presents

FUEL FACTS

60 helpful tidbits about the fuels that power our automotive enthusiasm

from the editors of:
Grassroots Motorsports
THE HARDCORE SPORTS CAR MAGAZINE

Welcome to Sunoco's

FUEL FACTS

With more than 60 years of Race Fuel expertise, we are not only the world's largest manufacturer of Race Fuels, but our experience and expertise ensures that every gallon of fuel we sell to our consumers is the highest quality.

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Contents

Fuel Facts produced by the staff of Grassroots Motorsports, your personal guide to the sports car world: ***grassrootsmotorsports.com***

part 1

FUEL BASICS

What you need to know about fuel, from when it comes out of the ground to when you need to fill up again.

What Separates a Race Fuel from a Street Fuel?

From the start, race fuels are typically cleaner and more consistent than pump fuels. The reasons why are due to economics and environment.

Pump gas is a product largely driven by cost, and standards allow a certain amount of agents that over time can cause gum and varnish. Since a tank of pump gas is usually consumed fairly quickly, the presence of those agents is rarely noticed by the consumer.

Race gas is produced for a more exacting consumer, so quality and consistency become the driving factors. According to Zachary J. Santner, senior specialist of quality at Sunoco, race gases start with a base product that, in rough figures, can be called 10 times cleaner than its street-bred counterparts. A tangible benefit of that cleanliness: Race fuels are a lot more stable and can be stored for at least two years without any noticeable changes.

Then there's consistency. As per EPA standards, pump gas formulas vary based on season and location. A winter-blend fuel, for example, is formulated to produce quick starts in cold weather. During the summer months, though, that winter fuel would lead to increased emissions. Altitude, local air quality and other factors can further affect the blend, and the end result can be dozens of variations for just a single brand and grade of fuel. Race fuels, Santner continues, are consistent. They come from one source, and the formula never changes. Running race fuels simply eliminates one variable from the equation.

Narrowing Down the Choices

Race gas comes in more than a single flavor. Your local track might just have one or two pumps, but there are many more varieties available–like, easily close to two dozen from just a single supplier.

While many of those fuels are race-only products, others are boutique formulas intended for street cars. A few questions can help narrow down which formula is best for your car.

Road or Track? Products sold as race fuels are not always restricted to track use. Example: Sunoco's 100-octane 260 GT is an extremely stable, street-legal product designed for high-performance street engines. (For those who have to meet California's fuel regulations, Sunoco also offers the similar SS 100.)

Oxygenated or Not? Some fuels are oxygenated, while some are not. Oxygenated fuels can help produce extra power. Without getting too technical, let's just say that extra oxygen plus extra fuel usually equals extra bang. Highly boosted engines also tend to prefer oxygenated fuels.

However, oxygenated fuels don't always favor long storage intervals. If your car tends to sit for long intervals–picture a classic that's only used occasionally–then a non-oxygenated product might be a better fit.

Leaded or Unleaded? Adding lead is an inexpensive way to increase a fuel's octane rating. But, as many of us already know, lead isn't super kind to the environment or to modern emissions equipment. Here's a basic rule: If your car has oxygen sensors in the exhaust or catalytic converters, don't use a leaded fuel.

Gas Station Basics That Aren't That Basic

Gasoline seems so simple: You pull up, you pump, you leave. But you have questions, right? So we ran a few common ones past Zachary J. Santner, senior specialist of quality at Sunoco .

How Can I Tell a Good Gas Station From a Substandard One? Busy stations are your friends, Santner notes, as gasoline can go stale as it sits. "A station that moves a lot of fuel, that's good," he explains.

One potential red flag is a slow pump. That could be a sign that its filter is full of dirt or has detected water due to phase separation–the pumps contain special filters that cut the flow of fuel when water is present. It shouldn't take more than 5 minutes to fill a 10-gallon tank. After all, Santner notes, stations want to get their customers in and out.

When Should I Refuel? Most modern cars feature an in-tank pump with the fuel itself cooling the unit. "Riding around on empty all the time probably isn't great," Santner notes, as that can potentially reduce the pump's life.

Does Fuel Type Really Matter? Top Tier fuels–Sunoco's are on that list–contain more detergents. Using more octane than recommended won't hurt the car, Santner notes, adding that these fuels offer a longer shelf life.

Why Do I Have to Turn Off the Engine While Fueling? "It's all a precautions thing," he says, as some industrial accidents have been traced to ignition sources–which can be eliminated by turning off the engine and also minimizing any static electricity.

Can I Safely Use a Single Container for Different Types of Fuel? In most cases, yes, you can use your race jugs to transport gas for your street car–with one big caveat: You shouldn't mix leaded and unleaded products.

"All of the fuels can be mixed," Santner says of unleaded gasolines, whether they're intended for race or street. "They're all essentially made from the same components. There's no reaction to worry about."

Technically, he notes, a container used to transport leaded fuels could pick up some trace amounts of lead. "It wouldn't be a lot," Santner admits, "but you probably wouldn't want to use that can with your daily driver." In that case, he recommends rinsing the container with some unleaded fuel before using it to transport any street fuels.

Is Your Gas Station a Good One?

Once you go beyond price, location and bathroom cleanliness, does where you fuel up really matter? It actually can, explains Zachary J. Santner, senior specialist of quality at Sunoco.

Fuel Matters: The top end of an engine can be a dirty, sludgy place, especially once you add crankcase gases to the mix. That mist of blowby and oil vapors present inside the crankcase? Unless the car is really old or something has been modified, it sends that dirty air back into the combustion chamber.

"The oily residue can build up on the backs of valves," Santner explains. "It's not good stuff." Those deposits can block the valves, causing various performance issues.

How do you combat the resulting carbon buildup? Top Tier fuels feature an added detergent package designed to keep combustion chambers clean–clean from oil mist, clean from the gums and varnishes found in fuel itself.

According to an AAA study, non-Top Tier gasoline averaged 19 times more intake valve deposits than Top Tier fuels. (And, Santner notes, all Sunoco pump fuels carry the Top Tier designation.)

Cleanliness Matters: Not all gas stations are created equal. Some are simply cleaner and better maintained than others.

"If it looks really dingy, they probably don't maintain their pumps and filters," Santner says. The pumps are fitted with filters, he explains, that are designed to prevent rusty particles as well as water from leaving the nozzle.

Season Matters: Different gasoline blends are sold during the winter and summer months, and they can have an impact on how easily your engine starts. In the most basic terms, the winter blends–generally sold from mid-September through springtime–feature a higher vapor pressure to assist cold starts.

If you plan to put away a car until spring, Santner says, maybe fuel up with a winter blend to help with that first start of the season.

Where Does Gasoline Come From?

Most of us know where babies come from, but what about gasoline? The answer goes deeper than "the pump," and understanding the process can help differentiate the various offerings.

Step 1: Crude oil is extracted from the ground. According to the U.S. Energy Information Administration, the U.S. imported about 8.32 million barrels of petroleum per day during 2022, with 52% of that coming from Canada. Next on the list: Mexico (10%), Saudi Arabia (7%), Iraq (4%) and Columbia (3%). According to that same report, during the same time period, the U.S. exported about 9.58 million barrels of oil per day—so the U.S. exports more than it imports. Via some combination of ships, rail cars and pipelines, that crude oil arrives at an American refinery.

Step 2: The crude can now be refined into various fractions, including diesel, kerosene and, yes, gasoline. At this point, the gasoline is still an unbranded commodity, although some additives are added—often antioxidants and corrosion inhibitors.

Step 3: Now let's just follow the path for gasoline. If not bound for export, it will head to a regional terminal—often via pipeline but possibly also by rail car.

Each pipeline, notes Zachary J. Santner, senior specialist of quality at Sunoco, can be used to transport different products: A load of gasoline could follow some diesel, with a mixed slug of fluid separating the two. (That slug would then be refined again at a transmix facility, he explains.)

Step 4: The magic that separates one brand from another happens at the terminal, Santner continues. "That's where detergents and other propriety additives are added," he says. "That's where a fuel would become Top Tier or not." Those extra detergents that define a Top Tier fuel, he notes, come at a cost, so not all brands opt for them.

Step 5: Trucks then transport the gasoline to the local stations. If you see a gasoline truck on the highway, he notes, it's doing local deliveries.

But what about race fuel? As a boutique product, Sunoco Race Fuels don't follow this path, he explains. They're all brewed in Marcus Hook, Pennsylvania, to a consistent, controlled recipe and shipped via dedicated containers.

How to Stretch the Gas Budget

A common question heard when discussing gasoline: How can I save money at the pump?

Instead of looking for a silver bullet that's bigger on hype than science–the latest fuel savers touted online somehow, magically, only need to be plugged into your cigarette lighter–start with the basics, suggests Zachary J. Santner, senior specialist of quality at Sunoco.

First, he says, drive with an eye on economy: windows up to improve aero efficiency, junk out of the car to decrease weight, and tires properly inflated to reduce drag. Running a non-ethanol fuel will yield more mpg, he adds, but the price of premium might cancel the gains found on the road.

Next, take some time to make sure the engine is operating at peak efficiency, he continues. Are your air and fuel filters clean? Ignition components at proper spec? Is the engine running at its ideal temperature, or do you have a cooling system issue? Are you using the oil recommended in the owner's manual?

What else can you do? Ensure that your fuel system is clean, Santner says. Running a Top Tier fuel will minimize internal engine deposits, significantly reducing the crud that can collect in injectors and on the backs of the intake valves.

What about tossing some fuel system cleaner down the filler? Well, not all cleaners are not created equal. Most contain a detergent and/or a solvent–see if the safety data sheets shine any light–and Santner notes that a detergent is more effective than a solvent. Picture a drop of dish soap dispersing the oil from a frying pan versus soaking dirty engine parts in a bucket of solvent.

To help your research and shopping, he shares two popular, effective fuel system detergents: PEA (polyether-amine) and PIBA (polyisobutylene amine). Solvents–not as effective but very popular in the marketplace–contain various petroleum distillates, things closely related to toluene, kerosene, naphtha and isopropyl alcohol.

Why don't all fuel system cleaners favor detergents over solvents? Well, those detergents cost more to produce.

part 2

NARROWING DOWN THE FUEL FIELD

With so many types of fuel available, which one is right for your vehicle?

Which Fuel Should You Use?

Which nozzle should you grab when filling up? When in doubt, read the manual. Assuming we're talking about a stock, production street vehicle, the owner's manual will explain which fuel to use—but, of course, questions might still remain.

Are All Octane Numbers Equal? In the U.S. and Canada today, gasolines are rated on the Anti-Knock Index (AKI). That's the figure found on our pumps and inside the owner's manual.

The worldwide standard, however, is the Research Octane Number (RON), so you might also find this one listed in the owner's manual, particularly for an older foreign car. The manual for a U.S.-spec 1984 Porsche 911 Carrera, for example, lists both minimums: 91 RON or 87 AKI.

What If the Local Stations Don't Offer Enough Octane? At higher elevations, you might notice octane minimums that are lower than the national norms. "At high-elevation areas, it's common to see the octane lower," explains Zachary J. Santner, senior specialist of quality at Sunoco. "In the mountains, less barometric pressure means that you don't need all the octane."

"It's not a bad thing," he adds. "It's simply science because of the less dense air."

What About Using Too Much Octane? Some of us have heard the rumors: Running too much octane will actually decrease performance. According to Santner, the science doesn't point towards octane rating as the culprit. "Many fuel properties play a part in the perfect fuel/engine combination. The evaporation rate is a usual culprit for a poor fuel/engine combination, not octane," he explains. "It's like having extra insurance."

High-octane fuel is also a more refined product, he continues, meaning it will age better and leave less deposits than a lower-grade product—big benefits for a car that might sit for a bit. "Vehicle mpg is impacted by a wide variety of conditions," he says. "Some modern cars can adjust to the higher octane of premium and provide slightly better mpg." The recipes used for pump fuel can vary depending on season and location. (Sunoco Race Fuels, he notes, are always blended to the same formula.)

Are High-Octane Fuels More Stable?

There's another advantage of higher-octane fuels: They're also more stable when it comes to storage.

