THE QUESTION OF FUEL

By John Copeland

The question of fuel tampering has plagued racing for decades, and for all the efforts by sanctioning bodies and tech officials, we're no closer to a workable solution than we were in the 60's. Those with the knowledge and the resources to circumvent the testing procedures have enjoyed an unfair advantage over their competitors. But fooling around with fuel isn't just unfair, it's dangerous. Few racers have the background in fuel chemistry to approach the task of getting more power in a logical, educated manner. Most just try a little of this and a little of that, mostly additives that they've heard about somebody else using, and hope for the best. The guy who said "A little knowledge is a dangerous thing" must have been talking about mixing up fuel. Maybe the best way to begin is to clear up some of the misinformation about fuel and additives and how they work.

We have to begin by understanding that all the horsepower our engines are ever going to make is stored in the fuel. It's that simple. The specific energy content of the fuel/air mixture is the key. The more fuel energy your engine can EFFICIENTLY burn, the more power it will produce. Lots of factors influence this fuel energy: gross volume, air/fuel ratio, density of the mixture, completeness of vaporization, and flame speed. You'll notice we didn't mention octane rating. That's because, in and of itself, octane rating does nothing to improve power output. All octane rating does is measure the ability of a fuel to resist pre-ignition (also, called detonation). Higher octane fuels allow the use of higher compression ratios, and THAT produces more power. While octane rating does influence flame speed, so do other factors. Let's look at each of the other factors one at time.

Vaporization is just what is sounds like; how well is the fuel/air mixture dispersed at the point of ignition. Incompletely atomized fuel burns more slowly and may not burn completely. It doesn't do you any good if it isn't completely consumed by the time the exhaust port opens. The completely it will burn. There are a number of additives that act to reduce the surface tension of gasoline and aid its vaporization. Unfortunately, most oils in common use have relatively high surface tension in solution with gasoline and so inhibit the vaporization process. Most gasoline manufacturers already add detergent-like additives to their fuel, so this ground has already been covered.

Flame speed is also pretty self-explanatory, but there are two sides to this coin. On the one hand, the faster the fuel/air mixture burns, the higher the expanding gas pressure will be and the longer that pressure will have to work on the piston before the exhaust port opens. However, since the ignition system is timed to fire before the piston reaches top-dead-center, some of that gas pressure will actually work AGAINST the piston as it completes the compression stroke. They call it "knock' in your family car, but it's really pre-ignition and it can be really destructive. It can literally chew the top of a piston away a little bite at a time. In less than a minute, at the RPM that today's two cycles run, the top of the piston is gone and you're done. In extreme cases pre-ignition can break pistons, and the damage that can do is impressive (and expensive). Higher octane fuels in general burn more slowly than low octane fuels, but other additives that have little or no bearing on octane rating can affect flame speed.

The density of the fuel/air mixture is the subject of a great deal of interest throughout the racing world. the cooler the charge of fuel and air going into the engine, the denser it will be. And the denser it is, the more potential energy there is in each incoming charge. remember, all the horsepower you're going to get is stored in that fuel and air, so the denser a charge you can get into the engine, the better. Superchargers and turbochargers increase the charge density mechanically by compressing it, but that generates a lot of heat in the mixture before it ever gets to the cylinder. Consequently, more and more "boosted" engines use intercoolers, radiators that cool the mixture and make it denser before it gets to the combustion chamber. Chilling the fuel in the tank has some merit, but maintaining the desired fuel/air ratio becomes extremely difficult if you begin to fiddle with the temperature of the incoming fuel. It's much more efficient to use fuel additives that have a high heat of vaporization to cool the charge. All liquids absorb heat energy when they change from a liquid to a gaseous state, that's how the freon in a refrigerator works. When a liquid is vaporized, like your fuel going through the carb and into the air stream, it gets colder. that cools the air it mixes with and the resulting fuel/air charge gets denser. neat, huh? Well, different liquids have different heats of vaporization. Alcohol's have a substantially higher heat of vaporization than gasoline (ever notice how cold it gets if you get some on your hand?), but other highly volatile options exist. In general, hydrocarbons with lower boiling points will have higher heats of vaporization..

Fuel/air ratio is really two subjects. First of all, and familiar to all of us, is the ratio that we can adjust at the carburetor. there is, of course, an optimum ratio of gasoline to air for most efficient combustion. this ratio is generally agreed to be approximately 7:1, 7 pounds of fuel to 1 pound of air. Unfortunately for most of us, the restrictions of running air-cooled engines make it impossible to approach that ratio. Instead, we pour substantially more fuel through our engines as a COOLANT. That's right, come detailed computer modeling in the 60's indicated that almost 50% of the fuel passed through an air-cooled two cycle engine was not consumed in combustion, but rather its vaporization within the cylinder leeched heat away. (See heat of vaporization above). that's why all the factory motorcycle racers are water-cooled cousins. they can simply run leaner fuel/air ratios that more closely approach the optimum ration. the goal at the carburetor is to get the leanest ratio that the engine's cooling capability will tolerate.

The larger, and substantially more complex side of the fuel/air ratio issue is how that ratio changes with different fuels and additives. the theoretical optimal fuel/air ratio for methanol, for example, it approximately 18:1 as opposed to 7:1 for gasoline described above. Nitroparaffins like nitromethane, nitropropane, and others are more like 70:1. That's **TEN TIMES MORE FUEL** for a given amount of air to burn correctly. What this means to the fuel mixer is this; as you adjust the chemical content of the fuel, you may substantially change the volume of fuel that the carb is required to mix for the engine to perform correctly. Legality not withstanding, adding require substantial modification of the passages in the carburetor to accommodate the volume of fuel enough improvement in power to be measurable. Most of the commonly use fuel additives actually have a lower specific energy content per unit volume than racing gasoline. But their higher optimal fuel/air ratio (called the stoichiometric ratio) more than makes up for the lower energy per volume with lots more volume.

Gasoline could be very accurately described as a chemical "vegetable soup" containing dozens of chemical compounds. Fuel chemists at every major oil company are constantly fiddling with the composition of their products in efforts to stay on top of the market. Cleaner burning, lower emissions, and better fuel mileage are at the top of their priority list, but they're also interested in things like stability for long-term storage, low VOC emission for handling, and other factors. Primarily, gasoline is a blend of several chemical families, including, but not limited to, Alkanes, also known as paraffin's, Iso-Alkanes like iso-octane and triptane, Cycloalkanes (napthenes), Alkenes (olefins), and Aromatics like benzene and toluene. Varying the ratios of these ingredients will modify the characteristics of the gasoline. To these basic building blocks the fuel chemists add an ever-increasing variety of modifiers to minimize gum formation, to prevent metal ion migration from handling equipment, and to accomplish lots of other goals. Many pump gasolines are now "seasonally adjusted" with alcohols, ethers, and other products to improve their performance in varying weather conditions. Racing gasoline is, in general, not subject to as much chemical monkeying around. Pump gasolines, with their constantly changing composition, as risky business, legality-wise. Just because a certain grade of pump gas from a certain pump passed tech for the last 10 years, is no guarantee that it will pass tomorrow. It's not necessarily that the test has changed, but that the gas may have.

In upcoming months we'll take a look at several of the more commonly used fuel additives; what they're supposed to do for you, and what the pluses and minuses are. We'll also meter and water test, and some of the newer, more sophisticated testing procedures. We'll hopefully unravel some of the mysteries and myths about fuel additives. And when its over, we'll look down the road a bit and see if we can see where this whole fuel thing is going. One word of caution, if you think this series is going to be a cheaters handbook, think again. With every illegal additive we'll discuss how tech can uncover it. but if you think this series will help you run faster, you're probably right. Hopefully once you learn how fuel really works, and what all additives do and don't do, if you're paying attention, you'll probably go faster. A many-time National Champion once told me that, after years of getting around the fuel rules, trying to pour gas and oil. "Every time I tried to juice the fuel and go faster, I hurt myself. And I expect 99% of the racers out there do the same." I expect he's right and, in upcoming months, we'll look at why.

THE QUESTION OF FUEL - PART 2 passing tech
By John Copeland

Last month we talked about some of the factors that influence the way fuel performs in your engine and, consequently, how it makes your engine perform. We talked about octane rating, and flame speed, and vaporization, and lots of other stuff and, hopefully, we didn't lose you in all the technical stuff. After all, all you really want to do is go fast and pass tech, right? Well, this time we're going to look at the passing tech part.

Since the fuel legality issue began, race officials and tech people have spent sleepless nights trying to figure out how to catch the cheaters. They've used baby bottles and fuel "sniffers" and all manner of chemical tests. The oldest test in common usage is the baby bottle test. Before many racers had access to some of the more sophisticated additives, we had methanol. Add enough methanol to gasoline (less than about 40? and you didn't gain anything) and a McCulloch or a West Bend, or a Clinton would really fly. It mixed well with gasoline, and with most oils in common usage at the time. Those of you who started karting after the Digatron meter was introduced in 19__ probably have never seen this test performed, but it really works.

