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DSPORT

IMPORT PERFORMANCE + TECH MAGAZINE

DSPORT JUNE 2014 (#142) TOP FUEL S2000 • 9.2SEC/DD EVO • 374WHP MIATA • TWIN-CHARGED EVO X • SCION DRIFT TEAM • SPARK TECH • FORMULA D 2014 & D1GP SEASON OPENERS

1:40.195 FUJI TUNING RECORD HOLDER

THE CARS

786WHP T/A S2000
Taking Aim at New Records

9.2-SEC DAILY EVO
Streetable and Nearly Unbeatable

MASCULINE MIATA?
Would 374whp Convince You?

TWIN-CHARGED EVO X
Turbo+Supercharged Garage G-Force

THE TECH

SCION DRIFT TEAM
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SPARK INTEREST
Science of Selecting the Right Plugs

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TOP FUEL S2000

GETTING
SCIENCE OF PERF

Text by Michael Ferrara // Photos by Jun Chen and Courtesy of Enerpulse and NGK

TODAY'S PERFORMANCE SPARK PLUGS PERFORM FEATS never before attempted by spark plugs of year's past. Factory engines and race engines are pushing more horsepower per liter than ever before thanks in part to forced induction and direct injection. Both of these technologies put an additional stress on the engine's ignition system. With the spark plugs representing the soldiers in the field, we decided to take a look at the technologies in use. Today, platinum and iridium have replaced nickel-alloys in many performance and long-service applications. So are a set of Iridium plugs right for you? What about the latest generation of spark plugs featuring plasma technology? The answer depends on your particular performance combination. Engines with marginal ignition systems or those with high-voltage demands will see the biggest performance gains from this family of super plugs.

RACING

1

PLUGGED
ORMANCE PLUGS

1. The Racing Plug

An iridium center electrode, angled side electrode, recessed insulator and cold heat range allow this plug to ignite mixtures and survive environments where street performance plugs would fail. Plug gaps are as small as 0.016″ and typically at or under 0.024″ on forced-induction applications.

2. Street Performance Plug

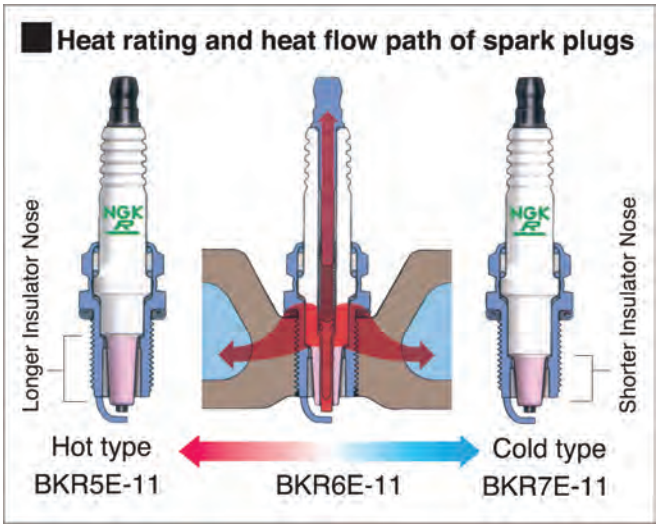
An iridium, platinum, silver or nickel alloy center electrode is typical for high-performance street plugs. Projected nose insulators and colder than stock (but higher than racing) heat ranges are typical.

STREET 2

FUNCTION OF THE SPARK PLUG

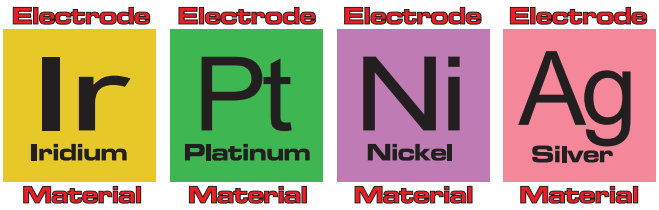
1. **Converts high-voltage energy from ignition coil to a spark.**
2. **Its spark initiates combustion.**
3. **Heat range of plug establishes the regulated temperatures of the plug.**
4. **Provides a window to the soul of the engine (in cylinder datalogger).**

HEAT RANGES



The length of the insulator will set the spark plug's heat range. The longer insulator nose will keep more heat in the spark plug, making a "hotter" plug. This heat will help prevent carbon fouling at idle and low-speed operation. However, a "colder" plug with a shorter insulator may be needed when horsepower levels are increased or wide-open-throttle operation is the norm.