There is science behind that answer, and we're going to crib from something posted on the Sunoco Race Fuels website by Zachary J. Santner, senior specialist of quality at Sunoco:

"87 octane fuels tend to be less refined and contain more unstable hydrocarbons. As the months pass during storage these unstable components react to form gums, varnishes and lower octane hydrocarbons. As a result, the octane can decrease within months for 87 octane fuels, especially when stored under less than ideal conditions. 93 octane fuels are more refined and contain more stable hydrocarbons. These stable hydrocarbons can last 2-3 times longer than 87 octane fuel. Even in proper storage, 87 octane gas can start to degrade in 3 months; 93 octane fuel should last closer to 9 months before degradation is noticeable. Keep in mind that 93 octane fuels are still susceptible to octane loss and vapor pressure decreases due to butane evaporation."

So, other than cost, is there a downside to always filling up with premium? "Filling up with premium when you don't need it can help to clean the fuel system because it contains cleaner components than 87 octane," Santner tells us. "No negative reasons to not use it, even in an 87 octane minimum car."

Race fuels, though, are a slightly different subject. Where street fuels are blended to meet a price point, race fuels feature better ingredients–and those ingredients lead to longer shelf life. If properly stored, Santner adds, Sunoco's race fuels can sit around for two years or more without degrading.

Is All Premium Gas the Same?

Not all premium pump fuel is created equal. "Yes, it is," you say, "the octane rating is right there on the pump." Well, there's more to fuel—even premium-grade fuel—than just the octane rating.

First, the octane rating of premium can vary: East Coast consumers usually have access to 93-octane fuel, while those west of the Mississippi often receive just 91 octane.

Fortunately, many modern cars can retune themselves to accept different octane ratings. For example, the Ford Focus ST spells out the differences in its owner's manual: 252 horsepower on 93 octane and 243 horsepower on 87 octane. "If this is a linear difference, that would put 91 octane making 249 horsepower," explains Zachary J. Santner, senior specialist of quality at Sunoco. "How about a 3-horsepower difference for East Coast versus West Coast fuels?"

But there's other stuff in gasoline that can affect an engine's performance—building blocks like, Santner notes, aromatics and olefins. EPA regulations have allowed the aromatic content of pump fuel to range from zero to 50% volume, while olefins can range from zero to 25% volume. These levels can vary depending on the brand of fuel, location of station and time of year, as pump fuels are often blended at regional terminals with the exact recipe determined by season, location, additive package and commodity prices.

"Fuels that can vary from zero to 50% aromatics and zero to 25% olefins will look and perform very differently," Santner explains. "Aromatics are very dense and have a BTU/gallon content that is 20% higher than paraffins found in gasoline. This would mean that a fuel with 50% aromatics would be able to provide much better miles per gallon compared to a fuel with 0% aromatics."

While it's rare to find a fuel with aromatics at either end of the range, Santner does stress how it's possible to find a wide variation among pump fuels—and why, when you see someone claiming dyno numbers between premium and regular fuel, other variables might come into play. (He also notes that Sunoco Race Fuels always follow the same recipe with zero variations.)

Was Yesterday's Gasoline Better?

Back in the day, pump fuel was just meaner. It had higher octane, the lead craved by the day's engines, and a smell that meant business. Everything was better then, right?

Sunoco even operated its Custom-Blended pumps from 1958 through 1972, allowing customers to choose the octane their engine needed. Eight grades were offered, ranging from Sunoco 190 all the way to Sunoco 260, billed as the highest-octane fuel available–one good enough for championship driver Mark Donohue.

Not sure how much octane you needed? Sunoco stations offered a chart that provided recommendations based on year, model and engine. If you had a 1967 Camaro with the inline-six or standard V8, for example, Sunoco recommended 200, a regular-grade product. If you'd ordered the high-performance V8, Sunoco said to consider Sunoco 250, billed as a super-grade fuel.

But what about octane numbers? As explained by Zachary J. Santner, senior quality specialist at Sunoco, stations didn't have to post octane ratings until September 1973. Sunoco 190, the economy-grade fuel, sported an octane rating of 87, while 260 checked in at 97.5.

While such high octanes may no longer be offered at the corner station–the lead that easily added octane was removed from street fuels long ago due to its dangerous effects on human health–Santner argues that today's fuels are actually a better product.

Removing lead while reducing the sulfur and benzene content allows modern fuels to be less hazardous for humans and the environment. Today's oxygenates, such as ethanol, help boost octane ratings without the use of lead.

Modern gasoline also contains better additives than fuel from the past. "Detergents help the engine remain like it was new, while antioxidants help fight the formation of gums and varnish," Santner says, adding that minimum detergent requirements started in 1996 due to an EPA mandate.

And if you're looking to go above the minimum, Santner offers some advice. Top Tier fuels, like Sunoco's pump products, contain more detergents than the minimum level, while Sunoco 260 GT is an unleaded, 100-octane product that can be blended with pump fuel to produce the desired octane. (And for those living in states that follow CARB regulations, Sunoco offers the similar SS 100.)

The Perils of Running Rich

Running an engine too rich doesn't just waste money. According to Zachary J. Santner, senior specialist of quality at Sunoco, it might cause several major driveline problems as well.

Fouled Spark Plugs: If the engine can't burn all the fuel dumped into the combustion chambers, hard carbon deposits can form on the spark plugs. The potential result? Ignition problems.

Hard Carbon Buildup: That carbon won't just stick to the spark plugs; it can build up on the tops of the pistons, too. "That can do funky things regarding drivability," Santner notes, adding that hard carbon deposits can soak up wet fuel–picture them behaving like a sponge–and then lean out the air/fuel mixture. Really heavy carbon deposits, he continues, can increase the engine's compression ratio, leading to preignition and higher operating temperatures.

Accelerated Engine Wear: Gasoline is a terrific solvent for motor oil. As Santner explains, likes dissolve likes–meaning that gas will dissolve oil. That extra gasoline in the combustion chamber? What do you think it's doing to the film of oil that should be protecting the walls of the cylinders? And if the engine runs so rich that gasoline gets down into the bottom end, you can imagine the terrible consequences for your bearings.

Clogged Catalytic Converter: Remember those carbon deposits we mentioned? Catalytic converters are also susceptible to them, and they can clog up the honeycomb substrate. Then bad things happen, from a car running poorly to backfiring to a catalytic converter coming apart.

The obvious solution to the above: Operate a properly tuned engine. An air/fuel gauge–AEM and others offer several options–can tell you exactly how well the engine is burning the gasoline. Running a Top Tier fuel, Santner adds, can also help combat those carbon deposits thanks to its extra detergents.

Are You Using the Wrong Fuel?

Gasoline is a rather complex substance. "You can't take apart the fuel and see how it works," explains Zachary J. Santner, senior specialist of quality at Sunoco. Instead, you have to look at the numbers.

For many of us just driving on the streets, choosing a fuel comes down to three qualities: octane, ethanol and cleanliness. (We're going to concentrate on just the fuel and not the artisan sandwiches available inside the store.)

Octane Matters: Octane doesn't magically dictate how much power a fuel makes. Instead, Santner explains, octane measures a fuel's resistance to knock or preignition–meaning more octane allows for engine specs that produce more power, specifically more compression and more boost.

Have a modern, high-performance vehicle? Odds are strong that it was built to take advantage of today's high-octane fuels.

But, as Santner cautions, octane levels were higher back in the '60s, when the old Sunoco 260 carried an octane rating of 97.5. Today's street-legal alternative: 260 GT (49 states) and Sunoco SS 100 (California). These 100-octane fuels can be found via specialty dealers–check sunocoracefuels.com for details.

Ethanol Matters: Ethanol is added to today's gasolines to increase octane, but it has a drawback: potential storage issues. For most people, though, this isn't an issue. "It's designed to be purchased and used," Santner explains.

Classic car owners, though, might run into issues if fuel is allowed to sit. A few solutions, Santner notes: Fuel up with a premium fuel, which is more stable than regular fuel; simply drive the car more; or run a non-ethanol fuel. (While not street-legal, Sunoco's Optima is designed specifically for storage.)

Cleanliness Matters: How can you get a pump fuel with a detergent package that goes beyond the minimum? Look for one carrying the Top Tier designation–and all Sunoco street fuels are on that list, Santner notes. Its detergent package is recommended by several automakers, including BMW, GM, Ford, Honda, Mercedes-Benz and Toyota.

Whether the engine is old or new, Santner says, a Top Tier fuel will prevent carbon buildup and clean away any that has already formed.

Blending Fuels to Get the Right Mix

Can you mix together different fuels to get what you need? In most cases, yes. "Our gases mix well with each other," explains Zachary J. Santner, senior specialist of quality at Sunoco.

Gas Math: When mixing fuels, a weighted average will get you fairly close, Santner explains. For example, a tankful that's three parts 90 octane and one part 110 octane would yield approximately a 95 octane mix. But before you start grabbing nozzles, a friendly reminder that leaded fuels will harm the catalytic converters and oxygen sensors found in modern cars.

Mixing for Octane: Most pump fuels now top out at 93 octane. That's fine for today's machines, but that '60s performance car might have been built back when octane numbers found at the corner station ran closer to 100.

If looking for a solution that's street-legal, Santner says, you could run Sunoco 260 GT, a 100 octane, unleaded street-legal fuel.

While straight 260 GT would provide more than enough octane in this case, if less octane was needed you could save some money by cutting it with pump fuel. A 50/50 mix with 93 octane, for example, would yield about 96 octane, and you could adjust as necessary. Those headed to the track could opt to instead mix in an off-road racing fuel.

Mixing for Storage: Today's oxygenated fuels usually contain up to 10 percent ethanol. The ethanol helps those fuels produce more power, but the ethanol also absorbs moisture over time, especially in an older fuel system that isn't entirely sealed. That moisture can eventually cause all kinds of problems.

Some stations offer non-ethanol fuels, with 89 and 90 octane usually being the upper limit. Need more octane than that–like closer to 93? Sunoco offers an unleaded fuel called Optima: 95 octane and no ethanol. It's not street-legal, the company notes, but its website adds that this fuel won't harm oxygen sensors and catalytic converters. If stored in a sealed, air-tight container, shelf life is more than three years.

Need Help Selecting a Fuel? Call the Experts.

When picking race gasoline, is it just about the basics–like octane, lead content and amount of oxygen?

Not so much.

Sometimes you have to look deeper, explains Zachary J. Santner, senior specialist of quality at Sunoco. He points toward Cyclone 17, a recent addition to the Sunoco Race Fuels lineup, as an example.

This leaded race fuel is aimed at radical engines, packing 117 octane and no ethanol. On paper, however, it also looks a lot like the brand's SR18, a leaded, ethanol-free product sporting a 118-octane rating.

To see the difference, he continues, you have to look deeper. "Make sure you're using the right fuel for your application," Santner notes. In this case, that new Cyclone 17 was designed for a very specific application: drag racing–although perhaps it could benefit some autocrossers as well.

A lot of drag racers don't fully warm up their engines before making a pass, Santner continues. Instead of launching a campaign to get drag racers to change driving styles, Sunoco instead worked with engine builders to create a fuel that better evaporates at colder engine temperatures. (That difference can be seen in the 50% evaporation temperatures found on the Sunoco Race Fuels website: 192 degrees Fahrenheit for Cyclone 17 and 209 degrees for SR18.)

The bigger take-home message for most of us here, though: It's okay to consult engine builders or fuel suppliers regarding fuel choice, and Zachary reminds us that he's just a phone call away at (800) RACE-GAS.

part 3

RACE FUEL BASICS

When it comes to racing, performance matters. So, how can you fuel your way to victory lane?

Buying and Storing Race Fuel

Gas stations can be found on nearly every major intersection. Finding one that sells race fuel, though, can be a little tougher. Fortunately, it's not like looking for the Lost City of Atlantis.

In addition to 54-gallon drums and even larger quantities, race fuels are usually also available in 5-gallon pails—and it's these smaller containers that open up the distribution network, eliminating the pumps and infrastructure usually associated with gas stations.