You see, while methanol is soluble (it mixes well) in gasoline, it is even more soluble in water. Add to that the fact that gasoline doesn't mix at all with water, and you've got yourself the fuel and put it in a container with volume markings on it. you could use a fancy graduated cylinder, or a measuring cup for that matter, but we mostly used baby bottles because they were cheap and had screw on caps, and were readily accessible. Anyway, you put a fuel sample in the baby bottle and you note the volume, say 4 ounces. Then you add an equal amount of water and shake gently. When the mixture settles down in the bottle, the water will be on tip and the gas and oil mixture on the bottom. Since you put in 4 ounces of fuel and 4 ounces of water, the dividing line between the two should be at the 4 ounce mark. But remember, methanol is more soluble in water than it is in gasoline. In fact, it likes water enough more than gas that it will leave the gasoline and devolve in the water. If your 4-ounce fuel sample is 25% methanol, when the fuel/water mixture in the bottle settles out, there will only be about 3 ounces of gasoline on the bottom and 5 ounces of water/methanol mix on the top. Pretty neat, huh?

It was messy, and it took some time, but it worked pretty well, and it still does. The baby bottle test is still a pretty good way for 4 cycle tech guys to spot stuff in the methanol that's not suppose to be there. Of course, in that case, you expect to see all the fuel absorbed into the water. Anything that doesn't, probably isn't supposed to be there in the first place.

With the introduction of the Digatron Fuel Meter, fuel checking went high tech. What the meter actually measures is called the *Dielectric Constant* of the sample. Some folks mistakenly thing that the dielectric constant and *conductivity* are the same, but they are very different. Conductivity is the ability to pass an electric current between two electrodes and is measured as 1/resistance with a direct current. Dielectric Constant is a measure of capacitance measured with an alternating current. While both distilled water and iso-octane have very low conductance, the dielectric constant of distilled water is 80 and iso-octane is 1.94!

Anyway, the Digatron meter measures the dielectric constant of the fuel sample. the national tech officials have specified that the meter be calibrated to -55 with the probe immersed in Cyclohexane, which has a dielectric constant of 2.023. After this calibration the probe is immersed in the fuel sample and it may not read 0.0 or higher. Additives like alcohol', or Propylene Oxide, or others, tend to align themselves with an electric field (chemists say they're "polar") and they have higher dielectric constants. It only takes a drop or two of these rascals to make the meter read in the (+) range and you’re illegal. Setting the meter at -55 gives you plenty of room for minor variations in gasoline composition or for different oils, but it will blow the whistle on most of the funny stuff.

By the way, while we're on the subject of the fuel meter, it is very important that the person doing fuel tech do it right, or he may end up tossing out innocent competitors. After the meter is calibrated, there is no need to put the probe back into the cyclohexane between every reading. In fact, doing so will mess up the calibration because every time you take the probe out of the fuel tank and put it back into the cyclohaxane jar, you dilute the cyclohexane with gasoline. you keep adjusting the meter for this contaminated cyclohexane, and the calibration goes straight to "you know where". It's only necessary to re immerse the probe and check the calibration if the reading comes up illegal. Then it's a good idea to recheck the meter and recheck the fuel.

The Digatron meter is very effective at detecting polar compounds used as additives, but there are two important shortcomings with this method. First of all, there are some chemicals that folks are experimenting with in their fuel that are non-polar, or that have a dielectric constant close enough to legal gasoline that the meter may not spot them. Some competitors have also found ways to use materials with low dielectric constants to mask the presence of other additives with higher constants. Fortunately, only a few karters have the knowledge to circumvent the rules in this manner, and fewer still are desperate or dishonest enough to do so. A larger concern for the reliability of the Digatron meter is that the oil companies' never-ending search for more mileage and fewer emissions has led to the addition of a host of new components to readily available pump gas. Some of these components may alter the dielectric constant of the fuel enough to read over 0.0 on the meter. No tech man wants to see an innocent competitor tossed out because the fuel he or she purchased had something in it that is shouldn't have. The problem is that the poor tech man has no way of knowing whether the fuel fails the meter because of something the oil company put in it, or something the karter put in it.

There is another way, however, to use the Digarton meter, and it borrows somewhat from the Baby Bottle Test as well. If we take a fuel sample and add a roughly equal amount of water to it, then agitate it, like in the Baby Bottle Test, we should get two clearly separated layers of liquid in the container, water on top and fuel on the bottom. Then take a reading with the digatron meter on the fuel portion of the fuel/water sample and a reading on a fuel-only sample from the tank. If nothing has migrated from the fuel to the water, the meter readings should be exactly the same. However, if the fuel contains anything that leaves the fuel to dissolve in the water instead, the reading of that fuel will be different than the fuel that was not exposed to water. It's probably a good idea to allow 5 points of leeway on the reading, plus or minus, to allow for any minor absorption of elements in the oil, but anything more than that is an excellent indicator that something is in the fuel that shouldn't be there. this test won't be able to tell you who put whatever in there, oil company or karter, but it's a reliable test for most of the commonly used illegal additives.

Finally, there are now, and have been, a number of chemical reaction tests for various illegal additives. Most involve adding a sample of fuel to a test tube containing some chemical. Tech officials must then look for some specified reaction, a color change, bubbling, or whatever. If properly designed and performed, these reactions can provide undeniable proof that the specific additive is present. The problem is, most tests like these require controlled conditions, or very accurate measurements of quantities, or experienced personnel to interpret them. Unfortunately, we rarely have any of these things at the track; conditions are marginal, it is impossible to measure quantities accurately enough, and we lack trained, experienced technicians to perform and interpret the tests. Furthermore, many of the chemicals required for tests like these are dangerous in their own right. Acids and hydrides are commonly used for detecting specific hydrocarbons, and both families of chemicals may react dangerously with unexpected ingredients in fuel, or even with water! As an additional test, and in the hands of trained, experienced personnel, they can provide a valuable additional tool for the fuel-tech man. but in the wrong hands, or under the wrong conditions, they can be more dangerous than the fuel additives they were designed to find.

THE QUESTION OF FUEL Part 3

Welcome back for the 3rd installment in our series about fuel. As I said at the beginning, the whole point of this series is to try to de-mystify the subject of fuel and fuel additives. Of course, this really applies primarily to the gasoline classes, although I'm told that some Briggs racers have been rumored to add a drop or two to their methanol when the pump-around wasn't being used. The fact is, there's a list of things that will burn as fuel in your engine as long as this page. Or longer. Lots of them you've heard of, and some you haven't. But all you amateur fuel chemists out there can't hold a candle to the high-powered research going on at oil companies all over the world, both for improved pump gas and for better racing fuel.

True confessions time: this project is turning out to be a lot more complex than I ever dreamed. A lot of you have written or called to offer encouragement and information. I've received dozens of reprinted articles and Faxes with additional information to work into upcoming articles. this is a subject of global proportions and I've spent the last few weeks reviewing literature from petroleum industry publications, racing magazines, all sorts of resources. To all of you who have taken the time to read the first 2 articles and send more material for me to review, my greatest thanks. Keep it coming. As long as there is more to report on the subject, I'll keep after it.

Whoever said "No good deed goes unpunished" must have been a writer. I know I always chuckled at the letters to car magazine editors pointing out errors in print. Now the shoe is on the other foot, so to speak. In the first installment I referred to pre-ignition as another term for detonation. Boy did I hear about that! Let me make this very clear, while they are similar in some respects, in many important ways detonations and pre-ignition are very different. Both are very destructive conditions and both are the result of combustion initiated by some force or condition other than the firing of the spark plug. Pre-ignition is the ignition of the fuel/air mixture in the cylinder, prior to the firing of the plug, most often by a 'hot spot" in the cylinder, the head, on the piston assembly, or on the plug itself. It can be a carbon buildup, an overheated sparkplug electrode, or a sharp bit of metal, like you might get in the head if the engine "swallowed" something and dinged up the top of the piston and the head. This premature ignition generates intense heat, not only from the combustion itself, but because the combustion happens earlier in the compression stroke that it should and the rapidly expanding hot gases are subjected to additional compression, generating more heat. The only good news here is that pre-ignition generally shows up pretty quickly as rapidly climbing cylinder head temperature. You may not always be able to hear pre-ignition, but, if you run a cylinder head temp gauge, and if you're not completely asleep at the wheel, it's hard to miss the warning signs.

