SPARK PLUG TECHNICAL INFORMATION (WHITEPAPER)

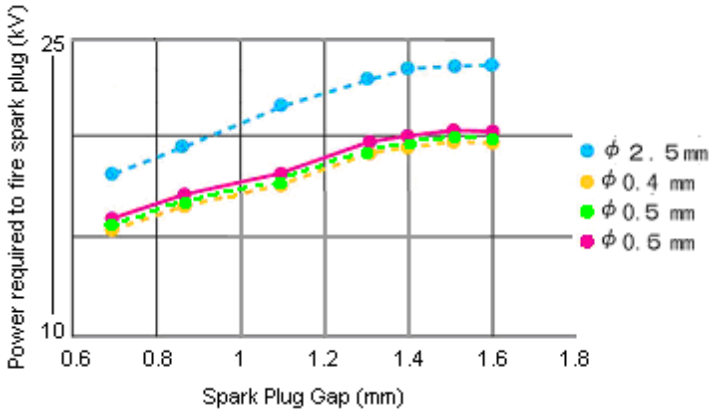
SPARK CENTER ELECTRODE and TIP DESIGN

The largest mis conception in the industry is that because copper is a better conductor than Iridium somehow it is superior. The industry is full of mis-information when it comes to spark plug center electrode design and this is one of the biggest of them all. While copper is superior in pure conduction capabilities, it does not form the electrode on any spark plug. Also, when designing a spark plug the criteria is not to conduct electricity, it is to create a spark arch. A majority of the electrical energy is wasted creating the initial spark when it could be used to maintain and initiate the spark across the spark gap. In this scenario a smaller center electrode usually always makes a better spark plug since it requires less voltage to fire. Even though a smaller center electrode fires with less voltage requirements then a typical copper spark plug there are many other things to take into concideration in the development of tip size.

For example, a center electrode with a very small diameter 0.1mm will prove to deteriorate very rapidly. A 0.4mm body is fast approaching the limits of this phenomenon while a 0.6mm iridium tip is well within the safe area for long term operation.

Finding a well balanced tip design is fundamental for creating a spark plug that has a long, high performance service life. In this documentation WeaponX has recorded how the optimal tip size for thier 360degree laser welded Iridium tip was found.

VOLTAGE REQUIREMENTS
FIG 1



In back to back comparisons of a 0.4 / 0.5 and 0.6 tip diameter the voltage required to fire the spark plug are all almost identical. Only when you take a spark plug with a common size center electrode (such as a copper or standard style spark plug) does the voltage requirement increase to a point where there is a compromise in power output. *(see FIG 1)*

In addition, electrons are emitted where the electrical field strength is greatest, this is from wherever the radius of curvature of the surface is smallest, for example, from a sharp point or edge. It would be easiest to pull electrons from a pointed electrode but a pointed electrode would erode after only a few seconds. Instead, the electrons emit from the sharp edges of the end of the electrode and as these edges erode, the spark becomes weaker and less reliable. If electricity prefers to jump from a smaller edge which spark plug design would be considered superior? Copper simply cannot be made smaller because of it's poor resistance to erosion. The Iridium design wins in 2 areas. The voltage requirement for Iridium is much less and the electrode can withstand erosion due to it's properties.