Finding Fuel: We just checked Sunoco Race Fuels' website for the greater Daytona Beach area—home base for Grassroots Motorsports—and were rewarded with a long list of retail outlets. The closest to us is Daytona International Speedway—not a surprise since Sunoco is the official fuel of NASCAR. Next on the list is our local speed shop. Then it's a mix of fuel distributors, motorcycle shops, race tracks, traditional gas stations and other businesses that serve the hobby—an alignment shop, for example, popped up in our results.

Shipping Fuel: Some companies and retailers will also ship those 5-gallon pails directly to your doorstep, although Fred McConnell, Director of Fuels Marketing & Motorsports at Sunoco, reminds us that the freight bill must be considered. If your local outlet doesn't stock your preferred blend, he offers a less expensive alternative: Contact your regional distributor. With enough of a heads-up, they can likely add your fuel to one of their regular stocking orders.

Storing Fuel: Properly storing that fuel, assuming that it's not used right away, can lengthen its shelf life. The Sunoco Race Fuels website offers some handy storage tips: Keep the containers full, tightly sealed, and away from daylight and major temperature swings. "Perfectly stored, most race fuels will last more than a year," their website says. "If you are not sure you can use the fuel up within two years, add a quality fuel stabilizer to the fuel as soon as you purchase it."

How Fresh Is That Race Fuel?

A common question Sunoco Race Fuels receives: Is this fuel fresh?

The short answer is often yes, but as explained by Zachary J. Santner, senior specialist of quality at Sunoco, the full reply is usually longer. Don't worry, he notes, the longer reply delivers the same answer: The fuel is fresh.

Sunoco usually sells its race fuels via pumps, 5-gallon pails and 54-gallon drums. The pumps can be found at select tracks and dealers—the Grassroots Motorsports staff, for example, can access them locally at Daytona International Speedway—while smaller outlets tend to carry the pails and drums.

The usual reason for the above question: the date marked on those pails and drums. These containers must meet U.N. packing requirements, meaning their year of manufacture must be stated on their certification label. "The pails are made well in advance" of the fuel, Santner notes, adding that pails and drums are often filled by regional distributors. They have the experience and hardware needed for the filling operation, he continues, including the special tools for properly sealing the containers.

"We don't have much concern because the fuels are so stable," he continues. Just how stable? Sunoco says most of its fuels have a shelf life in excess of one or two years when properly stored in a sealed container in a cool, dry location. Check the product's description for the specifics. "In the real world," Santner notes, "your garage or shed is fine."

To test that shelf life, Sunoco places containers of fuel in less than ideal conditions—like out in the elements for two years in Pennsylvania—and regularly checks the specs. "We get all the seasons," he notes.

Santner offers an additional storage tip: Keep that cap tightly closed. A loose cap—or even drum pump—can allow the vapors to escape, causing the fuel to go stale. As long as the container remains tightly sealed, he explains, any vapors will condense back into a liquid phase, maintaining the fuel's freshness.

What Should You Know About Adding Additives?

Why buy race gas when you can mix up your own high-octane fuel with an additive? These potions, auto parts store staples since the dawn of time, promise higher octane ratings, along with a thinner waist and whiter teeth. How can you lose? Well, not all additives are created equal–and the same can be said for street fuels mixed with said additives.

Octane Point: An octane point equals one-tenth of an octane number. When an additive promises to boost your fuel by "up to 10 octane points," it means raising the octane from, say, 92 to 93–if you're lucky.

Meet MMT: Many over-the-counter fuel additives contain MMT, short for methylcyclopentadienyl manganese tricarbonyl, which is very effective at raising octane. "We have done testing on fuel additives that contain MMT and they do raise the octane," says Zachary J. Santner, senior specialist of quality at Sunoco. But, he adds, there are a few caveats.

You Get What You Pay For: Octane additives without MMT aren't nearly as effective as additives with MMT. The lower-cost additives contain much less of the ingredient–or maybe even none of it. There's a big difference between an $8 "octane booster" and a $35 can of "race fuel concentrate." The safety data sheets will reveal exactly what's inside the bottle.

MMT Caveats: Sunlight is MMT's enemy, Santner continues. Sunlight will oxidize MMT, turning it brown and destroying its octane-boosting effect. MMT, in larger doses, will also leave orange deposits in the combustion chamber. "Using high-MMT fuel in an everyday vehicle can cause less miles between spark plug fouling," he adds.

Strong Foundation: When mixing up your own "race fuel," you're still limited by the base product–the pump gas that's engineered to be used right away while meeting a price point. Unlike street gas, however, race fuels aren't constantly reblended depending on the season. Plus, when properly stored, they can last at least a year or two.

Cleaner, Too: "Race fuels are also much cleaner than pump gas and even aviation gas," Santner notes. "Race fuel will keep carburetors and injectors clean, unlike pump gas where varnish and gum will build up over time."

Four Race Fuels to Consider

So many race fuels, so many choices. How to further narrow down the field? First, let's assume that we're talking about a modern, fuel injected car. Right away that discounts all of the leaded products. Zachary J. Santner, senior specialist of quality at Sunoco, notes that just four products would then cover many popular situations.

Street-Legal: Most race fuels are not approved for street use. In fact, 260 GT is the only Sunoco race fuel to carry 49-state approval. (SS 100 could be called the brand's California equivalency.) What does 260 GT offer over pump fuel? 100 octane. It's also a highly refined, fast-burning product, Santner explains. "Some people have noticed that instead of black exhaust tips they see gray or nothing there because it burns so much cleaner," he adds. Another benefit: longer shelf life than pump fuel.

More Power: A very popular fuel among those seeking max power from modern cars is 260 GT Plus, Santner explains. It's a 104 octane fuel that contains 13% ethanol. "That little extra ethanol helps with performance," he explains. "You can tune more on it due to the octane."

More Acceptance: Santner says that their 260 GTX is popular even though its octane rating is just 98. The reason? No alcohol. "Many racing series don't want [ethanol] because it masks other chemicals that can be added to enhance power," he explains. "Many series only test two properties at the track: specific gravity and dielectric constant. Gasoline has a pretty narrow dielectric constant range, but when you add ethanol, the range gets too wide to use the test." Sunoco 260 GTX is a spec fuel for several series, including Trans Am.

More Alcohol: For those looking for all the ethanol, E85-R has been popular, Santner continues. Where the amount of ethanol in the E85 found at the corner pump can range from 51% to 83%, E85-R always contains 85%.

One Way to Wade Into the World of Race Fuels

When do you think about making the jump from a pump fuel to a race fuel? Usually when you're looking for more: more octane, more stability, more consistency, more ethanol.

Zachary J. Santner, senior specialist of quality at Sunoco, admits that the choices can be overwhelming. "A lot of time," he says, "people are scared of race fuels." For those looking to move past traditional street fuels, he offers three easy steps.

Step 1: A street-legal, 100-octane fuel like Sunoco 260 GT represents a solid first step up from pump fuel, Santner explains. The extra octane creates a safe space to push and tune the vehicle, he says, but a special setup isn't required.

Like all Sunoco Race Fuels, he notes, this one is always made to the same recipe—meaning you won't have to alter your tune. Pump fuels, on the other hand, can change according to season, location or brand. Sunoco GT also doesn't require any special handling. (For those living in California, Sunoco offers SS 100, a similar product.)

Step 2: If you need more octane for the headroom to push things further, Sunoco offers 260 GT Plus. This one carries a 104-octane rating, meaning it can withstand more boost and more compression.

But there are some tradeoffs, Santner notes. First, this unleaded fuel isn't a street-legal product. Also, that extra octane comes courtesy of more ethanol plus MMT, an octane booster. That elevated ethanol content might require a tune that delivers more fuel, while sunlight can degrade the MMT—special handling and storage required.

Step 3: The 105-octane rating of Sunoco's Evo 10 might not sound like a big jump up, but this fuel is highly oxygenated via an extra dose of methanol. That methanol will help reduce heat, Santner explains, a big plus for forced induction engines.

The cautions here? Special handling, since this fuel also contains MMT and, again, more tuning. "You're going to need 5% more fuel volume than GT Plus," Santner advises.

Other Factors to Consider When Buying a Race Fuel

How do you select the proper fuel for your application? This decision tree of sorts can also help narrow down the choices.

Race or Street: If the fuel needs to be street-legal, then the recommendation from Zachary J. Santner, senior specialist of quality at Sunoco, is to go with either pump fuel or Sunoco's 100-octane 260 GT (or, for those living in California, their SS 100 instead). These street fuels can be mixed, he adds, so a 1:1 mix of 93-octane pump fuel and 100-octane 260 GT would yield 96 octane. For most track day enthusiasts, 93 octane is probably good enough, adds Fred McConnell, who is director of marketing for Sunoco and a racer himself.

Leaded or Not: Leaded fuels are not compatible with catalytic converters and oxygen sensors. Unleaded fuels will be limited to 104 octane.

Oxygenated or Not: Sunoco's oxygenated fuels contain alcohol, and that alcohol helps performance. Alcohol can have some drawbacks, though: Proper storage becomes key when you're talking about fuels containing alcohol. Alcohol is also such an effective cleaner that it could loosen deposits in older, dirtier systems and clog the fuel filter.

Displacement and Compression Ratio: "Octane numbers relate to how much heat and pressure a fuel can handle before autoignition," Santner says. However, he cautions, you can't simply pair an octane number with a compression ratio, as other factors must be considered. For example, piston diameter also must be considered: Bigger pistons can require more octane because the flame front has to travel further, he explains.

Redline: A fuel's aromatic content should also be considered. Fuels with a low specific gravity—0.700 to 0.720—have a low aromatic content and will burn faster. When would you want a faster-burning fuel? With very high engine speeds, for example.

However, a higher specific gravity doesn't always mean a slower burn rate. Alcohol-blended fuels burn quickly despite a specific gravity of around 0.791. When getting to this point of the decision tree, Santner adds, you might want to discuss the particulars with your engine builder and fuel supplier.

Diving Deeper Into Leaded Race Fuels

Lead was legislated out of pump fuel decades ago, but there's still a place that you'll find it: at the track. Adding lead to gasoline is an easy, inexpensive way to increase octane, something craved by high-compression, fast-spinning engines–especially those from the days before fuel injection.

But when faced with all of the choices, which race fuel is right for you? Zachary J. Santner, senior specialist of quality at Sunoco, notes that three products will cover most road racers requiring a leaded, high-octane product.

110 Octane: Sunoco's Standard, a 110-octane fuel, has basically been around since the '70s. Think of it as an entry-level race fuel, Santner says, "that can satisfy a pretty sporty performance build." Define sporty? He figures roughly below these three parameters: a 13:1 compression ratio, a 4-inch piston bore and a 7000 rpm redline.

112 Octane: "Supreme is for when people are pushing things a little bit further," Santner says of Sunoco's 112-octane leaded race fuel. "Supreme is a little lighter and has less aromatic hydrocarbons, so it burns a little quicker." How can you tell a fuel's weight? Check out its specific gravity. Faster burning and increased octane make it better suited to a more aggressive setup–figure engine speeds north of 7000 rpm, compression ratios up to about 15:1, or piston bores past 4 inches.

116 Octane: High-revving, high-compression, big-block engines–picture something extreme, like a big-block Corvette, 427 Cobra or Ford GT40–need a lot of octane plus a lightweight fuel that will provide a fast flame front across those large-diameter pistons. A 116-octane fuel like Sunoco's Maximal is designed for these situations, Santner explains.

What About too Much Octane? Too much octane won't hurt anything or cause power losses, Santner says, noting that if you're debating between 110- and 112-octane fuels, the 112 might be the answer since it would allow more ignition timing. "When you get to the higher end of Standard being the right fuel for you, you might want to look at Supreme," he says. The prices for 5-gallon pails are close, too: about $95 for Standard and $100 for Supreme. Figure about $115 for 5 gallons of the 116-octane fuel. And, we should note, prices drop when purchased by the drum or at a pump.

part 4

SPECIAL ENGINE NEEDS

While the basic fueling needs of an internal combustion engine holds true for most vehicles, some require additional consideration before you fill up.

Fueling Your Boosted Engine?