ELECTRODE ALLOY



ALLOY COMPARISONS

	Ir	Pt	Ni	Au	Ag
Melting Point (F)	4449	3216	2647	1945	1760
Strength (Kpsi)	159	20	97	19	19
Electrical Resistance	2.09	4.17	2.69	0.9	0.63
Hardness	240	40	160	25	26

Function of the Spark Plug

The primary function of the spark plug is to create a spark that initiates the combustion process within the cylinder. While this job sounds simple enough, the environment where a spark plug lives is far from friendly. A spark plug is subjected to electrical voltages that may approach 40,000 volts. In addition to the electrical shock, cylinder pressures may exceed 1,500 psi during combustion. At the same time, in-cylinder temperatures can soar above 2,000 degrees Celsius then instantly drop to outside temperatures when cool fresh intake air is drawn into the cylinder. If you have ever poured hot water in a chilled glass or ice cold water in a hot glass, then you've seen first hand the damage that can be done by thermal shock or loading. Yet through all this, a quality spark plug can survive and thrive.

A Better Plug

If you are looking for maximum performance, there are certain spark plugs that are designed to minimize misfires or maximize the combustion of the air-fuel mixture. If you are looking for maximum service intervals, there are spark plugs that are designed for limited gap erosion, allowing them to function two to five times longer than conventional plugs. If you are on a limited budget, there may be plugs available that provide a heat range that's optimized for your engine's modifications and your driving style.

Hot or Cold?

One of the most important considerations when choosing a replacement spark plug is being sure that the correct heat range is chosen. If the replacement plug that is chosen is too cold, fouling occurs. This leads to misfires, poor performance, increased emissions and reduced fuel economy. If the replacement spark plug has a heat range that is too hot, the results are even worse. The spark plug can become so hot that its temperature ignites the fuel before the spark ever has a chance to fire, this is termed "pre-ignition." Pre-ignition can lead to severe engine damage or melted electrodes at the very least. Most tuners end up using a plug that is one to two heat ranges colder than the heat range of the original equipment spark plug. However, ultra-high boost pressure or ultra-high compression ratios may require spark plugs that are three to four heat ranges cooler. Since the side effects of choosing a plug that's too cold are much less problematic than the results of choosing a plug that is too hot, it's always safer to start with a colder plug.

To determine if your plug is of the correct heat range for your level of modifications and driving style, you can inspect your plugs after a pass on the dyno or a few miles of driving on the street. If the firing end of the plug is covered in black soot and the insulator is also covered in soot, the plug that you have chosen is too cold for your application. If the firing end of the plug has a tan, light brown or light grey appearance on the insulator and electrode, you've chosen a heat range that's appropriate for your application. If the electrodes appear melted, rounded or blistering is apparent on the insulator, the heat range is too hot for your application.

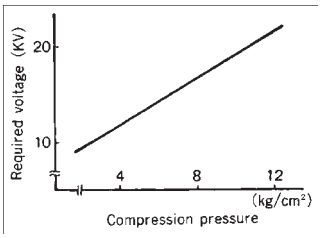
You may have seen some spark plugs advertise a "copper-core" construction. Spark plugs that utilize a copper-core construction will generally be superior in heat and fouling resistance when compared to plugs that do not have a copper-core. A word of warning about heat range nomenclature: some spark plug manufacturers use higher numbers to indicate a colder plug (NGK, Denso, HKS, A'PEXi, GReddy), while others use lower numbers to indicate a

Nickel-alloy is the most common material used for spark plug electrodes. It has high strength and hardness providing for a long service life. Platinum was one of the first premium alloys offered in spark plugs. While not as hard, strong or conductive as nickel, it offers an exceptional resistance to high-temperature oxidation and erosion. Hence, it can be used in applications where 100,000 miles is desired between plug changes. Iridium provides the best of both worlds. Since it is harder, stronger and more conductive than nickel or platinum, it offers exceptional performance along with a long service life.

colder plug (Champion, AC Delco, Bosch). Always check the manufacturer's catalog or web site to make sure that you are ordering the correct heat range.

