SCCA Enterprises Technical Bulletin

Fuel System & Fuel System Performance For The SRF

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Table of Contents

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1 OUTLINE

I have taken a few minutes to document some of the answers to questions I am getting on a regular basis related to engine health and fuel system performance. Much of this is common sense and can be accomplished with visual inspections, some quick tests or just spending a few bucks to install new components.

Fuel related problems can be blamed for engine related issues and even engine failures. If you suddenly lower the fuel pressure while on the track the engine will hiccup. Many of us have felt this and it's very easy to know something is wrong. This is a drastic example of what happens when the required amount of fuel is cut short. There are many other fuel related problems that can, for the most part, be unnoticed but cause engine performance issues and, in the right conditions, cause engine damage or engine failure. Variations in weather around the country coupled with significant differences in fuel quality are making it more important than ever to know your fuel system and verify that it is operating correctly. This technical bulletin will describe the fuel system related components, the issues that can develop with these components, and how to test and verify your system is working properly.

2 FUEL SYSTEM

Over the past couple years the issue of fuel pressure, fuel flow rate (supply volume) and fuel aeration[i] in the injector rail has been a frequent area of inquiry. Fuel pressure is simply the operating pressure of the fuel system. We can measure this on the fuel rail or anywhere between the output side of the fuel pump and the fuel rail. Fuel flow rate is the amount of fuel the pump can deliver over a given time. The flow rate is dependent on the fuel pressure. The free state flow rate is often very different from flow rate at higher pressure. Later in this document we will describe in detail how to measure the fuel flow on the car and verify the pump delivers proper volume at operating pressure. Fuel aeration is often the result of a worn out or damaged fuel pump. Aeration of the fuel reduces the efficiency of the fuel system. The mixing of pressurized air and fuel reduces the effectiveness (output) of the injectors and will lead to reduced performance and even engine failure. This may not be noticed without verifying each component's performance.

Knowing the performance and condition of each component in your fuel delivery system is important even if your car is equipped with a wideband 0_2 meter[ii], which is highly recommended. If your car is not equipped with an 0_2 meter it is even more critical that you know the performance of your fuel system in order to maintain good performance and prevent serious damage to the engine. Dirty fuel filters, degraded or kinked fuel hoses, weak fuel pumps, clogged injectors and other fuel system components need to be monitored for proper operation. By using a wide band 0_2 meter you have the ability to verify engine fuel system performance as well as diagnose fuel system related issues.

However, just using this 0_2 meter is not a substitute for routine maintenance and verifying the performance of the related components. The AFR measurement on the SRF is as an average of two cylinders at best and in some cases an average of all four.

2.1 FUEL PUMP AND COMPONENTS

The heart of any fuel system is obviously the fuel pump. The fuel pump is not a positive displacement pump; it has no valves to control the fuel in and out of the pump. It is a vane type. This type of pump is very poor at pulling or sucking fuel out of the cell. It is designed to push fuel (thus the importance of good plumbing on the suction side of the fuel pump). It also relies on the fuel to lubricate its internal parts. Running low levels of fuel in the cell and starving the pump near the end of an on track session greatly shortens the life of the pump. If it isn't working correctly many unwanted conditions can result. Before we begin testing and verifying your fuel pump performance we need to establish the proper operating conditions for the fuel pump and related components and provide some background on each parameter.

Flow Rate	22-24 Oz per 30 sec @ 40 psig & 13.2 volts (applied at the fuel pump leads)
Fuel Pump Bypass Valve	Progressive valve internal to the fuel pump nominally set to bleed pressures above 53-58 psig. This will vary from pump to pump and can be as low as 44 to 45 psig. In this case of low internal bypass valve pressure, you may start losing fuel flow due to internal aeration closer to 45 psig.
Typical Fuel Pressure for SRF	Between 38 and 43 psig @ WOT covers most weather conditions
Injector Duty Cycle	Injectors run at approx. 90% duty cycle (almost maxed out)
Fuel Filter	Kinsler PAPER Fuel Filter with 20 Micron Filtration (very fine)
Fuel Line	3/8"

Table 1 - Kinsler Fuel Pump and Fuel System Specs

FUEL FACT: THE EVER DEGRADING QUALITY AND UPREDICTABLEITY OF PUMP GAS IS CAUSING ISSUES THAT PREVIOUSLY WENT UNOTICED. HIGH LEVELS OF ETHANOL IS BECOMING THE NORM RATHER THAN THE EXCEPTION.

