

Spark Plugs: Fact and Fiction

Written by [Marlan Davis](#) on March 1, 2002



High-Performance Spark Plug Selection Can Be Boiled Down To Four Basic Steps

For the average stocker in good running condition, spark plug selection is a cinch—choose whatever brand’s on sale, look up the plug part number in the catalog, and go down the road. At the opposite extreme is the professional racer. Based on years of experience and reams of dyno and on-track data, special plug configurations have been developed by plug makers strictly for racing. But most car crafters fall between these extremes; their rides are not by any means stock, but neither are they used purely for racing.

How does the average person figure out the proper plug for a nonstock combination with an altered compression ratio, a bigger cam, aftermarket cylinder heads, and a power-adder like a turbo, supercharger, or even nitrous oxide? To find out, we consulted leading spark plug manufacturers—including Bosch, Champion, Denso, and SplitFire—to get the lowdown on modern high-performance spark plug design and application.

Basically, high-performance spark plug selection can be boiled down to four basic steps: Pick a shell design, choose an electrode gap style, determine preliminary heat range choice, and evaluate the preliminary selection in the car or on a dyno.

Shell Design

Most custom-built engines no longer have original cylinder heads—so the first thing you need to do is figure out the necessary spark plug thread diameter, thread length or “reach,” and the type of seat design required by the currently installed heads. Failure to select the right plug can result in inconsistent heat range and potential engine damage.

Some heads may accept several different shell designs. This can be important if you have a header clearance problem, or if the proper heat range is not offered in every shell. It pays to become familiar with your favorite plug maker’s catalog offerings and available heat ranges.

The porcelain end of today’s standard plugs is longer than that of equivalent plugs from the classic musclecar era. This may result in plug or plug wire interference on older headers. Possible solutions include shorter “lawn mower” plugs or special “shorty” plugs available from ACCEL and other manufacturers. Note that lawn mower plug heat range availability is extremely limited.

Electrode and Gap Design

When selecting the spark plug “nose” configuration, the simple rule to remember is: The more the spark plug is exposed to the air/fuel mixture, the easier it is to initiate combustion. Many specialized plugs have been developed for high-end race cars, but for most dual-purpose vehicles the choice typically boils down to either regular-gap (conventional) or projected-nose styles.

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The regular-gap plug is the traditional configuration factory-installed on many classic muscle cars. For modern high-performance work, it should only be used if there isn't enough clearance for a projected-nose plug. The latter style “projects” the spark further into the chamber than a standard plug, and will nearly always offer improved performance if there is sufficient valve and piston clearance, although many nitrous oxide users prefer to stay away from them because of excessive heat buildup in the tip that can cause detonation.

Projected plugs initiate the flame-front closer to the center of the combustion chamber, which has an effect similar to advancing the timing. This lets the total ignition advance be reduced, decreasing the chances of detonation while providing superior throttle response. A projected plug's longer core nose provides a hotter plug at low speed to help prevent fouling. As engine speed increases, the incoming air/fuel mixture flows across the core nose tip, providing charge cooling that effectively reduces the heat range for increased top-end detonation resistance. Today many race cars also used projected-nose plugs, albeit in highly modified form from the “civilian” versions—the ground electrodes are often cut back to help improve the flame kernel and reduce the voltage amount needed to fire the plug.

Heat Range

Controlling the operating temperature of the plug's firing tip is the single most important factor in spark plug design. “Heat range” is the relative temperature of the spark plug's core nose, and it is determined by the length and diameter of the insulator tip, as well as the ability of the plug to transfer heat into the cooling system. A “cold” plug transfers heat rapidly from its firing end into the cooling system and is used to avoid core nose heat saturation where combustion-chamber or cylinder-head temperatures are relatively high. A “hot” plug has a slower heat transfer rate and is used to avoid fouling under relatively low chamber or head temperatures. What's confusing is that a “hotter” (higher performance level) engine requires a colder plug because more power equals higher cylinder temperatures.

Critical factors affecting heat range include:

- **Air/fuel mixture:** Lean air/fuel ratios raise cylinder-head temperatures, requiring a colder plug. Rich air/fuel ratios require a hotter plug to prevent fouling. Mixtures that cause the plugs to read lean may contribute to pre-ignition or detonation. If not running an electronic engine management system, it pays to tune slightly on the rich side to avoid detonation.

