# Reading Spark Plugs; revised by the Author 10/12/2007

Contributed by Robert Fleischer
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## 1. PRELIMINARY DISCUSSION OF SPARK PLUGS IN GENERAL

Spark plugs are 'read' by looking at the combustion chamber end of the plug. You will be analyzing the color and condition of the central insulator and electrode; the outer electrode; and, the metal on the flat end portion of the spark plug, which is about 1/8th inch wide. Once you gained experience [it doesn't hurt to ask SEVERAL supposedly experienced mechanics to confirm your analysis], you will find that much can be learned from a look-see. Spark plugs are looked at to determine if they are worn to needing replacement; to see if the engine seems to be operating correctly; and to get some idea of specific problems. Reading spark plugs is an art, requiring experience, especially with modern unleaded fuels.

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Unless you have a very good reason for doing so, the stock factory heat range spark plug, with the factory gap setting, is preferred. You will probably find that Bosch brand spark plugs have the thread profile that fits your head's threads better.

WARNING!...Bosch has been adding resistors to its non-resistor spark plugs, and this is NOT GENERALLY a good thing for your Airhead motorcycle. Boxes and the spark plugs inside may not agree about the resistance. See the author's website for all the details.

http://bmwmotorcycletech.info/

The heat range of a spark plug, for all practical purposes, deals mostly, but not entirely, with the white [when new] ceramic insulator inside the spark plug; its length before it contacts the metal shell, its material, and the material of the center electrode. Mechanics [aka "Wrenches"] typically think of heat range as being primarily controlled by the length of this insulator, and that is, for the most part, correct. Exposed to the hot combustion gases, the insulating ceramic heats up, and must get hot enough to burn away any deposits of small quantities of engine oil and combustion byproducts, yet not so hot that it retains so much heat that it is destroyed...that CAN happen...one CAN see ceramic tips that are fractured or otherwise damaged. One also does not want the tip to be excessively hot for another reason, as a glowing red tip can pre-ignite the mixture before the spark occurs.

If the gasoline mixture is ignited before the proper point, the heat and pressures involved will...or can be... be monstrous. This effect under the worst circumstances is called detonation, and can DESTROY an engine VERY rapidly. If you should see wee tiny round balls (usually) of shiny, or nearly shiny aluminum metal, inside the spark plug, you have probably been experiencing detonation, and that is aluminum from ....perhaps...your PISTON!.....and this condition needs immediate fixing! There is another form of detonation, called pinging (or pinking), usually caused by wrong ignition timing or poor grade of gasoline. It can cause substantial harm if it is heavily repetitive. This is a rather metallic sound, whilst most real detonation is not heard, or is a much duller sound. In general, pinging is heard below 4000 rpm; and detonation usually occurs above 4000; on our Airheads. Pinging tends to occur not only from excessive engine spark advance timing; and/or poor octane of the fuel; but as one goes lower in altitude, the atmospheric pressure, and the amount of oxygen available in the air, increases, and allows higher cylinder pressures....making higher combustion

pressures.

If the plug is too "cold" in heat range designation, it will accumulate deposits, probably not fire every time it is supposed to, cause the engine to lose power and get poor gas mileage, and possibly eventually short-circuit from deposits and stop working. A spark plug is called a hot plug [or, a hotter plug] when the insulator is longer than some other spark plug, and that 'other' plug is usually taken to mean the stock factory plug. This hotter plug operates with a higher insulator temperature. It is called a cold plug [or, a colder plug] when the insulator is shorter, and the spark plug insulator operates at a lower insulator temperature. There is seldom any reason to not use the specified spark plug for an engine. Substitutes for most spark plugs are available from other manufacturers than the original, and for the Airheads, the NGK plugs have proven to be excellent; and the Champions and some others have proven to be iffy, particularly the quality of the metal threads.

GENERALLY, for many manufacturers, a number in the spark plug model numbering, goes UP as the plug gets HOTTER. This was NOT so with the early Bosch numbers, that look something like W225T2; and, for NGK plugs (then and now). The later Bosch system with numbers such as W5DC, conform to the 'larger number is hotter' method. Now there is another Bosch numbering system using 4 digits, which are hardly very informative, compared to the older numbering system, which is still in effect on the boxes (W5DC; W6DC; W7DC....and so on). A certain number in one manufacturer's model number does NOT necessarily mean it has the same heat range as the same number in another manufacturer. In fact they almost always are different. When BMW specified more than one manufacturer, in your owners or service manual, they TESTED those plugs. If YOU substitute a manufacturer and plug BMW did not specify, and do that substituting from the new plug manufacturer's cross-reference guide, you MAY find the plug is just a bit colder or hotter than the original; or, what you expected. In some situations, the substitute spark plug may cover, in one number/style/type, a wider or narrower heat range in itself. Some very clever engineering went into broadening the effective heat range of any particular spark plug. The Bosch W5DC covers a rather wide range, same for W6DC, W7DC, etc. The widening of the usable heat range for any one model number of spark plug is small, but it IS noticeable, compared to very old style spark plugs.