Time to fill up your forced-fed car? Time to discuss some science.

Science Fact No. 1: Boost brings the heat. Okay, most of us here know that. It's why forced induction is usually paired with an intercooler.

Science Fact No. 2: Ethanol has a cooling effect as it evaporates. If you pour some alcohol on your skin, you can actually feel that cooling sensation. Same goes for the ethanol in fuel, too. See where we're going here? Like a mechanical intercooler, an ethanol-blended fuel can help lower the air/fuel charge's temperature.

Science Fact No. 3: Race fuels are more consistently formulated. The sign at the local station might say that the fuel contains up to 10 percent ethanol, but how do you know the actual figure? Street fuels are constantly reblended depending on the season and other factors. If you tuned your engine on a certain fuel, you probably want to remove that potential variable at the track.

Science Fact No. 4: Ethanol fuels burn quickly. This makes smaller-displacement, high-rpm engines happy.

Science Fact No. 5: Higher octane allows for more boost. The same octane that prevents preignition and knock in high-compression, normally aspirated engines is especially important in highly boosted engines.

Science Fact No. 6: Ethanol needs more volume. If you're making the switch from pump fuel to E85, figure that you'll need about 40 percent more fuel, meaning bigger injectors and, likely, a higher-volume fuel pump.

Scientific Conclusion: What does all of this science mean? A forced induction engine making a lot of boost can take advantage of a high-octane, high-ethanol fuel like E85. And if, for whatever reason, you'd rather not run a fuel containing a lot of ethanol, at least look for one containing a high octane number.

What Fuel to Feed a Rotary Engine?

The rotary engine is a unique animal, combining low compression ratios with high combustion temperatures. It also requires a fuel that can deliver lubrication to the apex seals.

Since that sounds like a tall order for the fuel, we asked for product recommendations from someone who knows championship Mazda race cars: Jesse Prather of Jesse Prather Motorsports. "I will use either 89- or 91-octane pump fuel," he explains, citing the rotary's low compression ratio. "Many builders will claim to see more power on even lower octane levels, but I have not found that.

"When you port them for more power," he continues, "the main issue is keeping the combustion chamber oiled properly. The problem with this is that [standard] engine oil does not burn efficiently and leaves a carbon residue that can cause all sorts of problems. This is why we use racing two-stroke oil at a higher ratio."

For a turbocharged rotary, Prather recommends 91-octane fuel or higher. "For turbo use," he adds, "it's imperative to be aware of your timing and keep that lower for use with boost."

What would make the ideal rotary fuel? An ethanol-enriched fuel makes more power, Prather adds, but it's not legal under his racing regulations. A faster-burning fuel also helps increase power. "You have to wrap your head around the fact that the combustion chamber is always moving, and the port timing makes the biggest difference in overlap."

Can a specialized racing fuel be a better solution? "Combustion chamber deposits/buildup can be a death sentence for rotaries," notes Zachary J. Santner, senior specialist of quality at Sunoco. "Racing fuels in general are more refined than pump gas and will tend to burn cleaner, with less soot residue. Our unleaded race fuels also contain a healthy dose of detergent to prevent deposit buildup.

"Toluene is an aromatic–double-bond ring structure–hydrocarbon that burns slower than straight or branched hydrocarbons," Santner continues. "Our best fuels fitting these criteria would be Sunoco Optima, 95 octane, for non-ethanol use and Sunoco 260 GT, 100 octane, for street-legal use, where 10% ethanol helps performance and should be used if rules allow. I can't stress enough that I didn't pick these because of high octane: It's all the other properties that will make a fast-burning, quick-atomization, clean fuel that can offer great performance while protecting the engine."

What Fuel for Max Horsepower?

Do all fuels make the same horsepower? Not quite.

Octane Matters: "Engines that use higher compression ratios are able to operate at a higher efficiency," explains Zachary J. Santner, senior specialist of quality at Sunoco. "In order to run higher compression, you need higher octane or the fuel will pre-ignite."

A high-octane gasoline won't necessarily translate to more horsepower, but such a fuel will permit higher compression ratios and increased boost levels—things we tend to favor in our quest for more power.

Too much octane? Supplying an engine with more octane than necessary won't cause any issues, assuming that fuel still meets the engine's requirements regarding lead, ethanol and the like.

Ethanol Matters: "Oxygen is the limiting agent in the reaction," Santner says about the combustion process. "If we can burn more oxygen, we can burn more fuel and make more power."

Increasing the amount of oxygen sent into the combustion chambers often includes maximizing the usual suspects: boost, airflow, displacement and engine speed. It's why a high-winding race engine running big throttle bodies will make more power than the standard issue.

Adding more ethanol also adds more oxygen to the combustion process. "You're essentially increasing the displacement of the engine," Santner says of that last option.

Too much ethanol? Ethanol doesn't match the energy density of straight gasoline, so more is needed, requiring a higher-capacity system—think bigger injectors and increased fuel pump capacity.

Straight ethanol also has an extremely low vapor pressure, Santner explains, which could hurt an engine's cold-starting ability. E85 provides some gasoline to make the blend more civil. "Gasoline is a blend of many chemicals so it can work well in different climates," Santner adds.

Distillation Curve Matters: "Fuels that will evaporate more readily will help an engine reach its full performance potential," Santner explains. Gasoline is designed as a liquid for transportation and storage, he continues, but it needs to transition to a gas phase for combustion. "Liquid fuel can't burn."

Reid vapor pressure is used to measure the distillation curves of different gasolines, with a higher RVP indicating a fuel that's more eager to form an explosive mixture with air, so to speak. RVP numbers aren't printed on the pump but can usually be found online, especially for specially blended race fuels.

Too much evaporation? Most Sunoco Race Fuels, for example, have an RVP between 4 and 9 psi. With atmospheric pressure at 14.7 psi, Santner explains, a fuel with an RVP of 14.7 would actively boil at 100 degrees Fahrenheit. Fuel systems don't like to work with both gas and liquid, he continues, and the likely result is known as vapor lock—the engine simply won't run as intended.

What Is Vapor Pressure and Why Should You Care?

Know how stale fuel can leave an engine sluggish or hard to start? Or ever wonder why winter fuel blends can hurt miles-per-gallon numbers? A dive into fuel vapor pressure will explain why.

But first we need to quote the Encyclopædia Britannica (hence the extra u's): "Vapour pressure is a measure of the tendency of a material to change into the gaseous or vapour state, and it increases with temperature."

Gasoline is measured according to its Reid vapor pressure. "Reid vapor pressure is specifically related to how easily the fuel evaporates at 100 degrees Fahrenheit," explains Zachary J. Santner, senior specialist of quality at Sunoco. "Gasoline is a liquid for convenient handling but needs to easily vaporize so it can mix with air for complete combustion."

Liquid gasoline can't burn–it's the combination of air and gasoline vapors that ignites. That's why engines mix the two via a carburetor or fuel-injection setup.

A gasoline's Reid vapor pressure simply measures the amount of vapor coming of the fuel that's free to mix with oxygen for easy starting and fast throttle response.

Butane, one of the many compounds found in pump gasoline, is used to tailor gasoline's vapor pressure to the EPA specs for each U.S. state based on typical climate throughout the year. (Small side note: Sunoco notes that the vapor pressure specs of its race fuels remain constant year-round, as each blend follows a set recipe.)

Adding about 10% more butane in the winter–thus raising the vapor pressure–helps engines start in colder weather. However, butane contains about 20% less energy than gasoline, so the fuel efficiency will be slightly lower. Santner adds that Sunoco Race Fuels don't contain butane due to its tendency to quickly evaporate during the warm months of the racing season.

"If the fuel tank is vented to atmosphere, the butane can start to evaporate out unless the daily temperatures are below freezing," Santner explains. "This makes cold-weather fuel more susceptible to vapor pressure loss." To prevent it, fuel containers should be tightly sealed during storage.

Reread that previous paragraph and take home this fact: If a fuel supply is allowed to vent to atmosphere, the butane evaporates and contributes to smog, while the fuel left behind becomes harder to ignite. As they say in the biz, it goes stale.

One more note from Santner: "If you're using fuel in cold months, make sure it was purchased in cold months. A lot of people run into trouble when they try to start their snowblower on the gas they have left over from summer."

What Is Specific Gravity and Why Should You Care?

Fuels can vary by so many different properties. The biggies are octane, oxygen, lead content, and something called specific gravity, which measures the ratio of a substance's density against a standard. When that substance is a liquid, that standard is water.

Gasoline weighs less than water, and most blends have a specific gravity somewhere between 0.7 and 0.8. You might not choose a fuel based on its specific gravity, but that number can still reveal a lot.

Fuel Consistency: Race fuels can be called boutique products since they're produced in small quantities to a very tight recipe. "With pump gas, there's a huge variety from batch to batch and from refiner to refiner," notes Zachary J. Santner, senior specialist of quality at Sunoco. "With our fuels, we don't change the recipe ever."

The material safety data sheets will confirm that fact. The specific gravity of Sunoco Race Fuels' 260 GT, for example, is 0.734. For pump fuel, often just a range is provided, like maybe 0.7 to 0.8.

Burn Rate: All else being equal–same octane, lead and oxygen content–a lighter fuel burns faster. Take Sunoco's Standard and Supreme fuels. Both are leaded, unoxygenated race fuels offering similar octane numbers: 110 and 112, respectively. However, the Supreme weighs less, so in theory it should burn a bit quicker.

Fuel Metering: Specific gravity can affect float level and thus carb setup. "Modern injected engines are smart enough to adjust on their own," Santner explains. "The computer will need to adjust for a fuel with different specific gravity, but the driver would never really know."

Fuel ID: The specific gravity of a fuel sample can also help identify it; Summit Racing advertises a fuel hydrometer kit for about $250. Then add in the fact that many race fuels are tinted at the refinery. If you have a green fuel with a specific gravity of 0.762, for example, there's a good chance that it's Sunoco 260 GTX.

Fuel Health: Fuels get heavier as they age. Blame evaporation. A hydrometer can be used to monitor the freshness of a drum of fuel.

Why Not Avgas?

This isn't a new idea: Why not run aviation fuel when seeking more power? Thanks to its high octane and lack of ethanol, this avgas sounds intriguing.

High Octane: Pump fuel intended for cars and trucks is rated on the Anti-Knock Index, which is the average between the Research Octane Number and the Motor Octane Number. Avgas, however, is rated on a slightly different scale. As a result, the avgas 100 found at many regional airports would have about as much knock resistance as a 105-octane fuel intended for cars and trucks.

Highly Refined: Zachary J. Santner, senior specialist of quality at Sunoco, notes that avgas can be more refined and consistent than the fuel found at the corner store. Vapor pressure for avgas, he explains, often falls between just 5.5 and 7.1 psi; depending on the season and location, typical pump fuel for passenger cars can range from 5 to 15 psi. However, Santner adds that his company's race products never deviate, always following the same formula.

Zero Ethanol: Avgas doesn't contain any ethanol. While ethanol can help gasoline make more power, it can also cause hardware issues in older vehicles. "Can't pull your plane over on the side of the road if there's a problem with the fuel system," Santner notes.

Some Lead: Not only does lead cause smog, but it's not compatible with the oxygen sensors and other pieces of emissions equipment found in most cars built since the '70s. Even avgas 100LL, a newer, low-lead option, still contains lead—about 1.9 grams per gallon.

Legality and Logistics: Avgas isn't taxed for road use, and cars might not be welcome on the taxiways at the local airport.

Unnecessary Additives: Avgas contains some of the same additives found in pump fuel, including corrosion inhibitors and antioxidants that increase shelf life. However, some of its additives aren't found in car fuels—like compounds that prevent icing and static electricity. "It's just more additives that you don't need," Santner notes. "Car gas has additives designed for cars, and airplane gas has additives designed for airplanes."

part 5

EXPLORING ETHANOL BLENDS

Can ethanol help your engine or hurt it? Well, it depends.

Why Is There Even Ethanol in Our Gasoline?

Is that 10% ethanol found in most pump gasoline good or bad for your car, especially an older one? Like many things in life, it's complicated.

