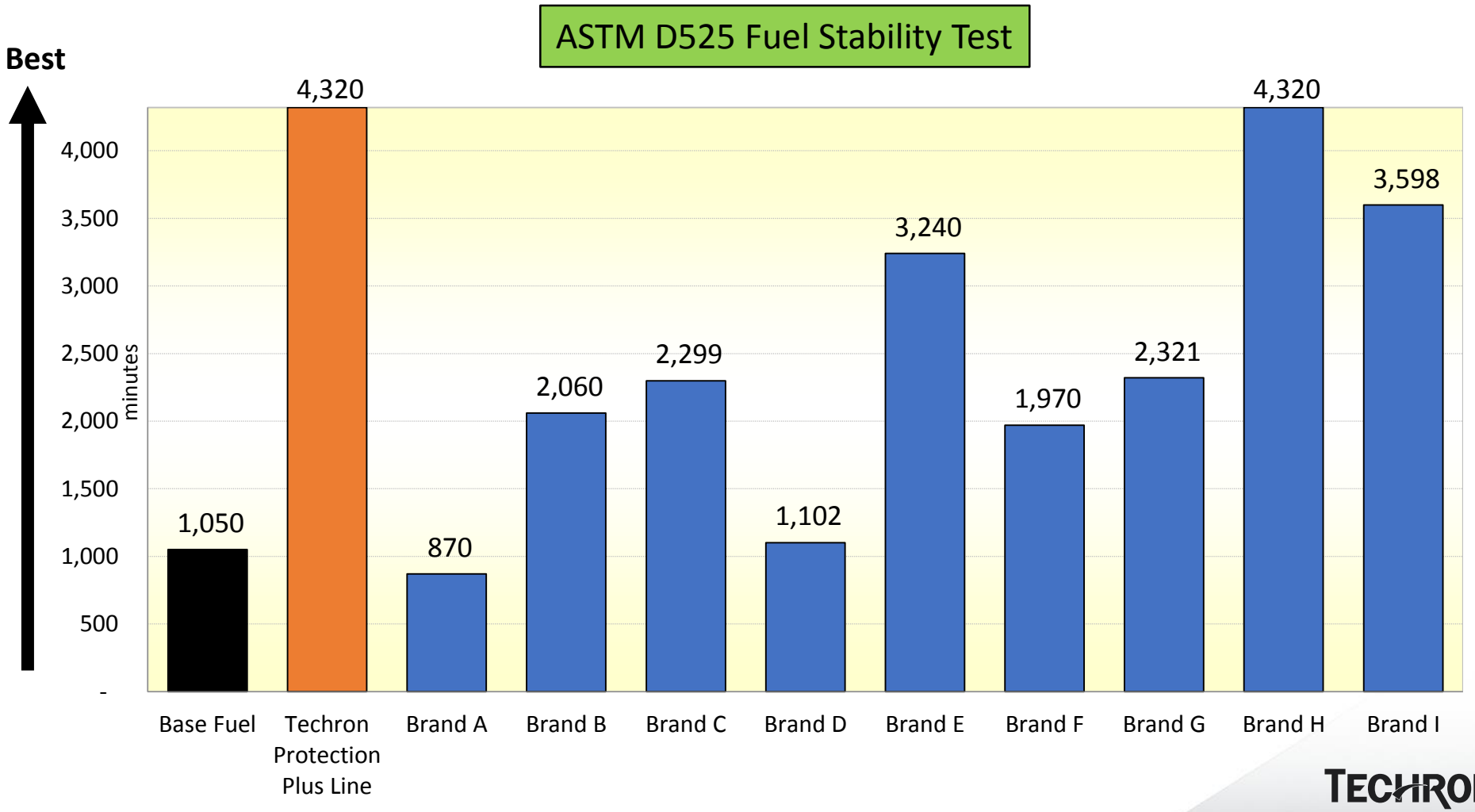
The oxidative stability was determined by exposing fuel dosed with Techron Marine and Techron Powersports & Small Engine to accelerated oxidation conditions in an enclosed chamber and recording the time the pressure drops 14 kPa(kilopascal) in 15 minutes. The longer it took for the pressure to drop by 14 kPa in 15 minutes, the more the material was resistant to oxidation. The test ends in 4,320 minutes if the pressure drop is not observed, and 4,320 minutes would be recorded for a material that has maximum oxidative stability. Both products showed improve performance over the base fuel and maximum oxidative stability.

Corrosion Inhibition

The corrosion inhibition of Techron Marine and Techron Powersports & Small Engine was determined by using ASTM D665. In this method, steel rods were rated for rust after four hours of exposure to a mixture of treated fuel and distilled or sea water at 38°C (100°F). For ASTM D665_A, solutions of Techron Marine and Techron Powersports & Small Engine were prepared in depolarized isooctane at the recommended treat rate and tested in distilled water. For ASTM D665_B, solutions of Techron Marine and Techron Powersports & Small Engine were prepared in a market fuel at the recommended treat rate and tested in sea water. Both depolarized isooctane and the market fuel were selected because they exhibit poor corrosion inhibition. Techron Marine and Techron Powersports & Small Engine showed maximum corrosion inhibition for each test.

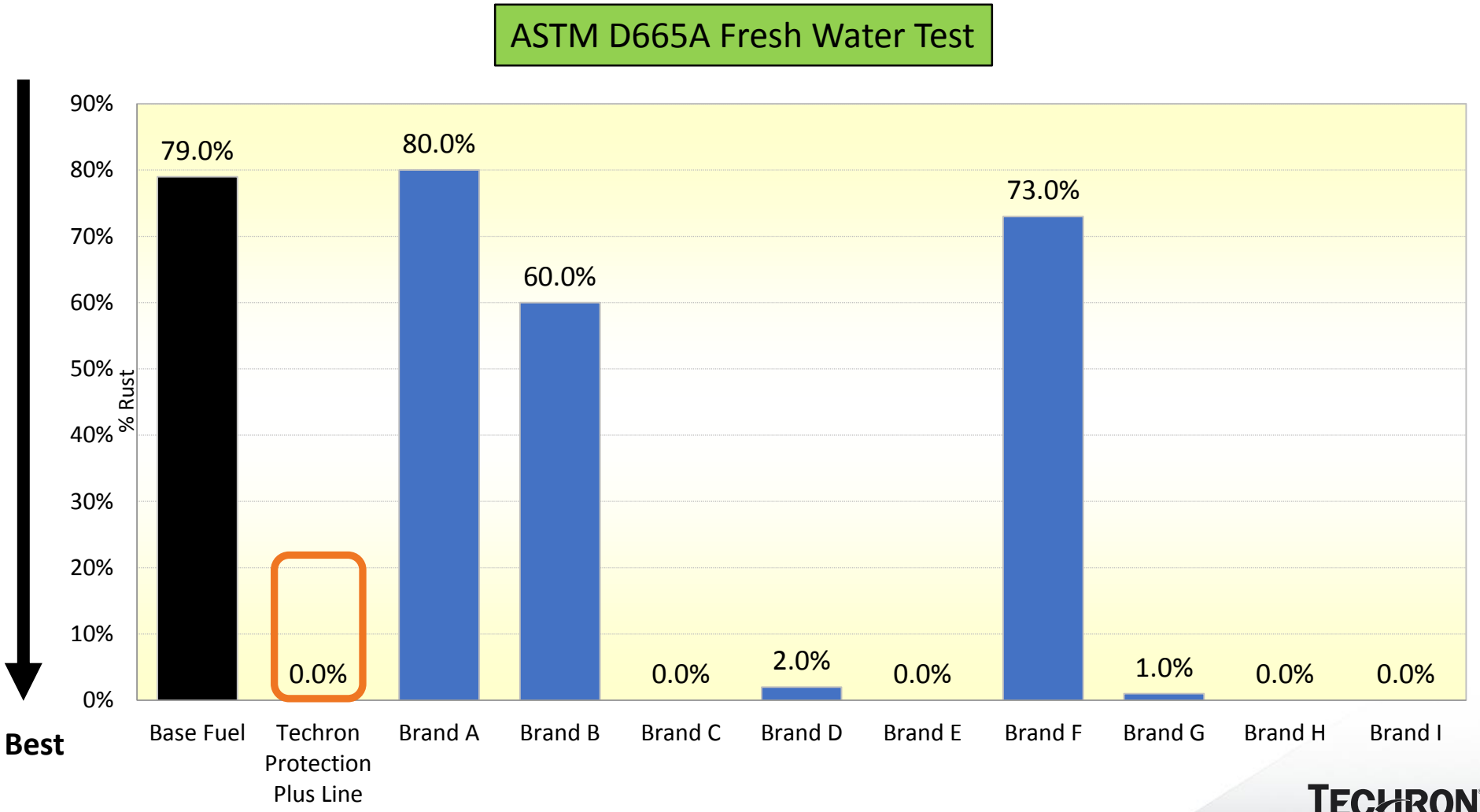
Maximum Fuel Stability

Techron Protection Plus line achieves the maximum result at 72 hours (4,320 minutes), proving maximum oxidation stability in this test.



