Spring 2020

Dear No-Rosion Customer,

In this, **our 25th year of operation**, we remain as committed and excited as ever to deliver you the highest quality engine fluids for the special needs of your special vehicles!

The business has changed a lot since we began in 1995, and so has the gasoline we all purchase at the pump. As gasoline formulations have evolved, we have continued to update the chemistry of our fuel additives in order to keep engines running optimally. This has required real commitment on our part, in terms of the ongoing R&D investments necessary for testing, formulating, and upgrading our chemistry. On a percentage-of-revenue basis, we almost certainly invest more in testing/development than any firm in the industry. This has always been, and continues to be, one of the key differentiators between us and our competitors.

It's not just fuel blends that have changed – so have engines, their combustion characteristics, and fuel delivery systems. As of 2017, **Gasoline Direction Injection (GDI)** accounted for 50% of all new engines built, with forecasts calling for 65% by the year 2022. (Source: SAE, Society of Automotive Engineers).

Injector deposits form quickly in GDI engines because injectors are located directly in the combustion chambers. This extreme high-temperature environment cokes (bakes) deposits onto injector nozzles, making them difficult to remove. Even small amounts of deposits on injector tips prevent optimal atomization of fuel.

Fuel additives face a tough task of cleaning/keeping-clean deposit-sensitive injectors. **Volatile low-flash point detergents** in many additives vaporize before residing long enough in extremely hot combustion chambers to facilitate complete injector cleanup – especially in turbocharged engines. The result: incomplete clean-up and failure to keep-clean.

Further complicating matters is that modern GDI engines have injector nozzles with a higher quantity of holes, with the holes being smaller in size. By increasing the quantity and reducing the size of injector nozzle holes, OEMs are able to reduce fuel droplet size, and better atomize fuel being sprayed into combustion chambers. The problem is that smaller nozzle holes clog easier than larger ones, especially in GDI engines that are more deposit-prone in the first place. This inhibits optimal atomization of fuel being delivered to the combustion chamber, resulting in power loss, reduced fuel economy, increased emissions, and general loss of performance.

No-Rosion Fuel System Combustion Optimizer is formulated with a **high flash point detergent** that allows it to reside in hot combustion chambers longer than most other products. This contributes to its overall efficacy of deposit clean-up and keep-clean. How do we know? Through repetitive and ongoing testing, using scientifically valid test protocols, which are prescribed by leading automotive engineering groups such as SAE, ASTM, and CEC.

We recently tested No-Rosion Combustion Optimizer in a brand new European test procedure called **TDG-F-113**. It was developed by the Coordinating European Council (CEC), in recognition of the specialized challenges of facilitating GDI deposit removal. The CEC is essentially the European equivalent of our SAE here in the US. We would have tested in the US, however, ongoing efforts by GM, SAE, and ASTM to develop a similar test have thus far have been unsuccessful. They do recognize the need for such a test, and their development efforts remain ongoing. Time being of the essence, we partnered with a leading ISO 17025-certified, CEC-member, independent engine test lab in Europe to run this test. At the time of this writing, per what we've been told, we are the first and only US-based fuel additive manufacturer to have tested using the new TDG-F-113 procedure.

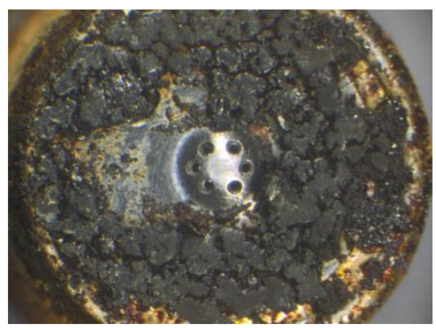
<u>Here's how TDG-F-113 works</u>. It is a 72 hour test that follows a standardized dyno procedure using Volkswagen's 1.4L TSI engine. This engine combines a supercharger for low end torque with a turbocharger and gasoline direct injection. It is run through a 48 hour "**<u>Dirty-Up</u>**" (DU) phase using high olefin content gasoline – what we refer to as "deposit-prone" dirty-up test fuel. Roughly 68 gallons of gasoline is consumed during DU test phase.

Then the engine is briefly shut down, and restarted for a 24 hour "**<u>Clean-Up</u>**" (CU) phase using the same deposit-prone test fuel that is treated with **No-Rosion Combustion Optimizer** at our recommended dose. Roughly 37 gallons of gasoline is consumed during the CU test phase.

During the entire 72 hour test, data is recorded in hourly increments via the engine control unit (ECU) that reports shift in <u>Long-Term Fuel Trim (LTFT)</u>. This is a measure of <u>percent change in injection time</u>. The ECU manages adaptive fueling to ensure correct gasoline stoichiometry, as measured by exhaust gas oxygen sensors. As injector nozzle flow rates <u>decrease</u> (due to deposit build-up on injector nozzles), the injector is held open <u>longer</u> by the ECU to ensure the same volume of fuel is delivered to the cylinder. Alternatively, as injector flow rates <u>increase</u> (due to deposit removal), injectors are held open <u>shorter</u> by the ECU. It is **<u>easy</u>** to track LTFT via ECU, which correlates directly to injector flow rates, and how they are impacted by deposit formation/removal.

