# Star Pro Formula Mazda

## Rumor Squashing Report

**"Your engine was tuned for maximum horsepower output, and any variation away from our specification will actually decrease power output"**.

This report was written to help dispel rumors of how to make more power with your Mazda RX-8 rotary engine. It will investigate sensors and how they interact with the MoTeC ECU (engine control unit) computer. You will learn why and how these sensors help keep your engine running at its maximum output. An extensive discussion of lambda will show you how to diagnose your engine problems to maintain maximum power.

**Topics** **Page**

## Air Flow Speed

Rotary engines require advanced control of airflow in order to make their max power. You'll notice the RX-8 engine has 3 valves.

1. Sequential Shutter Valve: This valve provides larger airflow paths into the engine as RPM increases. Without these additional airflow passages the engine would not breath enough air at high RPM's. If left open all the time, the air speed at low RPM would be too slow resulting in a reduction of power. This valve balances air flow speed to provide the best torque and power. It opens between 4500-5500 RPM.
2. Auxiliary Port Valve: More expansion of intake flow capabilities. This opens the $5^{th}$ & $6^{th}$ ports to help the engine breath above 6300 RPM. As in the SSV valve above, this also balances air flow speed to provide the best torque and power.
3. Variable Dynamic Intake Valve: This final valve provides intake supercharging at engine speeds above 7600 RPM. It opens the passages between each rotor so that the pulses from the intake actually increase the air pressure to the other rotor.

There is a detailed discussion of how and why these items work in the document "PFM Motec M400 Seminar June 2004.PDF" All three of these valve have to work in order to make max power. If any one of them doesn't, the engine will feel flat. This can *easily* be seen in the lambda recorded log.

## Lambda

What exactly is lambda? A Lambda sensor measures the oxygen in your exhaust stream. It doesn't measure mixture, it measures oxygen content in the exhaust with reference to the atmosphere. The amount of oxygen can be used to calculate your *Air-Fuel* ratio. A perfect stochiometric burn gives us a lambda value of 1.00, but this isn't where max power lies. Racing engines require slightly more fuel in order to make sure all of the air gets burned.

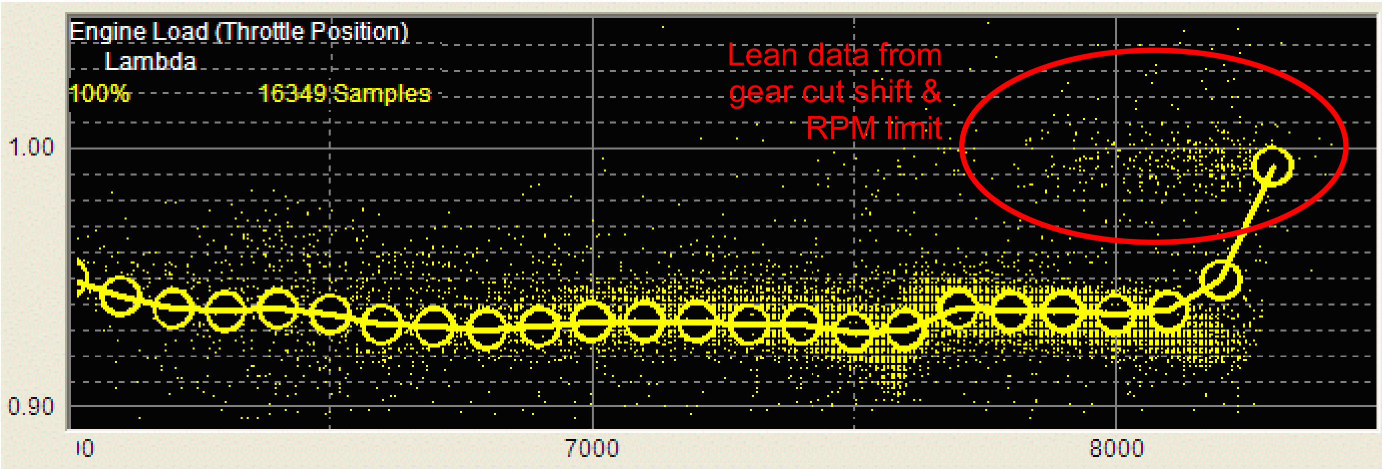
The MoTeC computer which controls the valves opening & closing for air flow, also controls the amount of fuel. It has been programmed to run the rotary RX-8 engine in the range of 0.91-0.94 lambda.