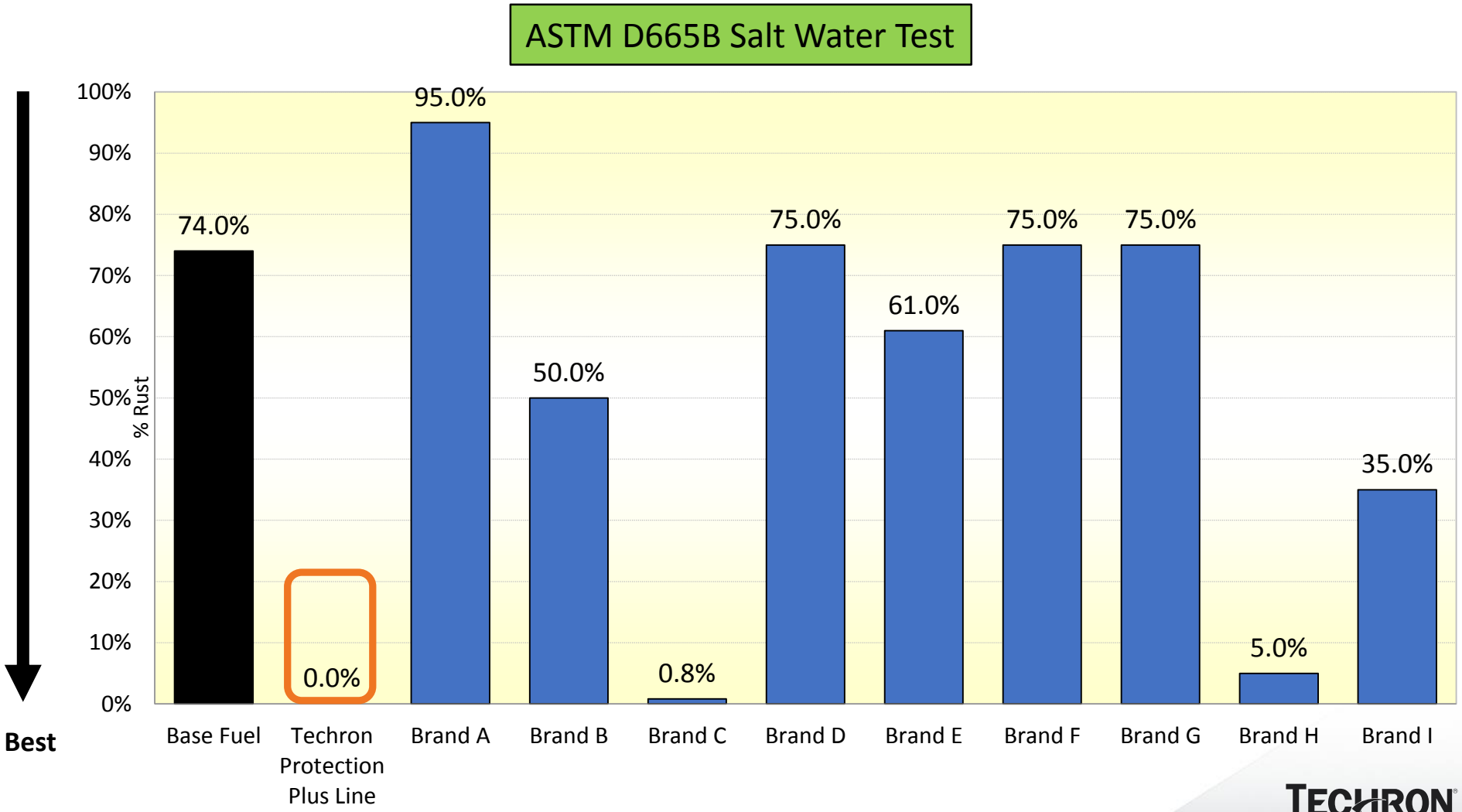
Fresh Water Corrosion Protection: 0% Rust

Techron Protection Plus line prevents any rust from forming when measured in fresh water in this test.



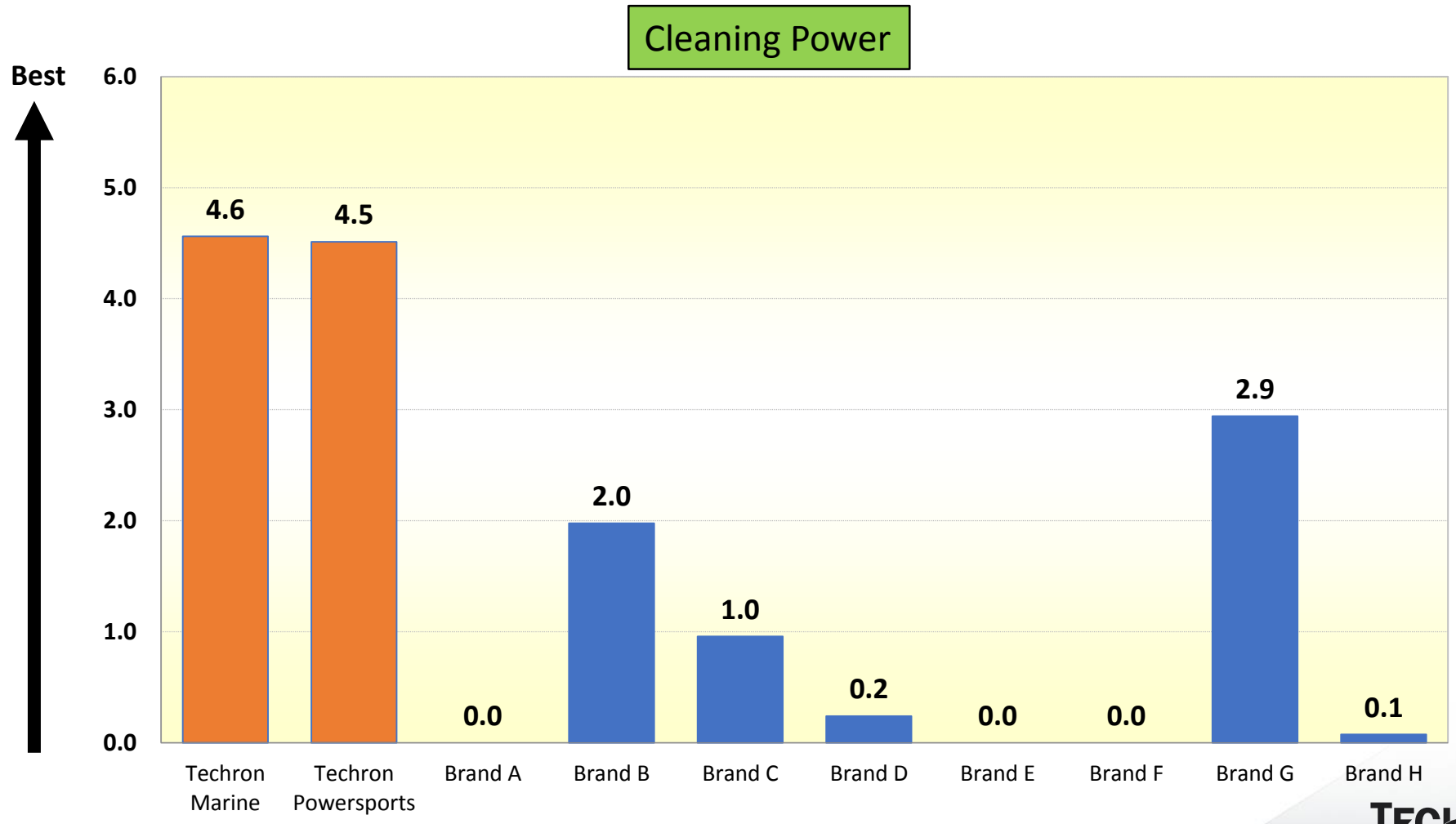
Salt Water Corrosion Protection: 0% Rust

Techron Protection Plus line prevents any rust from forming when measured in salt water in this test.



Detergency: Cleaning Power to Clean up and Keep Clean

To visualize the Cleaning Power of the Techron Protection Plus line, we employed the following formula: *(ppmv*% nitrogen*% non-volatile materials/quantity of fuel treated)*



Elastomer Stability Testing

The Techron Protection Plus line shows full compatibility with polymers used in fuel systems and engines in this test.

ASTM D471 Standard Test Method for Rubber Property—Effect of Liquids

TEST	Description	Measurement	Base Fluid * (No Additive)	Result (w/Techron additive)
Techron Protection Plus Line **ASTM D471**	HNBR-1 70 hours at 23 °C	% Volume Change	+40%	+38%
		Hardness	-14%	-13%
		Tensile Strength	-58%	-59%
		% Elongation	-48%	-49%
	FKM type 1 70 hours at 23 °C	% Volume Change	+2%	+2%
		Hardness	-2%	-3%
		Tensile Strength	-22%	-22%
		% Elongation	-4%	-12%

* Base fluid = E10 gasoline

Result = close material performance

FKM-1 = Viton fluorinated elastomer

Type 1 FKM are fluorocarbon copolymers based on vinylidene fluoride and hexapropylene fluoride. General purpose seals for aerospace fuel and automotive applications

HNBR-1 = Hydrogenated Nitrile Butadiene Rubber

HNBR is widely known for its physical strength and retention of properties after long-term exposure to heat, oil, and chemicals. The unique properties attributed to HNBR have resulted in wide adoption of HNBR in automotive, industrial, and assorted, performance-demanding applications.