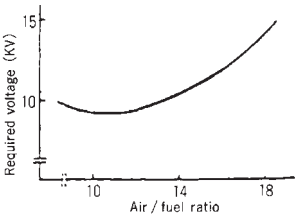
Spark Voltage

How does a spark occur? All spark plugs have air gaps. The gap is the space between the plug's center and side electrode. When the ignition system is triggered, high voltage electrical energy is sent down through the plug's center electrode. If the voltage of this energy is high enough, a spark occurs when the energy jumps from the center to the side electrode. So how much voltage is

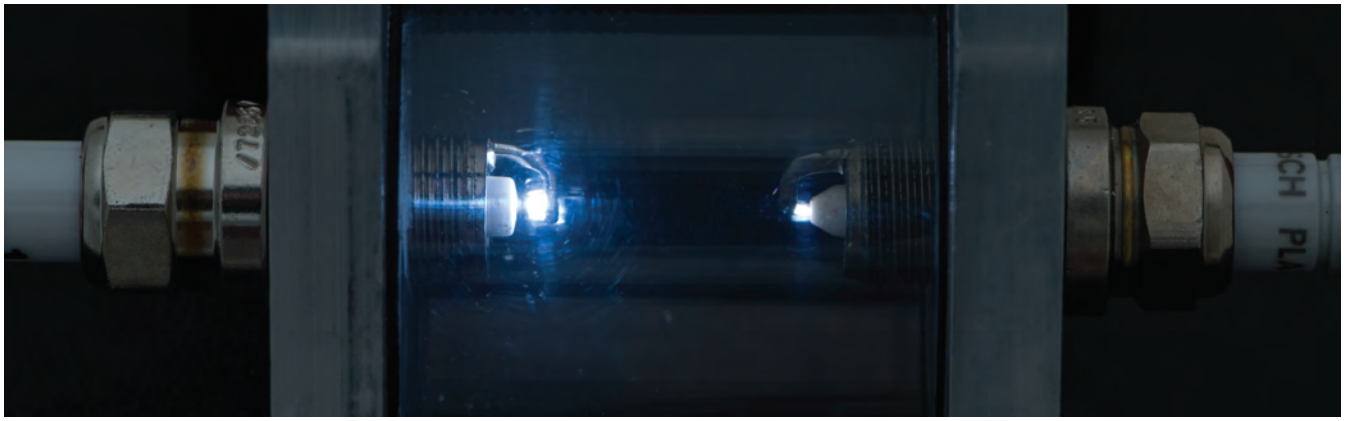


The amount of voltage required to make a spark in the cylinder is directly proportional to cylinder pressure. More pressure equals more voltage requirements. Hence the voltage requirements on boosted engines are much higher than naturally-aspirated engines.

needed for a spark to be produced? The answer is that it varies. Under certain conditions 10,000 volts may be enough voltage, where under other conditions 40,000 to 50,000 volts may be required. Higher compression ratios and high boost levels significantly raise voltage requirements.



Air-fuel ratios also influence the voltage requirements. Gasoline A/F ratios between 10.5:1 and 12.5:1 require the least voltage and are the easiest to ignite. Mixtures richer or leaner than this require higher voltages.



A pressurized chamber simulates the pressure inside the cylinder at the time of ignition. Higher pressures increase voltage requirement on the ignition system and deliver a more intense spark. Some plugs, like the Pulstar plugs, use a plasma technology to deliver an extremely intense and short duration spark. Notive the difference compared to the conventional plug under the same conditions.