Detonation, as so many of you correctly pointed out, is an entirely different animal. Detonation occurs when the fuel/air mixture ignites from the combination of heat and pressure within the cylinder during compression. Like pre-ignition, this ignition occurs independent of the spark plug firing, but, unlike pre-ignition, it can and does occur after the plug has fired. The charge expands from the spark ignition, exceeds the fuel's ability to resist spontaneous combustion, and it explodes. The result is the collision of two independent flame fronts and the results are violent! You've probably heard your car or truck "ping' on a hard pull in too high a gear. Well, that's detonation. Just as thunder is the collision of two air masses after a bolt of lightning separates them, detonation is the collision of two expanding gas masses. Thunder in your cylinder, so to speak, but much more destructive. If you can't hear it over the noise of you engine, and it goes on for very long, the results will be expensive. Often there is no significant rise in head temperature, but, if you use an exhaust temperature gauge, you may see a drop in EGT. Detonation exerts tremendous physical forces as well as thermal ones and it can break pistons, destroy ring lands, break rings, and even lead to bearing failure.

Detonation is of particular interest here because it is directly related to fuel quality. As we discussed before, octane rating is the measure of how well a particular gasoline will resist detonation. It is measured as a comparative figure to iso-octane, which is defined as having a 100 octane rating. While most engines in popular use in karting have relatively low compression, there are still conditions under which detonation may occur and that means you'd better fuel up with enough octane to resist that detonation. However, remember from our earlier discussion, higher octane generally means slower flame speed, and that's not particularly good in our application.

Long tracks, both enduro and some longer sprint tracks, call for numerically short gear ratios, sometimes as low as 4:1. That means your engine is going to be lugging a lot more than if you piled on hear and over wound it down the chute. Add to this the fact that most drivers set their carb settings on the straightway when the engine is approaching top end and engine loading is actually decreasing, and you end up with a lean condition in the midrange, right where the engine is doing all that lugging. Now factor in the increasing trend to shorter and shorter pipe lengths and the resulting scavenging of the cylinder by the exhaust pulse, and you've got a great recipe for detonation. (Note: to those of you using a slippy pipe, pulling it too soon or too fast has the same effect and wins you an quick ride on the detonation express.) The key factor here is the lean condition in the midrange.

Unfortunately, most head temp sensors simply can't respond quickly enough to see this lean condition as you transition through it. Exhaust temp can. One side effect of detonation issue, including head configuration, pip design, ignition timing, and squish band configuration. Al Nunley at Mayko Karting in California has written extensively on the subject and is, perhaps, as knowledgeable as anyone I know. If you want to know more abut the mechanics of detonation, specifically as they relate to kart racing, spin back through your old karting publications (I'm not the only one who keeps them forever, am I?), or give Al a call.

To combat detonation with fuel octane, you can either use a gasoline that has a octane higher octane rating by itself, like race gas, or you can doctor up lower octane gas with any number of additives. There are several commercially available add-in octane boosters on the market, and most contain some Tetra-Ethyl Lead or a substitute for it. The problem is, Tetra Ethyl Lead is the stuff the government made them take out of gas to make unleaded gas in the first place.! They keep a pretty tight rein on it these days and you can't really get what you really want from the over-the-counter additives. Another alternative is to blend your own gasoline with additives that will raise the net octane rating of the fuel. The trick here is to find additives that will do the job without coming up bogus at fuel tech. Alcohol's, including methanol, ethanol, iso-propyl, tertiary butyl alcohol, toluol, and xylol all have octane ratings over 100, but they absorb water, are to some degree corrosive, and, here's the kicker, they set the Digatron dielectric meter off, big time. On the plus side, they have relatively good potential power and combust completely. While they are, of course, poisonous in unburned form (so is gasoline), the combustion products are relatively clean and un-toxic. Aromatics like toluene, xylene, and benzene all have high octane potential, and all are present in some racing gasoline's in varying concentrations. They are also poisonous before combustion, but their combustion is not nearly as complete as the alcohols and their combustion products coming out the pipe aren't all that healthy either. Toluene and Xylene are readily available at paint and hardware stores, while Benzene (the best of the bunch, octane-wise) is virtually impossible to get in reasonable quantities because of government regulation. Benzene is high on the government's list of carcinogens, as well as being a vital component in manufacturing some illegal drugs; steel clear of this one! Analine is another octane booster on the government's "hit list". Like Benzine, it's used to manufacture illegal drugs but, maybe more importantly, it's a skin-absorbed poison, and very toxic. As I mentioned in an earlier article, the chemicals that you may have heard about somebody using in their fuel are, in most cases, **very dangerous**. As these articles go on we'll be sure to note the critical health and safety hazards of each potential additive we talk about.

In upcoming articles we'll be discussing these and lots of other additives with regard to their potential for improving performance in a karting application. But from the point of view of detonation and the damage that it can cause, alcohol's and aromatics have been the traditional routes to try to "jack up" the octane rating of pump gas. All this supposes that you can't get your hands on good old Tetra Ethyl Lead, the "real thing" octane booster-wise. Well, that's not necessarily so. Racing gas has Tetra Ethyl Lead in it, and so does aviation gas. There are even some leaded fuels still available in some areas for agricultural use. The point is, nothing currently available is as effective at controlling detonation as leaded fuel. It is readily available in a variety of octane ratings, from ratings just above pump gas to ratings over 115. Bearing in mind that you only want enough octane to prevent detonation, you should be able to accomplish that with a well-considered choice of commercially available gasoline. Or, if you choose, you might consider mixing a proportion of leaded racing gas or aviation gas with a lower octane pump gas to get the performance you need for your particular application. Just remember that octane does nothing to improve performance in and of itself. All it does is measure the ability of the fuel to resist detonation. and there is some evidence that it inhibits flame propagation (flame speed) across the combustion chamber and, thus , fuel with too high an octane rating may actually reduce engine performance.

Next time we'll talk abut the hottest subject in the karting fuel controversy right now: Oxygenated compounds. Until then, stick to the straight stuff, either from the pump or from a barrel. It's safer, and in most cases it will perform better for you.

THE QUESTION OF FUEL - PART 4 - OXYGENATORS
By John Copeland

By far the hottest (if you'll pardon the expression) topic in fuel chemistry these days is the subject of oxygenators. In their never-ending quest to formulate cleaner burning gasoline for the general motoring public, the major oil companies are using compounds to improve the combustion efficiency of the gas you can buy at the pump. Unfortunately, the real villain here isn't the gasoline, it's the poor efficiency of today's production automobile and truck engines. Better designed engines, operating at much higher temperatures, would go along way toward cleaning up tailpipe emissions, but, the truth is, it's much cheaper for them to try to fix it in the gas tank.

Oxygenators are, pretty much, just what they should like; compounds that increase the amount of oxygen available for fuel combustion. You remember from high school chemistry that a fire can't burn without oxygen. Well, it's the same inside your engine's combustion chamber. It needs adequate oxygen to burn the fuel. Unfortunately, in most circumstances we just aren't getting enough, either because the volume of air coming through the carb (remember, air is only about 20% oxygen) isn't sufficient, or because the engine can't manage the heat-load that a leaner mixture (one containing more air per unit of fuel volume) would generate. (Refer back to part 1 of this series for more about fuel/air ratios). Oxygenators are, in general terms, flammable compounds that contain at least a portion of the oxygen they need for combustion as part of their own composition. Gasoline, in it's basic, unaltered form, contains absolutely no oxygen. It must rely totally on airborne oxygen for combustion. Oxygenators can enhance combustion by assuming some of the burden of providing combustion oxygen.

These compounds have been around for a long time but, for the most part, their use has been limited to applications where their ability to furnish most, or all, of the oxygen for their own combustion meant that they could burn explosively. A good example is Tri-Nitro-Toluene, better known as TNT. But for the purposes of improving the quality of fuel combustion, significantly slower-burning, less unstable oxygenators are the focus of interest.

By far the most widely known oxygenators, and the most widely used in commercial gasolines, are alcohols and alcohol-related derivatives. But the fuel chemists at the oil companies have developed a whole new crop of these compounds in hopes of creating a leaner-burning, cleaner fuel/air reaction. This leaner, cleaner combustion translates, in your car or truck, to better fuel mileage and cleaner tailpipe emissions. We've all heard about gasohol as a catch-all name for gasoline/alcohol blends. For our purposes, we can pretty well dismiss all these alcohol blended gasolines because we already know that they won't pass the standard digatron meter test. But let's look at some of the other oxygen-bearing fuel additives that are finding their way into gasoline. Some of these are being added by the gasoline manufacturers and some are..., well, let's just say some are finding their way into kart fuel by other means.