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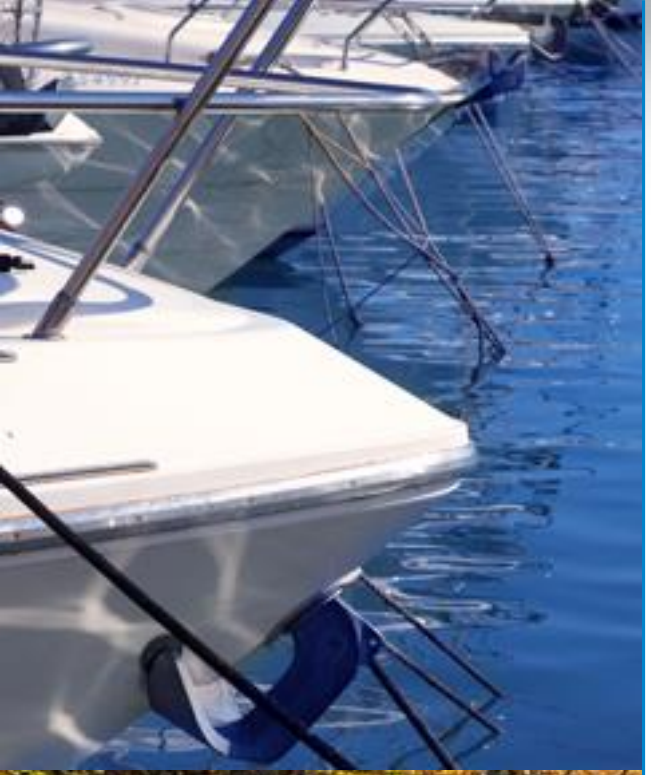

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Appendix

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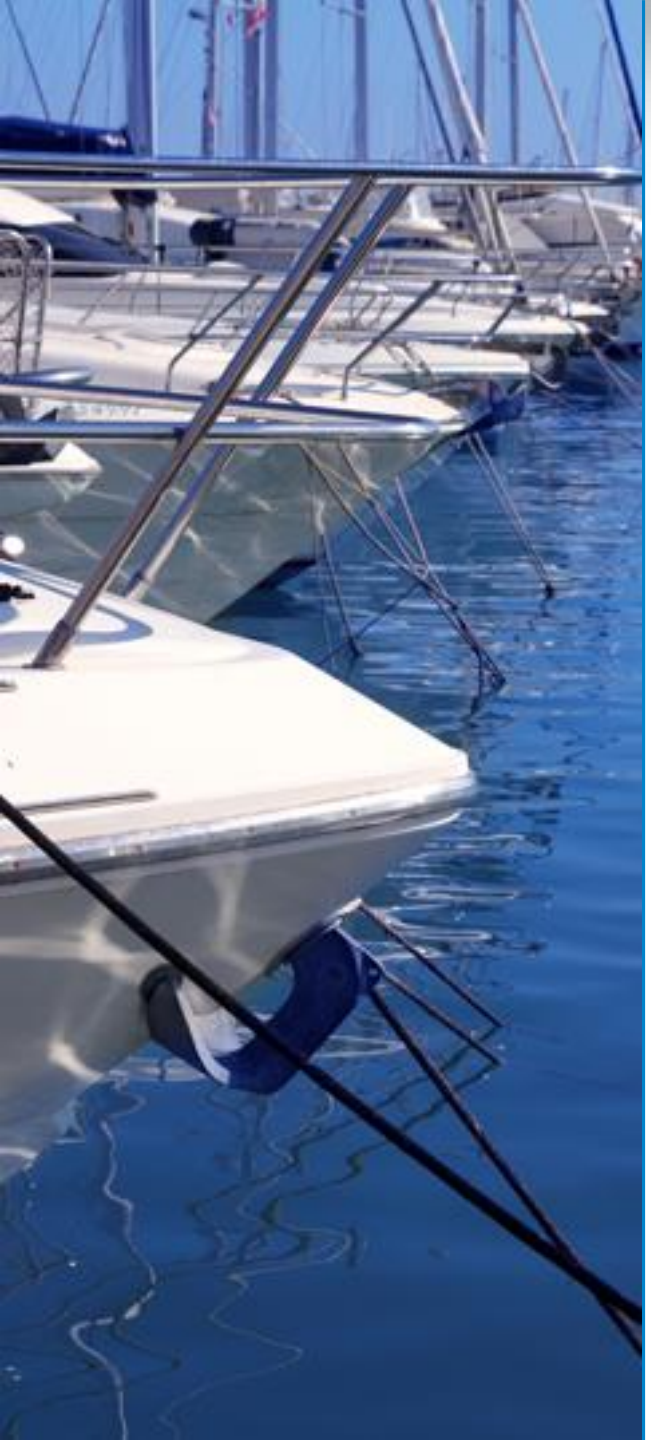

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Techron Protection Plus Line

Technical Performance and Methodology

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Performance Summary

Harmful engine deposits naturally build up over time degrading fuel economy, power, drivability and other performance attributes.

Techron Marine and Techron Powersports & Small Engine Fuel System Treatments are formulated with a unique combination of chemistries to provide outstanding performance. **Performance data includes bench tests, dynamometer engine testing, and field trials to mimic real-life performance.** This data set also includes outstanding performance in newer engine designs like gasoline direct injection (GDI).

Benefits	Marine	Powersports Small Engine
Alcohol and Emulsifier Free	✓	✓
No Water Uptake	✓	✓
Stabilizes Fuel	✓	✓
Prevents Corrosion	✓	✓
Detergency Keep Clean	✓	✓
Detergency Clean Up	✓	✓
Restores Fuel Economy	✓	✓
Maintains Power and Performance	✓	✓
Ensures Easy Starting	✓	✓
Full Material Compatibility	✓	✓

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Small Engine Two-Stroke Engine Cleanliness

Benefits of a premium fuel additive

- Keeps the piston and cylinder wall clean
- Maintains acceleration (full speed at wide-open-throttle)
- Provide a “like new” feel for the end user

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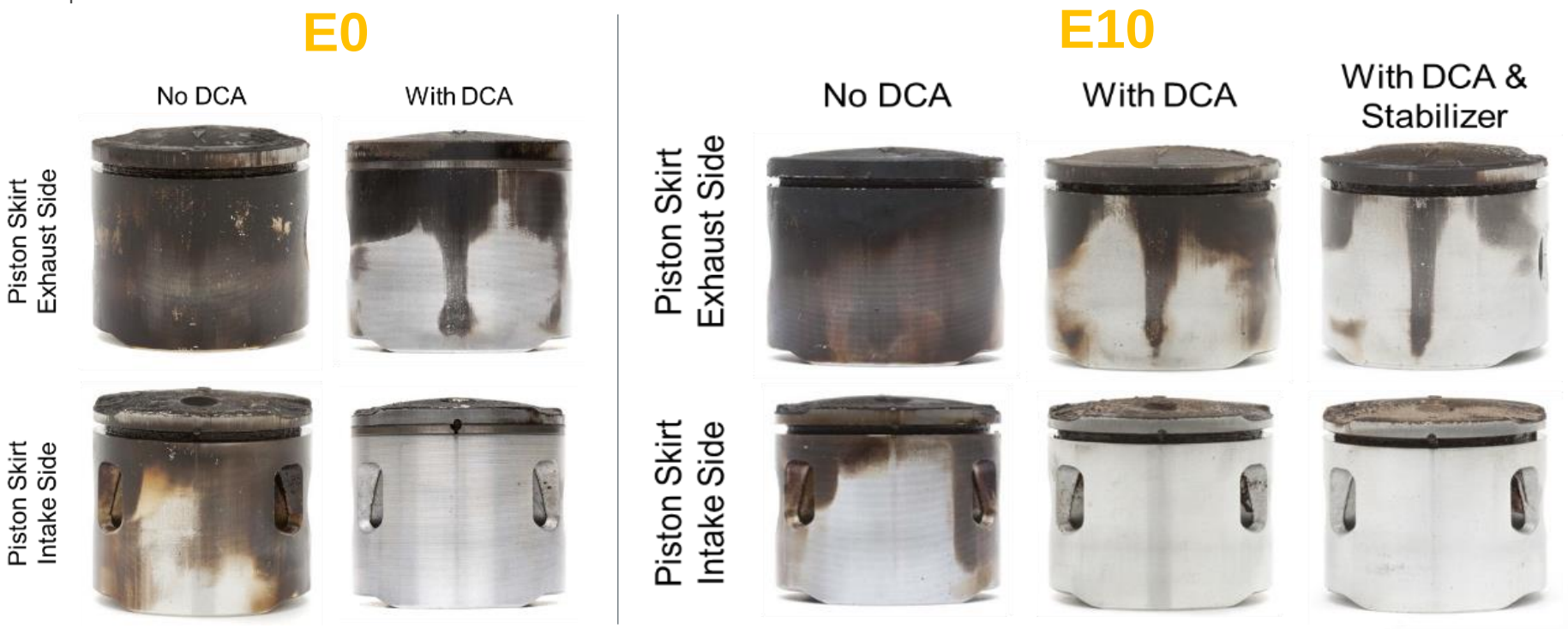
Small Engine - Piston Intake and Exhaust Rating

Use of premium fuel additives in 2-stroke engines was shown to provide a statistically significant difference in piston deposit formation. Improvement in acceleration data was also observed in the highly additized fuels when comparing wide-open-throttle data[1].

In general it is observed that the varnish is higher on the exhaust side of the piston versus the intake side (below). This effect is due to the increased heat associated with the exhaust port handling the post-combustion gases[2].

These figures illustrate how dramatic the difference is between the base fuel and additized fuel testing.

DCA = Deposit Control Additive



[1] Two-Stroke Engine Cleanliness via a Fuel Additive, SAE International, 2016-32-0048, Published 11/08/2016
- example pictures from SAE paper 2016-32-0048

[2] Yashiro, Y., "Reduction of Exhaust Smoke & Carbon Deposit at Exhaust Port in Two-Stroke Gasoline Engines" SAE Technical Paper 871216, 1987.

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Fuel injectors

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Injector Fouling and Cleanup Methodology

Background:
The US Environmental Protection Agency (EPA) and also the California Air Resources Board (CARB) have assigned a PFI (Port Fuel Injection) injector test to be required for gasoline additive qualification. The injector test method used is ASTM D5598, which was developed by CRC in conjunction with CARB, uses a Chrysler vehicle with a specified 2.2L engine. The vehicles must include the following properties: 1985-1987 Chrysler, 2.2L, 4 cylinder, turbocharged engine, and PFI.

Dirty-Up - PFI:
The cycle warms up the engine to its peak operating temperature. Fifteen minutes at 55 mph gets the engine to its operating temperature. The hot soak for 45 minutes then allows the engine to cool completely. This cycle is repeated until 10,000 miles on a test track or road is reached.

Clean-Up - PFI:
For the clean-up testing, the same ASTM D5598 driving cycle was adapted to be used with other vehicles for different amounts of mileage accumulation. The driving cycle was followed for about 2,000-3,500 miles on base fuel until the injectors showed significant evidence of deposit formation, and then the driving cycle was followed again on fuel additized with detergent levels found in Techron Marine and Techron Powersports & Small Engine. The EPA dictates that for the test to be considered a pass, all injectors must have at least 95 percent flow remaining. Before, after, and at various intervals during the test, the fuel injectors are removed and statically flow tested.

