Talkin' Tech:
Spark Plugs: Part One

Paul Crowe is back in this issue of The HOOK to discuss the "end game" of the ignition system, the spark plug. A two part series, he's examining plug basics in this issue with a extended discussion of plug reading in the July issue. Enjoy!

Spark plugs may be the most misunderstood aspect of engine tuning.
The function of a spark plug is quite simple. High voltage is forced to jump the gap between the center electrode and the ground strap of a spark plug. That spark hopefully ignites compressed fuel which expands and pushes down the piston. Without proper spark most engines will not run efficiently.

Let's discuss heat range, center electrode tip design, and material choices. That will help us understand how to read a spark plug.

Many people believe a "hotter" spark plug produces more power. The heat range actually has very little to do with performance. Heat range describes the operating temperature of the center electrode, often called the tip.
For NGK brand spark plugs the number describes the heat range. A smaller number indicates a hotter operating temperature. Autolite is the opposite so a smaller number indicates a cooler operating temperature.

According to NGK the basic structural factors affecting the heat range are:

- Surface area and/or length of the insulator nose
- Thermal conductivity of the insulator, center electrode, etc.
- Structure of the center electrode such as a copper core, etc.
- Relative position of the insulator tip to the end of the shell (projection)

The features of the plug and the heat range are critical for proper thermal performance. For anyone who inspects their sparkplugs after a long hard pull, you might have seen the effects of an excessively hot plug.
The optimal firing end temperature is approximately 500°C (932°F) to 800°C (1472°F). The two most common causes of spark plug problems are carbon fouling (< 450°C) and overheating (> 800°C).

Overheating:

In my opinion you want the coldest tip possible without fouling. That prevents auto ignition (fuel igniting without spark). Fuel generally needs a spark or concentrated heat source to ignite. The spark plug tip and outer edge of the exhaust valve are two common heat sources that cause auto ignition.

What are a few things that affect spark plug temperature?

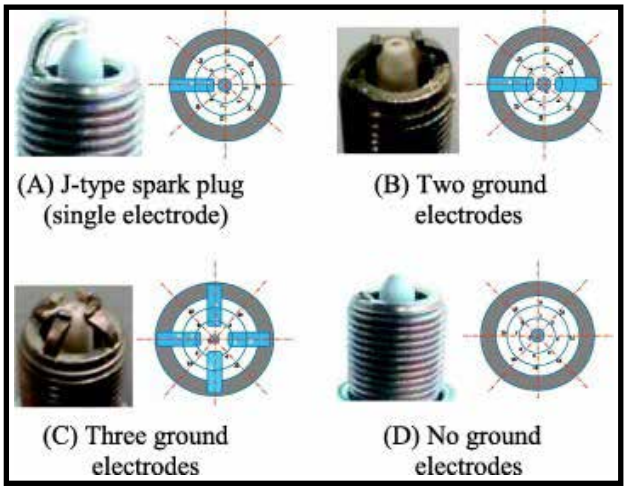
- Engine Speed and Load: High rpm increases plug temperature.
- Air-Fuel Mixture: Excessively rich air-fuel mixtures can cause the plug tip temperatures to de crease while excessively lean air-fuel mixtures can cause cylinder and plug temperatures to increase, possibly resulting in knock and/or pre-ignition.
- Fuel Type/Quality: Low quality and/or low octane fuel can cause knock which will elevate cylinder temperatures. The increased cylinder temperature also causes the spark plug, valves, and piston temperature to increase which leads to pre-ignition.
- Ignition Timing: Advancing ignition timing by 10° will cause the spark plug tip temperature to in crease by approximately 70° to 100°C.
- Compression Ratio: Significantly increasing the static/dynamic compression ratio will increase cyl inder pressures and the octane requirement of the engine

Tip design is critical for maximum performance

Tip design is often just a marketing ploy with no real science behind it.

What does that mean? Tip design is critical for flame expansion and wide ground straps block the growth of the flame kernel. Most of the time a fancy looking spark plug makes no sense from a purely scientific view point. Choose the spark plug with the thinnest ground strap and center electrode. This will maximize flame growth and minimize plug fouling. How about some proof?

In a scientific report by Ahmed A. Abdel-Rehim in Science Digest (Ain Shams Engineering Journal Volume 4, Issue 2, June 2013, Pages 307–316, found online at http://www.sciencedirect.com/science/article/pii/S2090447912000883), the article summarizes findings from scientists who studied the relationship between the number of ground straps and cylinder pressure (spark efficiency):

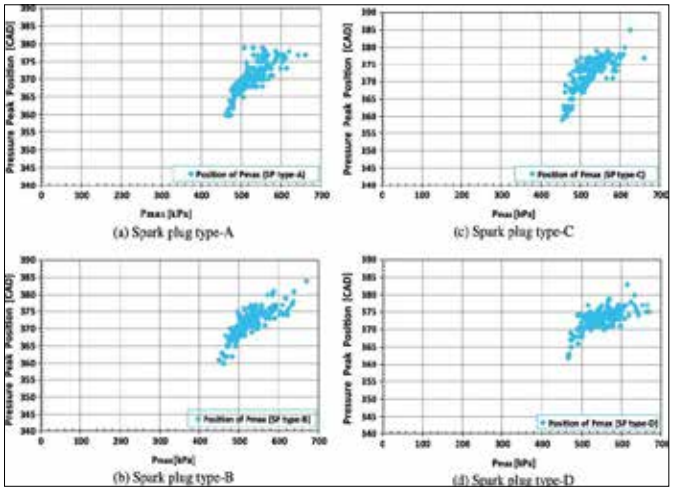


"The results presented in [3] and [7] showed that a spark plug with fine center and ground electrodes produced lower combustion variation with a reduction of approximately 3.1% in COV and 2.4% in the fuel consumption compared to regular spark plugs."