Propylene Oxide, CH_3CHCH_2O, has seen considerable use as a performance enhancer over the years. Even when we didn't know what it was doing, we knew it was doing something good. The fact is, Propylene Oxide does several things that racers like. It is highly volatile, boiling at only 93 degrees Fahrenheit, and has a correspondingly high heat of vaporization. That means that it helps cool the incoming fuel charge, thus improving charge density and improving power output. That helps leech some of the latent heat out of the engine as well. It also brings along some of it's own oxygen to the party in the combustion chamber. That means that it helps the rest of the fuel components burn more completely, improving the efficiency. Unfortunately, that additional oxygen tends to make the fuel charge burn with a somewhat higher heat of combustion, releasing more heat into the engine. This can more or less negate the positive heat-leeching effect. And it also puts the higher heat exactly where you don't want it; in the head and on the piston crown. In your car or truck, that higher heat and improved efficiency means fewer tailpipe emissions. On the kart track, it means more bang out of every drop of fuel going through the carb. Here's the downside. Propylene Oxide is bad for you, real bad. It is corrosive in contact with skin, just like battery acid. It is a skin-absorbable poison, fatal at 1500 milligrams per 2 kilograms of body weight. And it has been determined to be a class 3 carcinogen. Even if your are willing to assume the risks of using this material yourself, you are also exposing any competitor behind you to risk from incompletely combusted Propylene Oxide. Don't do it. Anything less than about 8% added to gasoline (by volume) has no measurable effect, but any more than about 3% will send the digatron meter sailing.

There are a couple of chemicals in the Nitroparaffin family that are of some interest as oxygenators. Methyl Ethyl Ketone, often referred to as MEK, appears on the surface to be an attractive oxygenator. A commonly used industrial solvent, MEK has the unfortunate property of consuming all it's own oxygen during it's own combustion, leaving none to benefit the remaining combustion process. Coupled with it's relatively low specific energy, it's basically a waste of time.

The same goes for Acetone, C_3H_6O, whose relatively meager supply of oxygen isn't even sufficient to support it's own combustion, much less lend any to the gasoline reaction. Acetone does have one attractive property, however. It is extremely hydroscopic, meaning that it attracts and absorbs water. In the old days, the McCulloch racers knew this and used to mix acetone with their alcohol to help suspend the moisture that the alcohol attracted and put it in a more combustible form. It will do this in gasoline as well and, since water is not soluble in gasoline at all, but acetone, even acetone that has absorbed some water, is soluble in gasoline, it's a good way to deal with water-contaminated gasoline. But there's no power advantage to be had here and, if you're having a problem with water in your gasoline, you don't need a chemical to fix it. You need a better gasoline supplier. By the way, ketones like MEK and Acetone are also really hard on rubber and plastic parts, like carb diaphragms etc. In concentrations of less than about 15% by volume it is impossible to see any change in the combustion process, while anything over 10% may dissolve your metering diaphragm before the day is done. Sounds like a bad bargain.

Nitropropane is a rather expensive Nitroparaffin that is, in the right form, about 70% as potent as Nitromethane. I say the right form because Nitropropane comes in two forms, called Nitropropane 1 and Nitropropane 2. Nitropropane 1 is the most readily available, because it is a sometimes-used cleaning solvent. Unfortunately, it is completely worthless as a combustion reactant for our purposes. Nitropropane 2, however, contributes significantly to oxygenation of the combustion process when used in concentrations of 10% or more by volume. It's primary hazard is that it is extremely volatile, sensitive to even ignition by static electricity. And at over $50 per gallon on the open market, few racers will be tempted to mess with it.

The Ethers are a family of oxygen-bearing hydrocarbons that have drawn increasing attention from the fuel industry. With a relatively high percentage of oxygen per volume (15 to 18%) they bring considerable free oxygen to the combustion process. But unlike the alcohols, they can actually improve vaporization over straight gasoline while reducing exhaust emissions in passenger cars and trucks. The result is what the industry calls "improved drivability" and relates primarily to cold weather starting and cold engine running. Of mo9re interest to us is the higher heat of vaporization and it's resulting colder inlet charge and heat leeching as mentioned above. The most widely known ether is Ethyl Ether, $C_2H_5OC_2H_5$, and it is the primary ingredient in automotive "starting fluid' sprays. Incredibly volatile, it will vaporize even at sub-zero temperatures and is just the ticket for getting your Chevy started on a bitter cold morning. Thankfully, we don't race in such conditions. For our purposes Ethyl Ether simply is tool volatile; it evaporates too quickly and at too low a temperature to render it a useful additive in karting. Besides, Ethyl Ether's tell-tale odor makes it very hard to hide. One other serious problem with some there's is their tendency to form unstable, explosive compounds called Peroxides. These dangerous compounds can develop when Ethers are exposed to either heat and/or sunlight, even in closed containers. For the most part, Ethers are relatively safe, health-wise. Like any other hydrocarbon, of course, they are harmful or fatal if swallowed, but most members of this chemical family that we are likely to encounter in fuel are relatively safe.

A very important exception to the previous statement is a material called Diethylene Ether, $C_4H_8O_2$, or more commonly referred to as Dioxane. With twice the oxygen per molecule of Ethyl Ether, it would seem to be an attractive oxygenator. **PLEASE READ THIS! DIOXANE IS A VERY POWERFUL SKIN-ABSORBED POISON AND A KNOWN CARCINOGEN**. It is neither safe to handle, nor to breath, nor to be around in any way. It's combustion products, in the form most likely to be emitted behind a kart, are also poisonous and carcinogenic. This is nothing to fool around with! Anyone foolish enough to monkey with this material has no business on the racetrack and no business in the sport! There is also a compound called Dioxane, but it is of no value whatsoever as a combustion additive, although someone may accidentally refer to Dioxane as Dioxane and vice-versa.

On a happier note, you may have heard about some new fuel additives from the oil companies called MTBE, ETBE, and TAME. These are Ethers too and the letters stand for Methyl Tertiary-butyl Ether, Ethyl Tertiary-Butyl Ether, and Triamyl Methyl Ether. The first two compounds are made by reacting Methanol or Ethanol with isobutylene and all three have found considerable success as gasoline additives, yielding significant oxygen to the combustion process. The oil companies have seized on MTBE and TAME, and more recently on ETBE, as environmentally friendly ways to enhance octane rating, improve drivability, and "stretch" gasoline through the use of renewable resources. It is unlikely that you would see any significant improvement in engine performance by adding these compounds in quantities beyond what the oil companies are already putting in the fuel, between 15% to 19% by volume. The only way to be sure that these compounds are not in the gas you take to the track is, as we've said before, to purchase racing gasoline from a reputable dealer of racing gasoline, from the drum. However, if you wish to experiment with them, and if you can find a resource to provide them, they are reasonable safe to use. Again, 15% to 19% is the industry standard. At this point we have not finished the research to determine how these additives will effect the Digatron meter or how much will send it over the magic "0.00" mark.

So let's summarize the subject of oxygenators. Given that we can't ever get enough oxygen from the limited amount of air the engine can suck down the carb throat to affect really efficient, complete combustion of the fuel, some oxygenators can provide additional "free" oxygen to enhance the combustion process. The most common of these are the Alcohols, but, because of their dielectric properties, they won't get past the digatron meter test at tech. Propylene Oxide and some of the other Nitro-Paraffin's are good sources of oxygen, but are corrosive to engine and carb parts, and some of them are very dangerous, health-wise. Ketones are, for the most part, worthless as oxygen sources, as they consume all their own oxygen during combustion, leaving none to improve the combustion of the other fuel. And, finally, Ethers can improve combustion, and liberate additional heat energy from the fuel, but require such large percentages to achieve the desired results as to be hard to conceal. And Dioxane, an Ether, is way too dangerous to monkey with.

One more thing; the use of oxygenators in air-cooled engines is a particularly awkward juggling act. Remember we said in the first installment of this series that tests had shown that we use almost 50% of the fuel that goes into the engine as a COOLANT. Well, when you bump up the oxygen level of the fuel mixture, whether by adding more air, or by adding oxygenators, the heat of combustion, and the temperature in the engine, will go up accordingly. Oxygenators, in effect, lean out the engine. given the cooling limitations of the air-cooled engine, the only option is to richen up the mixture and there goes any hope of a significant performance advantage. What we're saying is this: there is, most likely, one or more oxygenators already present in any gasoline you can buy at the pump these days. These compounds may cause your fuel to fail the digatron fuel meter at tech. The only way to avoid it is to buy race gas from a barrel. Adding oxygenators to fuel on your own is dangerous, to you and to your fellow competitors. Any performance gain that you might have achieved from the addition of oxygenators to your fuel is, if you use an air-cooled engine, most likely negated by having to run the mixture richer to compensate for the additional heat that the oxygen-enriched fuel generates when it burns.

Hopefully by next month we'll have some testing completed on both the performance effects of the additives we've talked about, and on the necessary tech procedures to spot the guys who are "juicing" their fuel. In the meantime, if you see somebody fiddling with their gas, ask them to stop. if they ignore you, tell the tech man. They're not just cheating, they're taking real chances with their health and with yours.