Clean-Up – Gasoline Direct Injection (GDI):
The same drive cycle in ASTM D5598 test method described for the PFI testing was also used for GDI testing. The 2.2L Chrysler specified in the ASTM D5598 test method is a PFI vehicle, so the test procedure was modified to be used with GDI vehicles. The test procedure was adapted to be used for clean-up testing, as the driving cycle was followed for 2,500 miles on base fuel to simulate real world deposit accumulation, and then run on fuel additized with the same amount of detergent as Techron Marine and Techron Powersports & Small Engine. At the start, completion, and various intervals during the test, the fuel injectors are removed, and the flow restriction is measured using a testing apparatus.

Injector Fouling and Power Consequences

One of the critical components of the fuel system, and a component vital to operation of a gasoline combustion engine, is the fuel injector. As injectors modernized, nozzle holes have increased, in number, and decreased in size. Decreasing the size of the injector nozzle holes decreases the droplet size formed when injected, thus improving the atomization and combustion. However, smaller holes are also more susceptible to being fouled by injector deposits. Shown below are several different director plates with different size and number of holes.

It is believed that the formation of these injector deposits starts with the oxidation of hydrocarbons, which may polymerize to form gums that stick to injector surfaces. Deposits are further formed and accumulate due to other sources such as particulates, exhaust gas recirculation, valve overlap, and other airborne materials, as well as being accelerated by engine heat soak-back.[1] **Deposit build-up on the nozzles and pintles of injectors can restrict the flow of fuel, which will reduce the volume of fuel injected for combustion, and thus reduce power.**

[1] K. Owen and T. Coley, "Influence of Gasoline Composition on Storage Stability and Engine Deposit Formation", ch.8, sec.3, pp.207-210.

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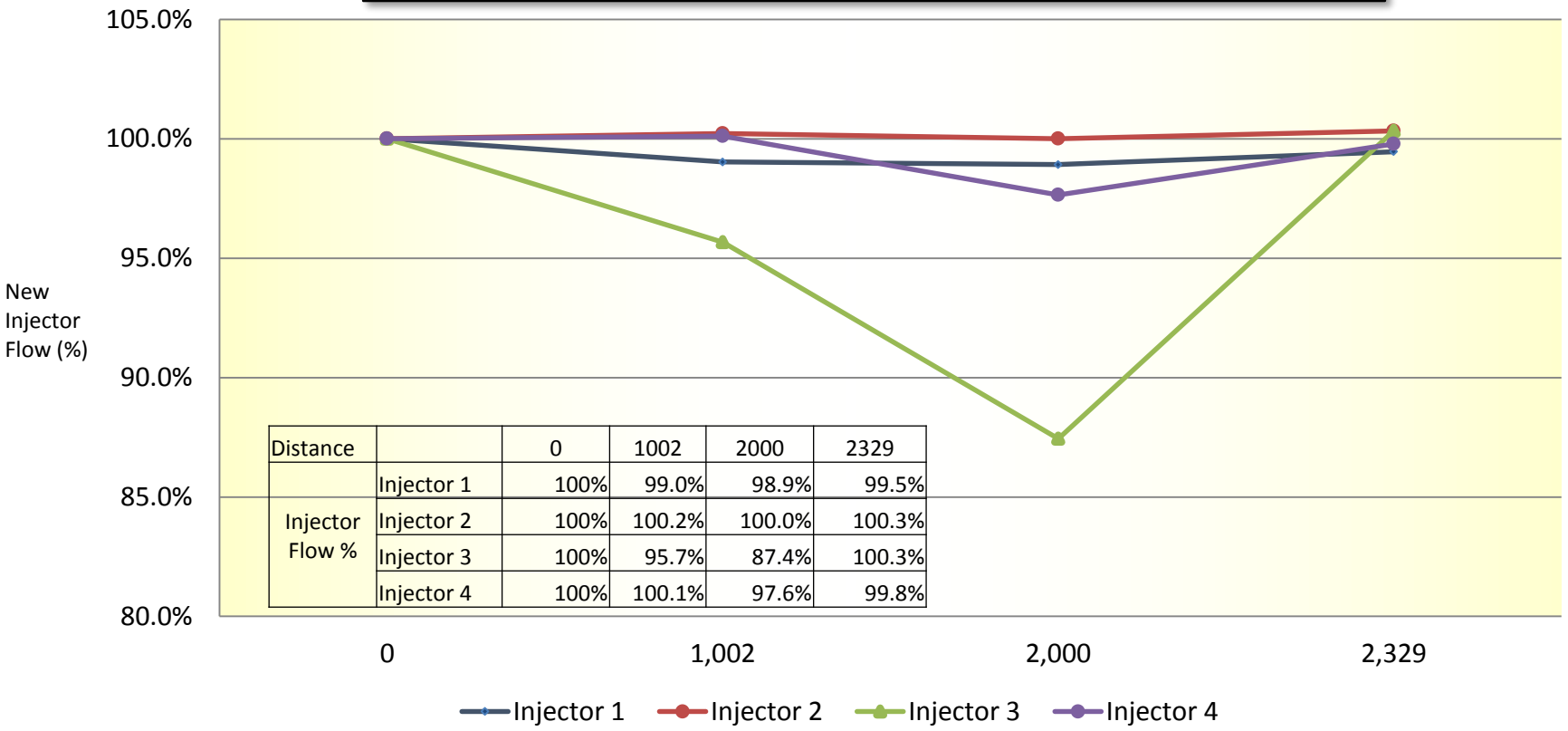
Port Fuel Injector (PFI) Cleanup Test
Chrysler 2.2L

Test Cycle: ASTM D5598 Driving Cycle
Engine: Chrysler 2.2L Tc, I-4, w/ MPFI
Duration: Buildup: 2,000 Miles, Cleanup: 329 Miles



Distance		0	1002	2000	2329
Injector Flow %	Injector 1	100%	99.0%	98.9%	99.5%
	Injector 2	100%	100.2%	100.0%	100.3%
	Injector 3	100%	95.7%	87.4%	100.3%
	Injector 4	100%	100.1%	97.6%	99.8%

Use of deposit control technology found in Techron Protection Plus line led to nearly 100% injector flow restoration in this test.

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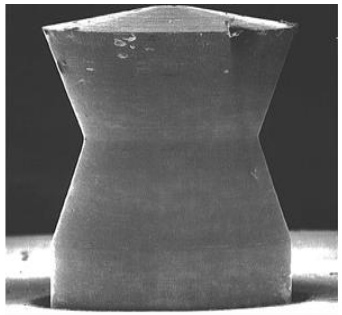
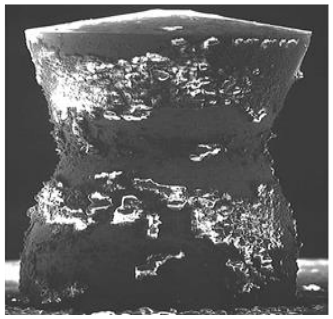
Port Fuel Injector (PFI) Cleanup Test
Chrysler 2.2L

Test Cycle: ASTM D5598 Driving Cycle
Engine: Chrysler 2.2L Tc, I-4, w/ MPFI
Duration: Buildup: 999 Miles, Cleanup: 1,005 Miles

Clean/Unrestricted



Dirty/Restricted



The two pairs of photographs above represent a clean injector flow pattern and tip (top) and the corresponding images when injector flow is restricted by 25% (bottom). The dirtiest injector when buildup was complete on the three tank cleanup test was 21% flow restricted. All of the dirty injectors cleaned up to within 1% of the original 100% flow, In this test, when using similar detergent levels as Techron Protection Plus Line.

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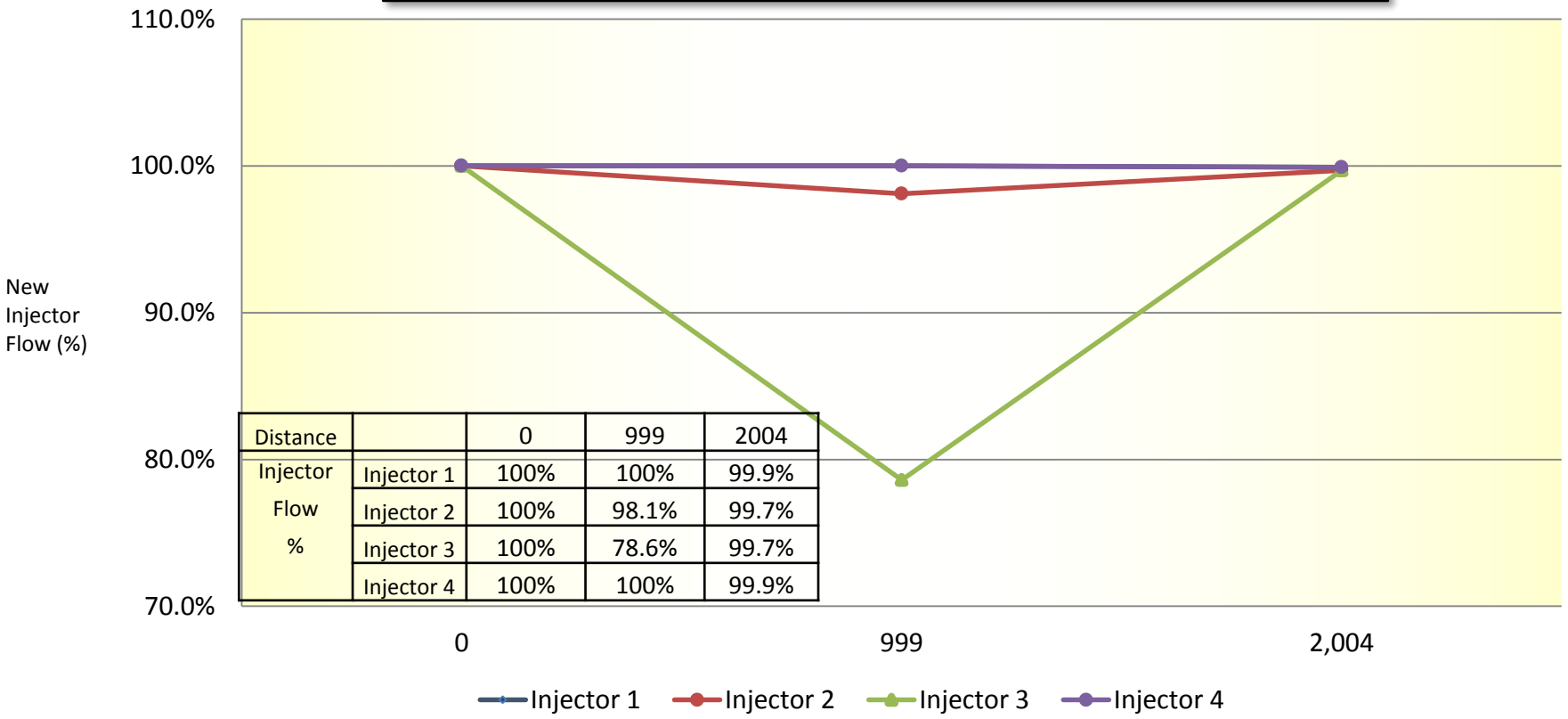
Port Fuel Injector (PFI) Cleanup Test
Chrysler 2.2L

