Ignition Systems, Rev. by Author, 10/30/2007

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More than you wanted to know?

I wish to emphasize that the following is a SIMPLIFIED explanation of ignition systems, although lengthy.

The earliest ignition systems that had any similarity to today's, were in the days of the earliest cars. At around the same time of the magneto's, there were wooden boxes with a vibrating electrical contact which sent battery energy into a coil of wire wound on an iron core. There was another coil of wire wound on that iron core, with many hundreds of times more turns, and these extra turns 'transformed' the lower voltage of the 'primary winding', fed by the battery, to a few thousand volts, and this was applied to the spark plugs. In many cases the spark was applied continuously. A bit later, a rotating switch with a contact for each cylinder, was used, and this was called a 'distributor'. The only problem with the vibrating contact system is that the spark output can not be set to 'fire' the spark plug at a very specific piston position.

Vastly more information is available on the Author's website, http://bmwmotorcycletech.info and there are numerous articles on the BMW airhead electrical system.

Magneto's are simply a permanent magnet method of using mechanical rotational energy (instead of a battery) to produce the high voltage needed to 'fire' a spark plug. Magneto's are usually equipped with a set of points (contact points plate), which are nothing more than a mechanically coupled ON-OFF switch...and the energy transfer from the small number of turns coil in that contact circuit is done at the moment the points open, which is set to coincide with a particular high energy alignment of the iron core with the wire in relationship to the magnet. The relatively small number of turns in the 'primary winding' coil acts the same way as in the vibrating points method just described....there is a 'transforming action'. This SAME transforming action is used in all coil ignitions. More on this later herein.

BMW used magneto's in the early models, prior to late 1969 when the /5 series was introduced. Magneto's are difficult to keep down in size when you need higher energy sparks. Lean burning engines demand high energy sparks. Magneto's one big advantage is that no battery is needed. For many reasons, magnetos are seldom used on engines today. Magnetos produce maximum spark voltage at higher speeds, as opposed to 'coil' ignition....which is another reason why magnetos were popular, particularly on some race engines a long time ago....besides the weight of a battery not being needed...race engines were not started by 'starter motors'. Magnetos were, and still are, used on some 'stationary' engines; and versions of magneto ignition are still used on some small motorcycles, lawnmowers, snowblowers, and many types of similar engined devices, ETC.

From the the time of introduction of the /5 series in December of 1969, until 1981 when BMW introduced the electronic triggered ignition, BMW's had coil ignition with the points contacts being driven off the engine camshaft, that same camshaft that operates the valves. The contacts, which are nothing more than a switch, have a capacitor, often called a condenser, wired across them. This system of contact points, capacitor, and coil, all being driven by a battery, was invented by an engineer from GM, and even now, this system is still called the 'Kettering' ignition. In our Airheads, the camshaft rotates at precisely half the crankshaft speed. At the forward nose of the camshaft is a bob-weight type of simple mechanism called the Automatic advance, whose purpose is to change the point of ignition timing in relation to the piston, in so far as slower rpm is concerned. This mechanism, up through 1980, has its own 'two-bump' cam, and it is THAT cam that operates the ignition points. The automatic advance is so arranged that the ignition timing 'spark advance' finishes all advancing by approximately 3000 rpm, in all models (except some very early /5 models, when it was at about 2000 rpm). In 1979 BMW put the points and advance mechanism in a canister, and made some improvements in the stability of the drive to it. The cam nose became a flat slot and offset coupling called an Oldham Drive. The latest

BMW canister design, incorporated in 1981 and later production, eliminates the points in favor of an electronic (magnetic) triggering device, called a Hall element, which, in turn, triggers a complex electronic triggering device we just call 'the module', located under the fuel tank on a small heat sink. The Module is nothing more than a fancy electronic circuit that functions as a switch for the current into and out of the coil(s), yes, just like the points in the older systems did. The electronics has certain timing and other functions added, and the module was updated a few times, as was the coil(s) used.

How does a coil make the spark, and WHEN does it occur? Modern coils consists of an iron core of multiple thin iron rod lengths that has wound around it TWO separate windings. One winding, called the PRIMARY, has a relatively low number of turns of a relatively thick wire. The spade terminals on your coil are connected to the beginning and the ending of this winding.

VERY well insulated from that primary winding, the high voltage winding, usually called the SECONDARY, consists of thousands of turns of a rather thin wire. In some ignition coils, the two ends of this winding go to two high voltage 'tower' terminals on the coil. In some coils, there is only one high voltage terminal, and the other end of the high voltage coil winding is connected to one of the low voltage winding terminals; which, in effect, since they are in the battery circuit, acts as a grounding or path return, for the high voltage. BMW uses both types of coils on its Airhead models.