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THE QUESTION OF FUEL - PART 5 - TESTING

In the previous 4 segments of this series; we've discussed the specific factors that influence fuel performance, commonly used fuel tech procedures, and the subject of oxygenators and other additives. Hopefully we've laid the groundwork for this month's subject; the actual test results. We've tested fuels and additives, both for performance and for legality.

Before we get to the subject of additives, a few words about the current state of fuel legality. As we've discussed earlier, the oil companies have been reformulating their products in the effort to improve fuel mileage and reduce tailpipe emissions. In most cases, this dictated that only reformulated gasoline may be sold in major metropolitan areas. To check this out and to determine if karters buying their fuel in major cities might be at risk, legality-wise, we obtained samples of 9 pump gasoline's from Chicago area gas stations. We then obtained samples of the same 9 pump gasoline's from stations here in Lafayette, Indiana. In addition, we also tested samples of 6 racing gasolines, from several geographical sources. We mixed each of these gasoline samples with Burris oil at ration of 20:1, mixing 4 ounces of Burris Castor and 2 ounces of Burris Blend per gallon of gasoline. All fuel samples were tested at 55 degrees Fahrenheit and, of course, the Digatron meter was calibrated to -55 with Cyclohexane. Here's the results:

	Octane	Meter Reading
Shell Premium (Chicago)	93	-8
Shell Premium (Lafayette)	93	-36
Shell Plus (Chicago)	89	-14
Shell Plus (Lafayette)	89	-39
Shell Regular (Chicago)	87	-11
Shell Regular (Lafayette)	87	-41
Amoco Ultimate (Chicago)	93	-22
Amoco Ultimate (Lafayette)	93	-40
Amoco Silver (Chicago)	89	-8
Amoco Silver (Lafayette)	89	-44
Amoco Regular (Chicago)	87	+83
Amoco Regular (Lafayette)	87	-39
Phillips Premium (Chicago)	92	+82
Phillips Premium (Lafayette)	92	-45
Phillips Midgrade (Chicago)	89	+71
Phillips Midgrade (Lafayette)	89	-42
Phillips Regular (Chicago)	87	+69
Phillips Regular (Lafayette)	87	-40
Unocal Race Gas	110	-46
Cam 2 Purple	114	-4
Cam 2 Blue	116	-20
Phillips B32 Race Gas	108	-43
ERC Purple	110	-36
ERC Blue/Green	114	-14

Two things are pretty obvious here. First of all fuel legality is highly variable, both from manufacturer to manufacturer, and from grade to grade. Secondly, obviously the composition of the fuels sold in the Chicago area are not the same as those sold in the Lafayette area, at least not at the time these samples were purchased. As we've said before, race gas is much less subject to changing composition. You should expect that any of the race gases listed here will test approximately the same as our results here.

Now on to the additives. In order to minimize non-additive variances, we mixed all additives with a base fuel of Shell Premium, 93 octane purchased here in Lafayette. This base fuel was then mixed with Burris oil at 20:1 as outlined above. That resulting fuel metered at -36 on the Digatron meter, just as before. The test procedure was as follows; the Digatron meter probe was immersed in a measured quantity of base fuel. Then the additive being tested was slowly added to the base sample until the meter reading exceeded 0.00 or until it became apparent that the testing would not exceed the 0.00 mark. At that point the percentage by volume of the additive being tested was calculated to determine the threshold of legality for that particular additive. Here's the results:

	Percent by Volume	Meter Reading
Propylene Oxide	1.75%	+1

Nitro Methane	0.80%	+1
Nitro Propane	0.20%	+6
Ethyl Ether	0.73%	+1
Toluene	59.00%	-8
Xylene	58.00%	-8
1,4 Dioxane	70.00%	-26
Hi-Rev 3:1	30.00%	-28
Klotz Coxoc	40.00%	-30

To help you interpret these results, 1.00% by volume is 1.28 ounces per gallon, or about one tablespoon of additive per gallon. From these results we can determine that it is extremely unlikely that a fuel mixture could pass the meter and contain enough Propylene Oxide, Nitro Methane, Nitro Propane, or Ethyl Ether to accomplish any measurable performance gain. It is also apparent that the Digatron test is insufficient to detect significant quantities of the other 5 additives tested. Obviously other testing procedures will be required to detect these.

In the second installment of this series we outlined a test using a combination of water absorption and the Digarton meter. In this test, 2 fuel samples are taken and, to one sample, an equal volume of water is added and the mixture gently agitated. When the agitated sample mixture is allowed to settle, the fuel portion of the mixture will be separated from the water portion, with the fuel portion on top. Digatron meter readings are taken from the fuel-only sample and from the fuel portion of the fuel-water sample. The readings should be the same. In the event, however, that an additive or additives are present that are more soluble in water than in gasoline, the relative meter readings will be different from one another. Allowing for some minor variances, any deviation of more than 5 points on the Digatron meter would indicate the presence of something in the fuel other than what the manufacturer put there. In this test the base fuel was Unocal race gas, again mixed 20:1 with Burris oil. To each sample we added 10% by volume of each additive to be tested, then the test was performed. Here's the results:

	Percent by Volume	Fuel only Reading	Fuel/Water Reading
No Additives	0%	-46	-46
Propylene Oxide	10%	+55	+36
Nitro Methane	10%	+15	+7
Nitro Propane	10%	+120	+251
Ethyl Ether	10%	-12	+10
Toluene	10%	-36	-19
Xylene	10%	-37	-22
1,4 Dioxane	10%	-40	-47
Hi Rev 3:1	10%	-42	-40
Klotz Coxoc	10%	-41	-30

What we see here is that this test detects the same additives as the Digatron test, but also picks up Toluene, Xylene, 1,4 Dioxane, and Klotz Coxoc, quite conclusively.

There is a 3rd test worthy of consideration that has come to our attention since the 2nd segment of this series was written. We are indebted to Art Verlengiere of RLV and Mark Weaverling, the highly regarded West Coast karting innovator, for sharing their experience with this test with us. The testing procedure is relatively simple; although it requires more accurate measurements and careful procedures.

Exactly equal amounts of the sample fuel, water, and straight methanol are combined in a graduated cylinder or other accurately calibrated container. the methanol will completely dissolve in the water, but the fuel will separate and rise to the top. Once the fuel has separated from the water and methanol solution, the line of separation should be exactly at a point 2/3 up from the bottom of the container. The use of a accurate graduated cylinder of at least 100ml capacity is recommended, allowing use of 30ml samples of each item. In this case, the separation line between the fuel portion of the mixture and the water/methanol portion, should be exactly at 60ml from the bottom, leaving the fuel portion at exactly the 30 ml that were originally added. Any reduction of this 30ml volume would indicate the presence of some additive that has left the fuel and gone into solution in the water/methanol solution. For our test we again used Unocal race gas as the base fuel and used 20% of each additive being tested. Here's the results:

	Percent by Volume	Resulting Fuel Volume
No Additives	0%	30ml
Propylene Oxide	20%	25ml
Nitro Methane	20%	29ml
Nitro Propane	20%	22ml

Ethyl Ether	20%	30ml
Toluene	20%	28ml
Xylene	20%	30ml
1,4 Dioxane	20%	22ml
Hi Rev	3:120%	31ml
Klotz Coxoc	20%	35ml

As you can see, this test does a good job of picking up some of these additives, particularly the Nitro Propane, 1,4 Dioxane, and Klotz Coxoc. While it's a little more trouble to do this test, it's another valuable weapon in the tech man's arsenal and it's occasional use should help deter fuel tampering.

As this is being written, we are in contact with tech officials at the NHRA, at IHRA and at the US Powerboat Association, all exchanging information about gasoline tech inspection and sharing ideas to help police this area. We'll pass along any new developments as they become available.

THE QUESTION OF FUEL - PART SIX   ADDITIVE PERFORMANCE TESTING
By John Copeland

In earlier segments of this series we've talked about fuel additives used to improve engine performance. We've looked at the basic properties of fuels that may impact how much energy they make available upon combustion and how some additives may increase (or decrease) that available energy. We've also looked at various means of detecting these additives and how the tech man can spot them in the field. Now it's time to take a hard-numbers look at what sort of advantage the fuel cheater can expect to gain from using these materials.

As you may recall from Part Five, we established a threshold of delectability for each of the nine additives that we have been testing, both on the Digatron meter, and with two different water absorption tests. In order to generate meaningful data for this performance testing portion of the project, we ran fuel samples with more than one concentration of the additive in question. For example, earlier testing showed the threshold of detectability for Propylene Oxide to be about 2% by volume, when mixed with otherwise legal race gas. We then ran dyno testing on that fuel with 2% Propylene Oxide added and compared it back-to back with the same sample without any Propylene Oxide. However, in an effort to demonstrate what, if any, effect running Propylene Oxide would have, if used in sufficient quantities, we also ran a sample with 10% added, also back-to-back against a legal sample. Hopefully this will address the question of "Oh yeah. Well I heard that Johnny Go-fast put some of that stuff in his gas and it gave him more top end between 18,000 and 19,000 RPM!" Let's find out if adding this stuff really works, and how.