PERFORMANCE THROUGHOUT SERVICE LIFE
FIG 2

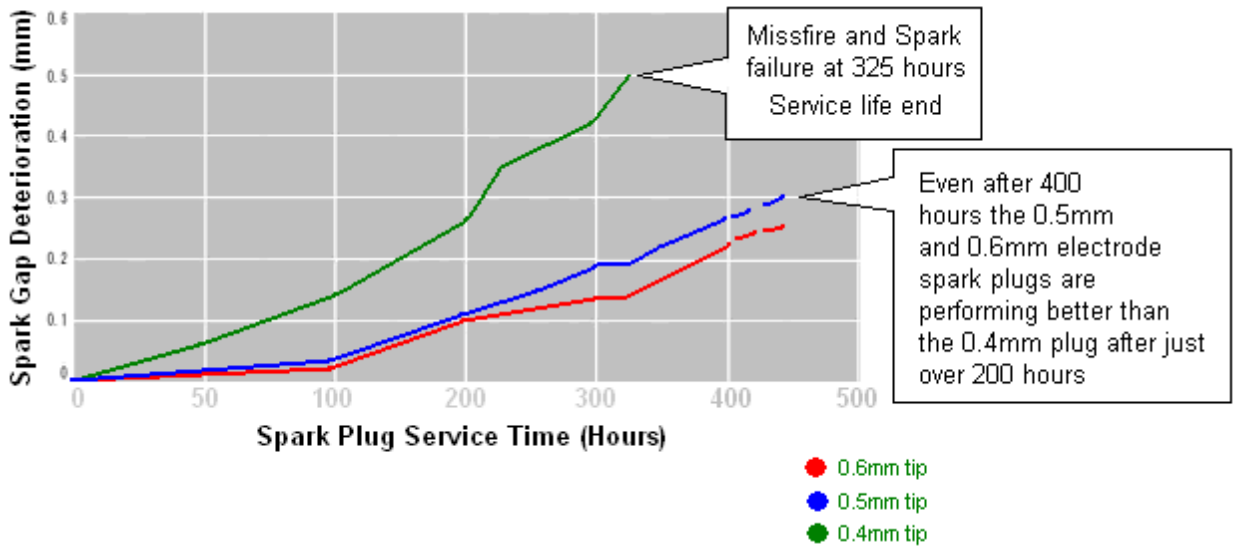


FIG 2 tests using a high power ignition system. With a 0.4mm center electrode the threshold at which ground strap degrdation rapidly increases since there is not enough surface area on the tip to equally distribute the spark along the ground strap. This effectively causes rapid deterioration on a small area directly under the spark center electrode. This, in turn, causes failure of a high output spark through the service life of the spark plug. Soon after failure of the spark plug, misfire events, engine horsepower loss and compromised gas mileage follow.

Using a 0.5mm or 0.6mm center electrode rapid deterioration is not an issue giving the spark plug center electrode just enough outer diameter for a long life span with a high quality spark output. Even after 400 hours of use they are both outputting a more accurate and intense spark than the 0.4mm after just 200 hours. Clearly, the advantage starts to make itself known. 0.5mm offers the best potential of both worlds.

In this test notice the rapid deterioration of the 0.4mm spark plug.

0.5 and 0.6 electrode requires less power over time to fire allowing for more engine power and efficiency over a longer duration of time.

Iridium electrode design is over 2000x harder then typical electrode designs allowing for the development of precious metal high temperature electrodes which allows for the use of a smaller center wire, which has sharper edges but will not melt or corrode away. The smaller electrode also absorbs less heat from the spark and initial flame energy allowing for a further enhanced output. This allows the Iridium design to outperform conventional copper plug designs for over 60,000 miles of use.

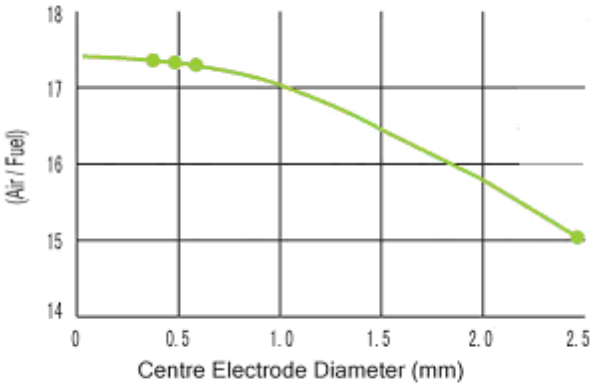
IGNITABILITY POTENTIAL

Ignitability is a measure of how effectively and efficiently a spark plug can ignite the air fuel mixture in the combustion chamber. The best way to measure ignitability is to lean out the air/fuel mixture until misfire occurs. This is because lean mixtures are difficult to ignite. This gives engineers an indication of which spark tip style will

gives better overall ignitability characteristics. These characteristics allow spark plugs to perform better under normal operation. The end result is more power, lower emissions and higher efficiency of the ignition system. Spark plugs with a smaller center electrode diameter offer better ignitability results.

