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# **Racing Technology and Premium Spark Plugs**

*Driving every day  
with racing heritage under the hood*

An industry White Paper

by

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## **I. RACING PLACES ENORMOUS DEMANDS ON SPARK PLUGS.**

Racing improves the breed. This is an old automotive adage, and today more than ever, racing definitely improves the breed when it comes to spark plugs – especially premium spark plugs. Racing is the ultimate test for a spark plug, and other than the given fact that the plugs must fire on command; spark plugs *must not fail in a race!* It doesn't matter whether it is a 200-mile dirt

track event, the Indy 500, or the 24 hours of Le Mans — the plugs cannot fail, and they have to work perfectly:

- The spark plugs must exhibit absolute, rock-solid durability
- They must ignite the fuel-air mixture for maximum power
- They must provide maximum fuel efficiency
- They must operate with minimum draw on the ignition system
- They must operate effectively with the particular fuel being used
- They must provide a strong, consistent spark from start to finish, however many hundreds of miles that may be

Racing, as it has for at least 100 years, provides a great developmental impetus and test bed for spark plug durability and performance, and what is learned at Indy or Darlington or le Mans helps improve the spark plugs installed in today's cars or trucks.

Take Indianapolis for instance. In addition to Ray Harroun's Marmon Wasp that won the very first Indy 500 in 1911, the past 16 Indy 500 winners and many in between have run specially developed premium spark plugs to get to victory lane. Spark plugs in today's Chevrolet, Honda or Infiniti Indy racing engines undergo tremendous stress, heat, and harmonic vibrations from running full throttle at 10,000-plus rpm for several hours without letup.

Although most spark plugs for Indianapolis and most other major racing events are actually hand made, they use the same basic design and the same premium metals and ceramics as the premium plugs used in passenger cars. The primary difference is in the center and ground electrode configuration.

Rather than welding the multiple ground electrodes onto a steel shell, the entire outer shell and ground electrodes on racing plugs are machined from a single piece of steel. This helps ensure maximum reliability under the extreme stress of racing.

### **Premium plugs use “race-bred” technology**

- Similarly, many premium passenger car spark plugs use multiple ground electrodes and precious metals, which are a direct result of their development and testing in long distance racing. In long distance racing, the voltage and the spark must remain constant for the entire race, and multiple electrodes minimize the effects of metal losses on both the center and ground electrodes, which can actually widen the plug gap and degrade the spark. Multiple electrodes -- and the use of precious metals -- ensure the integrity of the spark plug for an entire race. Spark plugs for most major race series use two or more ground electrodes and precious metals.

This is important for a couple of reasons.

First, the spark jumps in the cylinder radially from the multiple electrodes rather than axially from a single electrode. This provides better mixture accessibility, and multiple ground

electrodes provide greater assurance of creating a strong, *consistent* spark every time it is needed -- whether flat out in the straightaway at Indy or in heavy traffic on the freeways in L.A. or the [Cross Bronx Expressway](#) in New York.

Every time a spark plug fires, a tiny bit of metal is lost in the electrical discharge. Over the course of 500 miles at 10,000 rpm – or 50,000 miles at 2500 rpm in a passenger car -- this can degrade the plug's performance. Multiple electrodes and precious metals minimize this degradation from metal transfer.

Precious metals and multiple electrodes ensure ultimate reliability and durability, provide the correct, consistent spark to keep the engine running smoothly and efficiently, and keep emissions under control.

There are many variations in multiple electrodes. A new plug is just being developed for the Honda Indy engine utilizing three ground electrodes. These electrodes protrude slightly into the combustion chamber, providing better mixture accessibility for more power.

Another trend on the racetrack is the demand for smaller and smaller plug diameters. Smaller diameter plugs have been growing in popularity for years, and increasingly racing plugs are changing from 14-mm plugs to 12-mm and 10-mm plugs, and even calls for 8-mm plugs. Why? It gives engine builders more room for water jackets and bigger valves in already constricted cylinder heads. This has the engineers working nights, and these smaller plugs are already starting to appear in performance oriented sports cars. Soon they will be in conventional automobiles as well.