In order to insured uniformity of results, all samples were based on Phillips B32 race gas. Comparison testing on the dyno has shown that this high-quality race gas will produce consistently higher performance than 4 other race gasolines generally available, and substantially higher performance than any pump gas or combination of pump gases. As with earlier tests in this series, all samples were mixed 20:1 with Burris oil, mixing 4 ounces of Burris Castor and 2 ounces of Burris Blend per gallon of fuel. All testing was done on Fox Valley Kart's electronic engine dyno with periodic base-line samples re-run to insure repeatable data. Torque readings from, which horsepower is calculated, are accurate to .001 foot-pounds. All data, torque, RPM, cylinder head and exhaust gas temp, are collected by the computer 10 times each second, then computer averaged around each plotting point. While the absolute horsepower numbers may vary from one dyno to another, what we're interested in here are comparative fingers.

PROPYLENE OXIDE (CH_3CHCH_2O)

Propylene Oxide's primary contribution to the combustion process centers on it's high heat of vaporization. As we discussed in Part 4 of this series, this high heat of vaporization means that, as it passes from a liquid to a gaseous state in the carburetor, it absorbs a significant amount of heat and, thus, cools the incoming fuel charge significantly, making it denser. While Propylene Oxide brings along some of the Oxygen it needs for it's own combustion, it also takes additional oxygen from the carburetor air. It's specific energy is slightly less than that of gasoline, so don't expect any help there. It's combustion products are CO_2, CO, and water vapor. As you can see from the graph below, there is no measurable performance difference between the base-line fuel and the sample containing 2% Propylene Oxide, slightly above the threshold of detectability with the Digatron meter. However, by increasing the concentration to 10% by volume, well above what even the most bumbling tech man should be able to spot, we begin to see the effect of improving the charge density on the low end. This effect diminishes as RPM increases, probably because this higher air velocity through the carb dramatically improves the atomization of the gasoline and the resulting chilling of the incoming charge.

Conclusion: Yes, using Propylene Oxide may help the low end performance if used in sufficient quantities. But unless there is no fuel tech at all, you can't get away with running enough to get any improvements.

THE QUESTION OF FUEL PART 7 - TECH PROCEDURES REVISITED
By John Copeland

Last month we finally got the awful truth; if someone really wants to cheat with their fuel, they can, and the odds are, they'll get away with it. But how can the honest racer help keep the playing field level? How can you and your club keep fuel cheating under control? Let's start by getting a couple of things clear. Like it or not, legal fuel will always be defined as fuel that will pass whatever test is being used. That means that, whatever it says on paper, if you or your club or track don't tech fuel, then **fuel is open**! Likewise, if you don't tech it the same way every time, you jeopardize the credibility of the tech. It is critical that fuel tech be thorough, properly done, and fairly administered. Too many times tech people, even at the highest levels, have gone "head hunting" for a person whom they believed was cheating with their fuel. And their claims that the selection of who was to have their fuel checked was completely random, when everybody knew better, only made them look foolish and diminished the credibility of the whole process. We've already covered several fuel tech techniques in an earlier article, and we have a few more we'll share with you shortly, but first, let's look at the right way to use the Digatron meter.

We've all had our fuel checked with the Digatron meter lots of times, and it seems like every tech man does it different. But, hey!, if my fuel checks OK who cares how he does it? Well, you ought to care, because if the tech man isn't using the right procedure, you may be racing at an unfair disadvantage to a fuel cheater who slipped past the tech man because the testing procedure was wrong. Here's the way to do it right.

1. Turn on the meter and immerse the probe in cyclohexane. The cyclohexane should be in a plastic container, not glass. I know that Digatron supplies little glass bottles with the deluxe fuel testing kit, and they're real handy, but they can affect the meter readings. Always use plastic containers.
2. Allow the meter to "warm up" for at least 5 to 10 minutes before setting the knob to read -55. If you just turn it on and start taking readings, it will "drift" on you a bit. By the way, when you are "zeroing" the meter at -55, hold the probe in the middle of the container of cyclohexane, away from the bottom or sides. Something called the "Adjacency Affect" can change the meter readings if the probe is too close to the sides or bottom of the container.
3. The prescribed -55 setting is presumed to be at 60 degrees Fahrenheit. Temperature change will change the meter readings. The temperature of the fuel sample being tested and the cyclohexane standard must be about the same. A temperature difference of 5 degrees or more will make a measurable difference in the readings. When in doubt about fuel sample temperature, take a sample of the fuel to be tested, and let it sit next to the cyclohexane sample for about 10 minutes. Just be sure to put the fuel sample in a tightly sealed container so you don't lose anything to evaporation.
4. The meter should be re-calibrated every 30 minutes or so, to compensate for any "drift" in the zero point and to keep everything right. But here's where lots of folks mess up: Once the meter is calibrated, it is not desirable to re-immerse it in the cyclohexane after every fuel sample is checked. Doing so only dilutes the cyclohexane with random fuel carried back into the container on the probe. As the day goes on, the standard on which you are basing your testing will change. Not good. Instead, after each fuel is tested, gently shake any excess fuel off the probe and blot lightly with a paper towel.
5. Periodically clean the probe with aerosol brake cleaner and allow to dry completely. This product will evaporate completely and will not contaminate the next fuel sample. It is important to clean the probe occasionally because some of the oils in use may remain on the probe after the gasoline has evaporated. In most cases this is not a problem, but sometimes it can bite you.
6. Just as when you "zeroed" the meter in the cyclohexane, when you take a reading on a fuel sample, don't let the probe get too close to the sides or bottom of the tank. Otherwise the "adjacency affect" may change the readings. If a competitor does not have enough fuel to take a good reading in the tank, then he or she is obliged to draw a sample through the fuel line to the carb into a smaller container for testing. Of course, according to the rules, if a competitor cannot produce enough fuel to be properly tested, the tech man is required to disqualify them.
7. In the event that you find a fuel sample that does not pass the meter, that is, one that reads in + numbers, immediately stop testing, clean the probe as described above, and recalibrate in cyclohexane. Then test again. Fuel that fails under these circumstances should be considered illegal.
8. Moisture in the fuel will shift the meter in a positive direction. Rainy days, or even high humidity can cause fuel to come up illegal. Unfortunately, the rules do not allow for the tech man to vary the definition of legality just because it might have rained the night before! (Racers beware! I once saw a man lose a National event because he left his fuel in the kart tank overnight the night before the race and it picked up enough moisture to fail fuel tech the next day!)
9. In cases where a fuel sample reads illegal (or suspiciously low) on the meter, you may request that a sample of the oil in use be mixed with a known legal gas. While it does not affect the immediate question of legality of the racer's fuel for that race, it may help identify whether the problem is in the fuel or in the oil.

Using this procedure, the same way, every time will insure that fuel tech is fair and consistent. Now on to other issues.

Those of you who read part 6 of this series will recall that there are some fuel additives that generated some performance improvements and some that we did not have adequate information on to draw any conclusions. And if you remember part 5 of the series, you'll remember that not all these additives show up in testing with the Digatron meter. Even the water/Digatron test and the 30/30/30 test are not as definitive as we might like in some cases. Among these additives is 1,4 Dioxane, a very hazardous chemical. 1,4 Dioxane is, among other things, a carcinogen, and a skin-absorbable poison. This is nothing to fool around with! While 1,4 Dioxane will slide past the Digatron meter, there is now a definitive test to identify it in the field. We are indebted to the good folks at Precision Automotive Research, to the National Hot Rod Association, and particularly to a company called Germane Engineering in Provo, Utah for their work in developing a positive field test for 1,4 Dioxane. The test is a simple chemical reaction done with materials supplies by Germane Engineering and is available to bonafied sanctioning bodies and their tech people. It requires a few, easily obtainable supplies, and some care in handling, but the test itself is simple and relatively foolproof. Here's how it works:

1. Draw a clean fuel sample from the competitor's tank and put in a small test tube. Disposable eye-droppers work really well for this and are available very cheaply at any laboratory or medical supply. These are also known as disposable pipettes. The test tube should be no larger than 10ml capacity to be easily readable. Five ml size is ideal these are cheap and easy to obtain.
2. The test tube containing the fuel sample should be about 1/2 to 3/4 full. This will give the person doing the testing a clear view of any reaction. It's a good idea to write the kart number right on the test tube before doing the test to avoid any confusion.
3. Always wear rubber gloves when using the test reagent from germane Engineering. It is a strong acid of some sort and you definitely don't want to get any on your hands.
4. Hold the test tube by the bottom so you can get a clear view of what happens in the fuel sample and carefully squeeze ONE DROP of the Germane reagent into the top of the test tube.
5. As soon as the reagent hits the fuel sample, the oil in the fuel will drop to the bottom of the test tube. THIS IS NOT A POSITIVE TEST!
6. If, however, a white or light brown precipitate forms (like little snowflakes) at the point where the reagent hits the fuel sample, and it drifts down through the fuel, THAT IS A POSITIVE REACTION FOR 1,4 DIOXANE! Any fuel sample producing such a reaction should be considered illegal and the competitor disqualified.
7. Used test tubes and eye-droppers should not be re-used and should be properly disposed of. Always use new test tubes and droppers for each new test.