A standard spark plug's center electrode of 2.5mm diameter has more than 15 times the surface area of a fine wire center electrode. You can see that moving from a standard 2.5mm electrode plug to a fine wire plug results in a dramatic improvement in ignitability. *(FIG 3)*

FIG 3



During testing, limits to improving ignitability using a reduction in center electrode diameter are finite. Infact, past about 0.5mm the curve starts to flatten meaning that going to a 0.4 or finer electrode will yield almost no positive results especially since the 0.4mm center electrode has a tendency to deteriorate and electrode quickly.

At this point WeaponX decided that this negligible improvement in ignitability does not compensate for the loss of performance throughout the plugs service life. The 0.5mm fine wire electrode is superior to all others.

WEAPONX – IMPROVING IGNITABILITY BEYOND 0.4mm ELECTRODE DESIGNS

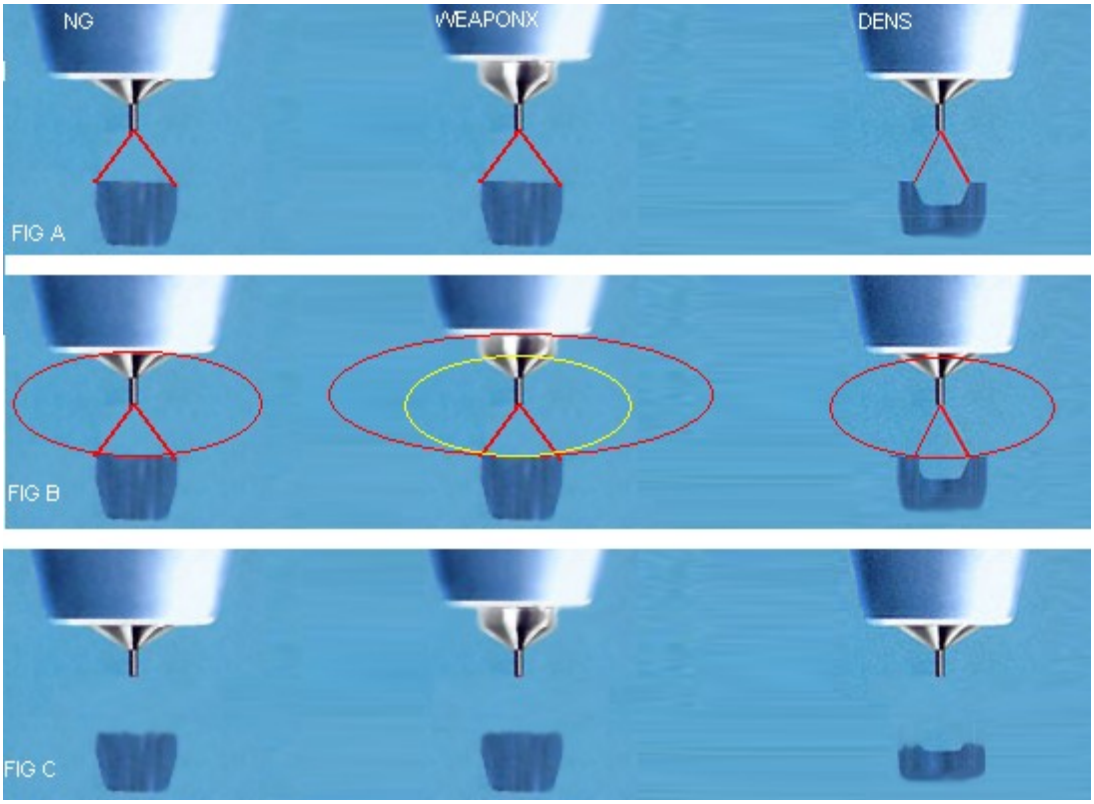
Even though WeaponX uses a 0.5mm fine wire Iridium electrode we have been able to surpase the ignitability potential of a 0.4mm design through the use of our exclusive CB insulator. This effectively brings ignitability potential to the next level. WeaponX uses a porcelin cutback on the center electrode to improve ignitability above an beyond that of an electrode with even a 0.2mm diameter.