Furthermore…

The COV (coefficient of variation) of the type-D spark plug was the lowest of the four main test spark plugs where it showed a reduction of 23.8% and 17.1% in the COV of IMEP and engine speed respectively compared to the base spark plug, SP type-A.

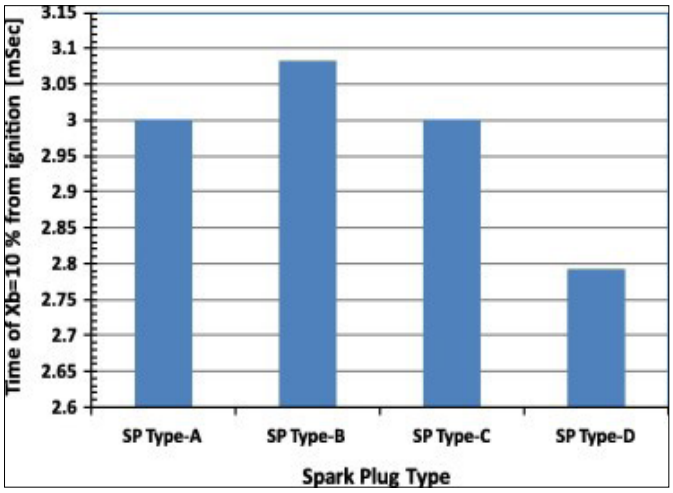
What does all this mean to us? It shows that multiple ground straps slow the initial fuel burn, blocks expansion of flame, and appears to cause a change in plug tip temperature which may adversely affect burn efficiency. The lack of any ground strap consistently outperformed the others.



Average values for the maximum pressure and the corresponding position for the four spark plugs:

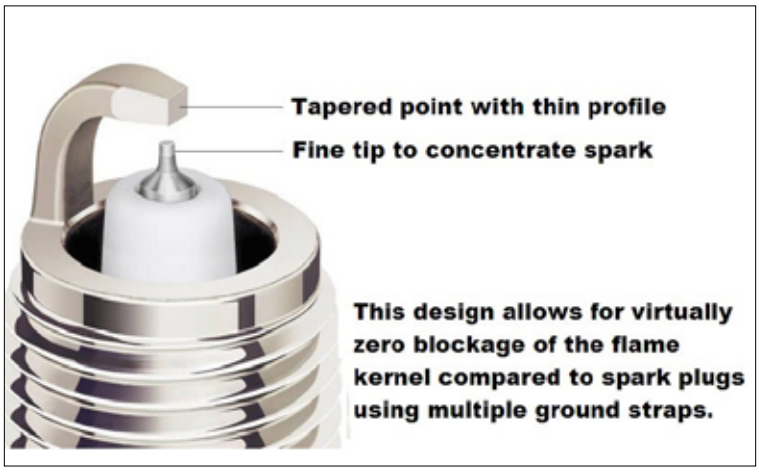
Plug type	Pmax average (kPa)	θPmax average [CAD]
Type-A	528	371
Type-B	527	372
Type-C	521	372
Type-D	549	373

The chart below goes a step further, providing proof that **no ground strap actually provides the best environment for initial flame kernel growth**. There are other reports showing that multiple sparks (especially at low rpm) improve efficiency and most likely reduce kernel growth time.



Multiple ground straps do not produce multiple sparks during a single event. In fact, NGK admits multi strap spark plugs are due to customer demand and hold no advantages except possible longer service life.

Harder materials such as Iridium reduce material transfer during the spark event. This extends the life of a spark plug especially with multi spark ignitions but generally will not help performance.



The more fuel you can ignite, the more expansion occurs, and the harder your piston is pushed downward to spin the crankshaft and perform work. Efficiency is important in ALL engines, especially low rpm tractor engines since there are less spark events in a given time frame and incredibly high loads.

Choose your spark plugs wisely!

What works in tractors?: Two factors must be considered with any spark plug. The thread diameter and thread length are critical for safe operation and proper heat range. Having a spark plug threaded way past the cylinder or cylinder head will change the effective heat range of that spark plug. The threads should be even with the chamber or adapter it is threaded into.

If you use 18mm plugs which were common on 1930-50's tractors the Autolite 386 (resistor type) or NGK AB-7 (non resistor) have worked well for us.

If you use 14mm plugs I am fond of NGK BR8EIX or even BR9EIX for pulling tractors. This is an Iridium type spark plug with fine electrode.

There are 12mm and 10mm NGK plugs but so far I have not used in tractors, only modern motorcycles. The main focus should be choosing the proper diameter, thread length, and heat range that fits your engine.

Next time we will get into the art of reading spark plugs and tuning.