Test Cycle: ASTM D5598 Driving Cycle
Engine: Chrysler 2.2L Tc, I-4, w/ MPFI
Duration: Buildup: 999 Miles, Cleanup: 1,005 Miles



Distance		0	999	2004
Injector Flow %	Injector 1	100%	100%	99.9%
	Injector 2	100%	98.1%	99.7%
	Injector 3	100%	78.6%	99.7%
	Injector 4	100%	100%	99.9%

Use of deposit control technology found in Techron Protection Plus line led to nearly 100% injector flow restoration in this test.

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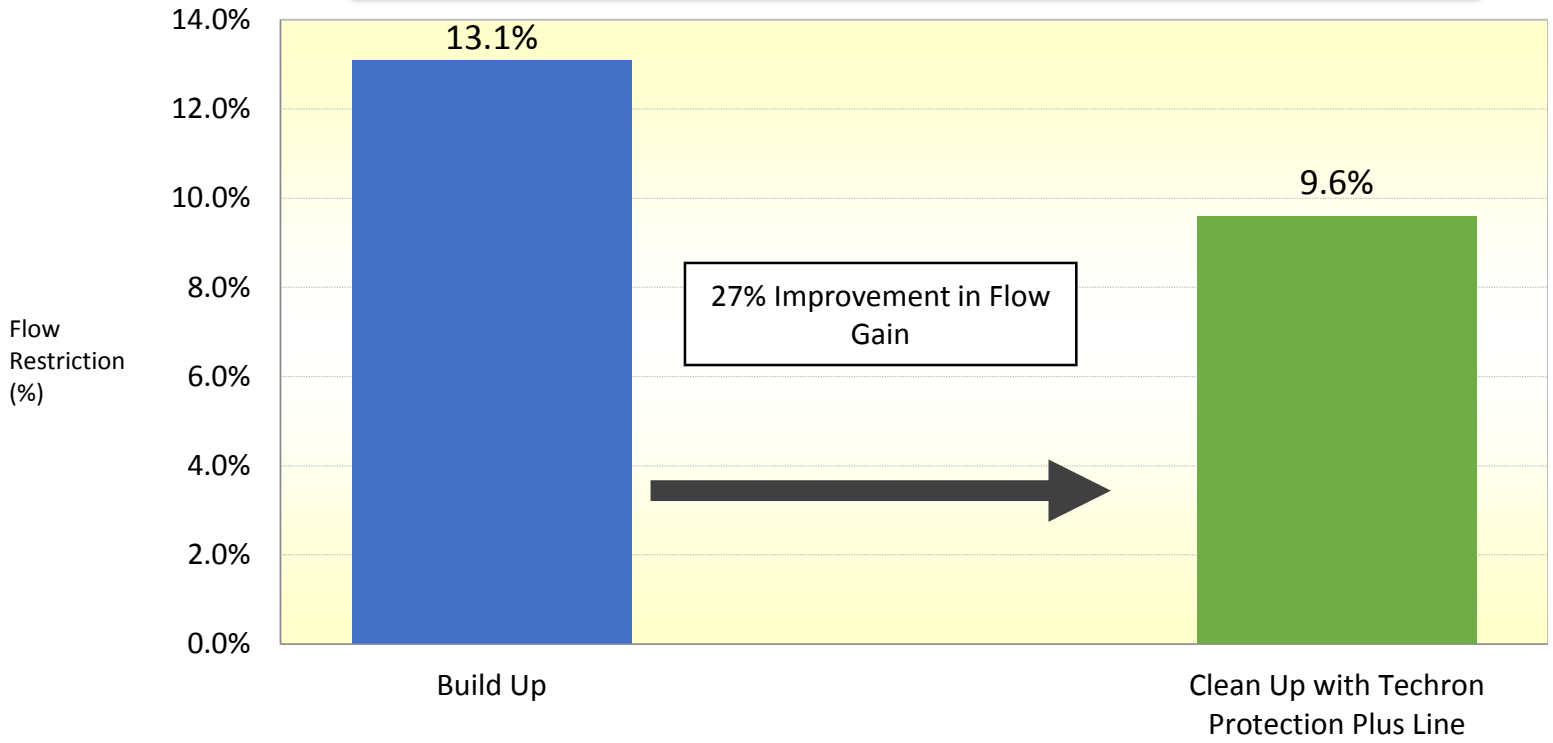
Gasoline Direct Injection (GDI) - Injector Clean Up Test
Mitsubishi 1.8L GDI

Test Cycle: ASTM D5598 Type
Engine: 1.8L Mitsubishi GDI
Duration: Buildup: 2,500 Miles, Cleanup: 2,500 Miles



The use of deposit control technology found in the Techron Protection Plus Line products resulted in the reduction of injector fouling from 13.1% to 9.6% in this test.

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Intake Valves

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Intake Valve Deposit Testing

Background:

Intake valves are one of the components critical to the operation of gasoline combustion engines. In port fuel injected (PFI) engines the intake valve allows the mixture of fuel and air to be introduced into the combustion chamber; however, in GDI engines the intake valve only controls the air that is drawn or forced into the cylinder. **Before the combustion event occurs, the valve must close and seal the cylinder in order to prevent lost energy (power). The cleanliness of the valves is paramount in order to maintain the correct intake flow past the valves and allow the valves to close properly.**

Deposits can form and accumulate on intake valves, and these deposits often can build up to the point where engine operation and performance is adversely affected. A number of variables, such as fuel type, fuel additives, lubricants, engine design, valve temperature, and others contribute to the amount and nature of these deposits.

In GDI engines the fuel is injected directly into the combustion chamber, so the fuel bypasses the intake valves and the atomized fuel does not pass through the intake ports. Even though fuel is not being sprayed onto the intake valves, deposits still accumulate due to a number of factors such as oil from the valve stem, engine heat soak-back, particulates, valve overlap, exhaust gas recirculation, and others. Consequently, the deposits formed in GDI engines tend to be of a different nature and have a tendency to form more on the valve stem, while the deposits formed in PFI engines have a tendency to form further down on valve at the neck and closer to face. Furthermore, since the fuel is not sprayed directly onto the valves, or the accumulated deposits on those valves, fuel additives tend to be more effective in removing deposits in PFI engines than in GDI engines.

Investigation has shown that intake valve deposits form as either soft and sticky deposits, or hard and brittle deposits. Additionally, increased amounts of alcohol in fuels also leads to an increased rate of intake valve deposits.[3] It has been shown that intake valves deposits adversely affect driveability and exhaust emissions by absorbing hydrocarbons as liquids and upsetting the air/fuel ratio. Hard and brittle deposits can break free and interfere with valve seating, or become lodged in the ring belt or between the piston crown and valves or cylinder head. The interference from these deposits can result in power loss and valve burning. Soft, sticky deposits can end up on the valve stem, which then can harden and cause failure and engine damage.[4] **It has been proven that the correct type and dosage of fuel additives can effectively remove and prevent the formation and accumulation of these harmful intake valve deposits.**

[3] B. Bitting, et al., "Intake Valve Deposits – Fuel Detergency Requirements Revisited," SAE Paper No. 872117, 1987.
[4] K. Owen and T. Coley, "Influence of Gasoline Composition on Storage Stability and Engine Deposit Formation" in Automotive Fuels Reference Book, 2nd ed. Warrendale, PA: SAE, 1995, ch.8, sec.3, pp.210-212.

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Intake Valve Deposit Test Methodology

Methodology:

In the 1990's the US EPA decided to use the ASTM D5500 test method, using the 1985 BMW 318i, as a standard for examining the propensity of a fuel to form deposits on the intake valves. The vehicle includes the following properties: 1985 BMW 318i, 1.8 Liter, 4-cylinder engine, PFI, Single overhead camshaft (SOHC), automatic transmission, and air conditioning. The cycle developed for this method uses a combination of city, suburban and highway driving speeds shown in Table 1.

Table 1. ASTM D5500 Driving Cycles[5]

Mode	Ave Speed (mph)	%
City	25	10
Suburban	36	20
Highway	55	70

This test cycle is followed with the vehicle running on additized base fuel until the vehicle accumulates 10,000 miles. Before, after, and periodically during the test the intake valves are removed and weighed to determine the mass of the deposits that have accumulated or been removed. Depending on the amount of deposits remaining, the test run is declared a fail or a pass.