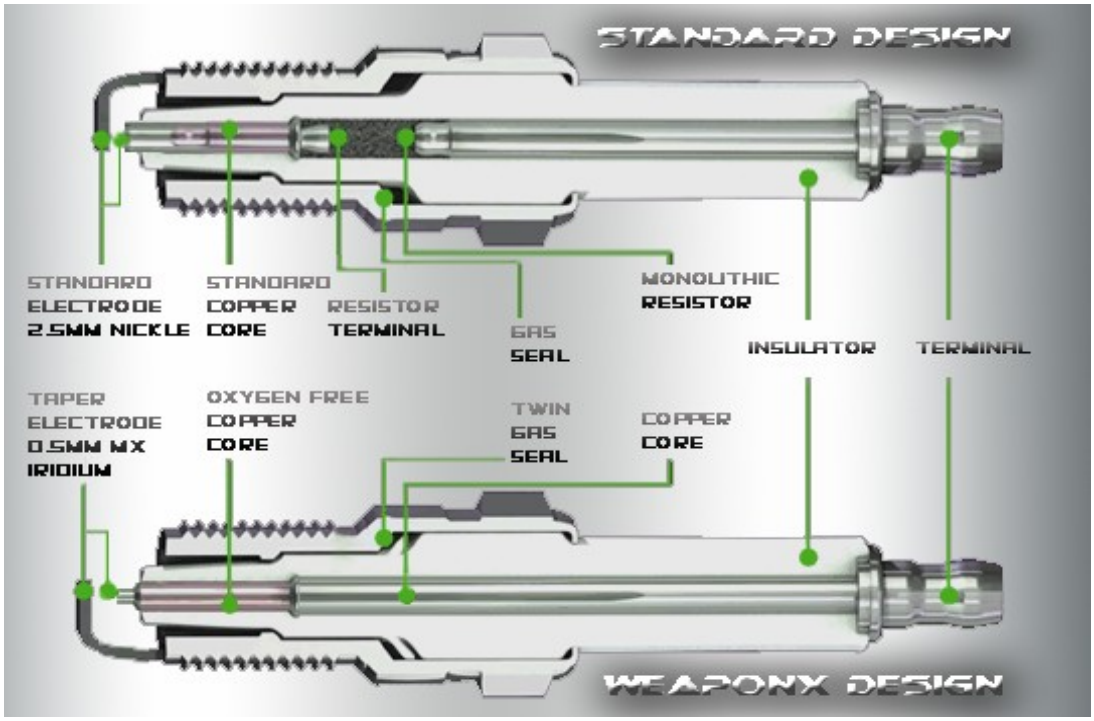
The more the spark plug tip is shrouded the harder it is for the spark plug to light off the fuel air mixture. The easier it is for fuel and air to make it to the spark kernal the better the combustion event. Also, the more open the area around the spark kernel the greater the ability for the flame front to propagate. The faster the flame front starts to propagate the more complete the combustion, the more power gained.

With WeaponX's advanced tip design our 0.5mm Iridium tip actually surpasses the ignitability of a 0.2mm fine wire electrode while still offering a long, high performance service life of our 0.5mm center electrode design. *(see FIG A and B)*

*In **FIG A** you can see leading competitor spark plugs vs the WeaponX spark plug. The WeaponX is designed with a drawn back porcelin insulator which opens an area for fuel / air which greatly increases ignitiability. This also allows for faster flame front propagation.*

*In **FIG B** you can see that the initial flame front on the WeaponX spark plug grows faster and more intense than the competitor spark plugs. (yellow indicates competitor flame front size vs the WeaponX flame front)*





GROUND ELECTRODE DESIGN – further increasing ignitability

The ground electrode strap is a key area of spark plug development. While the U groove is an interesting concept the actual area increased for flame front propagation through slotting the ground strap does not justify the U groove vs WeaponX's exclusive porcelin cutback design. Infact gains on the u-groove are almost non-existant and reduce service life of the spark plug dramatically. Note **FIG C.** There is rapid deterioration of the U groove ground electrode since the material present on the ground strap becomes minimal after slotting. Over time the U groove design plug deteriorates and so does the overall performance of the spark plug. Tapered style ground electrodes holds tolerance over time and offer longer service life and performance. Also note above **FIG B.** The spark prefers to jump to the outer edges of the ground strap where the competitor U grooved plug prefers

to jump to the inner edges shrouding where the spark kernal and flame front start.