2.1.1 Fuel System Terms and Definitions

- Fuel Flow: If your output is less than the specified rate the engine will not receive the proper volume of fuel even though the pressure may be within the specified range. If this flow rate falls low enough it will cause engine damage and eventually failure.

- Fuel Bypass Valve: This is an internal (within the pump) bypass valve that prevents the fuel pump from flowing fuel above the bypass limit. This has little meaning or influence on the SRF. However, trying to achieve fuel pressure above this specified range can result in aerating the fuel and a decrease in fuel flow and quality.

- Fuel Pressure: If you find your car is requiring more than 43 or 44 psig or less than 37 psig to achieve the proper air fuel ratio under full load you need to ask yourself what is wrong. Don't just blindly begin increasing or decreasing your fuel pressure. Due to the high alcohol content in most pump gas these days, frequent fuel filter changes are recommended. I would also recommend having your injectors cleaned on a regular basis. We have also seen fuel lines break down more often due to alcohol effects, so inspecting these often and/or changing them at the end of each season or two is also recommended. There are other factors that may be at fault if you constantly require fuel pressure outside this range. Consult your CSR for other electrical and component related issues.

- Injector Duty Cycle: This parameter is given for reference and has little meaning to us as we can't adjust this, or even measure it. (It can be measured by using diagnostic tools and test equipment) It's shown here to demonstrate how much fuel we require at WOT. If we are taxing the injectors at the high end of their output, any other restrictions can often cause fuel related issues.

- Fuel Filter: The filter we use is a service and maintenance item. Be sure to inspect this during your yearly maintenance and replace as needed. The higher levels of alcohol deteriorate these faster than years past.

- Fuel Line: Be sure to use the proper size fuel line in your system. Anything smaller will limit the volume of fuel getting to the injectors. Also be sure to use quality fuel rated line. This is especially important in the fuel tank. These lines are submerged in fuel and can deteriorate which will cause fuel system issues if care is not taken when choosing the fuel line and routing it within the cell.

2.2 *TESTING YOUR FUEL PUMP*

Now that we understand the fuel system in more detail it's time to test the fuel pumps flow output. The flow rate is dependent on operating pressure and temperature. For the most accurate results it is best to check the flow output of the pump at operating pressure and as close to operating temperature as possible. This can be done just after a session for best results. However, the most important factor is the pressure. If you are not going to be at the track anytime soon, you can still test the fuel pump. In this case your results should be within the specified range, but may be slightly higher or lower than race conditions.

The simplest and quickest way to test the fuel pump involves running a fuel test hose from the return side of the fuel rail to a collection container and cycling the fuel pump on and off in 30 second intervals. Each time you cycle the pump on, fuel will fill the container until you turn the pump off. By measuring the fuel collected each time you can get an average fuel flow per 30 seconds. The master switch can be used to cycle the fuel pump on and off by running a jumper wire across the fuel pump relay. This process is detailed step by step below.

NOTE: KEEP A FIRE EXTINGUISHER NEAR WHENEVER WORKING WITH THE FUEL SYSTEM

2.2.1 FUEL PUMP FLOW VERIFICATION PROCEDURE

1. ECC Test Plug: Looking at the open of the test plug with widest flat surface up. Insert a jumper wire in the upper far left pin location (most cases this will be a black wire with an orange tracer) Figure 1 / 1a / 1b Attach loose end of the jumper wire to ground. Verify the jumper is installed correctly. Turn ignition switch on and then Master Switch to run the fuel pump continuously. The fuel pump should run continuously until the master is turned off. If it doesn't re-check the jumper wire.

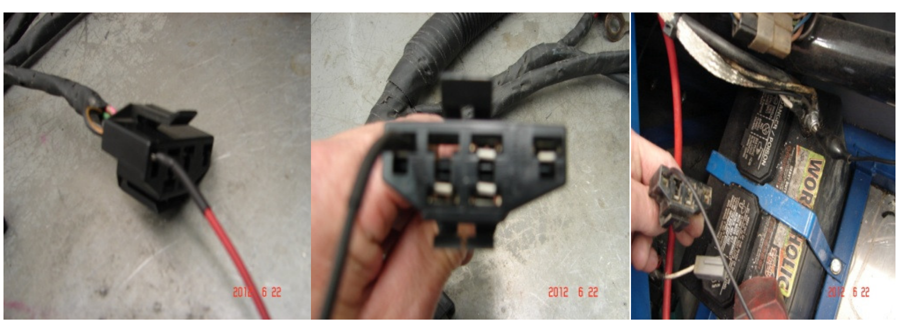

Figure 1 / 1a /1b -ECC test plug pin to ground

2. Figure 2 / 2a Remove -6 fitting just below the Ford spring lock fitting and attach female -6fitting or Spring lock barbed hose fitting on the return side of the fuel rail (Shown in figure 2) with a separate length of hose. The length of this hose should be long enough to clear the side of the car where your measuring container can be located on the ground. Approximately 3 to 4 feet. Clear hose works best because it makes it easy to see the condition of the fuel as it would enter the injectors. Place the end of the hose in the measuring container.