A rich mixture produces a lower number.
A lean mixture produces a higher number.

**Max power is seen around 0.92 – 0.93 lambda**

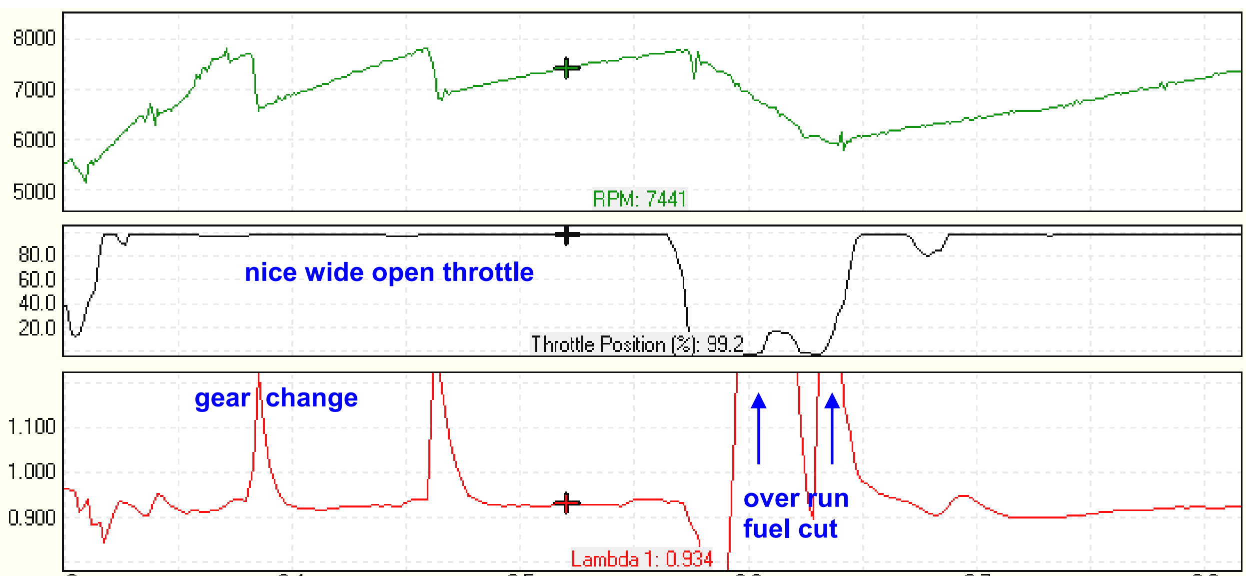
A mixture richer than this, tells us that we have too much fuel or not enough air.
A mixture leaner than this, tells us that we have too much air or not enough fuel.

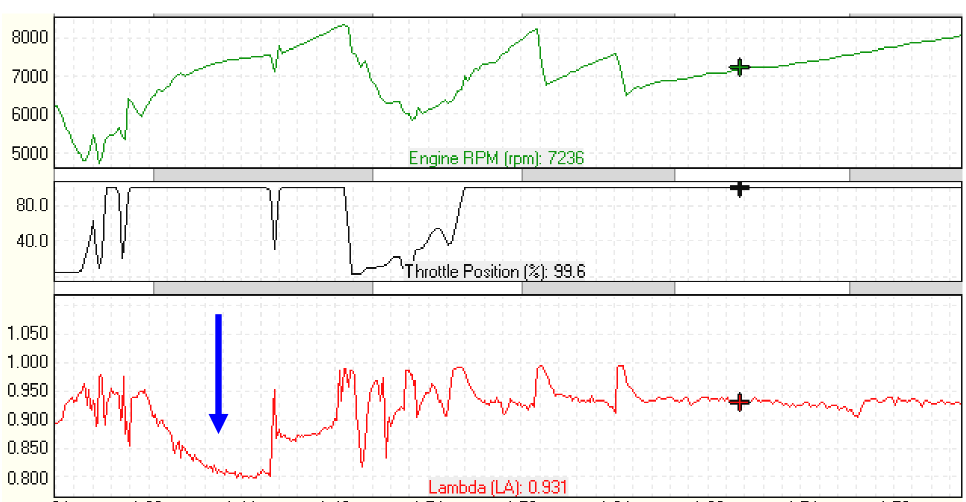
Richer mixtures (lower lambda) will reduce fuel economy and result in power loss. Leaner mixtures (higher lambda) will elevate temperatures (EGT, oil, and water) and reduce power. If you run the engine too lean then it can cause detonation.