WeaponX's narrow taper increases flame front propagation and ignitability while still allowing for a long high performance service life.

OTHER PERFORMANCE ENHANCEMENTS

LOWER SPECIFIED INTERNAL RESISTANCE

WeaponX has designed the Extreme X and SuperX and spark plugs with high output in mind. Since WeaponX spark plugs are classified differently then our competitions we do not have to follow FCC guidelines for noise emissions which mandates the use of a "resistor" style spark plug. WeaponX ExtremeX spark plugs are classified as non-resistor and offer a lower internal resistance than competitor iridium spark plugs.
Federal guidlines for FCC noise supression mandate that all street driven vehicle spark plugs must adhere to standards that effectivly reduce the power output of the spark plugs. Typical street oriented spark plugs reduce power output by using internal resistances ranging from 5000 to 10,000 ohms compromising spark energy. Figure 4 demonstrates the increased power required to initiate a spark in the electrode gap when resistance levels rise. By reducing internal resitance in the circuit spark output and ignitability characteristics increase above and beyond the competitions design.

Since the WeaponX design uses less resistance in the ignition circuit energy saved by initiating the spark at a lower voltage is available to sustain the spark. Figures 4, 5 and 6 demonstrate the added voltage in the spark gap that was otherwise required to overcome the resistance in the spark plug during combustion.

FIG 4

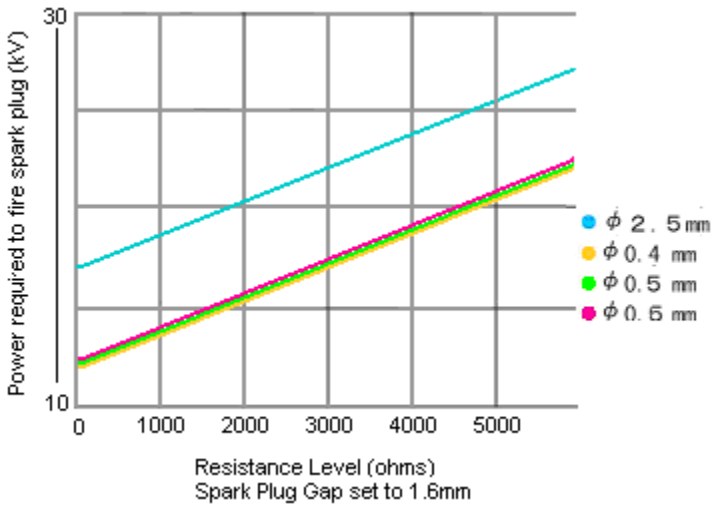
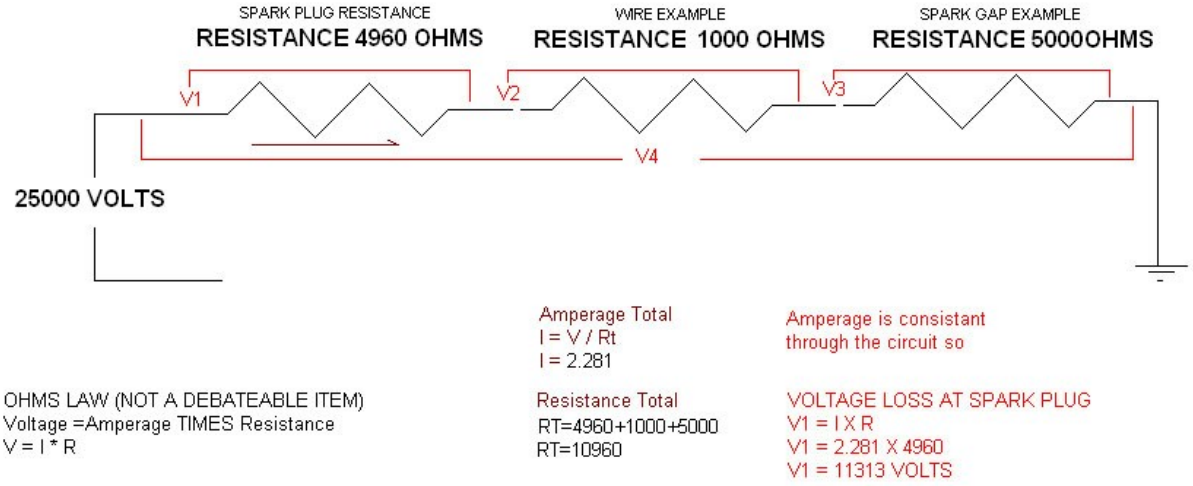
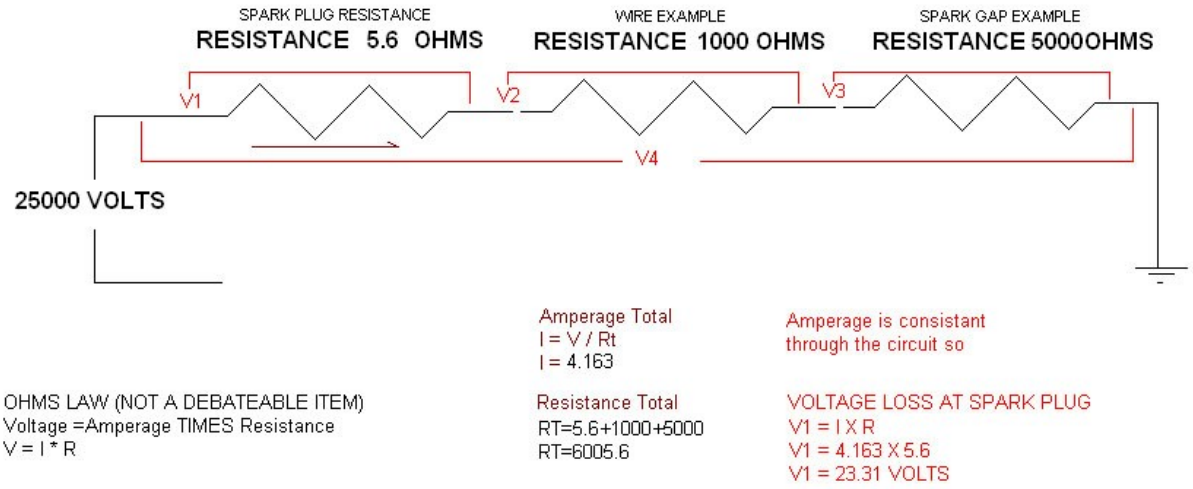