During the 3 year development of TDG-F-113, the CEC noted that tracking shift in LTFT is also the **<u>most accurate</u>** means of quantifying GDI injector deposits. It was identified that, although interesting on an anecdotal basis, <u>visuals and weights of deposits on injectors do **not** correlate accurately to change in performance</u>. This is one of the reasons why removal of injectors during the test for <u>visual analysis</u> and <u>weighing</u> (as a means of quantifying gains/losses in deposits and therefore performance) does <u>not</u> produce valid results. Also, repeat engine starts and stops during removal/replacement of injectors to obtain visuals/weights <u>disrupts the regularity of the deposit formation process</u>, and further interferes with obtaining accurate, meaningful, <u>real-world</u> results.

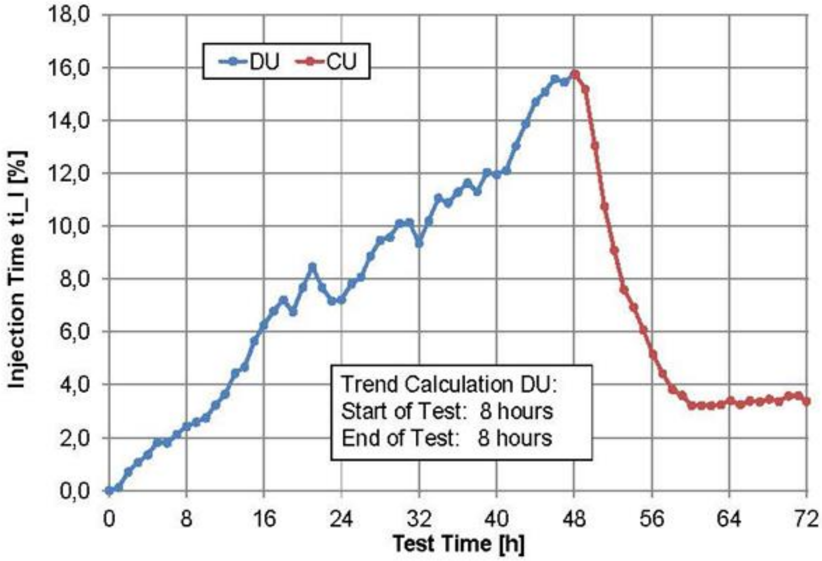




In the photos above, the clean injector <u>at left</u> performs at <u>100%</u>, and tests at 0.0 percentage point (pct pt) shift in injector time. Due to heavy deposits clogging the injector holes, the <u>middle</u> injector performs at only <u>84%</u>, and tests at 16.0 pct pt shift. The injector at <u>right</u> performs at <u>96.5%</u>, with 3.5 pct pt shift – **<u>in spite of heavy deposits</u>**. This photo is zoomed in, to show that the fuel additive dissolved away enough of the deposits from the <u>critical area of the nozzle holes</u> to perform almost as new. This shows why tests that attempt to identify injector performance visually and/or by quantifying deposit weight can, and will, yield inaccurate results.

The photos <u>below</u> show fuel atomization occurring real-time. The injector at <u>left</u> is functioning at <u>100%</u>, and the injector at <u>right</u> is functioning at <u>84%</u>. (Note the heavy <u>deposits</u>, which are <u>inhibiting flow and atomization</u>.)


With these understandings in place, let's review the hourly data points for injection time during the TDG-F-113 DU/CU test using test fuel treated with **No-Rosion Combustion Optimizer**, as depicted in the graph below.



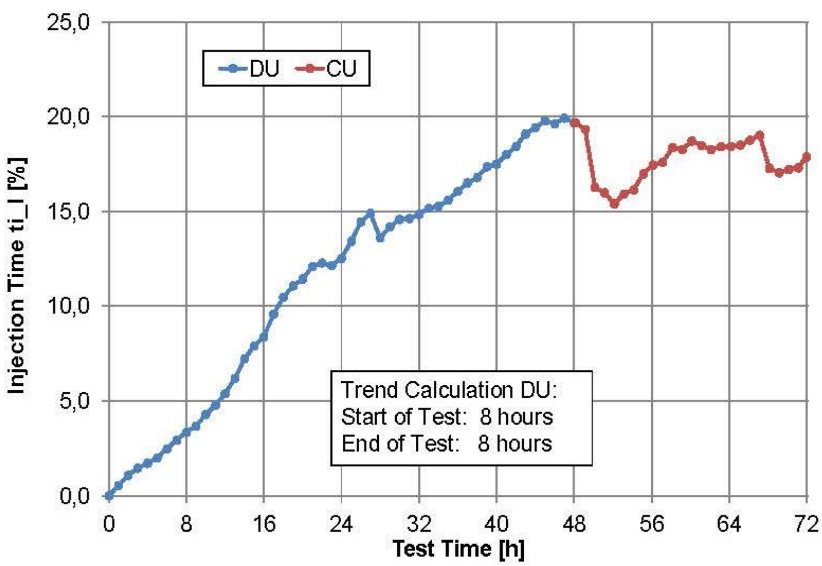
Looking at the Dirty-Up (DU) portion of the curve (in blue), we see immediate deposit formation as soon as the test begins. By the time the engine has run only 8 hours, injectors are already remaining open 2.2 percentage points (pct pts) longer in order to deliver the same quantity of fuel to cylinders. At 16 hours, this has increased to over 6 pct pts longer, culminating in an almost 16 pct pt increase in injection time by the time the DU phase concludes at the 48 hour mark.