Figure 2 / 2a - Return Side of Fuel Rail

3. Purging the System: Turn master switch on and off 1 or 2 times. This is done to check for leaks and to bleed the system. Empty the measuring container. Make sure to hold the container to keep it from spilling during the test.

4. Fuel Pump Voltage: It is **very important** to verify the fuel pump supply voltage is between 12.0 and 12.6 volts during the test. Before beginning, verify the voltage at the fuel pump during a 30 second test run. If needed, charge the car's battery before testing the fuel pump. (Do not leave the battery charger hooked to the car battery during the test. This will raise the fuel pump voltage too high and invalidate the test results.)

5. Perform Test: Turn the master switch on for 30 seconds. Pay close attention to the *quality* (amount of aeration, which would be visible as air bubbles) of fuel and the *amount* of fuel pumped into the container. For best results perform several tests and average the results.

6. Analyzing the Results: The flow rate for a 30 second period should be no less than 21-22 oz.

2.3 *FUEL PUMP ISSUES*

If your fuel pump has an output flow rate within specification you're done. Remember to keep up with maintenance to ensure your car continuous to operate as it should. If you see less than ideal flow output from your pump, below are some common causes.

2.3.1 SOME CAUSES OF LOW FUEL PUMP VOLUME

- Restrictions of any kind in the supply fuel line
- A worn pump with damaged drum or vanes
- Starving the pump for fuel
  - Poor surge box location
  - Dirty filter - If you run a pre-filter just before the fuel pump verify it's clean. In addition, some older surge boxes had a ball type filter within the surge box. Remove this to eliminate any restriction.
  - Collapsed supply line inside the tank
- Using excessively high fuel pressure causes the internal bypass valve to recirculate fuel more often and lead to aeration and decrease supply volume

2.3.2 FIXING LOW FUEL FLOW

- Borrow a rebuilt or new fuel pump and retest the output
- Have your fuel pump bench tested to verify the flow rate at atmospheric pressure. If your fuel pump tests OK on the bench, check the supply line inside the fuel cell. The lines inside the cell become old and degrade over time and can collapse.
- If your system requires excessively high fuel pressure find the cause. The higher the pressure becomes the greater the likelihood for aeration within the fuel. For high pressure systems look at these items: Mass Air Flow (MAF) sensor[iii], dirty Fuel Injectors and EFI wiring problems. These are a common cause of needing to use high fuel pressure to get the correct AFR.

Bottom line: Verify that your entire fuel system is in good operational condition and working properly.

2.3.3 TODAY'S ALCOHOL BLENDED FUELS

ALCOHOL BLENDED FUEL CAN CAUSE POTENTIAL PROBLEMS

Fuel line is used to feed fuel from the surge box to the fuel pump. The feed line inside the cell is submerged in fuel blended with ethanol (alcohol) that can damage the line. While alcohol is hard on all the fuel lines, the ones inside the fuel cell are continuously soaked in alcohol and are more susceptible to degradation. Fuel line was never meant to be submerged in alcohol based fuel. Today's fuel blends cause the inside and outside of the line to get soft, collapse or develop blisters between the layers (which are very hard to find). The addition of heat increases the problem. To help eliminate this issue there are several new products that can be purchased from your local CSR; a new kink and alcohol resistant in cell line kit (Available: July 2012) as well as an in-tank fuel pump kit (Available: July 2012).