Racing gives invaluable testing of advanced spark plug design, durability and performance in an incredibly harsh environment. Increasingly, what is learned at the racetrack influences everyday spark plugs. And much of what is designed into premium spark plugs could well represent the future of spark plug use for efficient, economical driving.

## **II. RACING TECHNOLOGY AND EVERYDAY DRIVING**

The engines the first high voltage spark plugs were designed for 100 years ago had low compression ratios and low specific output. Today's passenger car engines require a much higher degree of ignition performance and reliability than ever before:

- Operating conditions generate pressures of up to 120 bar or 1706 PSI in a well-prepared race engine or up to 80 bar or 1137 PSI in a highly tuned street car engine.
- The ignition system delivers voltage of 30 to 40 kV
- No misfiring is allowed in order to meet emissions standards
- Plug performance must be consistent over the expected life of the plug under all operating conditions, including cold start, idle, part or full load.

Spark plug misfires that used to go virtually unnoticed can cause real problems in today's street engines. The new generation of onboard diagnostic systems (OBD) can detect ignition misfire

and also track and tabulate it to predict emission failures -- even an occasional misfire may trigger a fault code within the OBD that may cause the "Check Engine" light to come on.

"Premium" spark plugs may be the answer to all these requirements.

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### **Precious metals add long-term efficiency**

Perhaps the greatest innovation in spark plug design over the years is "pure platinum" technology, combined with multiple electrodes. As early as the 1960's engineers recognized the value that platinum added to automotive plugs: it provides improved corrosion and erosion resistance and imparts a longer performance life than the standard copper core center electrode plug design.

The use of platinum not only broadens the heat range beyond that achieved with a copper core center electrode design, but also provides extremely consistent performance, a reliable spark and a longer performance life.

Engineers pioneered the use of platinum in automotive plugs for street applications when they evolved the platinum tipped plug design into a spark plug featuring a center electrode that is 99.9 percent pure platinum. The "pure platinum" center electrode is sintered, or heat fused, into a unique extended ceramic insulator. This design eliminates the air gap between the center electrode and the insulator.

This spark plug provides two key advantages: first, the plug is able to reach its self-cleaning temperature within seconds; and it better maintains its optimal operating temperature, which results in smoother acceleration and no misfiring. The plug's tapered ground electrode provides improved access to the air/fuel mixture, resulting in more efficient combustion, and because platinum is extremely erosion and corrosion resistant, the electrode gap remains virtually unchanged, eliminating the need to ever regap once the proper gap is set.

### **Maximum fuel efficiency, quicker starts**

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Other performance benefits include maximum fuel efficiency, quicker starts and reliable cold starts, all over a longer performance life.

Plugs such as these utilize a revolutionary firing technology, called surface air gap. This design increases the electrode gap for better ignition, without increasing the voltage requirement, by using the benefits of surface discharge. The larger gap enables the production of a larger flame core, and therefore better ignition properties.

A unique four-ground electrode design virtually eliminates wear, improves fouling resistance and improves ignition performance over a wide range of operating conditions.

### **Longer, more powerful spark**

Surrounding the center electrode are four “surface air gap” ground electrodes made of a special wear-resistant nickel alloy, which is enhanced by the addition of yttrium-alloy. The angle and position of the four electrodes creates multiple spark paths that cause the spark to jump sideways. This has a self-cleaning effect on the insulator and results in a longer, more powerful spark that reduces misfires for improved engine performance, better fuel economy, lower emissions, smoother acceleration, and longer performance life.

Additionally, these plugs never need gapping, as the electrode gap is precision factory-set and never requires adjustment – and the multiple yttrium enhanced ground electrodes resist erosion so the gap maintains its correct setting for the life of the plug.

Tests show that this design can improve fuel economy up to 4.8 percent over “ordinary” single electrode spark plugs. Plus, cleaner combustion means lower emissions.

