FSCCA Technical subject: Fuel and the proper Air/fuel adjustments

The stoichiometry of automotive fuels can vary from as low as 6/1 A/F (air fuel ratio) to as high as 15/1 A/F (air fuel ratio). Because of this variation the Ideal A/F ratio for your FSCCA car cannot be obtained without knowing, in detail, what you are using as fuel or you specifically tune the motor to a specific fuel.

When you are trying to create the Ideal A/F ratio this affects the performance of the engine but also can predict the destruction of the engine. Not only is it the A/F ratio a concern but the vapor pressure, octane rating, combustion chamber temp, burn rate, Ignition timing, and many more items. The developer of the engine map has to consider the fuel being used. When Enterprises developed the current map, pump gas was slightly different. This difference can now cause some competitors problems with engine failures, if adjustments are not made. In order to discuss proper Fuel injection tuning you have to discuss what kind of fuel you are using.

Let me first say that pump gas varies from purchase to purchase even from the same pump. Race gases that come in a can vary as well but you get the same variation every time you buy it. That's a big difference. Pump gas can work in the FSCCA car but it is more difficult to keep it adjusted properly. There are some tools required to tune any fuel system. In today's world a wide band lambda meter is a required tool. YOU CANNOT PUT DIFFERENT GAS IN YOUR CAR EVERY TIME YOU RUN IT AND NOT ADJUST THE FUEL SYSTEM TO MATCH THE FUEL. You cannot assume that because your buddy runs the same gas, that your car will use the same settings. The variables that can effect A/F ratio, are altitude, fuel temperature, combustion temperature, injector flow rate, battery voltage, fuel pump flow rate, as well the fuel variations.

The following is a method you can use to check and adjust the fuel system on a FSCCA car.

1st.pick a fuel that you can count on being the same every time you buy it.

2nd store that fuel in a sealed container, and keep the lid on it except to dispense.

3rd know the stoichiometry of the fuel you are using.

4th install a wide band lambda sensor in your exhaust or use an exhaust gas analyzer with A/F ratio meter

5th operate car on the track while data logging the lambda sensor or run on a chassis dyno and record A/F ratios.

6th adjust A/F ratios to the maximum torque reading you can observe (this should occur at about 5,000 rpm) and then richen the mixture slightly (about .1-.2 % richer). If the max torque method is not available, than adjust A/F ratio to approximately 90 % of the stoichiometric number of your fuel. e.g. If stoichiometry of your fuel is 14.7 to 1 then, (14.7 x .9 = 13.2), the ideal A/F ratio will be about 13.2 to 1. Adjusting the fuel pressure regulator is the easiest method to change A/F ratio.

Increasing fuel pressure richens A/F ratio and lowering fuel pressure leans A/F ratio at Enterprises we use Fire Power #324 unleaded 100 octane, from Precision Fuels, for all calibrations. The Ideal A/F ratio for this fuel in our engine is 12.6 to 1. With our, injectors, fuel pump, and voltage of 13.2-13.6 volts, our fuel pressure is set at 40 PSI. This fuel can be purchased from Precision Fuels or you can do your own testing and adjustments for the fuel you wish to use.

7th Finally, spark plugs or exhaust pipe color are also a good thing to monitor. Usually the plugs and tail pipe should be a light tan color if they have any color at all. Unleaded gas produces vary little color on spark plugs, so it is completely normal to have no color on the plugs and tail pipe. Any change in A/F ratio will take a long time to show up on a spark plug or tail pipe, so I am not recommending that you adjust the A/F ratio by reading spark plugs, but it is a simple quick check. You can be relatively sure that if the plugs / exhaust are white, the motor is lean and you are probably damaging the motor. The white color you're seeing is often the melting of the aluminum in the combustion chamber and depositing it on everything. Dry black is not too uncommon to see on the spark plugs and tail pipe. I would consider it normal because the engine runs so rich on start up and

white color you're seeing is often the melting of the aluminum in the combustion chamber and depositing it on everything. Dry black is not too uncommon to see on the spark plugs and tail pipe. I would consider it normal because the engine runs so rich on start up and idle it will blacken the plugs on start up. If spark plugs are black and wet you need to perform a cylinder leakage test (CLT) to determine if the rings or valves are damaged. Normal CLT testing should be done after every race weekend. Normal CLT numbers should be from as low as 1% to as high as 10%. Any higher and you are having a deterioration of the mechanical condition of the engine.

What's changing on your car with out you knowing or monitoring?