The ASTM D5500 method can be used to determine the continual deposit control effect of additives, but it was not designed to measure deposit clean-up in a one or multiple tank applications. We have adapted the ASTM D5500 driving cycle to be used to test other vehicles at different amounts of mileage accumulation. The same driving cycle shown in Table 1 is used to simulate the real world conditions that build up deposits using the base fuel, and then the vehicle is run on fuel additized with the same level of detergency as Techron Marine and Techron Powersports & Small Engine for a given distance. Periodically the intake valves are removed and weighed to determine the clean-up performance.

FORD IVD Keep Clean Test

The FORD IVD Engine Test, modeled after ASTM D 6201, is a dynamometer test used to evaluate the tendency of a gasoline to form intake valve deposits. The engine is operated on a two-phase cycle simulating variable city/highway driving to form intake valve deposits. The test is first run with a specially blended base fuel in order to ensure the minimum severity requirement are met, greater than 500 mg/valve deposits. New valves are then installed and the test is run with additive in the same test fuel.

[5] ASTM Standard D5500, 98 (2008). "Standard Test Method for Vehicle Evaluation of Unleaded Automotive Spark-Ignition Engine Fuel for Intake Valve Deposit Formation," ASTM International, West Conshohocken, PA, 2003, DOI: 10.1520/D5500-98R08, www.astm.org.

Injector Fouling and Cleanup Methodology

On the left, in Figure below, shows an example of dirty intake valves that have a buildup of deposits in both PFI and GDI engines. On the right, it shows examples of intake valves that have been cleaned with additized fuel.

Engine Design	Dirty Intake Valve	Cleaned Intake Valve
PFI		
GDI		

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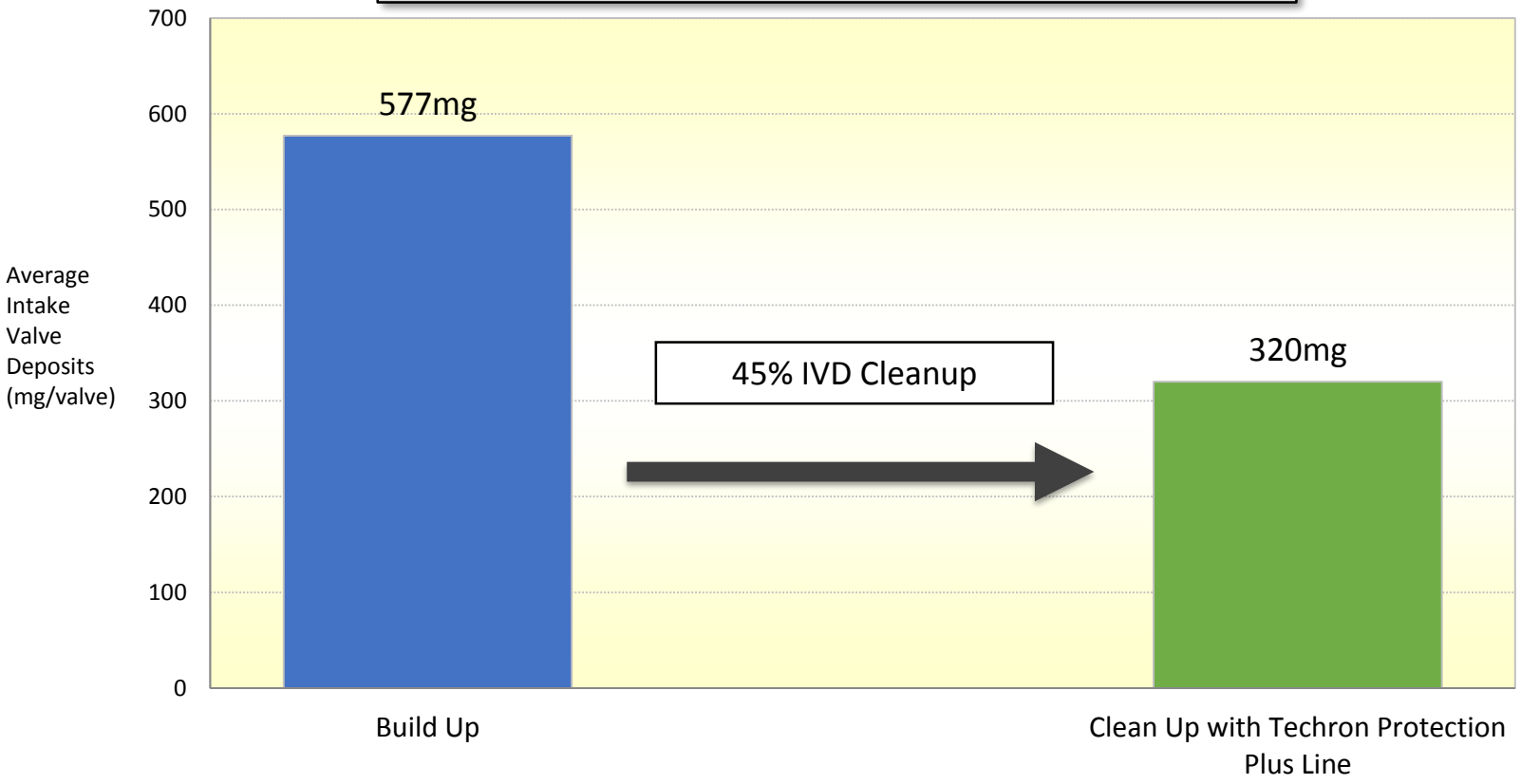
Intake Valve Deposit (IVD) Cleanup Test
Ford 2.3L Ranger

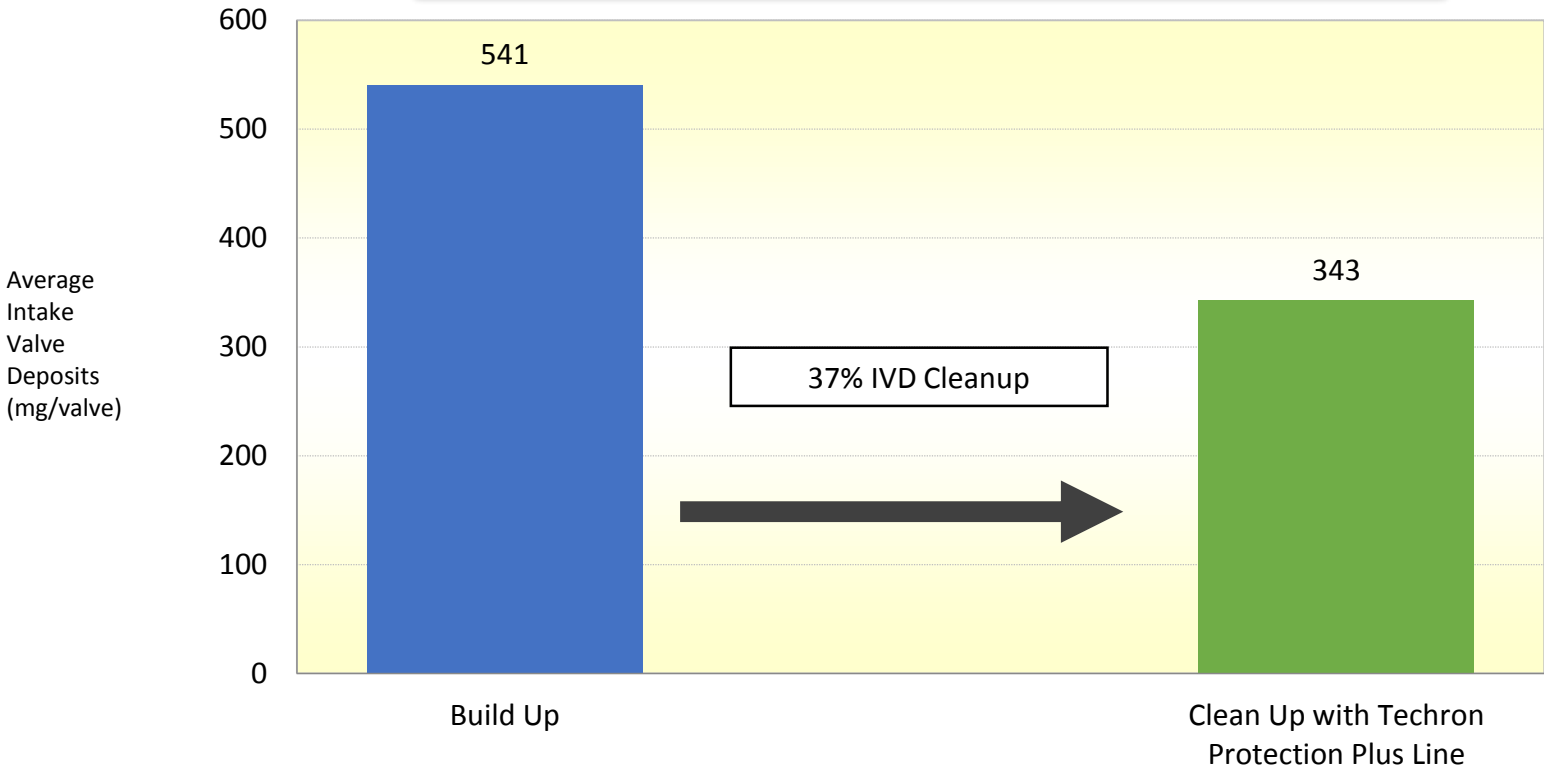
Test Cycle: Motored Dyno D5500 Type Road Simulation Cycle
Engine: 2.3L, V-4 w/MPFI
Duration: Buildup: 12,500 Miles, Cleanup: 3,500 Miles



Use of detergents levels found in the Techron Protection Plus Line led to 45% IVD Cleanup in this test.