### **III. THE EVOLUTION OF PREMIUM SPARK PLUGS**

The invention of the high voltage automotive spark plug in 1902 was pivotal in the development of the internal combustion engine, which was, in the early days, plagued by the inability to sustain continuous, reliable ignition of the fuel/air mixture. Fouling was a particular problem in early automobile engines, and spark plugs had to be removed and cleaned regularly. The high voltage spark plug and high voltage magneto system changed all of that.

And the premium spark plugs of today, while highly advanced in materials, lifespan and refinement, owe a lot to this original design.

In the early 1900's, as today, auto racing played a key role in advancing spark plug technology. In 1903 a Mercedes equipped with high voltage spark plugs and magneto won the Gordon Bennett Race in Ireland that year -- one of the earliest international automobile races in history. The resulting improvements in ignition systems led to the manufacture of high voltage spark plugs for motorcycles, airplanes, and dirigibles. In the 100 years since, advances in spark plug technology have produced spark plugs with longer service life that create more complete combustion, resulting in greatly reduced exhaust emissions and substantially more power and efficiency.

The last 20 years have seen the emergence of race-bred premium spark plugs with dramatic improvements in materials and design -- and dramatic benefits to everyday driving.

Platinum technology was first used in the early '60's in the Porsche 917 endurance racer. The design of that engine was such that it was virtually impossible to change spark plugs without removing the motor from the chassis – a potentially “fatal flaw” in events such as the 24 Hours of LeMans.

In 1985 the premium spark plug market was created when the platinum plug was introduced. Platinum as a material provides better conductivity plus greater resistance to corrosion and erosion in the modern engine with today's fuels. In this pioneering design the center electrode is made entirely of **pure** platinum that is sintered, or heat fused, into a unique extended ceramic insulator, resulting in a stronger spark and a longer plug performance life. In 1998 platinum center core spark plugs with four ground electrodes were introduced, featuring four times the amount of platinum for the most powerful spark. And in 2001 a premium plug with double the platinum and two ground electrodes was introduced by the same manufacturer. This offered the motorist choices in spark plugs for all levels of premium performance.

### **Tests show real advantages**

To validate the improved performance of these surface air gap plugs with a pure platinum core and multiple ground electrodes, extensive testing was conducted in the laboratory and in the field:

- The first test measured the energy transfer efficiency of the four electrode platinum plug compared to conventional and other premium plugs with a single ground electrode design. This certified laboratory test measures the additional pressure generated by the spark discharge in a pressure chamber. Higher pressure equals a higher energy transfer spark. Critical ignition condition in **the** engine usually occurs during idle and at operating points near idle. When the cylinder is not full near idle, the temperatures and pressure are usually lower, with a higher internal EGR rate. These conditions, and drivability and emissions, can be improved by better ignition, and tests show that the four electrode platinum core plugs transfer more energy efficiency to the air/fuel mixture.
- As a spark plug wears via erosion and corrosion, the gap between the center electrode and ground electrode gets larger. The larger the gap, the more voltage is required to produce a spark, and the capability of the ignition system is exceeded and the plug misfires. In the **multiple ground electrode, pure platinum center electrode plug**, the nickel-yttrium alloy, combined with the platinum core electrode and multiple ground electrodes, minimized the wear, maintains a constant gap – and avoids increasing voltage requirements over time.
- Roush Industries, an independent test lab, measured the fuel consumption for **the** four electrode platinum core plug, as well as, that for original equipment and other premium single ground electrode plugs. Fuel savings up to 4.8% were found in the four electrode, platinum core plugs. Tests were conducted in accordance with Federal Test Procedure 75FTP and HFE.
- Tests for carbon fouling were simulated in a cold cell by repeatedly cooling, starting and operating the engine without letting the spark plugs reach their self-cleaning temperature. When the carbon deposits built up on the tip of a spark plug during cold starts and subsequent warm-up, tests indicated that the four ground electrode spark plugs had up to 33% better cold restart reliability than conventional plugs.

In every category, the racing heritage of racing spark plugs clearly helps increase efficiency, durability and driveability.