Assuming the system has mechanical points and a capacitor, here is how the system works:

Battery voltage through the ignition switch is applied to one spade terminal on the coil, which is one end of the mentioned PRIMARY winding. On some coils, that terminal is numbered, and on some it has a + symbol, and on some it has both. The other spade terminal on the coil, the minus (-) end, connects to the non- grounded, insulated, points contact. A capacitor (condenser) connects to the points wire and to chassis ground via its metal case. Conventional wiring systems used by the Germans use a standardized numbering system, and terminal #1 is negative (-) and #15 is positive (+). Since the power into the coil from the battery is applied one way or the other to terminal #15, it often marked +. Since the switched end of the coil (switched to ground by the points or module) is in the chassis connection end of the coil, that coil terminal is marked #1 or - or both. It is important that coils be properly connected for this + and - polarity, otherwise the electricity going to the spark plug cap terminal will be of wrong polarity and possibly have a harder time for the spark to occur at the spark plug, under some circumstances.

One of the points contacts is mechanically and electrically connected to the metal plate of the points contact assembly, and thereby completes the circuit to the battery negative terminal, through the engine casing, etc., when the points are closed, touching each other.

When the points are closed, which they are for a MUCH longer time of rotation, compared to the time they are open (this is what is meant by dwell angle, as a portion of a single rotation); the current from the battery flows through the coil, and back to the battery via the points. If you think about how 'pointy' cam, and imagine points connected to the cam via an insulating block material, you will understand the difference in points closed to points open TIME, per rotation of the cam.

During the time that the points are CLOSED, the iron core in the coil is building up a magnetic field, hopefully up to the

maximum the iron core coil will accept. If the engine is rotating relatively slowly, the design is such that this maximum does occur. When the desired position of the particular piston on its compression stroke is reached, the points, adjusted to do so by rotating the entire plate (or entire canister on 1979-1980 models) will JUST BARELY begin to separate. The adjustment process is called 'timing the ignition' and is done every 5000 miles or so on points ignition models. The points contacts, and rubbing block (which is lubricated by a felt against the cam) do wear, and the points usually need replacing at 15-20,000 miles or so; unless an aftermarket 'amplifier' has been installed. At this exact instant the points begin to open, the circuit is broken, and the coil cannot accept any more current from the battery as it is then no longer a completely connected circuit.

As a more technical note here, when the points first CLOSED, the current to charge the coil magnetically began at a low level, just exactly WHY is not going to be discussed here... then increased until it reached a maximum allowed by the resistance of the primary winding. This magnetic charging 'curve' (an exponential function for you questioning types) and the reason behind why it is not instantaneous, is a matter of electrical theory for engineering nerds such as myself. Once the coil is fully magnetized, there is no electrical reason to have the battery draining further into the coil. The small cam that drives the points is arranged to have a 'dwell' that is adequate, for any range of rpm the engine will work at...and an additional safety amount. IF the coil(s) were operated on an engine that was capable of enough rpm (or, number and cylinders and rpm), the coil output would drop off. Another way of saying this is that as the number of outputs a coil produces rises above a certain number, the coil can not fully be magnetically charged, as there is not enough TIME between spark events. If the situation is bad enough, INsufficient spark plug voltage will occur. This does NOT happen with our airheads, as rpm and number of cylinders is rather low, compared to coil capability.

Dwell used in our airheads has varied over the years, and was reduced in the /5 era, when some Authorities (Police) models with metal shielded coils overheated. Still, the dwell is far more than just adequate, for a coil on a two cylinder engine at Airhead capable rpm.

At this exact instant the points open, the coil is 'loaded' with magnetic energy, which has to go someplace (don't ask why, that is beyond this posting).

Some have asked about making measurements at the points to 'static time' the engine. This is acceptable, and BMW even provides an "S" mark for that, to begin the timing process, but the correct method is to finalize with timing the engine at the maximum advance point rpm. We actually use a slightly higher rpm to be SURE that the advancing has stopped increasing. But, yes, you can use an ohmmeter or a voltmeter, or a piece of the very thin 'cigarette' rolling paper. If you use an ohmmeter, leave the ignition off or you might burn out the meter. Either type meter is connected across the points (DO NOT try this with the full electronic ignitions with Hall devices), which in some cases is easier to do by connecting the meter at the appropriate terminal on a coil. At the timing point, the ohmmeter indication will increase (more ohms).

If using a voltmeter, turn on the ignition, and the timing is when the voltage rises suddenly from zero (it will go to approximately battery voltage).

If using cigarette rolling paper, which is extremely thin, the timing point is when the cigarette paper can just barely be pulled through without grabbing.

You must rotate the engine in the forward direction VERY SLOWLY when finding the exact timing point. Some do that with the spark plugs out, some with them still in place; some do it with an allen wrench into the alternator bolt. I prefer bumping the rear wheel in top gear.

Remember that capacitor/condenser I have mentioned? During the longish dwell time the points were closed and the coil charging up in magnetic energy, that capacitor is electrically SHORTED by the points. At the instant the points separate the tiniest amount, ...that mentioned timing point, ...the capacitor now suddenly receives the voltage created by the magnetic field in the coil. I will restate that slightly....at that instant, the coil 'tries' to charge the capacitor with its energy, which it changed from magnetic to electrical. Since it takes TIME for a capacitor to 'charge up', the coil dumps energy into the secondary winding. This is a GROSSLY wrong statement if you are an electrical engineer...but it simplifies the explanation, since it basically is true. The secondary winding now develosp the high voltage to fire the spark plug(s) by transforming action. The primary winding voltage is increased in the secondary, by the magnetic coupling means, and the increase is approximately the RATIO of primary winding turns to secondary winding turns. NOW you know why there are MANY more turns of secondary winding wires...and why the secondary winding must be of very small gauge wire, in order to fit inside the coil dimensions. The points contact winding (the Primary) also sees an increase in voltage, since transformation is not perfect, nor is the condenser function, although much lower in value. The bottom line here is that the approx. 12 volts of the battery is now transformed by the ratio of the number of turns between the two windings....and we get a big voltage to fire the spark plug.