There is a fair amount of science involved in designing spark plugs, a lot more to them than one might expect, and it is not my intention to delve deeply into the subject. I have gotten into this a bit because there MAY be occasion for SOME to want to use a different heat range plug, or have the knowledge on how to do that. Today's spark plugs such as that W7DC, actually cover a somewhat wider usable heat range area, than previous plugs, as I noted above. It is unlikely this will be further improved upon, or, by very much.

The exposed tip (often called an 'extended tip') that BMW uses, is the correct style, your Airhead should have a non-extended type plug, nor a resistor type plug (use of a resistor plug can degrade engine performance), nor a so-called 'platinum' plug [with its very small diameter thin central electrode]. Caveat: I have personally not run tests with Bosche's new Platinum +4 plugs, with an extended nose. SO FAR, I see no reason to use them. The BMW combustion chamber shape, the effective type of swirl to the gas mixture....ETC., demands the extended tip style of plug. If you substitute a non-extended nose [tip] plug, you are on your own as your own engineer, and heat range and mileage (yes) and performance will likely suffer. Just one reason is that the incoming fuel charge is used by BMW to cool that plug tip area. This does not happen well at all with non-extended tip spark plugs. The shape of the combustion chamber, angle of the valves, ETC., all contribute to the nature of the swirling gases going by those plug tips. If the plug tip is not in the mainstream, so-to-speak, things don't work as well. It is important that the spark plugs be installed with crush washers. The manufacturer's prefer you use a fresh crush washer each time...not really 100% absolutely necessary, but does give more repeatable results IMHO. It is fairly important, unless you have very educated hands, to use a torque wrench....and to torque to specifications. If not torqued to specifications, the heat transfer is not consistent. If overtorqued, you can damage the heads. BMW has used 16-18 foot pounds in most literature for its spark plugs. That is for NON-oiled (NEVER oil spark plug threads!!), NON-antiseize compound on the threads. Once antiseize is used, you must CONTINUE to use it, as it works itself into the aluminum alloy of the head threads. Under NO circumstances must you use such a high torque as 16-18 footpounds with antiseize. My personal specification for the standard 3/4 inch length 14 mm spark plug installed in an aluminum BMW head, with a faint amount of antiseize compound, is approximately 13+ footpounds. Use of a quality nickel antiseize paste is HIGHLY recommended by ME...although its use is somewhat controversial.

For those with the 1/2 inch reach [length] BOTTOM spark plugs (dual plug heads), the torque should not NORMALLY exceed 10 foot pounds with antiseize. This is due to the thinness of the metal in the lower spark plug hole area, and I cannot recommend ANY setting without the use of antiseize compound. Some folks use the 3/4 inch reach 14 mm spark plugs on top and bottom, with spacers on the bottom plugs. Some have welded that spacer to the bottom, and that works fine, and normal torque can be used. Some folks use a one-step HOTTER plug for the BOTTOM plug, due to its tendency to run slightly oilier, etc. Some fewer folks have bottom spark plugs of an even smaller thread size, but the selection is not great, and one must torque exceptionally carefully.

If you have dual plugged heads do NOT insert the longer top spark plugs into the lower threaded holes without spacers!!! That, and overtorqueing at any time WILL cause $$ damage. Crush washers do vary, as do the threads and fit, and PROBABLY up to 10 foot pounds can be used safely on BOTTOM plugs, providing a known good torque wrench is used. The rule of thumb for tightening spark plugs,,,,in fact almost any threaded object that has a lubricant (such as antiseize compound), is to use about 30% less than dry specifications. One must be especially careful to not overtorque lower plugs. Many just use a fresh crush washer on the lower plugs, hand tightening CAREFULLY until the washer JUST finishes crushing. Most will find this to be about 10 ftlbs.

NEVER EVER oil the spark plug threads....oil will carbonize from the heat....and you will have thread damage eventually. If the threads are carboned-up for any reason, and the spark plug does not unscrew relatively easily...or, worse, seizes somewhat during the unscrewing, then apply a very thin penetrating oil or even kerosene, overnight, to soften the carbon, and remove the spark plug carefully, clean the threads, and remove the oil.

2. TEST RIDE AND ANALYSIS PROCEDURE

FIRSTLY: It is best to begin with brand new spark plugs. Once you have enough experience, you can probably use plugs with a considerable number of miles on them. Install them properly torqued. The ignition system MUST be in good condition, with resistor caps measuring OK, coils not having an open secondary winding, proper timing is set, valves set properly, and so on.

One of the purposes of the Test Ride and Analysis Procedure is to get the carburetion jetting within a reasonably close range.