FIG 5



Voltage loss at the spark plug with this example using a standard spark plug is 11313 volts.

FIG 6



Voltage loss at the spark plug with this example using a WeaponX spark plug is 23.31 volts.

IMPROVED ENGINE POWER THROUGH REDUCED RESISTANCE
Lowered resistance has proven to increase available voltage at the spark gap. At the moment of ignition 2000 more volts are typically available and over 11000 volts during the ignition process. This effectively allows the air / fuel in the combustion chamber to be reliably ignited when the PCM commands a spark event increasing the accuracy, spark kernel size and overall power of the spark.

HIGHER POWER OUTPUT FOR GREATER ELECTODE GAP
All these improvements mean one thing, more available performance. With these techniques overall available spark gap size can also now be reliably increased. Because our design provides more available voltage at the spark gap it also effectively allows the gap size to be increased to above average values improving engine performance and fuel mileage. This also allows the ignition system to perform with less overall stress to wearable items such as igntion coils allowing for a longer and better performing service life.

DUAL 360 DEGREE BLOWBY SEALS AND DETONATION PREVENTION
WeaponX has balanced the attributes of a ribbed anti flashover tower section with a higher than average cross section of material to provide exceptional power transfer and energy retention characteristics.

The 360 upper and 360 lower steel seals help make blowby through the center of the spark plug non-existant by reliably tapering and sealing the inner section of the spark plug. This extra seal helps eliminate blowby at the base of the spark plug in extreme operating environments.

PLATED BODY
WeaponX spark plugs have a nickle cadmium or zinc plated bodies which resists corrosion, improves the service life and improves the spark plug bodies electrical properties. This effectively increases the electrical potential at the ground electrode which helps maintain reliability, improves performance and reduces corrosion by holding up to harsh in cylinder environments.