Why Is Ethanol in Gasoline? Back in olden times–up until the '70s–lead was added to gasoline to increase its resistance to knock. This tetraethyllead was found to cause smog and other issues, however, so it was eventually banned from pump gasoline. To further help reduce smog, in the '80s an oxygenate called methyl tert-butyl ether, also known as MTBE, was added to gasoline.

Small problem with MTBE: As noted by Zachary J. Santner, senior specialist of quality at Sunoco, MTBE has a "low threshold to be detected by nose and taste." In other words, a little goes a long way as far as making groundwater smell bad.

Today, ethanol is used to elevate the octane of pump fuel. The 87- and 93-octane grades regularly found at the pump, Santner explains, leave the pipelines with 83 and 90 octane ratings, respectively; it's that 10% or so of ethanol added at the distribution terminals that increases the octane to its final values.

But don't think of ethanol as a cheap fix: The science says that ethanol also increases horsepower. In fact, Santner notes, when NASCAR Cup teams moved from ethanol-free fuel to Sunoco Green E15, a product containing 15% ethanol, all of the teams were able to retune for more horsepower. In the most basic science terms, extra oxygen means extra horsepower.

Why Is Ethanol in Fuel an Issue During Storage? The presence of ethanol in gasoline tends to become a hot topic of discussion as winter approaches, a time when many cars are put away.

Another feature of ethanol: It's hygroscopic, meaning it can absorb moisture from the atmosphere. For most motorists, that's not an issue because they use up the fuel soon after purchase. The problem arises when ethanol-enriched fuel is allowed to sit for a while.

The easiest fix for winter: Fill up with ethanol-free fuel. Sunoco offers Optima, an ethanol-free fuel designed for storage, while local options can be found at pure-gas.org. If you can't obtain this type of fuel, Santner adds, a higher-octane gasoline will age better than a lower-octane product.

Should You Consider Running E85?

It's a common question, especially among gearheads: What really happens if you run E85 in a car not designed for E85? The answer, as it so often is: It depends.

For a more detailed answer, we turned to Zachary J. Santner, senior specialist of quality at Sunoco. "There are definitely some compatibility issues," he explains, adding that ethanol can be tough on parts not designed for it.

What Is E85? Unlike straight gasoline, ethanol contains oxygen—about 34% oxygen by weight. That oxygen can help ethanol-enhanced fuels produce more power than those without.

However, not all E85 fuels are equal. That's because the E85 designation does not guarantee the exact amount of ethanol found inside, as the EPA allows it to range from 51% to 83%. (As Santner notes, though, Sunoco E85-R always contains exactly 85% ethanol and 15% race fuel.)

Tuning for E85: Heavily oxygenated fuels, like E85, require more fuel volume than traditional fuels. Santner ran the numbers on Sunoco's E85-R against its 260GT, a 100-octane, unleaded product. The math says that E85-R would require 30 percent more fuel. Your mileage will vary, but that's a common bump needed when running E85. Delivering that extra fuel will likely require higher-flowing injectors and fuel pump. Expect some tuning, too.

Damage From E85: Will E85 hurt a fuel system not designed for it? It depends. The EPA says that all passenger cars built for 2001 and later can handle E15, meaning they can take some ethanol. Santner cautions that ethanol can act like a high colonic for the fuel system—and all of that freed junk can lead to clogged fuel filters and injectors.

Ethanol is also hygroscopic, meaning it will absorb moisture from the atmosphere. A vehicle designed to run on E85 will feature hardware that can handle damp fuel, especially over time. Can yours? And if not, what can you do to shorten the amount of time that the E85 sits in the tank?

So, back to the original answer: It depends—and you might want to talk to other owners of your make and model who have already made the jump to E85.

Why Does E85 Run Cooler and Make More Power?

Does E85 run cooler and make more power than traditional gasoline because a website says so? No, it's because science says so. And while you can, in fact, argue with science, rarely will you win.

"The key player here is the heat of vaporization," explains Zachary J. Santner, senior specialist of quality at Sunoco. Heat of vaporization, also referred to as enthalpy of vaporization, refers to the amount of energy a liquid absorbs from its surroundings as it changes from a liquid to a gas.

"When things evaporate," Santner explains, "they actually absorb heat from the surroundings." As each molecule flies away and leaves the nest, so to speak, it takes some energy with it. As a result, the liquid left behind has a lower average energy.

All liquids have an enthalpy of vaporization. For gasoline, it's about 150 BTU per pound. For ethanol, that figure climbs to 360 BTU. (For a real-life example of enthalpy of vaporization at work, notice how rubbing alcohol cools the skin as it evaporates.)

Then add in the fact that an engine requires 30% to 40% more E85 than traditional pump fuel to make combustion–so that's even more cooling at work. "So anywhere ethanol evaporates, it's cooling," Santner adds.

Ethanol can make more power, too, since it contains more oxygen–about 34% oxygen by weight. "More oxygen means more fuel," Santner explains, "so more horsepower."

But this isn't a free lunch. Not only will the engine drink more E85, but that E85 can be trickier to store because it wants to evaporate and absorb moisture quicker than gasoline. A closed container–and closed vents in a fuel cell, if so equipped–are paramount.

Santner points to a possible suspect for E85's bad rap regarding its short shelf life: the gasoline component of the mixture. Pump E85 is required to contain only 51% to 83% ethanol, and the gasoline component could well be 83 octane. Sunoco E85-R, he notes, always contains 85% ethanol along with Sunoco race fuel–so about 100 octane for the petroleum part.

Tuning for Today's Oxygenated Fuels

Many of the fuels found at today's pumps are oxygenated, meaning alcohol has been added. You can see it right there on the pump: "May contain up to 10 percent ethanol."

Why is the alcohol–ethanol, technically–in there in the first place? Good question.

Oxygenated fuel provides a few benefits: It helps reduce air pollution as well as reliance on nonrenewables. It can provide more horsepower, too. "Gasoline with 10 percent ethanol contains about 3.7 percent oxygen," explains Zachary J. Santner, senior specialist of quality at Sunoco. "This extra oxygen will increase the efficiency of your engine, creating additional horsepower. However, the engine will need to use more fuel volume, which is why mpg goes down."

But will a carbureted engine automatically adjust to take advantage of that increased efficiency? Likely not, but the Sunoco Race Fuels website contains some handy info on the subject:

"In simple terms, you should start with adding enough extra fuel to offset the increased oxygen content. What does that mean? Well, let's say you were running Supreme, which has no oxygen. If you switch to EXO 2, you will need to add approximately 10 percent more fuel to offset the 10 percent oxygen content.

"The extra oxygen effectively leans out the air/fuel mixture, so you need to add enough fuel to get the air/fuel mixture back where it belongs. Actually, a safe way to introduce EXO 2 to your engine would be to go even richer than you think the engine needs. Remember, engines can tolerate being rich a lot better than being lean!"

Sunoco admits that it isn't a carburetor expert, though: "So have a conversation with your carb builder if you need to know how their carbs need to be re-jetted."

Another useful tool to get your carburetors properly dialed in for today's oxygenated fuel? A chassis dyno that's equipped with a wideband air-fuel gauge and run by a competent operator.

Making Your Own Ethanol Blend

Let's say your car isn't configured to run on E85, but you'd still like to take advantage of the benefits offered by ethanol–like more power and a cooler-running engine. Can you run a smaller concentration to get some of the perks? Quite possibly.

Welcome to modern times, when most pump fuels contain some ethanol. It's a renewable resource that also increases a fuel's octane rating. Most pump gasolines carry the E10 designation, meaning they contain up to 10% ethanol.

E85, as the name suggests, contains even more ethanol. The standard, however, allows the content to range from 51% to 83%. By the way, ethanol content testers start around $15.

While the extra oxygen found in ethanol allows an engine to make more power, there's a tradeoff: More ethanol is needed to make that power, hence the need for higher-capacity injectors and fuel pumps. Plus, the fuel system components must be compatible with ethanol.

So, if E85 is too much for your system and E10 isn't enough for your wishes, can you make your own blend that's somewhere in the middle? Yes.

"In the grand scheme," notes Zachary J. Santner, senior specialist of quality at Sunoco, "gasolines are blends of hydrocarbons. So you can continue to blend them for your own desired purpose."

Let's say, for example, that your fuel system can handle some ethanol but can't deliver enough to support E85–like, maybe E40 sounds like the right concentration. You can mix in some E85 or E98 and, using a weighted average, compute the final blend. (Sidebar here: While the ethanol content of pump E85 can vary, Santner notes that Sunoco E85-R always contains 85% ethanol; likewise, the brand's E98 recipe never changes.)

Here's that weighted average formula:

$$\frac{((\text{volume pump gas}) * (\%\ \text{ethanol in pump gas}) + (\text{volume E85}) * (\%\ \text{ethanol in E85}))}{(\text{volume pump gas}) + (\text{volume E85})}$$

Does More Oxygen Always Mean More Power?

The promise almost sounds too good to be true: Get more horsepower just by using a certain type of fuel. What's in these magic elixirs? Oxygen. A lot of it. But like most seemingly miraculous solutions, today's highly oxygenated fuels come with a potential tradeoff.

The Promise: It's right there in print on the Sunoco Race Fuels website: "Evo 10 produced a 17% HP gain against 93 octane pump gas when tested at our local performance tuning shop." Evo 10 is an unleaded, highly oxygenated, 105-octane race fuel that's 10 percent oxygen by weight. Typical pump gas containing 10 percent ethanol by volume contains only 3.7 percent oxygen by weight.

The Proof: Zachary J. Santner, senior specialist of quality at Sunoco, references a dyno chart produced by a supercharged Ford Coyote V8. Running Evo 10, the Ford produced a max of 879 horsepower. When fed a competitor's 105-octane unleaded fuel, the engine topped out at 866 horsepower.

The Science: "A simple way of looking at this is that gasoline has a high energy density—BTU per gallon—when compared to other fuels," Santner explains. "So, one tank of gas can make you go farther than other fuels. When looking at energy density and air/fuel ratio together, you can see how much energy is produced during combustion. Some fuels release more energy when combusted with 1 gram of air. These fuels will offer higher power output from an engine. The components in Evo 10 allow it to release slightly more energy for the amount of air burned when compared to gasoline."

The Extreme: He offers another example: "Nitromethane has only 38 percent the energy density of gasoline. When combusted with 1 gram of air, nitromethane releases over 2.1 times more energy. Nitromethane wouldn't win the miles-per-gallon comparison, but the energy released in combustion is much higher."

The Tradeoff: Like Santner noted, that extra performance comes with less fuel efficiency. All fuels are a compromise, he notes. "You can't argue with chemistry."

Why Not Methanol?

Running methanol as a fuel sounds great–even more performance potential at a lower price. But, first, some considerations:

Methanol is the simplest form of alcohol, and Sunoco sells it, denatured with 2% gasoline, under its E98 label. "Methanol and ethanol are commodities and used in massive amounts in the chemical industry," explains Zachary J. Santner, senior specialist of quality at Sunoco. "The source can be from various feedstocks." Methanol will kill you dead if consumed, though.

A 54-gallon drum of Sunoco E98 retails for close to $435. The same dealer retails a drum of Sunoco E85-R, a race fuel that contains 85% ethanol, for close to $445. But while methanol costs less than the race fuel, Santner notes, racers will use a lot more of it, negating the advantage.

Sunoco 260 GT, a popular race fuel, has a stoichiometric air/fuel ratio of 14.1:1. The ideal air/fuel ratio for E85-R is 9.8:1. Methanol is happiest around 6.5:1. "This ratio is mass air/mass fuel," Santner explains. "If we take the inverse of these ratios, we can have mass of fuel needed per mass of air brought into engine. Methanol would be 0.15 while 260 GT is 0.07, meaning roughly half as much fuel mass is needed. Since twice as much mass of methanol is being evaporated in the intake, there will be even more cooling in the intake, leading to a denser air/fuel mixture."

While methanol is popular in some forms of motorsports, sports car racing isn't always on that list. The fact that methanol burns clear can be an issue. Many sanctioning bodies either specifically ban it or don't list it under their approved fuels.

part 6

KEEPING THINGS CLEAN

If you keep your vehicle looking spick-and-span, shouldn't you do the same for the inside of your engine?