A. You need to find a road that will allow you to do the testing. Yes, an adjustable dyno would be really nice...but they and their usage is costly, so it is the roads for most of us! You need to take your spark plug torque wrench with you; and, probably a regular spark plug wrench for removing the plugs...and, some gloves to allow you to handle the hot spark plugs. Try not to drop a plug...once dropped, even if it looks ok, it should be thrown away! DO NOT keep a dropped plug for 'emergency spare'. Finding the right road conditions may not be particularly easy!...especially if you live in a flat area.

For a really good evaluation, you need to do test runs separately in the 1/2 throttle, 3/4 throttle, and full throttle positions. With full mechanical carburetors, often referred to as slight carburetors, this is self explanatory. With CV carburetors, and, yes, they also have slides...but also have a butterfly valve tied to the throttle..... the throttle on the handlebars only indirectly controls that carburetor 'slide' assembly. Because of this, the rpm's, and load must be considered rather moreso than with the pure slide carburetor. The rpm's need to be considered on the full mechanical slide carburetors too, but it is less critical for them. After many years of doing these tests, on both types of carburetors (and with fuel injectors),

I feel that on all airhead models,... the tests need to be done at ABOUT 5000 to 5500 rpm (R45 and R65 models at 6000 to 6500). Lower than 4500 does not work well. Even higher rpm could be used for the full throttle MAIN jet test. There is nothing critical about the rpm, but you need to be above a certain point on the horsepower curve, and those rpm will work fine.

Keep in mind what you need to do: You need to find a road, at least a mile of which is relatively straight, and of such a UPward slope, that you can HOLD the throttle position (1/2, 3/4 or full) at APPROXIMATELY the rpm noted above. Obviously you must select a gear that allows this. The longer the road stretch, the better the spark plug readings are seen. I prefer a couple of miles. You CAN NOT do this test properly unless you can HOLD the throttle position. You may have to use the brakes a bit, hopefully little or none. A nice steep mountain pass with a goodly uphill gradient is my favorite.

B. Find that long hill, experiment with the gear selection and throttle, etc., until you can do the three tests thusly: Ride at the specified approximate throttle setting and rpm for the mile or so (half mile minimum). At the end of the distance, snap the throttle full off and pull in the clutch and shut off the engine, trying to do this all at the same time. Coast to a stop,...[in gear with the clutch pulled in if you have to]. ...try to not let 'moving on the road' in itself rotate the engine, for more than a FEW hundred feet. Letting the movement on the road rotate the engine, with the throttle off, will tend to mask the spark plug readings, especially if any oil is being burned.

C. Remove the spark plugs and take a look at that 1/8th inch wide metal at the end of the plug, and the outer electrode attached to it. I recommend all the plugs (on a dual plug model) be pulled, at least for the first test. There should be no sign of any melting/erosion of that outer electrode. Since you already know that your ignition timing and advance unit, etc., are OK, any sign of that is cause to suspect serious pre-ignition. The metal areas should have a very light blackening or a bit grayish. If a touch of dull black carbon is on these areas, you are in the OK to slightly rich area. Slight to serious richness (really dark carbon) can come from many different reasons, which include very high float levels...or leaking float needles; a slide needle set too high, too large a main jet by far (at full throttle and maybe 3/4 throttle), etc. The performance is usually better with just a touch of light gray-black. If shiny black, that is oil fouling...likely from worn rings or bad valve guides. If the plug metal (and insulator) looks like new, you are probably running too lean. NOTE that reading the ceramic center insulator is difficult, and requires practice, and the colors shown in various spark plug books may be wrong....gasoline additives vary a lot these days!

If running really excessively lean, the bike will perform badly, and may well improve during a test run if you turn the enrichener (choke) 'on' "slightly", seeing what effect that has, which can be a good test. Excessive leanness can come from not just the needle/needle jet setting or even size of needle, but float level too low, leaking carburetor-to-head adaptors, too small main jet, insufficient fuel flow from clogged tank screens or filters, etc. If really quite lean, the bike will probably buck quite a bit, surging.

D. Next, look at the ceramic insulator surrounding the center electrode. The condition of that insulator will tell you a lot about the heat range of the spark plug (you had previously torqued the plug to specifications, didn't you?). Analyzing heat range is a bit of an art, as is analyzing the metal in the previous step. Practice and checking with really experienced wrenches is the best way to learn. The insulator should be almost white, but not like new. Over many many miles, the insulator tip will gain some color, and the color is rather dependent on the make and type of gasoline. But, using a new plug, and the throttle test outlined, will not show that much color. The end of the insulator, the end tip that is, and perhaps about 3/16 inch or so inwards from the tip, should have a touch of color, this depends on the type of oil and the compounding of the gasoline, so color can vary. Typically it is a very light tan, but could be slightly grey-black, or even faintly yellowish or orangish. These colors all will be, if the mixtures are correct, rather subtle. Under NO circumstances may the insulator be dead white and/or blistered (blistering, if present, and sometimes one must use a magnifying glass to see it, is a sign of the coming serious damage you will soon experience). The center electrode should look good and certainly no signs of melting or eroding.

snowbum (#1843)