VOLTAGE REQUIREMENTS

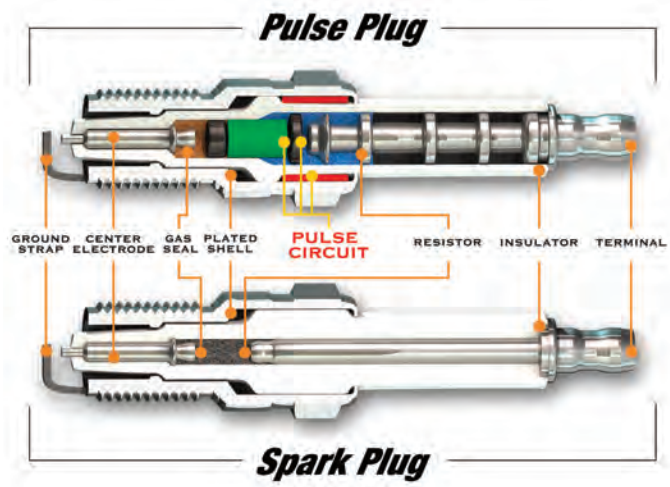
	Increase	Decrease
Increase Spark Plug Gap	X	
Increase Cylinder Pressure	X	
Leaner Air / Fuel Mixtures	X	
High-Swirl Combustion Chamber	X	
High EGR	X	
Reduce Electrode Diameter		X

Smaller is Better?

Peak performance requires that misfires are minimized. The diameter of the center electrode and the width of the spark plug gap influence the voltage requirements for a spark to occur. With all other factors being equal, spark plugs with smaller center electrodes will be able to generate a spark at a lower voltage than spark plugs with a larger center electrode. Smaller spark plug gaps also reduce the voltage requirements for a spark. When gaps go too small, the spark kernel may be too small to initiate combustion.

Remember, spark plug electrodes will erode over time and the plug gap will increase. Don't run a gap that's on the edge of a misfire. When the sharp edges wear off the new plugs and erosion begins, a significant amount of misfires may result.

Voltage requirements are a function of gap length, electrode diameter, cylinder pressure and gas density. The bigger the spark plug gap, the higher the minimum voltage to initiate a spark. As for electrode diameter, the smaller the diameter the lower the voltage required for a spark to occur. With cylinder pressure, the higher the pressures in the cylinder (the result of high compression ratios and high boost levels), the more voltage required for a spark to occur.



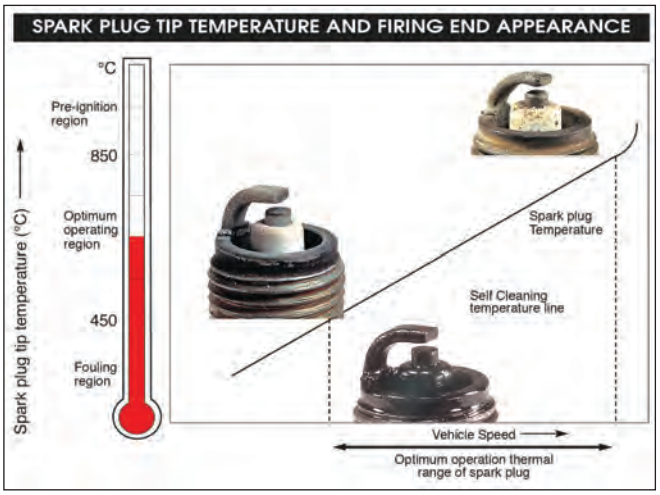
CONSIDER WHEN SELECTING

1. Proper heat range for application.
2. Proper electrode gap.
3. Desired service interval for plug.
4. Benefits of premium alloy electrodes.
5. Need for reduced diameter center electrodes (boosted applications).
6. Availability/practicality of using a spark plug solution with "plasma" technology.

Pulstar uses a plasma technology to produce a very short duration, high-intensity spark. In many street applications, this spark profile provides increased performance, fuel economy and reduced emissions. We've personally tested the plugs on a number of applications with very favorable results. Pulstar offers plug solutions for most applications/usages requiring a factory or one-step colder heat range.