How Top Tier Street Fuels Keep Your Engine Cleaner

When you stop to fuel up your street car, what's the most important draw? Price? Location? Points? Clean toilets? Artisan sandwiches sporting the perfect amount of lettuce?

Probably not the gasoline itself, right? After all, aren't all pump fuels the same?

Well, no.

Some gasolines qualify as Top Tier. These fuels meet the performance standards set forth by a group of vehicle makers: BMW, General Motors, Stellantis, Ford, Honda, Toyota, Volkswagen, Mercedes-Benz and Navistar.

"The Top Tier gasoline program was started by auto manufacturers who wanted cleaner fuels to reduce mechanical failures of their vehicles," explains Zachary J. Santner, senior specialist of quality at Sunoco.

What makes these fuels so special? Detergents.

"Gasolines with higher amounts of detergent can prevent gunk and deposits from building up on valves, pistons, fuel injectors and intake runners," Santner continues. "A clean engine will perform better, get better mpg and lower emissions. Top Tier fuels come from the same refineries as all other fuels but are given a higher treat rate of detergent at the terminal level. A Top Tier fuel like Sunoco can help keep your engine cleaner than a fuel that meets the government's lowest additive concentration of detergent."

In 2016, AAA set out to test that claim, running both Top Tier and non-Top Tier fuels through a 2.3-liter Ford engine mounted in a dyno cell. Each fuel was run for 100 hours, simulating about 4000 miles of real-world driving. After each fuel sample, the engine was disassembled so that deposits could be measured.

The full report covers 33 pages—you can find it at aaa.com—but here's its take-home message: "The test engine operated on a Top Tier gasoline averaged 19 times fewer intake valve deposits than when it was operated on non-Top Tier gasoline."

Not all brands carry the Top Tier designation, but Santner notes that all of Sunoco's pump products do, no matter the grade, the location or the time of year.

How Dirty Fuel Can Lead to a Dirty Engine

Is dirty gas fouling up your engine, leading to clogged injectors and combustion chamber deposits? Possibly. But first, what exactly do we mean by dirty gas?

The fuel delivered from that gas station pump—called a dispenser in the biz—could contain water or foreign matter. Something we learned from PetroClear, maker of filters for those dispensers, is that fuel filter requirements vary from state to state. PetroClear's site shows that Georgia, for example, has specific limits regarding water and particulate material in the fuel, with dispensing equipment requiring filters of 10 microns or finer—the same spec that Holley recommends for a fuel-injected engine.

The filter requirements across the border in Florida? None. The site lists more than a dozen other states without filter specs for fuel dispensers, including California, Illinois, New York and Ohio. "There probably are filters," notes Zachary J. Santner, senior specialist of quality at Sunoco, "but no requirements for how fine a filter."

The fuel itself could contain contaminants, too. Less refined fuels will carry more gum, varnish and other unstable compounds than more refined fuels. What fuels are more refined? Generally speaking, higher-octane products or race fuels.

Fuels that qualify as Top Tier will also contain more detergents, and Santner notes that all Sunoco pump products meet that standard. Those detergents, Santner continues, can wash away deposits and keep them from forming.

Why does all this matter? Dirt, gum and other stuff in your fuel can lead to carbon deposits inside the combustion chamber, especially on the back sides of the intake valves. This can be an even bigger issue for a direct-injected engine, as the injectors don't constantly wash the backs of the valves.

Then add in the deposits caused by oil from weak valve guides or the crankcase ventilation system. Those carbon deposits are porous, too, and can absorb fuel—"almost like a sponge," Santner adds—preventing the fuel system from accurately providing fuel to the engine.

How to protect against these deposits? With a clean fuel—one high in detergents—and a clean fuel filter.

Cars That Sit Need Clean Fuel, Too

Think fuel cleanliness isn't important for classics that don't get driven much? Wrong.

If anything, explains Zachary J. Santner, senior quality specialist at Sunoco, a Top Tier fuel that's high in detergents might be even more important for an older car that spends a little extra time in the garage.

Our story starts back in the 1990s, as new minimums for fuel additive standards allowed gasoline retailers to decrease the levels of detergents found in pump fuel. Soon after, though, the problems started: increasing reports of engine issues due to combustion chamber deposits.

So, in 2004, a group of automakers—the biggies, including GM, Ford, Toyota, Volkswagen, BMW and Mercedes-Benz—released its own standard for gasoline detergent. It was called Top Tier Detergent Gasoline, and retailers could voluntarily join the program. (A current participant list can be found at toptiergas.com.)

A 2016 study by AAA aimed to see if Top Tier fuels really kept combustion chambers clean. Both Top Tier and non-Top Tier fuels were run through the same engine for 100 hours to simulate about 4000 miles of real-world driving. The engine was cleaned and freshened between fuels. Parts were weighed and inspected.

According to AAA, the deposits from Top Tier fuels averaged 34.1 milligrams per intake valve, while the non-Top Tier fuels left behind a significantly higher average of 660.6 milligrams.

Those deposits found on the valves, Santner explains, come from fuel and engine oil. Fuel can contain residual gums that stick to the valves, and oil can travel past valve seals on a worn engine.

Picture an older car that's been sitting, he continues. As it sits, a little bit of oil seeps onto the backs of the valves. When the engine is then fired up, some of that oil is burned, some is washed away by the fuel, and some gets coked onto the backs of the valves.

A fuel high in detergent can wash away that carbon before it does damage, Santner says. "There's enough detergent to keep things clean," he adds of Top Tier fuels. "At Sunoco, all of our grades are Top Tier."

How to Keep Carbon Deposits Out of Your Engine

Given a choice, most people would rather not have carbon deposits inside their engine. Just picture what that gunk is doing to the engine's performance.

But what exactly causes those deposits? And, more importantly, how do you keep them at bay?

How Deposits Form: "Fuel can leave deposits, and oil can also leave deposits," explains Zachary J. Santner, senior specialist of quality at Sunoco.

But your car runs on gasoline, not oil, right? To help combat pollution, since the 1960s, crankcase ventilation systems have directed blowby—the oily and gasoline-filled vapors found inside the engine—back into the combustion chamber. "Rather than letting that oily air leave the engine," he explains, "you burn it."

Both oil and gasoline contain hydrocarbons, and when heated to high temperatures but not combusted, they form carbon-like deposits via the coking process. For a visual, Santner says, picture the carbon buildup found on the bottom of a frying pan.

Another Cause: Incomplete combustion—possible due to an inefficient tune—can also leave carbon deposits inside the combustion chamber.

And one more: The dissolved gums and varnish found suspended in the fuel can also form carbon deposits. Gum is a natural byproduct of the refining process, and a certain amount is allowed in the final product.

How to Make Deposits Go Away: Other than disassembling the engine and sending the parts through the parts washer, how to keep these deposits at bay?

"Fuel is a really good solvent," Santner says, "and they put in additives to make it even better." Those additives include detergents that help prevent deposits while reducing those already allowed to form. From a AAA study comparing Top Tier fuels to those not made to that standard: After 100 hours on a dyno—enough to simulate 4000 real-world miles—the non-Top Tier gasolines left 19 times more carbon inside the engine.

How can you tell if a fuel contains suitable detergents? Santner recommends looking for one carrying the Top Tier designation—and, he notes, all of Sunoco's fuels are on that list, from regular up through premium grades.

Does Your Engine Need an Upper Cylinder Lubricant?

We've seen the bottles lined up at the auto parts store: upper cylinder lubricants. Their brightly colored packaging promises increased performance and decreased wear. After all, the labels state, the top end of your engine is a vulnerable place.

So what does the science say about this?

Gasoline serves as an efficient degreaser and, as explained by Zachary J. Santner, senior specialist of quality at Sunoco, alcohol is an even more effective one. If you feed an older car that's long lived on a diet of subpar gasoline a healthy dose of alcohol, Santner continues, that sudden cleaning can lead to issues in the fuel delivery system—like a clog somewhere in the works. That alcohol is simply cleaning away years of accumulated sludge.

Unlike petroleum products, he continues, that alcohol doesn't leave behind any residue that can provide some level of lubrication, thus allowing a metal-on-metal situation to develop. Picture valve stems that, thanks to the cleaning properties of alcohol, are now running dry. Scary stuff, right?

These upper cylinder lubricants, he explains, add some lubrication properties into the gasoline. The products are simply mixed into the gasoline.

The big question: Should this problem keep you awake at night?

Santner wouldn't worry about it if running a standard pump fuel, even one labeled as E15. Go all the way up to E85, he says, and it might be something to consider depending on your setup. Still, he's not terribly concerned about the need for adding an upper cylinder lubricant—at that point, he notes, perhaps it's something to at least track, monitor and treat should the need arise.

So when is an upper cylinder lubricant needed? When running fuels that nearly contain all alcohol—like E98 or methanol. "When you enter these worlds of alternative fuels," he explains, "there are considerations." He does see a lot of drag racers running upper cylinder lubricants as these fuels are simply more prevalent in that world.

part 7

HANDLING FUEL SAFELY

With great power comes great responsibility, so heed this advice when it comes to fuel.

Gasoline Makes a Terrific Degreaser, Yet This Practice Can Kill You

The Science: People have been cleaning greasy parts with gasoline for decades, and the science explains why it works so well: "Number-one rule of solubility is likes dissolves likes," explains Zachary J. Santner, senior specialist of quality at Sunoco .

In this case, gasoline, oil and grease are all formed from hydrocarbons. The big difference lies simply in the length of the chains–science talk for how far each product is refined.

The Safety: More science explains the danger of using gasoline as a solvent. Compared to kerosene, diesel fuel and proper parts-cleaning solutions, gasoline has a high vapor pressure, meaning it easily evaporates from an uncapped container. Those gasoline vapors then pool on the ground–picture the fog machine chugging away the last time you saw Iron Maiden or Judas Priest.

Now the big concern: Those pooled gasoline vapors are quite combustible, easily ignited by a welding spark, pilot light or other common source. Now you're standing in the middle of fire, which, despite what you might think, is not very metal.

The Solution: How do we know that proper cleaning solutions offer a safer alternative to gasoline? Check the safety data sheets–easily found online–and look at the flash points.

OSHA defines a flash point as "the minimum temperature at which a liquid gives off vapor within a test vessel in sufficient concentration to form an ignitable mixture with air near the surface of the liquid." Then there's a line for those who don't own a lab coat: "The flash point is normally an indication of susceptibility to ignition."

Gasoline has a flash point of 40 degrees below zero, meaning it's flammable once it's warmer than that temperature; CRC Parts Washer Solvent, in contrast, has a flash point of 204 degrees Fahrenheit. "The liquid won't produce enough vapor to support a fire until 204 degrees," Santner explains.

Another alternative: water-based cleaners that, Santner continues, rely upon surfactants and emulsifiers to suspend oil and grease in the cleaning solution and remove them.

How to Handle Gasoline Safely and Remain Fire-Free

A gas fire burns hotter than a thousand suns–okay, maybe it just seems that way–and thanks to the low viscosity of gasoline, it quickly spreads, turning a small problem into a big one.

So let's be careful out there. Zachary J. Santner, senior specialist of quality at Sunoco, offers some basic safety practices.

If you get a hole in your drum, pail or other fuel carrying device, think quickly and rotate the vessel so the hole is now at the top. Gravity will help you with the rest. In the panic of a fuel leak, Santner says, people often forget the basics.

Technically, gasoline doesn't burn as a liquid. It's the vapors that ignite. More science: As temperatures rise, more vapors boil off, meaning a greater likelihood of combustion. Santner's safety tip: If possible, handle fuel when ambient temperatures are lower. How can you put that into practice? If you have a choice, try to fill your fuel jugs earlier in the day or later in the evening.

Five-gallon pails are sealed with a quick-release pull tab. Before pulling that tab, Santner cautions, make sure the opening is at the highest point, meaning you should be careful when opening the pail on an incline. If the pail is sitting on an incline and that tab is pulled while fuel is surrounding the opening, the sudden release of pressure can send fuel flying–possibly right into your face.