Intake Valve Deposit Cleanup Test
Ford 2.3L Ranger

Test Cycle: ASTM D6201
Engine: 2.3L, 4 Cylinder w/MPFI
Duration: Buildup: 50 hours, Cleanup: 50 hours



Use of detergents levels found in the Techron Protection Plus Line led to 37% IVD Cleanup in this test.

Chevron

Combustion Chamber

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Combustion Chamber Deposits

Background:

Combustion chamber deposits have a number of negative effects on engine operation and performance. Fuel type, fuel additives, fuel to air mixture ratio, lubricant, coolant temperature, engine design, and operation all contribute to the amount and composition of combustion chamber deposits.

Investigations on combustion chamber deposits have shown that they consist of carbonaceous and inorganic parts, and these deposits form from the combustion of the fuel as well as lubricants which enter the combustion chamber. The heavy ends of the gasoline, such as polycyclic aromatics, can be difficult to combust and partial combustion will lead to the formation of carbonaceous deposits. One common effect, considered the most important effect, of combustion chamber deposits is the increase in the octane requirements. The octane requirement typically will increase between two and 10 numbers over new engines. This increase in octane requirement arises from the insulating effect and the increase of compression ratio as a result of the presence of deposits in the combustion chamber.[6]

This insulating effect will also increase the levels of NOx emissions due to the increased temperature. Additionally, these deposits can lead to spark plug fouling and misfire. If combustion chamber deposits heat up and glow, they can become potential ignition sources and cause surface ignition.[7] Partially burnt hydrocarbons can also be introduced into the lubricant and form sludge in the crankcase and other areas. Valve overlap and exhaust gas recirculation in some engines also lead to these partially burned hydrocarbons appearing in the fuel intake system, and can increase the amount of deposits. [8] Significant build-up of these deposits on the piston top in engines with small squish clearances can also lead to combustion chamber deposit interference, which is when there is physical contact between the deposits on the piston top and the cylinder head, and results in loud metallic banging noise.[9] These deposits can also flake off and potentially interfere with the proper seating of valves, resulting in low compression pressures.[10]

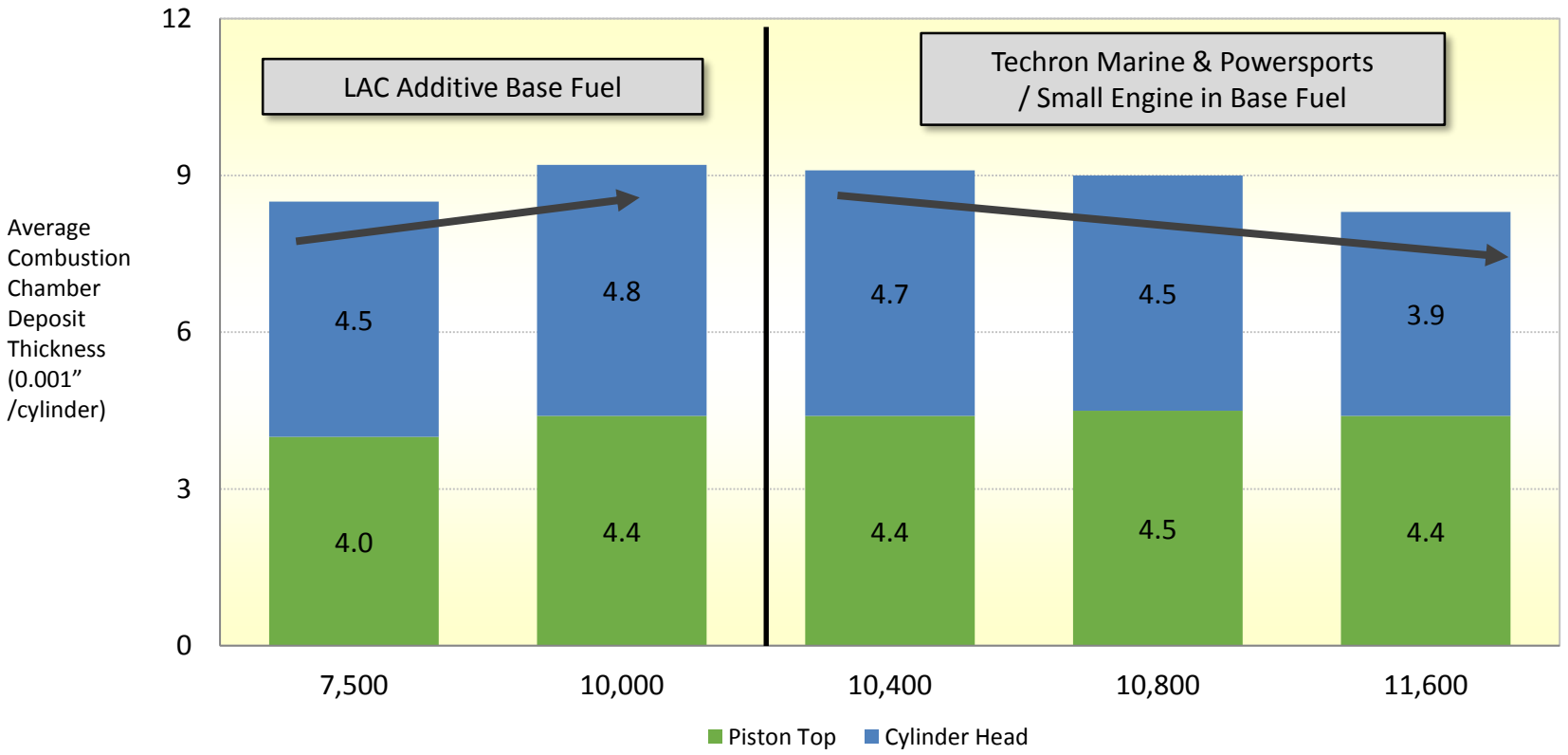
Methodology:

The test procedure used to determine CCD clean-up is the same test procedure used for IVD testing. The ASTM D5500 is adapted for the accumulation and clean-up of CCD. The driving cycle outlined in Table 1 is followed for 1,200 to 2,500 miles until significant evidence of deposit formation is present, and then the cycle is followed for about an additional tank of fuel which is additized with the same level of detergency as Techron Marine and Techron Powersports & Small Engine. At the beginning, end, and throughout the test, the CCD thickness is measured using a Fischer Permascope.

[6] K. Owen and T. Coley, “Gasoline Combustion” in *Automotive Fuels Reference Book*, 2nd ed. Warrendale, PA: SAE, 1995, ch.6, sec.7, pp.135-13.
[7] Chevron Corporation (Staff of Chevron Products Company Div.), “Gasoline and Driving Performance” in *Motor Gasolines Technical Review*, San Ramon, CA: Chevron Corporation, 2009, ch.1, pp.6
[8] K. Owen and T. Coley, “Gasoline Volatility”, ch.7, sec.8, pp.191-192.
[9] K. Owen and T. Coley, “Influence of Gasoline Composition on Storage Stability and Engine Deposit Formation”, ch.8, sec.3, pp.214-215.
[10] Chevron Corporation (Staff of Chevron Products Company Div.), “Gasoline Vehicles – Deposit Control”, ch.6, pp.79

Combustion Chamber Deposits (CCD)

Buildup: 12.5K Miles – Base w/Lowest Additive Concentration (LAC) Additive
Cleanup: 1.2K Miles – Techron Marine & Powersports / Small Engine in Base w/LAC Additive



In the GM 4.3L Sierra truck, average combustion chamber deposits were measured. The data above shows a trend of gradual combustion chamber deposit cleanup with the continued use of Techron Marine and Powersports / Small Engine at the recommended dose rates in this test.

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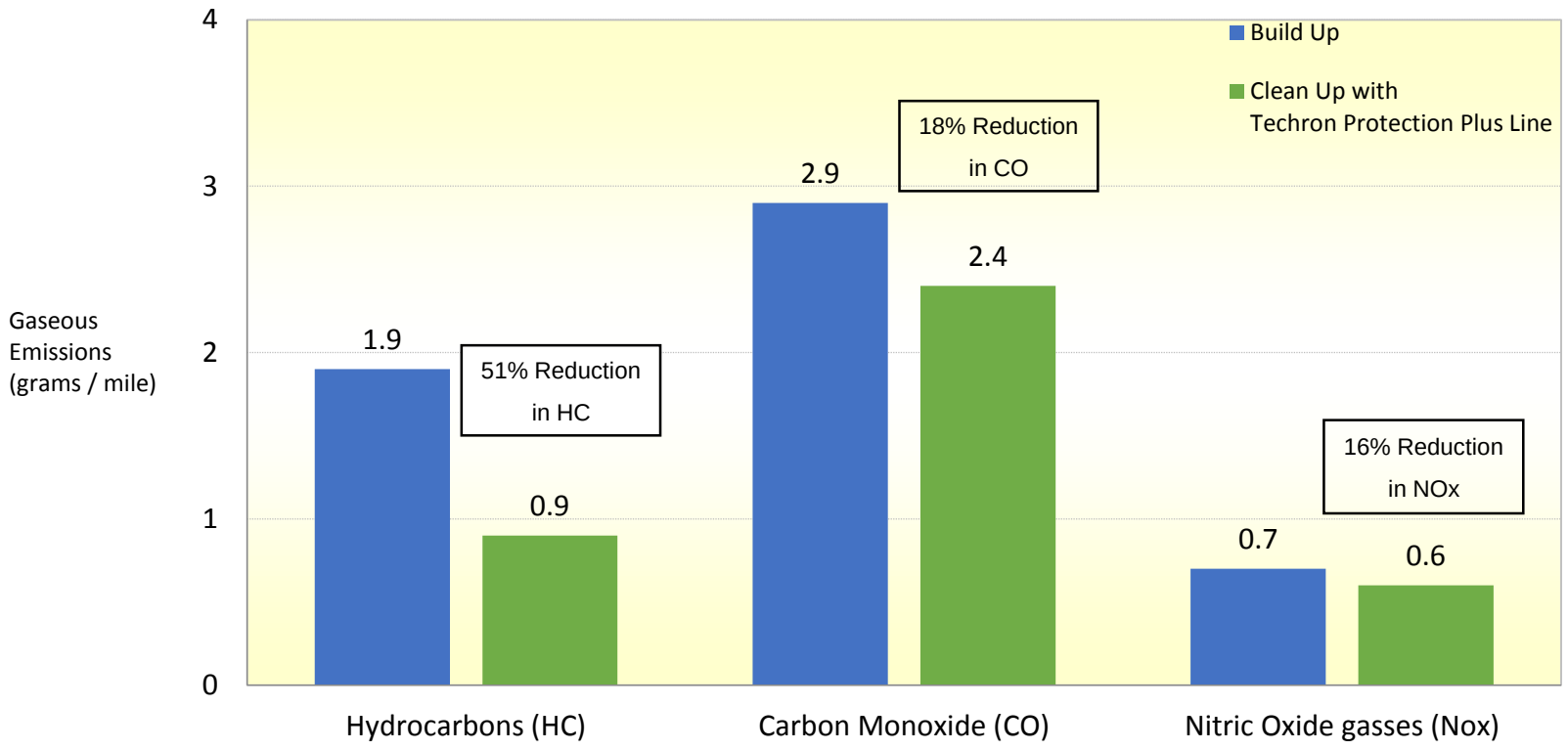
Mitsubishi GDI Vehicle Test – Emissions Impact