All lambda readings should be examined at steady WOT – wide open throttle. There are numerous reasons that Lambda numbers will read excessively lean such as:

- gear cut shift
- RPM limit
- traction control
- pit speed limiting
- over run fuel cut
- throttle acceleration
- throttle deceleration




What you don't want to see are places where the lambda goes rich. The picture on the left shows the APV valve not opening at 6300 RPM. The value goes below 0.85 lambda.

There are 2 different lambda sensors available for your car. One can be read by the MoTeC ADL, the other is read by the MoTeC ECU. Both can be logged in the dash, but each sensor has its own advantages and disadvantages. Either sensor will require the *"lambda option"* in a MoTeC device.

| **Bosch LSM-11** | **Bosch LSU-4** |
|---|---|
| Measured by ADL | Measured by ECU |
| No calibration required | User calibration required |
| Old sensor technology | New sensor technology |
| more tolerant to leaded fuels | leaded fuels shorten life of all sensors |
| more tolerant to higher exhaust temps | high exhaust temps shorten life |
| Heater always on | ECU controls heater |
| can drain battery in car | never on until engine gets started |
| Cost around $340 | Cost around $180 |

### Bosch LSM-11

This sensor is fairly rugged, and can withstand a lot of the heat and lead used in the Pro Formula Mazda car. However, it is more expensive and not quite as quick or accurate as the LSU sensor. This sensor is read only from the ADL display dash, so you can more freely replace your ECU. If you use this sensor, please try to keep the main switch in the off position, due to its full time heater. Your battery will drain down after a few hours of being on, making starting the car more problematic. This sensor should be mounted after the muffler, but can still work and survive for some time if placed before the muffler. Under normal conditions, the LSM-11 sensor might last an entire year. It also does not require any calibration.

### Bosch LSU-4

This sensor is read only from the ECU. **Therefore if you purchase a new ECU you will also have to purchase a new *"lambda option"* for that ECU.** The lambda options get locked to the device, whether you're talking ADL or ECU. The LSU sensors are cheaper and have better accuracy. The increased accuracy is due to the pump cell 5-wire technology. The sensor must be kept in a specific temperature range, which the ECU can control. Because the ECU can keep the sensor at one temperature, it can stabilize and record values better. Note, if you place the sensor before the muffler there will be too much heat. The ECU can only add heat, not take heat away. If the sensor is diagnosed as too hot, it must be moved further away from the engine. This sensor will most likely not last a whole season. The LSU-4 can be air calibrated to improve accuracy throughout its life span.

> note: The channel labeled "lambda 1 ZP" in your ECU logged data represents the heater control. It should lie between 60-80. A value of 40-60 is acceptable but not recommended. A sensor that is too hot will have a value under 40. If the sensor is too cold the value will be over 80.

### Failed Lambda Sensors

There are two particular parts of the lambda sensor that can go bad. These fail on most accounts from either too much heat, thermal shock, too much lead or contamination.
**Heater:** If the heater element goes out, the LSM sensor will still read once the exhaust gas heats up the sensor. The LSU sensor won't read at all. You can easily check if this is the case by measuring the resistance of the heater. When cold it will be around 3 ohms.

**Sensing element:** When this part of the sensor goes bad, your readings will go lean. The LSM will slowly drift out of calibration and read lean. The LSU sensor will also drift into a lean reading then eventually stop working.

## Fuel Compensations

The MoTeC M400 monitors environmental parameters and changes the fuel mixture 'on-the-fly' to meet these conditions. This way you'll get the same lambda readings anywhere you run the car. In cold weather, hot weather, sea level or 5000 ft in Colorado. There are 4 sensors on your car which automatically changes the mixture.

- MAP – manifold air pressure or air box sensor completes the density compensation and accounts for any 'ram-air' effects found at high speeds. It follows the ideal gas law PV=nRT.
- ET - engine temperature sensor enriches the mixture when the water temperature is cold to help with cold start.
- AT - intake air temperature sensor partially adjusts for air density based on the intake air temperature. It follows the ideal gas law PV=nRT.
- FP - fuel pressure and fuel supply are critical to maintain the proper air/fuel mixtures. Fuel pressure has an exponential relationship to fuel flow through an injector resulting in large errors if it is out of specification.