Many pump gases have varying amounts of Ethanol added and therefore varying Stoichiometry. Ethanol has a stoichiometry of 9 to 1. If you mix 10% ethanol (8.9/1) with 90% gasoline (14.7/1) you get fuel that has a stoichiometry of about 14.1 to 1. If I now take that times 90% (from step 6), that means my new ideal A/F ratio is 12.6 to 1. When you run fuel with 10% ethanol and you do not enrichen the A/F ratio your motor will be leaner compared to fuel without Ethanol. The difference from 14.1/1 to 12.6/1 is lean enough to cause motor damage over a period time. Please read the article on detonation to understand damages that occur to engine. Your local gas stations will have varying amounts of ethanol in their tanks. As you can see a small change by the local gas station can change things significantly. Ethanol, in pump gas, can vary from 0%-15%). To determine the amount of Ethanol or alcohols in the gas a water test can be performed. Stoichiometry is only one of the variables

Let's look at the fuel temperature. As the temperature of the fuel rises so does the fuels ability to vaporize and expand. Temperature changes due to whether and how well your engine compartment vents. Fuel that is vaporized or partially vaporized flows at a different rate then liquid gas. This decrease in flow rate leans the engine. Fuels with lower boiling points can be a problem when it is hot out. In the spring and fall when temperatures are cooler this can also be a problem because the fuel will not vaporize well enough. In both cases the motor is lean, this is why you have to choke a cold engine.

Another variable is battery voltage. Just because your car started does not mean the battery voltage is sufficient to run the engine properly. As battery voltage drops the voltage to the fuel pump drops. As the fuel pump voltage drops the pressure drops, which causes a reduction in flow to the injectors. DO NOT RUN YOUR CAR WITH A BATTERY BELOW 12VOLTS. It will run below 12 volts, but not properly. Battery voltage is so important in an EFI engine that the engine can crank and sound normal while cranking and not start because the voltage is too low for the ECU and injectors to work. Low battery Voltage leans the engine.

What does all this mean in summary?

Your FSCCA car is a true racecar that needs adjustments made. It is not a streetcar designed to work under multiple conditions like your daily driver. In order to make proper adjustments a Lambda meter is required. What will normally happen if the A/f ratio is incorrect, for a period of time, for any reason, is a failed engine. Usually the engine will fail mechanically because of another factor causing the temperature in the combustion chamber or other areas to rise. You should take note that the gauges on your dash are related to temperature and battery voltage. This is because it's not A/F being wrong that ruins the engine. It's the fact that when A/F is wrong the temperature melts the engine and the driver has to stop and find out why the motor is hot before it melts. I have included two articles on gasoline's and what to consider.

Why not simply use pump gas?

Pump gas should be used for what it was intended, passenger cars driven on the street. It is not intended for race engines nor stock engines that will be used on the track in competition. Pump gas is designed for low cost and fuel economy, not performance. Excessive carbon deposits from pump gas can build up on piston crowns and cause pre-ignition when the engine is run hard.

The stronger argument against pump gas is that it will vary considerably from state to state, month to month, per EPA mandate. That means you may seldom buy the same fuel twice, even if you purchase from the same gas station. The markings on the pump do not reflect the changes in octane, vapor pressure, distillation, and other properties. Put pump gas in your tow vehicle, put a good race gas in your racing vehicle.

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Fuel tech

Precision AutoResearch

The impact of RFG fuels on racing fuels and fuel testing

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Recent changes in Federal Regulations issued by the EPA as mandated by the Federal Clean Air Act of 1990 (which became effective April 1996), requires the use of Reformulated Gasoline (RFG). This has produced some unforeseen problems for Race Sanctioning Bodies.

Our purpose is to provide some insight to the emerging fuels situation, and to clarify existing fuel standards so that Chevron-Phillips Company and other major refiners may continue to supply high quality racing fuels which are unquestionably legal, safe to use and which meet EPA and industry standards.

The EPA has required that all gasoline sold in selected markets be reformulated to meet new specifications for commercial gasoline in an attempt to meet Federal Clean Air Act standards. Currently, RFG gasolines represent the majority of gasolines sold in the US and the trend is expected to continue and increase. In addition, unleaded racing gasoline, much of which is sold at the retail pump, has been blended to meet EPA requirements as

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A number of important fuel specifications have been reduced, such as: olefin, benzene and aromatic content, distillation curves, sulfur and phosphorus content, and vapor pressure. A detailed list of RFG fuel specifications is shown in Appendix A.