- **Spark advance:** Ignition timing has one of the greatest effects on plug temperatures. It becomes more critical as compression ratios increase. More timing raises combustion temperatures, calling for colder plugs.
- **Compression ratio:** Increasing the mechanical compression ratio raises cylinder pressure, resulting in higher cylinder temperature. The higher the compression ratio, the colder the spark plug needs to be. According to Champion Spark Plugs, for normally aspirated, gasoline-fueled engines, a good rule of thumb is to go about one heat range colder for each full point in compression ratio increase from 9:1 through about 12.5:1, and two heat ranges colder for each point increase between 12.5:1 and 14.5:1. Beyond 14.5:1, 3-4 heat range reductions per point may be needed.
- **Gasoline quality:** With musclecar-era leaded gas, the lead is attracted to the hotter (core-nose) part of the plug, causing glazing. The spark runs down the core nose instead of jumping the gap. Going to a slightly colder plug helps prevent lead-glazing. However, with today's cleaner-burning oxygenated unleaded gas, an equivalent engine needs to run plugs about 1-2 heat ranges hotter than originally specified (many plug manufacturers have revised their catalogs accordingly).
- **Methanol:** Methanol has a higher octane level compared to gasoline (allowing an increased compression ratio), contains 50 percent oxygen by mass (requiring a much richer air/fuel ratio), and has a reduced latent heat of evaporation (which cools the incoming air/fuel charge and allows a denser mixture). The net effect is to require a plug that's at least one step colder than normal for an equivalent gasoline-fueled application.
- **Nitrous oxide:** N₂O raises cylinder temperatures and may require a plug 1-2 heat ranges colder. Lower output street systems may get by with standard heat ranges if nitrous use is held under 10 seconds.
- **Supercharging/turbocharging:** With increased pressure and temperature in the chamber, two or more heat ranges colder may be needed. Extreme high-boost race-only applications may need a surface-gap plug.
- **Sustained acceleration:** Prolonged acceleration or high-speed driving raises temperatures and calls for colder plugs.
- **Elevation:** Leaning the mixture and advancing the timing can partially compensate for lost power and efficiency caused by increasing elevation. Spark plug heat ranges should stay the same as at sea level unless racing above 3,000 feet, where one step hotter usually suffices.

Test and Evaluate

With a new or unknown combination, play it safe. Always start at least 1-2 heat ranges on the cold size of the mean heat-range for the series of plug you are running. At worst, you may experience some plug fouling. On the other hand, a plug that's too hot can cause detonation and damage the engine.

Determining the optimum heat range is a trial-and-error process. You run the car, then “read” the plugs by closely inspecting and analyzing the condition of the plug tip and insulator. Once you find the correct heat range that prevents fouling without contributing to pre-ignition or detonation, changing to a hotter or colder plug won’t alter engine performance. Set up the engine for optimum air/fuel ratio and timing first, then fine-tune plug heat range. Reading plugs on the street is not the same as in racing. On the street, as mileage piled up, a properly burning plug traditionally had a clearly visible brown or grayish-tan color.

Today’s pump gas may use additives that cause a discoloration of the plug core nose; they could be pink, purple, or blue. Do not consider this coloration as an indication of heat range when reading spark plugs.

In racing, the primary concerns are the color of the ring that forms on the insulator base and the condition of the electrodes. When both tuning and plug heat range is correct, after a full-throttle run the fire-ring with leaded racing fuel should be a light reddish-tan. There will be a corresponding coloration on the inside of the threaded portion. Plugs with bright-plated threads may be easier to read than those with black-oxide threads.

To ensure accurate readings under racing conditions with leaded fuels, the engine must be shut-off cleanly at full throttle and the car placed in Neutral with sufficient remaining momentum to coast into the pits or to a stop near the end of the strip. The readings are useless if the car is driven into the pits after a run. For more information on reading and diagnosing plugs, see the article [Spark Plug Tuning, Pro Stock Style](#).

Dual-purpose street/strip machines rank among the toughest cases for determining proper plug heat-range selection. They spend weekdays under stop-and-go driving conditions, with occasional full-throttle acceleration runs. It is hard to select one heat-range that provides optimum plug performance under all conditions.

Assuming that the need for sustained full-throttle acceleration can be anticipated in advance, the optimum solution is to carry an extra set of cold plugs for racing duty only. Having the proper plugs on hand for your application should ensure that your engine will get fired up with no gaps in its performance potential.