Looking at the Clean-Up (CU) portion of the curve (in red), running the **fuel treated with No-Rosion**, we see immediate deposit removal as this phase begins. At 12 hours into CU (60 hour mark), enough injector deposits have been removed to reduce injection time shift down to 3.5 pct pts, at which point it levels off. This represents **78% restoration of injector fuel flow** as a result of deposit clean-up.

It should be emphasized that the deposit-prone test fuel used is of **purposefully POOR QUALITY**, with low oxidative stability, and high olefin content. It does not represent anything even close to what you purchase at the pump. This fuel is, of course, used because it RAPIDLY forms deposits, and represents a very TOUGH and challenging test. By reducing the amount of time necessary for deposit formation from WEEKS (as with normal pump fuel) to HOURS (as with deposit-prone test fuel), the test run-time is shorter and easier to manage.

Also important to note, at the 60 hour mark, the red line remains almost flat. This indicates that the detergent is strong enough to **keep up** with the deposit-forming tendency of the test fuel. (More on that in a minute.)

Now let's review the performance of a **competitor fuel additive** that we tested at manufacturer's recommended dose, in the same deposit-prone fuel. It represents the top-selling product, as found at all major retailers.



Looking at the Dirty-Up (DU) portion of the curve (in blue), we again see immediate deposit formation as soon as the test begins. By the time the engine has run only 8 hours, injectors are already remaining open 3 percentage points (pct pts) longer in order to deliver the same quantity of fuel to cylinders. At 16 hours, this has increased to over 8 pct pts, culminating in a 20 pct pt increase in injection time by the time the DU phase concludes at the 48 hour mark.

Looking at the Clean-Up (CU) portion of the curve (in red), running the **fuel treated with competitor product**, we likewise see deposit removal as soon as this phase begins. At 4 hours into CU (52 hour mark), enough injector deposits have been removed to reduce injection time from 20 down to 15 pct pts. **BUT!** …then an interesting thing begins to happen. **Deposits begin to re-form**, and accumulate again – in spite of the presence of the additive. This indicates that the additive is **NOT** strong enough to **keep up** with ongoing deposit-forming tendency of this deposit-prone fuel. The red line once again resumes its upward curve as deposits re-form.

There is another slight reduction in injection time at the 67 hour mark of about 2 pct pts, indicating a secondary slight CU. It is short lived, as the additive can't **keep up** with deposit formation. When the test concludes at 72 hours, it has only removed enough deposits to have **restored 12.5% of injector fuel flow**. If run beyond 72 hours, it would predictably show continued increases in deposit formation, as it continues to struggle keeping up with ongoing deposit formation, with possible repeat, short-lived, slight CU intervals.

What does this tell us? The high flash point detergent in **No-Rosion** is strong enough to remove 78% of injector deposits **and** keep injectors clean to within 3.5 pct pts of new. The **top-selling competitor** removed only 12.5% of deposits, and was unable to prevent recurring deposits. The difference in deposit removal performance tells us that No-Rosion's clean-up ability is **six times** more effective than the competitor – and that No-Rosion is able to keep a system clean even when used in the most "challenging" deposit-prone test fuel. The competitor is not.

At this point, you may be saying to yourself: Okay, that's great. No-Rosion is good at cleaning deposits from injector nozzles in modern GDI engines, and keeping them clean. But what about my old car? How is this information relevant to **me**, and **my old cars with carbureted engines?**

Unstable ethanol-containing fuel forms sticky gums that cause accelerator pumps/check valves to stick, and restrict jets in carbureted engines. Engines in old cars also often have "legacy deposits," which reside in combustion chambers and on piston crowns/intake valves. They are well-formed, have been in place for years, and are stubborn to remove. Just as stubborn as coked injector deposits in the high temperature environment of combustion chambers in modern, high compression, turbocharged, small displacement GDI engines.

It takes a powerful detergent to remove/prevent sticky gums in carburetors and legacy deposits in old cars. In this way, using No-Rosion Combustion Optimizer in your older car will not only keep carburetors clean and prevent deposit build-up when used with today's fuels, in many cases it will also clean and remove legacy deposits that have been reducing engine performance for YEARS, without you even knowing it.

Interesting side note: GM and SAE continue development work on their own version of TDG-F-113. We are hearing that, when ready, it may be incorporated into the requirements for the TOP-TIER gasoline specification in the future. We'll keep you posted on this possible development in future newsletters.

On behalf of the entire No-Rosion team, I'd like to thank you for your support over these 25 years. We look forward to continuing to be of service over the **NEXT 25 years**, and beyond.

Sincerely,

Applied Chemical Specialties, Inc.