Despite the temptation, don't completely fill a fuel container. Leave some head space, he cautions. Otherwise, the expansion and contraction of the fuel can damage the container. This is why, he explains, a 55-gallon fuel drum actually only contains 54 gallons of gasoline.

Gas vapors are heavier than air. Why should you care? Are you working around fuel in the shop? Realize that those fuel vapors could be pooling around your feet, right where potential ignition sources await. Adequate ventilation is your friend.

Yes, static electricity can ignite gasoline. You know those signs about not placing a gas can inside a pickup truck bed when refueling? Santner says they're there for a reason.

Use the right tool for moving fuel between containers: either a syphon or drum pump intended for gasoline. Don't rig up something with beer brewing equipment, and/or compressed air he cautions.

A Potentially Deadly Fuel DIY

Can't find storage-friendly, ethanol-free gas locally? Did you know you can make your own? There are countless videos on YouTube showing the process–but before you rush off to watch them, keep reading.

The Theory Behind Home-Brewed, Non-Ethanol Fuel

Gas companies add ethanol to most pump fuels to increase the octane rating while also tapping a renewable resource. But that same ethanol can also attract moisture from the atmosphere, leading to long-term storage issues.

While non-ethanol specialty fuels are available–the Sunoco Race Fuels catalog contains several options, for example–some people have taken to creating their own using a process detailed in countless YouTube videos.

First, they simply add water to some pump fuel. The water attracts the ethanol from the gasoline and, thanks to phase separation and density, settles at the bottom of the container. Syphoning out that water/ethanol mix yields a fuel supply that's theoretically free of ethanol.

The Reality Behind Home-Brewed, Non-Ethanol Fuel

Zachary J. Santner, senior specialist of quality at Sunoco , notes a few concerns regarding this process, with a very big one involving safety: Gasoline vapors are rather flammable and, thanks to having vapor density heavier than air, might collect unnoticed around your feet. One spark could then ruin your day/life.

Ethanol is added to fuel to increase its octane, so removing that ethanol yields a fuel that's more susceptible to knock. In rough terms, this process would turn 87-octane fuel into 83, 93-octane into 91.

Santner also notes that the phase separation used to pull the ethanol from gasoline is impacted by ambient temperature. "The colder the temperature, the better the phase separation will be," he notes. But even under ideal conditions, he continues, this process could leave the fuel containing less than 1% water: "Any of that little dissolved water could lead to corrosion."

Santner also notes that the antioxidants added to gasoline to extend its shelf life are often water-soluble, so this homebrewed trick intended to create the perfect storage fuel could have the opposite effect by removing the additives designed to protect the fuel when sitting.

What Happens to Gasoline as It Ages?

Like many things in life, gasoline isn't forever. As gas sits around, parts of it evaporate and can escape the fuel container–and we say "parts of it" because gasoline is a fairly complex substance.

Gasoline is made up of aliphatic and aromatic hydrocarbons–let's call them open chains and closed rings. The light ends, technically known as short-chain aliphatic hydrocarbons, evaporate first, leaving behind the long-chain aliphatic and aromatic hydrocarbons. You don't need to own a lab coat to understand the results: A fuel that's light on short-chain hydrocarbons is harder to ignite because it needs a higher temperature to vaporize enough fuel to support combustion, explains Zachary J. Santner, senior specialist of quality at Sunoco.

Scientists have developed antioxidants to protect gasoline from undergoing the process of oxidation. Oxidation can lower the octane rating and increase the amount of gum in the fuel. However, these antioxidants are consumed as they react with oxygen. Regular-grade gasoline is designed to be used quickly and doesn't have the high-antioxidant package found in high-octane gas. On the other hand, Santner notes, race fuel's expensive antioxidant package gives it the longest shelf life in a sealed container–up to three years in some cases.

As gasoline evaporates, it also leaves behind gum, a technical term for the varnish residue that can gradually build up inside a fuel system. "There is a spec for how much dissolved stuff can be in fuels," Santner continues. The standard test for pump gasoline allows 5 milligrams of gum per 100 milliliters of gasoline, he adds, while, for example, Sunoco's race fuels contain a tenth of that.

Another issue: The moisture inside the air that we breathe is attracted to the ethanol found in most pump gasoline. Water does not burn nearly as well as gasoline.

Why are the aging issues related to fuel not a more common topic? For one, most gasoline is consumed rather quickly: People tend to fuel up and then drive around. Those of us who let cars sit can mitigate problems by storing fuel in a tightly sealed metal container and choosing the right type of gasoline–either an ethanol-free or a highly refined, high-octane product.

What's Lead Got to Do With It?

Lead is no longer found in street fuels, but it's still a popular ingredient in race gas. Time to explain.

Why Lead in the First Place? Tetraethyllead has been added to gasoline for nearly a hundred years. "It's a very cheap and effective octane booster," explains Zachary J. Santner, senior specialist of quality at Sunoco. Just 6 milliliters of tetraethyllead, less than 0.2 percent by volume, is the difference between the 120- and 100-octane reference fuels used for octane testing, he continues.

Why Did Leaded Fuels Go Away? To meet the emissions standards introduced in the 1970s, car manufacturers began installing catalytic converters. Lead oxide, a byproduct of combustion, leaves a residue on catalytic converters, rendering them useless. Lead as a fuel additive quickly fell from favor.

What Happened Next? Less lead in pump gas resulted in lower octane ratings. As a response, engines were detuned. Remember the glorious muscle cars of the '60s and early '70s? That all ended around 1973.

Why Is Lead Used Today in Race Fuels? The science hasn't changed, as lead still remains an inexpensive, reliable, effective way to add octane to a fuel. Sunoco, for example, still relies on lead to boost octane above 105. These race-only leaded fuels can't be used with oxygen sensors or catalytic converters, of course.

What About Alcohol? Fuels containing a high percentage of alcohol–think methanol–will, like high-octane fuels, also fight knock. However, fuels containing a lot of alcohol also require increased fuel flow, which requires specialized equipment. Small side note here: The lab tests done to determine a fuel's octane rating can't accurately score highly oxygenated fuels. "We developed this scale for measuring gasoline," Santner explains, "and now we're trying to use this scale to measure fuels that aren't like gasoline–E85, for example. Finding consistent information on octane of highly oxygenated fuels is very difficult."

Anything New on the Horizon? Look for a new wave of unleaded, high-octane fuels. Santner notes that Sunoco just released another high-octane unleaded formula called Evo 10 to its line of fuels. It's 10 percent oxygen by weight and carries an octane rating of 105 (R+M)/2.

part 8

SOME BASIC FUEL CHEMISTRY

Fuel just doesn't come out of the ground. Find out what goes into preparing the recipe that powers your vehicle.

Winter Fuels for Wintertime

Does your car sit over the winter? If so, do you wonder whether or not it will start in the springtime? Filling it with the right gas can help.

So, what defines the "right" gas? Science.

Vapor Pressure Matters: In many parts of the country, pump fuels are reconfigured for the colder months. What makes these so-called wintertime fuels so special? A higher vapor pressure.

Vapor pressure defines the rate at which the fuel evaporates, turning from a liquid state to a gas. It's these gasoline vapors that actually ignite.

The vapor pressure of gasoline naturally decreases when ambient temperatures drop, however, so the refineries reblend the fuels during the colder months to raise vapor pressures. (Since those gasoline emissions also contribute to smog, vapor pressures are lowered accordingly during the warmer months.)

If you're going to periodically run the engine during the winter months, especially one fed by a carburetor, explains Zachary J. Santner, senior specialist of quality at Sunoco, having a tank full of fuel blended for winter will help it start.

Quality Matters: Premium fuel contains more than just higher octane. The antioxidants found in premium fuel will also last longer, and during long storage periods, they become your friends and allies. These antioxidants are consumed as they react with oxygen.

"Premium is more stable and has a smaller appetite to eat up the antioxidants, so it will remain protected for longer," Santner continues. "Regular is much more unstable and will consume the antioxidant much faster. After it is all consumed, there will be varnish development and color change." That varnish, caused by the gum left behind as fuel evaporates, won't help your fuel system.

Race fuels sold by Sunoco, he adds, already have an additive package containing a fuel stabilizer. Plus, the brand offers a fuel specifically designed for storage: Optima is a very clean, non-ethanol fuel that's packed with stabilizers. When properly stored in a sealed, opaque container, it can remain fresh up to three years.

Fill It Up Before Parking for the Winter?

A common question regarding wintertime storage of a car: Fill up the tank or not? Is it better to have that tank full of fuel or air? Well, we asked an expert, asked Zachary J. Santner, senior specialist of quality at Sunoco.

His first tip? Fill up the tank before any prolonged parking: "A full tank won't have as much headspace and won't breathe as much," he says. That full fuel load will prevent moisture from condensing in the tank–moisture that can lead to stale fuel and corrosion. Whenever Santner has encountered a rusty gas tank, he says, the damage is usually found at the headspace.

"If you can," he notes, "fill it up with non-ethanol." Non-ethanol fuel is less likely to absorb moisture from the atmosphere than the ethanol-enriched fuel commonly found at the corner station.

If you can't find non-ethanol fuel, he continues, then fill up with premium. The higher-octane fuel is simply more stable, he explains, and won't go stale as quickly as regular-grade fuel.

Sunoco's Optima combines both of those properties into one fuel designed for long-term storage, he says. It's a high-octane, oxygen-free fuel that's packed with antioxidants and corrosion inhibitors.

If you don't have a fuel designed for storage handy, Santner suggests combining pump gas with a fuel additive–ideally one with an anti-oxidant package containing sterically hindered phenols. That info likely won't show up on the safety data sheet, but he advises that the popular red additive does work well.

To properly mix the additive with the gas, first pour the additive into the tank. Then fill up the rest of the tank with gas.

Where the car sits also matters, says Santner. Storing the car in a garage will help keep moisture at bay. A climate-controlled garage is best, but any garage is better than outside.

Lawn and Garden Equipment Needs the Proper Fuel, Too

Race tracks may occasionally go quiet, but engines constantly buzz away. You can likely hear them every single day: Just listen for all of the small engines powering lawn equipment.

Like our performance cars, these small engines can have special fuel requirements. A biggie that helps small engine performance: Fuel that is free from moisture.

How does moisture get into the fuel system? Easy: The moisture that's part of the air we breathe is attracted to the alcohol found in most fuels. As stated right there on the pump, most gasoline sold today contains up to 10% ethanol.

Where modern cars feature closed fuel systems that prevent the vapors from escaping into the atmosphere, most lawn equipment makes do with an open fuel system. A simple vented cap provides the necessary pressure equilibrium between the tank and the outside world.

And that vented cap also allows air—complete with some moisture—to enter the tank. The moisture then mixes with the fuel. The result can range from no operational issues at all to an engine that runs poorly or even won't start.

Zachary J. Santner, senior specialist of quality at Sunoco, admits to salvaging more than one piece of discarded lawn equipment from the side of the road. The usual culprit that sends mowers and the like to the curb? A bum carburetor caused by fuel issues, he reports.

He offers an easy way to keep moisture out of your small engine's fuel supply: Consider a gasoline that's free from ethanol, especially for really small engines that can easily choke on moisture (like those found in string trimmers) and those that sit for a while (like rarely used rototillers, snowblowers or leaf chippers).

Most big-box home improvement stores sell ethanol-free fuel right there in the power equipment section. A 110-ounce can—not quite a full gallon—can retail for about $2 5.

Santner adds that Sunoco Race Fuels makes a fuel specifically engineered for storage: When properly kept, the brand's ethanol-free Optima has a shelf life north of three years. This 95-octane fuel is also highly refined to be free of gunk—varnish, waxy residue and other trash that can stop a mower dead. A 5-gallon pail sells for about $95, making it more economical than the stuff sold in the lawn and garden center.

Do Additives Actually Work?

You've seen them: rows upon rows of brightly colored bottles, each promising more than the last. Improved fuel economy! Cleaner engine internals! A full head of hair!