### **IV. PREMIUM PLUGS FOR EVERYBODY?**

Premium spark plugs, increasingly, appear to be the future of spark plugs for those who drive with them and those who sell and install them.

From a marketing as well as a driver's and installer's standpoint, there are sound reasons to view premium spark plugs as the future of spark plugs.

But first, consider four critical challenges facing the U.S. spark plug aftermarket:

#### 1. Declining market volume

It is widely acknowledged that the spark plug aftermarket in the United States has been declining due mainly to extended change intervals, unleaded fuel, and the development of more sophisticated ignition systems. Currently 95% of all domestically produced vehicles have OE recommended 100,000-mile spark plug change intervals. Our challenge in the aftermarket is to market products that provide exceptional value and consistent long-term performance advantages that encourage consumers to install new plugs before 100,000 miles.

#### 2. Margin erosion

The competition between non-differentiated products in a declining market inevitably leads to market price and profit erosion. The solution lies in providing the aftermarket with true product innovations that deliver on customer expectations. This is essential to maintaining market price and position.

#### 3. Substantial inventory application duplication effects on ROI

In a declining price-segmented market the value of a full coverage, multi-brand spark plug assortment may no longer be profitably viable. The solution lies with highly focused manufacturers who can provide the aftermarket with a strong branded product line that provides optimal performance, with full coverage and a minimum number of SKU's.

#### 4. The long term viability of spark plug manufacturers

Major manufacturers must be willing to make the investments required to be in the spark plug business and grow market share.

Now, let's talk about the market.

As it has since the early 1990s, total aftermarket spark plug sales continue to decline at a 3.5% pace, however, the premium spark plug segment continues to demonstrate sustained growth. Research indicates that premium plugs that represented just 10% of the market in 1995, now make up over 25% of the units sold for automotive applications. Expectations are that number will increase to over 45% by 2005.

### **Growth is achievable**

Growth is achievable in all channels of aftermarket distribution by using innovation and technology to meet consumer expectations on efficiency and performance. From the motorist's perspective, most of ~~the~~ issues that were discussed above from a racing perspective apply equally to spark plugs for everyday driving. Spark plugs don't last forever, or deliver horsepower improvements beyond the engine manufacturer's stated limitations. The goal of spark plug manufacturers is to use technology and innovation to deliver a product that enables the engine to operate at a peak level of efficiency over a longer performance life.

Premium spark plugs, with advanced surface air gap technology, pure platinum center electrodes out-perform today's standard plugs and in turn yield real performance and efficiency benefits. And consider this again – spark plugs operate under extreme heat and pressure. Each time a plug fires, a minute particle of metal is lost. After several thousand miles most spark plugs erode between the center and ground electrodes, and ~~to effectively~~ widen the gap. The plugs become less effective, require more voltage from the ignition system, and ~~may~~ eventually misfire. At this point the performance and efficiency of the automobile also becomes less efficient. This reduced fuel efficiency, rough idling, misfires during acceleration, hard starting, and higher emissions levels.

Premium spark plugs perform better and more efficiently than ~~ordinary~~ standard or conventional plug designs. They often provide a longer peak performance life, and *significant* fuel economy savings.

As discussed above, tests indicate, for instance, that surface air gap **plug** designs can provide up to 5 percent better mileage than standard spark plug designs. These plugs produce a more powerful spark, consistently, for more efficient combustion, smoother idling and better acceleration. They resist carbon fouling for up to 33 percent better cold restart reliability -- and they place far less voltage demand on the ignition system, long after ordinary plug requirements have begun to increase due to gap erosion.



## **Superior, lasting efficiency and performance**

Surface air gap technology with premium material electrodes are the future of spark plugs, whether it's on the racetrack or on the highway. For the consumer, premium plugs will almost certainly pay for themselves within a year in fuel savings and driving performance satisfaction.

And for the professional spark plug installer, consider this -- premium spark plug sales will continue to grow in consumer popularity, while standard spark plug sales diminish. Recommending a quality premium spark plug not only provides a higher level of value and satisfaction to consumers, it also helps the aftermarket distribution channels by offsetting the negative effects of an eroding market.

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