Again, this test was developed for the National Hot Rod Association by Germane Engineering under license from NHRA and they alone own the rights to it. Test materials are available only to bonified sanctioning bodies and only when accompanied by a strict non-disclosure agreement. Any organization wishing to make use of this important testing tool should contact Germane Engineering.

I want to stress again, use of 1,4 Dioxane is very dangerous, and no club, or track, or sanctioning body should fail to take every possible step to curb it's use.

Last month I told you that we did not have sufficient information to report on two additives tested previously; Klotz COXOC and Hi Rev 3:1. We now have that data and can report that both these products generate POSITIVE REACTIONS to the test outlined above. With the use of this test that are both now easily detectable and should not prove to be any problem for the tech man.

I STRONGLY urge you to contact your local track or club, and any shops in your area, and tell them about the findings concerning products containing 1,4 Dioxane. This is a case of where we, the karters, will have to provide the enforcement for manufacturers who, apparently, have chosen not to regulate themselves. Take an active role. Police this at a local level and protect yourself, your family and your sport. The best way to stop the sue of this stuff is for the manufacturers to stop making it. And economics dictates that they'll stop making it if we stop buying it! Now that we have a dead-reliable test for 1,4 Dioxane that is cheap and easy to do, every track, every club, and every tech man ought to be doing this, every race. WE MUST NOT TOLERATE THE USE OF 1,4 DIOXANE UNDER ANY CIRCUMSTANCES!

One more thing about these additives: It's important that you understand that the purpose of this series of articles has been to educate the karting public. This is not a witch hunt. What separates karting from most other forms of motorsport is that, for most of us, karting is and end in itself. While many karters aspire to drive at Indy or in the

Daytona 500, most of us do this because we love it and we know, deep down, that this is how we'll satisfy our love of racing, and that there is no Indy Car or Winston Cup ride in our future. Karting is not a matter of life and death, and it shouldn't be. It's about fun, fair competition. It's about testing yourself, not about testing the tech man. I can't believe anyone in karting is so driven that they would knowingly jeopardize their health, or that of their families, their friends, or their competitors for the sake of a small advantage in performance.

What I do believe is happening is that karters are using 1,4 Dioxane, or products containing 1,4 Dioxane, without knowing it, or knowing what the hazards are. I know of at least one team owner who openly admitted that his fuel contained one such product, but didn't know what was in it or that it was dangerous or illegal. When their fuel failed the Dioxane test they were surprised, and when they found out what they had been running all season they were more than surprised, they were angry! "How could anybody who cares about karting sell this stuff?" "How Could they not tell buyers what the hazards are?" Good question.

In the weeks ahead we will be working with a group of concerned karting industry leaders to pressure the companies who are making and selling these products to stop. In an industry that has historically been unable or unwilling to regulate itself, this will be an interesting undertaking. Of course, we'll keep you posted on how it develops.

Next month will bring the last of the planned installments of "The Question of Fuel" series. As I've said before, I really didn't start out intending this to be an 8 part series. But the depth of information that came to light while researching this, plus the level of interest from around the country, has driven the expanding nature of this work. We will, of course, bring you periodic updates as new developments arise. But next month we'll try to wrap it up by taking a look at what we should all expect in the future, fuel-wise. Clubs and tracks around the country are all trying to do the right thing and keep the fuel cheating under control, and they're doing it by a variety of different methods. We'll look at those, and at the pros and cons of each. We'll try to offer some suggestions for immediate remedies if your club or track is having fuel problems, and we'll try to look way down the track to see what's available as a long-term solution.

THE QUESTION OF FUEL   PART 8- WHAT'S THE SOLUTION?
By John Copeland

It's been about a year since we started looking into the whys and where-for's of gasoline as a manageable kart fuel. And by manageable, I mean: 1) readily available, 2) reasonably priced, 3) delivers acceptable performance in today's engines, and 4) can be easily and reliably checked for compliance with current tech regulations. Together we've looked into what factors affect how a fuel liberates it's energy during the combustion process. We've also come face-to-face with the rather untidy and unpredictable formulation of today's crop of available pump gasolines. the continued tampering with the formulation of mass consumption gasoline, whether by government mandate, or market pressures, makes any efforts to develop standardized testing procedures a very risky business indeed. We already know that gasoline from a source that passed the Digatron test last season (or even last week) may not pass today. We should expect this situation to get worse rather than better. While the Digatron test was a significant milestone in fuel tech, the introduction of ether-based products into gasoline, today primarily in the form of Methyltertiary-butyl-ether (MTBE), by the oil companies in efforts to boost fuel mileage and reduce tail pipe emissions, has reduced the usefulness of this benchmark. While the Digatron meter will definitely point out the presence of alcohols, ethers, and other highly polar compounds, we can on longer be certain how they got there. Did the competitor 'juice' his fuel to gain an unfair advantage? Or did he innocently purchase fuel that was already tainted by the manufacturer? No tech man wants to throw out an innocent competitor, but there must be some way to keep the fuel tampering under control. As long as racing gasoline is not governed by the same regulatory and market forces that affect pump gasoline, it will continue to be the most attractive alternative to address this dilemma. And to those who howl at the cost of racing gas, take a look at the real cost difference. Even if race gas is $6 a gallon, subtract the $1.20 a gallon you've been paying for pump gas (that leaves $4.80 difference) and multiply by your actual usage for a day of racing. If you're running sprint or dirt, you'll be hard pressed to burn up more than a couple of gallons a day (or night). So we're talking less than $10 here. Big deal. And you enduro racers, even with a Friday practice day you burn what, maybe 5 or 6 gallons in three days. That's less than $30. the fact of the matter is, until there is a better alternative, using racing gasoline is the surest way to avoid having all your driving talent go for naught at the tech shed.

Enough about the problem. What's the solution? It should come as no surprise that there are folks all over the country working on this one. During the course of writing this series I have heard from karting organizations from coast to coast, as well as from people involved in snowmobile racing, motorcycles, and the American Power Boat Association. Everybody's facing the same problem. And these people and their organizations have tried, and are trying, lots of different solutions to deal with it. Let's look at a few of them.

In some areas the approach has been "spec fuel". In fact. some organizations on the East Coast have been doing this for some time. It's just a variation on the Klotz KL-200 plus gas comparison test with the Digatron meter that has been outlined I the tech books for years. The organization selects a particular brand and grade of gasoline, and in some cases oil too, and declares that the competitor's fuel sample must meter within some range (usually 5 points) of that standard. The test assumes that the fuel that is selected is untainted with additives or other chemicals that would alter the meter reading. It also assumes that the quality of the specified gasoline will remain constant throughout the season. I have been told by some officials that their local fuel dealer has assured them that this would be the case. That's all well and good, but, unfortunately, the local fuel dealer has no more control over what the refinery is doing with the composition of the fuel they deliver to him than the consumer does! He gets (and we get) whatever comes in the truck. And in many cases, it may vary from delivery to delivery. An evening spent watching tanker trucks load at a nearby refinery revealed a tremendous variety of truck markings being loaded from the same source. While I watched, in the span of only 3 hours I saw trucks marked with signage from 7 discount gas-station chains, *and 2 major oil companies*, load up from the same fuller-tube. The fact of the matter is, neither you nor the dealer has any real idea where the gasoline you buy came from, or, more importantly, what's in it. So setting a numerical reference on the Digatron meter based on a "spec fuel" is a very risky business, both for the organization, and for the racer. The exception to this, of course, is if the "spec fuel" is a specially formulated racing gasoline. As I've said before, these products are carefully controlled by their manufacturers to ensure consistent quality and freedom from contamination. In areas where this sort of "spec fuel" program is in use, it can only be expected to work if the baseline fuel is a racing gasoline.

Secondly, we understand that the Digatron meter measures the dielectric constant of the sample. But it's readings are not linear. That is, if adding 5% of something to the sample moves the meter reading 10 points, that does not necessarily mean that adding 10% will move it 20 points. In fact, depending on the additive, doubling the quantity might not move the meter reading at all, or it might jump dramatically! From this we can say that applying some arbitrary allowance of variation from the meter reading of the "spec fuel" cannot provide a accurate look at the sample, or any determination as to whether or not it has been tampered with by the competitor. Finally, this comparative method of using the Digatron meter as the sole determinant in tech ignores the fact that, with a little experimentation, a dedicated fuel cheater can use some additives to "mask" the presence of other additives in the fuel. that is, by adding materials that have a very *high* dielectric constant, it is possible to effectively hide additives with a somewhat *lower* dielectric constant. As long as the finished fuel generates a reading within the required range, the fuel passes tech. No, there has to be a better way.