Yes, we're talking about fuel additives. What exactly is in those concoctions? The answer can vary greatly. In theory the safety data sheet, usually available online, spells out their contents–helpful info should there be some kind of an incident. Sometimes, though, the SDS just provides a possible range of concentrations for individual ingredients.

For a real-world example, let's take a closer look at a popular additive that promises a cleaner, better-performing engine. (We won't name it, but let's say it's one that has been promoted for decades.)

The SDS lists kerosene among its ingredients. The kicker: According to the SDS, the amount can range from 15 to 97 percent. Similar huge ranges are provided for several other additive ingredients.

Kerosene, which is often used in fuel additives as a filler or carrier for the active ingredients, isn't the worst thing to feed an engine, explains Zachary J. Santner, senior specialist of quality at Sunoco. "Kerosene is a really good solvent," he explains, "and it's relatively safe as far as bottling it and putting it in stores."

Thanks to the vague information found on the SDS, however, exactly what is being fed to the engine remains a mystery. The bottle might contain all active ingredients, or it might be mostly filler.

For those who feel the need to use these aftermarket additives, Santner recommends following the directions on the bottle. Too much solvent can be harsh on gaskets or other internal components. "If one is good, two isn't always better," he adds.

How can you keep your engine clean in the first place? Using a Top Tier Detergent Gasoline can certainly help, he says. This standard was unveiled in 2004 so auto manufacturers could easily specify a fuel deemed clean enough for use in their engines.

More information on Top Tier Detergent Gasolines can be found at toptiergas.com, and Santner notes that all Sunoco products are on that list–all grades, all stations, all seasons. (Something that we noticed: Offering clean restrooms and artisan sandwiches doesn't guarantee a spot on this list.)

What's Really In That Additive? The Safety Data Sheet Tells All

How do you know what's really in those fuel additives at every auto parts store? Read the safety data sheet, usually easily found online. Section 3 will list the product's composition.

We took a deeper look at a popular fuel treatment aimed at the enthusiast market. The promises are too tough to ignore: increased horsepower, more torque, cleaner injectors and reduced emissions. A 16-ounce bottle, street price about $11, is said to treat one tank of gas.

The SDS says that the product's main ingredient–listed to range from two-thirds to three-quarters–is a blend of aliphatic and aromatic hydrocarbons C-2 to C-20. Sounds exotic, right? "That's gasoline," explains Zachary J. Santner, senior specialist of quality at Sunoco, "most likely being used as a solvent for the additive. This ingredient is fluff; nothing special about this gasoline will help treat fuel."

The fuel additive under our virtual microscope also contains 20% to 30% 3-Oxa-1-heptanol, another exotic-sounding compound. A quick search of the listed CAS number–a specific code assigned to every chemical substance–reveals that it's just a relatively nonvolatile, inexpensive solvent also known as butoxyethanol or butyl glycol. An 8-pound jug, roughly a gallon, retails for about $20.

The final ingredient listed, comprising no more than 5% of our 16-ounce can: glycerides, mixed decanoyl and octanoyl. Its CAS number quickly reveals the composition in question: glycerides with fatty acid chains that are used in many consumer products, including soaps and cosmetics. Santner explains that it's likely used here as an emulsifier that allows polar and non-polar chemicals to stay mixed together. It also helps keep dirt suspended in solution.

So, some math says that the $11 fuel additive contains about 20 cents worth of gasoline and about 75 cents worth of a common industrial solvent. Then add less than an ounce of the emulsifier.

Or, Santner notes, you could just buy a race fuel that always follows a clean, consistent, proven recipe.

Antioxidants, Fuel Stabilizers, and You

It's a common wish: eternal youth. When it comes to gasoline, there's an entire industry seeking to grant that wish by offering a never-ending supply of fuel additives. Why? Because old, stale fuel can cause all sorts of problems, from gum in the system to starting issues.

Fortunately, picking the right nozzle at the pump can deliver a fuel with a longer shelf life. Generally speaking, premium fuel ages better than a lower-grade product. Fuel free of ethanol does better over time as well.

So, back to those fuel additives stocked at the corner auto parts store. In addition to hope and promises, what else can be found in those colorful plastic bottles?

One way to peek inside: Check out the safety data sheet, a standardized form designed to assist workers who might handle that substance. Some manufacturers make it easy to download the SDS; sometimes a bit of internet sleuthing is required. Section 3 of the SDS will always list the compound's ingredients.

The SDS for a popular fuel stabilizer–picture a red liquid in a clear bottle–notes that 95% of the product contains "distillates (petroleum), hydrotreated light." The listed CAS Registry Number, a standardized system for identifying chemicals, tells us that we're looking at a petroleum distillate better known as kerosene or jet fuel. For this application, it serves as the carrier.

The other 5% contains the important stuff, something called "phenol, isopropylated." Despite having a name that ends with "ol," explains Zachary J. Santner, senior specialist of quality at Sunoco, this is not an alcohol. It's a fuel antioxidant. Pump fuel also contains antioxidants.

"Antioxidant additives sacrifice themselves to react with unstable components that are caused by oxygen in the air," Santner continues. "They prevent unwanted reactions that generate gum and turn the fuel brown." (This is why fuels specifically designed for storage, like Sunoco's Optima, are highly refined, free of ethanol, and packed with antioxidants.)

Is there a problem with adding an extra helping of antioxidants? As usual, the answer depends, Santner says. While the antioxidants prevent fuel degradation, they won't retroactively rejuvenate aged fuel. And there's a reason why directions are printed on the side of the bottle: Overdosing on fuel antioxidants can lead to longer chain hydrocarbons, resulting in wax, gum or sludge buildup.

Toluene or Xylene: A Legit Low-Buck Octane Booster?

Need to add some octane to your gasoline? Why not follow the old hotrodder's trick and just dump in some toluene or xylene? Yes, that move will increase octane, but first let's back up and look at the science involved—because, of course, there's no such thing as a free lunch.

What Is Octane? Octane is the measurement of gasoline's resistance to preignition. Higher octane ratings mean greater ability to run higher compression, more boost, increased engine speeds and the like—you know, things gearheads are very likely to do.

What Are Aromatic Compounds? Toluene and xylene, along with benzene, represent aromatic compounds: chemical compounds of just hydrogen and carbon arranged in a ring structure. They're products of crude oil that contain high BTU levels.

So What's the Problem Here? Benzene is the simplest and most common of those three aromatic compounds, explains Zachary J. Santner, senior specialist of quality at Sunoco, and was once common in gasoline. "Then they found it has a harsh impact on humans and the environment," he adds, noting that benzene is now heavily regulated.

Toluene and xylene, the next most common aromatics, offer similar density, burn speed and BTU content, he continues, and can be found in some of today's race fuels. Both, in fact, can also be found at your local hardware store as paint thinner—figure about $2 5 a gallon.

While toluene and xylene will increase BTU rating and octane, Santner notes some concern of too much aromatics in a fuel: low vapor pressure, thus poor starting characteristics when cold; degradation of rubber and plastic parts, so the possibility of fuel system failures; and slower burning speeds because those same strong chemical bonds that increase octane will also take a while to unravel.

There's a reason gasolines are blended according to a recipe, Santner says, as each component plays a specific part. Playing home chemist could quickly lead to unintended consequences. "If they want higher octane," he continues, "it's easier to just buy some of our 100 octane and blend it in."

Fuels for a Post-Apocalyptic World

It's the end of the world as we know it. No birthday party. No cheesecake. No jellybean. The big question: How on earth are you going to power your post-apocalyptic death machine?

Gasoline: As the past hundred years have shown, gasoline makes a fine fuel for cars. "Gasoline's energy density is pretty high," notes Zachary J. Santner, senior specialist of quality at Sunoco. In very simple terms, this means that gasoline provides a lot of energy relative to its mass. It's why a tank of gas will take the average car a few hundred miles.

But gasoline might not be perfect for wandering the Wasteland. Under ideal conditions, its shelf life is somewhat limited—one to two years, max, for peak performance. Gasoline is also rather tricky to refine, especially with limited resources, Santner continues, noting that the same is true for kerosene and Jet A-1 fuel.

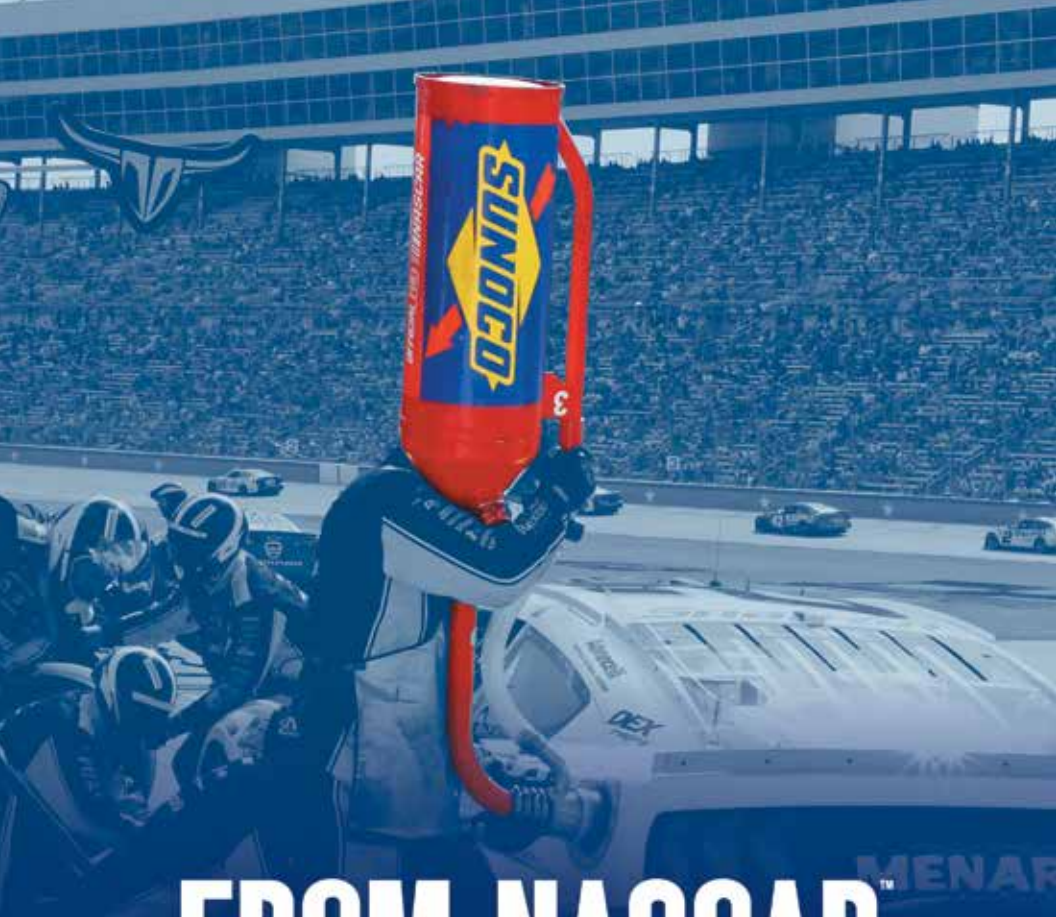
Diesel: "It is currently blended with more biomass than gasoline," Santner notes. Diesel substitutes can also be relatively easily brewed from biomatter. This could be a strong contender.

Ethanol: It can be sourced from many kinds of fermentation, but home-distilling alcohol past 95% isn't easy. "You could surely burn a 95% ethanol/5% water mixture," Santner says, "but water does cause issues with corrosion and fuel systems."

Propane, Methane and Other Liquified Petroleums: The short answer, Santner says, is that these all have less energy density than gasoline. A possible refueling source, however, could involve capturing methane released from decomposing organic matter, including that found in landfills. (For a related idea, revisit Bartertown from the third "Mad Max" film.)

Pyrolysis: Heating certain materials in the absence of oxygen—plastics or organics like coal—releases flammable gases that can then be burned for fuel. The Lane Motor Museum's collection includes a 1938 Citroën converted to run on methane gas derived from heated coal. It can travel about 30 miles on a load of coal.

Electricity: Another option, assuming you can power your generator and also schlep around batteries.



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