The elimination of lead compounds (TEL, TML) and other organometallics (MMT) has made it substantially more difficult to produce fuels with octane numbers suitable for high performance street engines, let alone for competition use. While racing fuels containing lead compounds continue to be available at present, pressure may be mounting for their discontinuation. Canada recently banned lead in racing fuels (later rescinded under pressure) and even NASCAR is moving toward lower (9.5) compression engines, perhaps in anticipation of unleaded racing fuels. While we believe that leaded racing gasoline should not be eliminated in the foreseeable future (needed for vintage and existing race engines), the cost and continued availability of certain components may become a future issue.

The use of oxygen bearing compounds (alcohols and ethers) have been accepted methods used by the industry to meet octane requirements. In addition, some states have provided strong tax incentives to encourage the use of ethanol blends (gasohol). Although component content and concentration limits have been defined by the EPA, the methods employed (and therefore, the exact end product specifications) to meet this mandate vary by refinery, season and locale.

Historically, many race sanctioning bodies have prohibited the use of oxygen bearing additives in an effort to control the use of alcohols, nitrogen bearing compounds such as nitrous oxide, nitromethane, nitropropane, etc, and to prohibit the addition of some compounds such as ethylene oxide, whose sole purpose was to increase the oxygen content of the fuel. Prior to 1996, fuel testing was easier than it is now. Virtually all fuels were pure hydrocarbons and most "doping" consisted of using components used by NHRA top fuel racers which were usually soluble in methanol.

Tests were devised to detect banned components: the water test for methanol and methanol soluble substances, the Godman DT-15 (Digatron) di-electric test for polar substances, the acid drop test (Germane) for water soluble oxygenates, (i.e. dioxane), and eventually laboratory analysis, Infra-Red (NIR) and Mass Spectrography, if resources, both human and financial were available.

Here's the problem; all pump gasolines found in major market areas, as well as most unleaded race gasolines are illegal under current rules.

Virtually all EPA mandated fuels (RFG) will contain some amount of oxygen bearing compounds (alcohols & ethers). Exact levels will vary by refinery, season and locale. Unleaded race gas will almost certainly contain oxygen bearing compounds in order to provide suitable octane levels. The oxygen concentrations will vary from 1.8% to 2.7% by weight. Therefore the Digatron readings will increase substantially and will vary widely. Since refiners will face changing blendstock streams, consistency within a certain brand and type may vary as refiners experiment to satisfy customers.

In order to permit the legal use of commercial pump gasoline (not gasohol) as well as unleaded racing fuel, the Digatron set point must be re-calibrated. ***The Digatron calibration setting recommended by Chevron-Phillips Chemical Company is: -75 @ 60°F using fresh cyclohexane.*** The earlier setting of -55 is both outdated and unfair to entry level competitors who may wish to use commercial pump gasoline or unleaded race fuel. By changing the Digatron setpoint to -75 instead of -55, many of our current fuel inspection problems will be eliminated and we will be able to use current and future pump gasolines as well as unleaded race fuels.

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Chevron-Phillips Chemical Co, with the support of other refiners, has spearheaded a nationwide drive to standardize fuel legality issues across the full range of Motorsports activity and Motorsports Sanctioning Bodies. The proposed revision has been accepted by several Race Sanctioning Bodies and many more are considering making a change. The scope includes Snowmobiles, Jet-Skis, Motorcylces, Sports Cars and Go-Karts. When the facts were properly understood, no Sanctioning Body has found reason to oppose the revision.

One objective of Chevron-Phillips Chemical (a view shared, I'm sure, by the other racing gasoline refineries, i.e. Unocal, Sunoco) is to supply consistent, high quality, trouble-free fuel to all racing competitors, along with the expertise necessary to obtain best performance results. We do not condone, and in fact, actively discourage the tampering, dilution or alteration in any other way, of fuels which have been carefully blended, tested and manufactured. This includes the use of nitrogen compounds, anilines, MMT content or the addition of any non-EPA approved additives. Specifically, we are concerned about the addition of any carcinogenic or harmful aromatics (benzene, dioxane) or carcinogenic precursors. In addition, we feel strongly that proper handling, transport and storage procedures should be known and followed.

In addition to fuel content, we are concerned about exhaust emissions which can be very harmful to competitors, particularly young adults. Fuel components and exhaust emissions which are considered very harmful are those listed in the Threshold Limit Values for Chemical substances handbook published by the American Conference of Governmental Industrial Hygienists. A partial list of substances which should be banned by all Race Sanctioning Bodies can be found at the end of this article..

Highly carcinogenic emissions in high concentrations often overlooked are: oil mists at the starting line of races, formaldehyde emissions from methanol fueled engines, and butadiene from heavy hydrocarbons. Perhaps it would be possible to consider the possibility of requiring a warm-up lap prior to the start of every race. Cold starts in alcohol burners and two stroke engines are literally the kiss of death.