HIGH GRADE UPPER TERMINAL
WeaponX upper terminals are manufactured in aluminum which is a superior conductor than the competitors metal upper terminal. These terminals are spun on and stamped in place for exacting tolerances. This allows for exceptional drop in fit and finish, especially when used with our line of high end ignition coils. Competitors use a poor quality metal steel upper terminal that sometimes doesn't not conform to specifications requiring high tolerances or friction fit applications.

COPPER CORE
The copper core spark plug with a nickle electrode has been standard issue for many manufacturers on the 2.5mm design spark plug for years. Internally these spark plugs are able to harness the advantages of copper in order to maximise energy transfer to the electrode. Our iridium spark plugs also harness this copper core to maximise energy transfer, and with our MX iridium electrode out conducts a typical copper core spark plug with nickle electrode by 35% to further maximize the electrical conductivity of the spark plug.

IRIDIUM MX CENTER ELECTRODE MATERIAL

WeaponX developed an Iridium / Rhodium alloy that is superior to all other conventional spark plugs based on hardness, strength, electrical properties and melting point. The new alloy is composed primarily of Iridium with Rhodium mixed in to prevent oxidation and errosion wear. This alloy mix is extremely hard and has the greatest potential for resistance against wear in demanding environments. This means the life of the spark plug can be extended beyond typical designs while delivering superior performance characteristics. WeaponX spark plugs at over half the life expectancy will still out perform a typical brand new copper based spark plug.

360 DEGREE LASER WELDED IRIDIUM MX ELECTRODE

WeaponX also produces our products in state of the art manufacturing facilities delivering high tech processes such as our 360 degree laser welded tip which holds up to harsh in cylinder environments while delivering the best possible seal and electrical contact.

SPARK PLUG HEAT INDEX PROPERTIES

As power levels rise so does the incomming air / fuel. As a result of this Spark plug heat index must be correctly chosen for the vehicle in question.

The spark plug structural factors that determine heat range are:

- Gas volume being determined by space formed between the metal shell and the insulator nose at the firing end.
- Surface area and/or length of insulator nose at the firing end.
- Thermal conductivity of the materials for the insulator, center electrode and more importantly the overall design.
- The total structure of the center electrode.
- The relative position of the insulator tip to the shell end.

The spark plug operational factors affecting temperature are:

- The internal combustion engine's air-fuel ratio.
- The overall compression ratio of the engine.
- The internal combustion engine ignition timing.
- The octane of the fuel.
- The engine RPM and overall load.

As the volume of air rushes into the cylinder the greater the spark plug projection the greater the probability of spark blow out. Because of this, the higher the power levels the less projected into the cylinder our spark plugs become. This effectively moves the spark kernel from the inrush of air helping to eliminate spark blowout while increasing performance and reliability of the ignition system.
The reverse holds true for a lower power engine. As power levels decrease so does the inrush of air/fuel into the combustion chamber. In order to reliability ignite the lower volume of fuel and air it is best to project the spark kernel to the center of the combustion chamber moving the spark kernel directly into the air/fuel path.

Spark Plug Specifications

	K5RF-ipt	*K6CF-ipt*	*K7CF-ipt*	*K8CF-int*
Resistance	~3.2–6.5k/ohms	~0.8-1.8ohms	~0.8-1.8ohms	~0.8-1.8ohms
Thread Reach	17.55mm	17.55mm	17.55mm	17.55mm
Thread Type	14mm	14mm	14mm	14mm
Hex Size	5/8" Hex	5/8" Hex	5/8" Hex	5/8" Hex
Seat Type	Tapered	Tapered	Tapered	Tapered
Tip Type	0.5mm Iridium	0.5mm Iridium	0.5mm Iridium	0.5mm Iridium
Ground Electrode	Fine Taper	Fine Taper	Fine Taper	Fine Taper
Center Electrode	IridumMX	IridumMX	IridumMX	IridumMX
In cylinder projection	Projected	Projected	Semi-Projected	Non-projected
Projection Reach	3.7mm	3.1mm	2.6mm	1.2mm
Heat Index (NGK)	5	6	7	8
Cutback Technique	Yes	Partial	Non	Non
Body Plating	Nickle	Zinc	Zinc	Zinc
Typical MAX HP	450hp	600hp	725hp	850hp

Any questions please respond to us at.

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