There is one input that also adjusts the mixture, which is not automatic. The fuel trim knob has 4 adjustments which get added to the automatic adjustment. We will discuss all of these adjustments in detail later. For now lets discuss the sensors in detail.

### MAP Sensor

The manifold air pressure sensor measures the air box pressure. Consider this a measurement of the barometric pressure plus any ram air effect at high speeds. The amount of air molecules in a given cube change with pressure, and air pressure also changes with altitude. Because of these we must change the amount of fuel going into the engine. It is based on the ideal gas law PV=nRT. Your car will run at the top of Pikes Peak with the same lambda values as it will at sea level in Florida. The channel gets reported in the ECU data as "EMAP" and in the ADL data as "Air Pressure before Throttle".

*The goal of this compensation is to maintain a 0.92-0.93 lambda mixture.*

### Air Temp Sensor

The air temp sensor measures the temperature of the air flowing into the engine. Because the amount of air molecules in a given cube change with temperature, we need to adjust the amount of fuel going into the engine accordingly. This compensation works to maintain the same lambda readings over a wide range of air temperature. It is based on the ideal gas law PV=nRT. The compensation only works for a range of 0°-60°C / 32°-140°F. This channel is reported in both the ECU and ADL as "AT" or "Air Temp".

These sensors or connector wiring can fail from vibration. If you have a sensor that fails it will start to drop its reading and look like noise on your trace when graphed. Eventually it will flat line at a default of 20°C / 68°F.

*The goal of this compensation is to maintain a 0.92-0.93 lambda mixture.*

### Engine Temp Sensor

The engine temp sensor measures the temperature of the water/coolant in your car. When the car is cold there is extra fuel added to help with any cold starting problems. Once warmed up, the engine no longer requires additional fuel and this sensor won't adjust your mixture.

Below 60°C / 140°F: adds fuel to assist with cold starts
from 60°-100°C / 140°-212°F: does nothing
above 100°C / 212°F: adds a small amount of fuel to prevent overheating (0-5% max)

### Fuel Pressure Sensor

The current control maps were generated based on a fuel rail pressure of 40psi. Any pressure above 40psi will create a rich mixture, below 40psi will create a lean mixture. The series mandates a fuel pressure window from 38psi to 42psi. The Fuel pressure sensor is optional.

If you connect a fuel pressure sensor, the MoTeC ECU will adjust your injector time to compensate for the measured pressure. There are limits, it will only adjust for pressure readings between 36.3psi & 42.5psi. Readings above 42.5 will simply compensate as if it was 42.5, readings below 36.3 but above 0 will compensate as if it was 36.3. If you don't run a sensor then there will be no fuel pressure compensation.

*The goal of this compensation is to maintain a 0.92-0.93 lambda mixture.*

### Fuel Trim Knob

This knob will allow the driver to adjust his mixture by 4 different positions. These correspond to percentage of fuel change, -2%, 0%, +2%, +4%. This input should be used for diagnostic purposes only as it will generally only result in a slight reduction of engine power output. The amount of compensation is reported under the channel labeled "Fuel Comp 1" abbreviated as "F(FC1)%" which is available in both the ECU and ADL logs.

## Conclusion

If you can not maintain 0.91-0.94 lambda, then most likely you have a problem with your engine. Using faulty sensors to force the ECU into leaning out the fuel mixture will not produce more power. *If your engine is running rich then there is a problem somewhere.* Leaning the mixture out will not restore power to its original maximum. You must find the real problem. Below is a list of known issues that can result in a bad lambda reading.

Causes lambda to read 0.87-0.90

- Spark Plugs are bad
- Muffler is old
- Muffler screen fell out
- Air filter is dirty
- Helmet blocking air intake
- Coils are bad
- AT sensor bad / broken wires

Causes lambda to read 0.80-0.86

- Valves not opening
  - vacuum tank has a leak
  - check valve damaged
  - solenoids damaged from heat
  - small hole in a vacuum hose
- APV not working
  - motor damaged by heat soak
  - motor housing melted
  - broken wire on connector