3 TUNING NOTES

- Never rely on tuning with more than 44/45 PSI of fuel pressure
  - Check the quality (amount of aeration) of the return fuel if you think there could be a problem
- Use a quality wideband O_2 sensor; if at all possible, data log its output along with fuel PSI. A little money spent on an O_2 sensor can save you a lot of money in the long run.
- Oil temperature is a good indication of piston temperature and load. Oil aids the cooling of the piston dome. At some point the oil temperature becomes too elevated and is not as effective at aiding in the cooling process. At this point the fuel requirement goes up to maintain proper AFR.
- On your first laps out on the track avoid 40 to 80 % throttle and high RPM. The stock engine mapping is lean and the ignition timing is advanced during the warm up period. Prior to going on the track it's always best to warm the engine until the thermostat opens. This is aided by starting the car at the 5 minute mark while waiting on the grid. On the first lap or two it's best to use more throttle and less RPM (i.e. short shift) than light throttle and high revs.
- The highest engine load is near peak torque (between 4,100 and 4,300 RPM), which is where the greatest potential for detonation lies. Keep that in mind when tracking AFR.
- Surge box placement can be critical at some tracks, talk with your CSR about service or recommended placement of the surge box.
- Unless enduro racing, for maximum fuel pump life, 1.5 gallons in the cell at the end of your sessions is a safe lower limit.

4 SUMMARY

In summary, I highly recommend the use of a fuel pressure gauge and wide band O_2 meter. If you have a data system, its best to log this data so it can be reviewed after the session. This can be used to tune your car for different conditions (geographic location, fuel quality, air conditions) but equally as important this data can be used to keep track of your engine performance and trouble shoot any engine related issues. If you don't have the luxury of these instruments these steps can be used to ensure your engine is working at its peak.

- Frequent filter changes
- Cleaning of the fuel injectors
- Inspection and changing your fuel lines
- Dyno trips during the year to verify overall performance (Chassis dyno is often the area where engines find trouble. This should be done AT YOUR OWN RISK and by someone with experience with this type of racecar. Your average dyno tuner is not familiar with our car. Without a fan they will overheat your SRF on the first pull! Also tuning to the lean range of optimal without knowledge of the differences in dyno environment versus on track is potentially life threatening to your engine. You can hurt the car on the dyno and not know it, only to have it blow up a few races later.)

We all do this for fun, so race your buddy hard and clean!
If you follow these recommendations you will do a lot more racing and socializing… and a lot less repairing your car.

Enjoy!!
Mike Davies

5 ABBREVIATION LIST

AFR	Air Fuel Ratio
CSR	Customer Service Representative
EFI	Electronic Fuel Injection
HP	Horse Power
MAF	Mass Air Flow
O_2	Oxygen
Oz.	Fluid Once
PSI	Pounds per Square Inch
PSIG[iv]	Ponds per Square Inch Gage
RPM	Revolutions Per Minute
SRF	Spec Racer Ford
TBD	To Be Determined
TQ	Torque
WOT	Wide Open Throttle
λ	Lamda

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[i] Aeration (also called **aerification**) is the process by which air is circulated through, mixed with or dissolved in a liquid or substance. For our application this means air mixed with the fuel resulting in less than 100% fuel mixture at the injectors.

[ii] Wide band O_2 meter is used to measure the Air-Fuel-Ratio (AFR) of the engine. This can be used to verify proper performance as well as diagnose engine related issues. AFR is the mass ratio of air to fuel present in the engine. If exactly enough air is provided to completely burn all of the fuel, the ratio is known as the stoichiometric mixture. For our engines and fuel this is an AFR equal to 14.7 (This ratio is different for other fuel types such as diesel or alcohol). Maximum HP is achieved at an AFR less than stoichiometric. Lamda (λ) is often a term used to describe the AFR of an engine. Lamda is the ratio of

actual AFR to stoichiometry for a given mixture. For our engines a Lamda of 1 is the same as 14.7 AFR. With this knowledge the next question many ask is what Lamda makes the best HP and TQ in the SRF? This paper is not a tuning guide for the SRF. However, in the interest of making sure we don't run these at point that will cause engine harm, this should be followed: A Lamda of .87 is a typical maximum power maximum TQ compromise. Remember that test equipment may vary as much as 2-3% so be careful if you try and push the Lamda above .9 because you may actually be running above .92 or worse. Remember maximum torque occurs when we also have maximum cylinder pressure and this is where Lamda (or AFR) is most critical. Be aware of this when tuning your SRF.

[iii] The Mass Airflow Sensor (MAS) is often the issue with bad running cars. They are sensitive hot wire meters and care should be taken when cleaning them. Never blow compresses air straight at the wires. The air contains small particles of sand an can damage the units. These are FORD parts and can be obtained from your local CSR or found used on Ebay. The cost ranges from $75 used to $350 new with no core.

[iv] PSIG is a unit of pressure relative to atmospheric pressure at sea level. (Atmospheric pressure at sea level is 14.7 psi) Tire gages and most other pressure gages we use are calibrated to read zero PSI at sea level because we require the difference in pressure.