Spark Plug Life

The elements on the spark plug that wear over time are the center and side electrodes. The size and material of the electrodes determine the service life of the spark plug. Conventional plugs use a nickel-alloy center electrode typically measuring about 2.5mm in diameter. Most manufacturers recommend changing conventional plugs every 25,000 to 35,000 miles, but performance and economy gains are best when these conventional plugs are changed every 10,000 to 15,000 miles. Platinum plugs use a platinum alloy center electrode (which can also contain a small amount of Iridium). The center electrode on most Platinum plugs is about 1.1mm in diameter. Most manufacturers recommend 60,000 to 100,000 miles as an interval for changing the plugs, but once again changing at 40,000 to 50,000 miles should deliver a slight improvement in power and economy. During the last ten years, Iridium plugs have hit the performance scene. Some of these plugs have ultra-fine center electrodes that measure just 0.4mm in diameter. Although a 0.4mm iridium center electrode is only 13% of the size (in area) of a platinum electrode (less than 3% of the area of a conventional nickel electrode), Iridium's superior corrosion and wear resistance give an identical service life to a 1.1mm platinum plug.



SOME OF THESE PLUGS HAVE ULTRA-FINE CENTER ELECTRODES THAT MEASURE JUST 0.4MM IN DIAMETER.

Get Ignited

All automotive engines that run on gasoline rely on a spark for ignition. Without a good spark, it doesn't matter how much air and fuel was stuffed into the cylinder—no spark means misfire, and misfire means a loss of power.

Today's spark plugs are much different than the one's found in the cars that your parents drove when they were your age. Advances in material science have provided better materials for the construction of spark plugs. Platinum and Iridium have replaced nickel-alloys in many performance and long-service applications. Are a set of Iridium plugs right for you? The answer depends on your particular performance combination. Boosted or high-compression applications will see the biggest performance gains from this family of super plugs. Additionally, vehicles with direct-fire or marginal ignition systems will also reap big benefits.

READING THE SIGNS

While new technology provides consumers with tools to monitor combustion chamber performance, technicians have been observing or "reading" spark plugs for decades to get an idea of what's going on inside a motor. Seen here are spark plugs indicating a number of problems within the cylinder.

Dry Fouling – This is a common result in use of a colder heat range spark plug in an engine that doesn't operate frequently at higher temperatures. If this was a spark plug rated at the factory heat range, other problems could be an overly-rich AFR, electrical problem causing misfires or extended operation of little to no throttle load.

Wet Fouling – While this is possible with an excessively cold plug or rich AFR, a wet-fouled plug like this is more likely the result of oil or some other contaminant being introduced into the combustion chamber. The smell and appearance of the liquid on the plug would be a key indication at what the problem is.

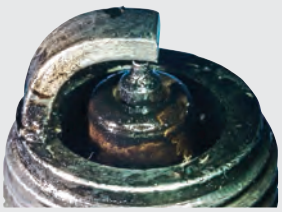
Deposits – Spark plugs peppered with deposits indicates oil or some other contaminant entering the combustion chamber. Instead of fouling out the plug, the liquid material evaporates and leaves behind crystal-like particles capable of deteriorating the plug and engine internals quickly.

Speckling Plug – Seeing this condition is the first sign of too much heat on the spark plug. Before assuming a step colder plug is the only solution needed, make sure the engine itself isn't overheating, the AFR isn't too learn and that the timing isn't over-advanced.

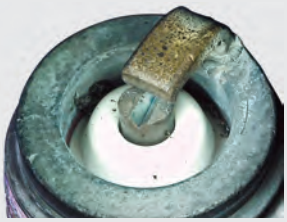
Melted Electrode/Cracked Insulator – This is what eventually happens to plugs that face either extreme or extended conditions that cause a plug to speckle. The excessive heat literally melts the metal and the violent detonation breaks away the ceramic insulator. If a spark plug is pulled out of an engine looking like this, expect to have more engine parts needing replacement.


NORMAL


DRY CARBON FOULED


WET OIL FOULED


DEPOSITS + CRACKED INSULATOR


OVERHEATED METAL SPECKLING


MELTED ELECTRODE