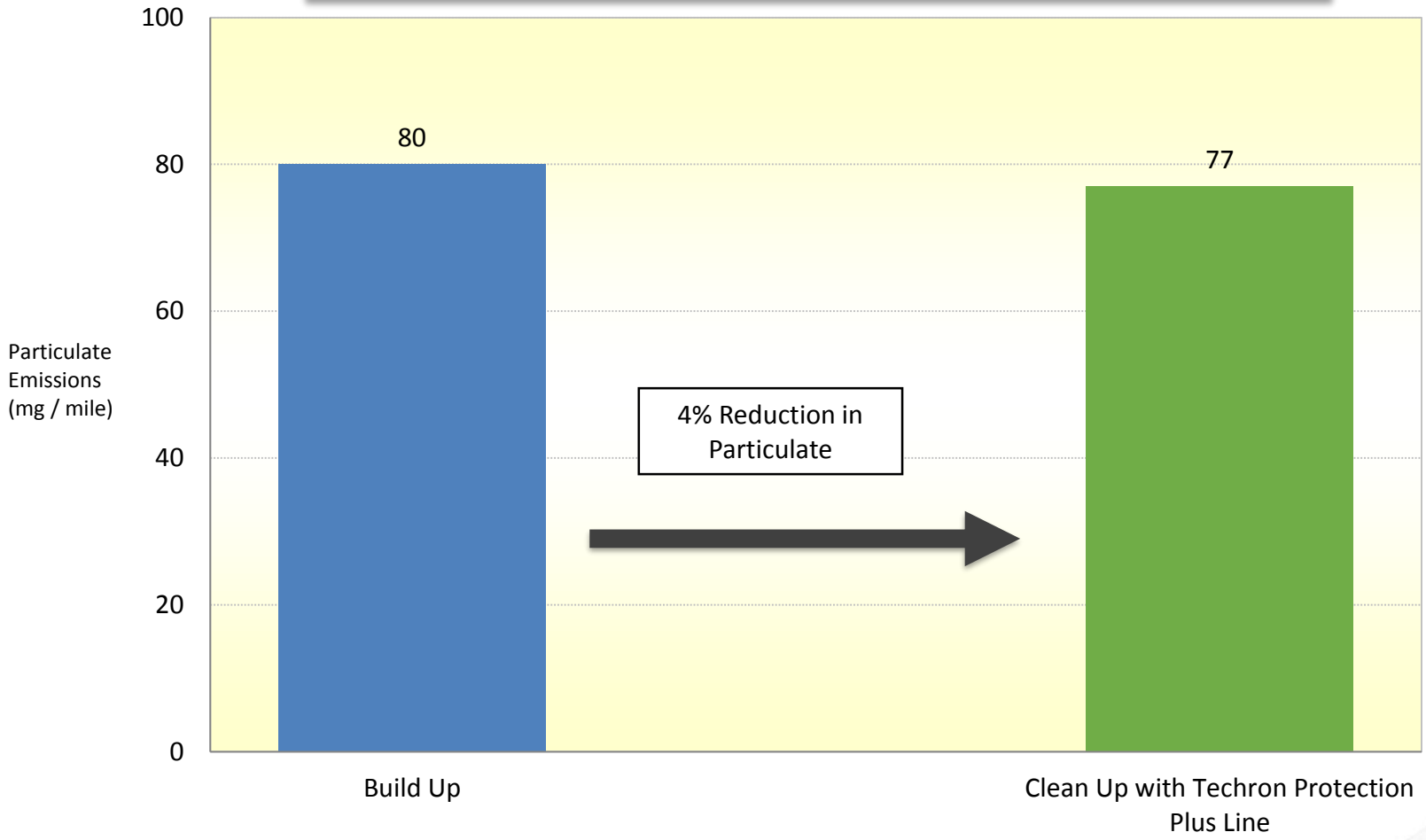
Test Cycle: ASTM D5598 Type
Engine: 1.8L Mitsubishi GDI
Duration: Buildup: 2,500 Miles, Cleanup: 2,500 Miles



Clean up of the injectors from the use of detergents equal to that of Techron Protection Plus resulted in reductions in all of three gaseous emissions in this test.

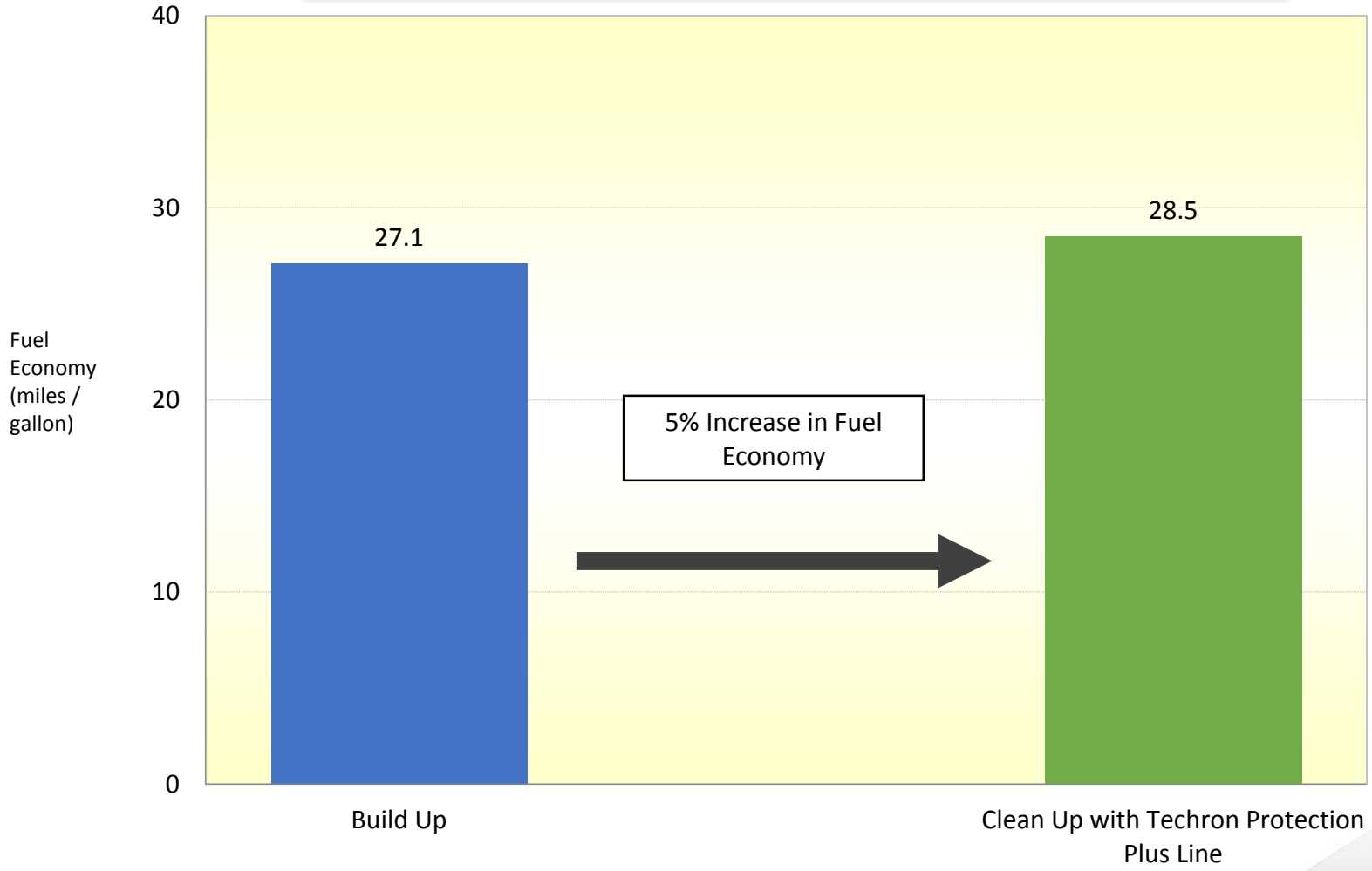
Mitsubishi GDI Vehicle Test – Emissions Impact

Test Cycle: ASTM D5598 Type
Engine: 1.8L Mitsubishi GDI
Duration: Buildup: 2,500 Miles, Cleanup: 2,500 Miles



Mitsubishi GDI Vehicle Test – Emissions Impact

Test Cycle: ASTM D5598 Type
Engine: 1.8L Mitsubishi GDI
Duration: Buildup: 2,500 Miles, Cleanup: 2,500 Miles



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