In addition to the change in Digatron setpoint, we further recommend the use of the FirePower Digatron Test Kit as a method of improving measurement accuracy and to provide a recognized source for fuel sample laboratory analysis. The FirePower Digatron Test Kit has been designed to assist recognized race sanctioning bodies with the difficult task of monitoring fuel legality. The details of the FirePower Digatron Test Kit are found in the accompanying sidebar. The Test Kit is available to race sanctioning bodies from Digatron or from Precision AutoResearch. The enclosed Digatron Fuel Test Protocols have been adopted by Digatron on a nationwide basis.

Laboratory testing of race fuels by independant laboratories has been extremely well received. In every case where competitors have been informed regarding the list of banned substances, and where they were aware that fuels would be lab tested, the usage of illegal substances has virtually disappeared.

The establishment of clear, workable and enforceable fuel standards would be helpful to competitors, Sanctioning Body Officials, tech inspectors and fuel suppliers. Perhaps you may wish to ask your Competition Board to review and certify the use of recommended test procedures and of FirePower race gas blends (as a representative sample of similar products from other quality refineries) as legal fuels which may be used with full confidence.

It is our hope that continued cooperation between race fuel suppliers and Race Sanctioning Bodies will produce a racing enviornment that is both fair to all competitors and free of dangerours and harmful substances. If you or your Competition Board should desire additional information, or specific technical information, please do not hesitate to call upon us. We'd like to help.

Illegal/ Banned Fuel Substances

Fuel samples submited for laboratory analysis will be tested for the presence of the following substances.These substances do not normally appear in any gasoline and are deemed to be illegal fuel components or are harmful to the health of competitors.

Alcohols (all types)
Aldehydes
Aminodiphenyl
Benzine (in excess of EPA limit)
Benzidine
Beryllium compounds
Bromine compounds
Butadienes
Chlorinated compounds
Chromates
Dioxanes

Ethyl acrylate
Ethylene oxide
Hydrazine compounds
Methylene dianailine
Naphthylamine
Nitrogen compounds
(Nitromethane, et al.)
Styrenes
Toluidine
Xylidine
Other _____

...and all other substances as requested by recognized Race Sanction Bodies or deemed to exceed Threshold Limit Values (TLV) or Biological Exposure Indicies (BEI) as listed by the American Conference of Governmental Industrial Hygenists (ACGIH).

Unleaded and RFG fuel specifications

Permit the use of any unleaded gasoline (RFG, not gasohol) which is EPA legal for sale at the pump, except for detergents which may be added.

Component		Limit	Test
RVP		7.0 psi	ASTM D-323-58
Benzene		1.20%vol	ASTM D-5580-95
Olefin		10.0% vol	ASTM D-1319-9x
Aromatics		30.0% vol	ASTM D-5580-95
Oxygen content	min	1.80% vol	ASTM D-4815094
	max	2.70% vol	
Lead		.050 g/gal	ASTM D-3237-79
MMT		0	
Phosphorus		.005 g/gal	ASTM D-3231-73
Sulfur		80 ppm	ASTM D-2622-94
Distillation	T50 max	220°F	ASTM D-86-90
	T90 max	330°F	

Specifically banned are the *addition* of organometallics (TEL, TML, MMT) nitrogen

Distillation	T50	max	220°F	ASTM D-86-90
	T90	max	330°F	

Specifically banned are the *addition* of organometallics (TEL, TML, MMT) nitrogen bearing compounds, aniline and carcinogenic aromatics. All substances listed in hazmat list (Appendix B) are specifically banned. May contain oxygenates to increase octane but may not exceed limits set by EPA for street legal RFG fuels.

Leaded Racing fuels

Leaded fuel must be 100% petroleum derived hydrocarbons and must meet ASTM D-4814 specification for gasoline. Detergents may be added.

Component		Limit	Test
RVP		9.0 psi	ASTM D-4814
Specific Gravity		0.69-.79 (60/60°F)	ASTM D-4052
Benzene		5.0% vol	
Olefin		10.0% vol	
Aromatics		50.0% vol	
Oxygen content	min	1.80% vol	
	max	2.70% vol	
Lead		6.0 g/gal	ASTM D-3237
MMT		0	
Phosphorus		.005 g/gal	
Sulfur		80 ppm	
Distillation			ASTM D4814 per ASTM D-86

Specifically, the *addition* of organometallics (TEL, TML, MMT), nitrogen bearing compounds, anilines and carcinogenic aromatics are prohibited. All substances listed in hazmat list (Appendix B) are specifically banned. Oxygenates are permitted to boost octane, but may not exceed limits set by EPA for RFG fuels.