For complex reasons during the above process, the capacitor, which has a capacitance value selected to approximately match the coil(s) inductance value (an electrical term), reduces (but does not eliminate totally) the electrical arc (sparking) at the contacts, giving them a much longer life. So, the capacitor has TWO functions!

In a system as described, the high voltage output of the coil has a rather complex type of waveform, but it is definitely polarized (positive and negative). That is why the two spade terminals on the coil must be connected to the correct wires on the coils with one high voltage tower output. While that coil WILL fire a spark plug if the coil is connected backwards, the effective energy at the spark is reduced, as the hot spark plug tip does its spark jumping job easier if it receives negative voltage. At least, that is the commonly spoken theory. In reality, it is complex. In models that have one coil with two output towers, the NON-firing cylinder spark plug has vastly less air pressure, since it is not on the compression stroke, and the spark jumps that plug much easier, leaving plenty of energy left to fire the other cylinder which is on the compression stroke. The coil output is also designed to be higher, and the electronic ignition is used to ensure that the coil CAN be a higher output type. High voltage is always potentially dangerous to humans. Voltages over maybe 40 or 50 can create pain, and can cause DAMAGE to your body. The high voltage of a spark plug is dangerous to some folks in particular, and the high energy of the high voltage in particularly the electronic ignition models can be VERY dangerous. Be careful!

SPECIAL NOTE: For those of you with dual plug ignition conversions: TWO dual output coils are wired with the primary windings in series ; the high voltage secondary outputs have a positive and negative output at any one particular coil's

terminals, the same as the above single coil with two outputs. The operation is very similar.

In our BMW electronic ignition models (1981+), the points are replaced by some semiconductor parts (Hall elements/devices) that produce a triggering signal by the proximity of a specially shaped rotating metal plate. The electrical signal from these devices is very small, and the signal is applied to the electronic current amplifying circuit inside the module under the gas tank. The triggering devices are VERY sensitive to stray magnetic and electric fields. That is why the spark plug wires must NOT be disconnected if the engine is running, and why 5000 ohm spark plug caps are a must. This system is very reliable and requires no regular maintenance, with the exception of checking the timing every 10K or so, and reapplying heat conducting grease to the module under the tank every couple of years. The timing changes VERY slowly over VAST mileages, mostly due to wear on the timing chain/sprockets.

No matter what the method, contacts or electronics, some means must be available to change the timing of the spark in relation to the piston stroke, as the rpm increases. The reason is MAINLY that as rpm increases, there is less and less time for the ignited mixture flame to completely burn, so the spark must occur EARLIER in the process. BMW has used a mechanical advance device, sometimes called an ATU (automatic timing unit) in all its airhead models. This mechanical device is simply a pair of movable shaped metal weights (with calibrated springs), that move from the at-rest position to farther and farther outward as rpm's increase, up to their preset stops. Centripetal force causes the change...just like a weight on a string that you could rotate at speed over your head. By carefully designing the weights for shape, etc., the factory is able to give the optimum...or nearly so...'advance curve'...so that the proper timing occurs at the rpm found best by dynamometer and road tests. It is by no means perfect, or even nearly so since no device such as the automotive type of vacuum advance/retard is added. On a practical basis, this works out PERFECTLY OK. Earliest /5 models used about 2000 rpm for the maximum point of advance, but later models used about 3000. Use of the early advance units (2000 rpm) is often impractical, causing pinging with today's low octane requirements, but can give modified engines on premium high octane fuels more very low rpm acceleration...in an area of rpm not good for the engine to be operating in with heavy throttle anyway. As previously mentioned, there were changes in this advance unit over the years, including the weights, the cam profile (changed dwell) and springs tension. I can identify your advance and its stock characteristics if you supply me the Bosch number stamped on the outer part.

There are other types of ignition systems for 4 stroke engines, one popular high performance type is called a 'capacitor discharge ignition'. If carefully designed, the spark can occur so fast that it will fire fouled spark plugs. They are NOT needed or desirable, on our BMW airheads. There are various types of aftermarket electronics conversions for the BMW airheads. At least one from Germany is very expensive and very fancy, and uses triggering right off the crankshaft, eliminating any instability or aging of the chain and sprockets. One American type eliminates the points (Dyna), although they have other models; including an 'amplifier' designed to be used with the points. The popular manufacturer's of these aftermarket ignition items for Airheads are Dyna; and, Boyer, the Boyer having a built-in advance curve, and not needing the BMW mechanical advance. The Boyer advance curve is adequate, although it does not match the Airhead's exact requirements.

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