Another approach is to actually *provide* legal fuel to the karter at the track; to contract a vendor for legal fuel to be at the track on race days and suggest that anyone not confident in their fuel's ability to pass tech purchase fuel from him. This puts the burden on finding a reliable vendor on the club or track management and also offers the opportunity for the embarrassing discovery in tech that the "track gas" isn't legal after all. I have seen this happen more than once, where competitors discovered in post-race tech that the fuel they had purchased at the track was contaminated. At one National event, the top 6 finishers in the first race of the day were disqualified and dismissed from the tech area before the problem was discovered. Once they had left the tech area, officials correctly ruled that, despite the error, they could not return and be reinstated. It was an awkward and extremely difficult situation that could have been avoided if only the officials had teched the "track gas" first. In a sport (and a nation) that many think already has too much regulation, telling people they *must* run the "track gas' is not a very popular position. But providing a reliable source at the track at least assures that everyone has access to legal fuel, if they choose to purchase it. I should point out that the selection of a vendor is critically important to the success of this approach. Of course, the consistent quality of the fuel must be assured. But also, while you should expect to pay some premium for the service of having someone bring his truck to the track, the selling price of the fuel must not be abusively high. In some cases it may be appropriate for the club or track to pay the vendor a "service fee" above and beyond the price of the fuel to insure that those additional costs are not passed on the karter in the form of unreasonably high fuel prices.

An extension of this approach that is finding some success on the West Coast is to not only *provide* legal gas at the track, but to actually *require* that everyone use it. It's a lot like the "pump around" so common in 4 cycle racing these days. the track or club actually purchases the gasoline, mixes it with oil at some recommended ratio, and *dispenses* it, directly into the competitor's fuel tank. Here's how it works. At the pre-grid, the karters are required to present their karts with fuel tanks empty and the fuel line disconnected from the carb. The tech man watches the karter connect the fuel line to the carb and safety wire it. The tech man then dispenses the desired amount of fuel into the tank and the tank is sealed. Before the karter may return to the pre-grid for the next qualifying, heat race, or whatever, he must drain any remaining fuel from the tank. Regardless if he spun out and killed it on the pace lap of the first heat, before he goes to the grid for the second heat the tank must be empty and the fuel line off the carb again. I presume this make for some pretty expensive gas going into the tow vehicle, not to mention the oil. And on the subject of oil, the folks I spoke to said their clubs simply selected a different oil each year from those in most common use, and announced that it would be the oil, and in what ratio, for the season. On the surface, this is a pretty good system. It assures that the officials have pretty much complete control over the fuel being used. However, the removal of any opportunity to choose your fuel, or your oil, rubs a lot of people the wrong way. Particularly the oil If your engine builder has told you he wants you to run 4 ounces of Castor and 2 ounces of Yamalube R per gallon in the engine he built for you, that's what you ought to run. Maybe the engine builder has some specific reason for that recommendation, or maybe it's just the result of his years of experience. In either case, finding out that the supplied fuel will be mixed with 3 ounces of Red-Line (for example) is not going to inspire much comfort in you or your engine builder. But this is a minor issue compared to the question of **time!** Remember, you can always make more friends. You can sometimes make for horsepower (*that may cost you friends*). And you can try to make more money (*that will bring you false friends, but may help pay for the horsepower*). **But you can never make more time**. The controlled dispensing of fuel on the pre-grid consumes manpower and no small amount of time from the program. Even if everyone arrives at the pre-grid early (that would be a first), it's simply a matter of having to go through all the steps, one kart at a time. I've been told by some people that, in order to implement this type of program, they had to cut the number of classes the track ran in half! While you might agree that reducing classes is sorely needed, this is not the way you'd like to do it. Delays and downtime between races aggravate karters and bore what few spectators we might have. And the more thorough the tech man's inspection to assure that no additive is already in the otherwise empty tank, the longer this thing takes. Racers come to the track to *race*, not to stand around. The more waiting time increases, the more disgruntled the racers will be, and the less likely that they'll come back next week. We need to be looking for ways to get race programs finished sooner, not ways to stretch them out loner.

All these are workable approaches to the problem of legal fuel. But we've heard from some karters out there that have questioned whether we need to be teching fuel at all. Now wait a minute!! Before we dismiss this suggestion as a permitting an "open season" for fuel cheating, let's take a closer look.

The question then wasn't what fuel could be run, but rather what could be done to the carb to allow alternative fuels to be run. After years of crying and wringing their hands about what would become of the sport if everyone was allowed to run whatever fuel they wanted, IKF (they were the only sanctioning body then) opened up the restrictions on carb passages to allow everyone to run methanol. Almost overnight methanol became the overwhelming choice of karters, and the use of nitrobenzene, and hydrazine, and other additives virtually disappeared. Given the choice, and the freedom to drill their carb passages to the required sized, racers found that straight methanol gave them the best performance, improved tune-ability, and was easier on the engines. Maybe there is something to be said for learning from history. Certainly today's 2 cycles are a far cry from the Macs. And the Walbro carb used on the Yamaha and other piston ports is a virtual soda-straw, throttle bore wise, compared to the carb on the McCulloch. But if the rules were to allow it, and if the carbs could be drilled to make it easy and reliable to do it, I'll bet it wouldn't take long before everybody was burning methanol. If the carb passage sizes were controlled so that the extraordinarily high volumes of additives like nitromethane and such required for combustion were not attainable, the question of fuel legality would take care of itself. Tech would be a simple matter of a couple of no-gos in the carb passages.

I know of several innovative karters who are testing in this area already. They report that they can efficiently burn 100% alcohol through an otherwise unmodified Walbro carb, with very little re-drilling of passages. they also report not only improved performance, but also less plug fouling, cleaner combustion chamber and piston crown, and no ring sticking from carbon and gum buildup. Incidentally, one racer who is experimenting with Methanol fuel points out that, even with the higher fuel consumption using Methanol, at $2.25 a gallon, he's saving money over the $4.50+ he was spending on race gas. This is definitely something to look into. As is so often the case, local clubs and organizations will have to take the lead on this and try it. If it helps solve the fuel problem, eventually the national sanctioning bodies will follow suit. We'd all like to see the big organizations take the lead on things like this, but it doesn't always work that way. Someone will have to do the leg-work first. Will it be your club or track? Ask about it and discuss it. And, please, let me know how it works.

There is absolutely no reason to think that, without some radical re-thinking, the fuel situation is going to get any better. The oil companies are going to continue to meddle with the composition of gasoline, whether dictated by the government, or for competitive market reasons. Faced with an ever-changing product, karting will have to redefine what constitutes legal fuel, either by changing the tech techniques, or by changing the fuel itself. Tom Stinitz, President of Digatron Instruments, tells me that, at present, they have no plans to introduce any fuel testing instrument other than the DT-15. He is aware of the DT-15's shortcomings but, unless or until some alternate testing protocol is developed, they don't know what they should design to facilitate it. Perhaps there is someone out there with an idea of how to test fuel in such a way that changes in the manufacturer's additive package won't influence the results. I'm no chemist (although I've learned a lot of chemistry in the last year on this project), but maybe one of you is. It's a big challenge, and one that will have a long-lasting impact on the sport. One thing is certain, though, We can't keep doing things the way we have been. It's bad enough to let fuel cheaters pervert the spirit and intent of karting. But it is even worse to unfairly disqualify perfectly honest competitors because the tech techniques we are using have not kept pace with the fuel that is available. If the enormous growth of "outlaw" tracks has taught us anything, it should be that rinky-dink rules are unwelcome and unwanted in karting. And fuel tech that is unfair, or outdated, is just that, rinky-dink.

Well that about wraps it up on the subject of fuel for now. Hopefully we all know more now than when we started. (I know I do!) We've looked at what the fuel does and doesn't do in the engine, and what additives do and don't work, and in what quantities. But, mostly, we've hopefully done away with some of the mystery, the "smoke and mirrors" that surround what we and our fellow competitors are burning. I continue to believe that the vast majority of karters are honest, hard-working racers who want to compete fairly. Oh sure, there are a few who insist on trying to win by beating the tech man instead of winning fair and square. But I really believe they are at risk of being tossed out in fuel tech because either their fuel was tainted by the manufacturer, or because our tech procedures are not adequate to deal with today's crop of commercial gasolines. To paraphrase a famous jurist, "It is better for 10 guilty men to go free, than to wrongly punish 1 innocent man." Let's put the considerable talents and resources of the karting community to work and develop a workable solution to take us into the next century. Thanks to all of you who have provided input on this series, and we'll see you at the track.