



DUAL PLUG IGNITION SYSTEMS
AND THE BMW TWIN

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The Elusive Goal:

World would you like to improve every aspect of your engine's performance, without detriment to any of its existing qualities? This apparently elusive goal is easily attained by the use of a dual-plug ignition system, which, on the larger twins, compensates for the results of the design deficiencies which we have all come to accept as 'character' since the original R75/5 engine gradually grew to a litre.

The Problem:

The basic problem with the larger Boxer engines is one of poor combustion in the low-to-mid speed range; this is mainly caused by the enforced location of the spark plug at one side of a very wide combustion chamber, and is further aggravated by the angle of the 'uphill' inlet port, which is required in order to place the carburettors where they will not foul our ankles. A central plug location cannot be incorporated, as the combined valve diameters do not provide sufficient space between their seats.

These deficiencies combine to produce a flame front which is required to travel across a large area, and which, due to poor propagation, expires before it has been able to consume all of the available fuel/air mixture. The residue is therefore available to detonate spontaneously as the piston approaches the Top Dead Centre position. The quantity of this unburnt fuel, and the associated 'Pinking' effect produced by its detonation, is increased by the combination of low speed and large throttle openings, such as is experienced during high load operation, when the engine is being provided with more mixture than can be usefully consumed.

The Answer:

The theoretically ideal method of dealing with this problem would be to improve flame propagation by increasing the level of turbulence within the combustion chamber at the end of the compression stroke, so presenting a rapidly rotating mass of homogeneous fuel/air mixture to the relatively slowly advancing flame front. This, however, would require drastic modifications to the piston and combustion chamber shapes.

A simple alternative is to provide an extra spark plug on the opposite side of the combustion chamber. This extra plug, if operated simultaneously with the original, will effectively halve the distance which the flame front is required to travel before complete combustion is achieved; in other words, a greatly increased rate of combustion will be produced, with an obvious improvement to the level of thermal efficiency.

How is all this achieved? Well, as we know, our existing inefficient system does not consume all of the available fuel/air mixture; the improved combustion efficiency which we plan to produce will enable the incoming mixture to be weakened throughout the range, even though a greater quantity of it will be gainfully consumed. This combination of rapid and complete combustion will not leave the residue of unburnt fuel available to detonate near TDC, so eliminating the 'Pinking' effect.

What is Pinking?

Pinking takes place when the fuel/air mixture is able to rapidly detonate (ie: Explode) rather than be burnt in a slower and controlled manner. This effect can have three causes:

(a) Excessive heating of the incoming fuel/air charge, due to poor heat transfer from the combustion chamber through the cylinder head and piston, or the presence of "Hot spots" such as can be formed by side exhaust valves, incorrectly rated spark plugs, or glowing carbon deposits. Many years ago this problem was particularly noted on engines with iron cylinder heads, which did not conduct heat as well as a similar aluminium type. Iron heads and side valves, of course, are now almost unknown, except on the Russian flat twins!

This effect is now produced by an excessive build up of carbon over the combustion space, which acts as an insulation layer, and is caused by modern low lead fuels. The anti-detonant additives now used in place of tetraethyl lead promote an increased rate carbon growth by a factor of approximately five times!

(b) Low levels of turbulence within the combustion space, caused by insufficient "Squish" effect (The incoming charge is caused to move around the combustion chamber at high speed, as the piston approaches the ignition point - generally achieved by use of an asymmetric combustion space.

(c) A poor inlet port shape, which does not progressively accelerate the incoming charge to maintain good fuel atomisation, so permitting fuel to drop out of suspension in the slower air flow, and gather in puddles at the base of the port. The older R100, with 40mm ports, is particularly susceptible.

The problem described at (a) can best be reduced by regular use of a fuel additive, which will reduce the rate of carbon growth, and slowly soften existing deposits, which will then be "blown out" of the combustion space.

The deficiencies detailed at (b) and (c) are often combined, but in either case the fuel tends to "settle out" of the air, and forms ultra-rich areas within the combustion space, which cannot be ignited by the flame front, and therefore detonate under the influence of the increased temperature and pressure. This effect can be almost eliminated by a dual ignition system. The presence of heavy carbon deposits, with their associated heating effect, accentuates these problems.

Implementation:

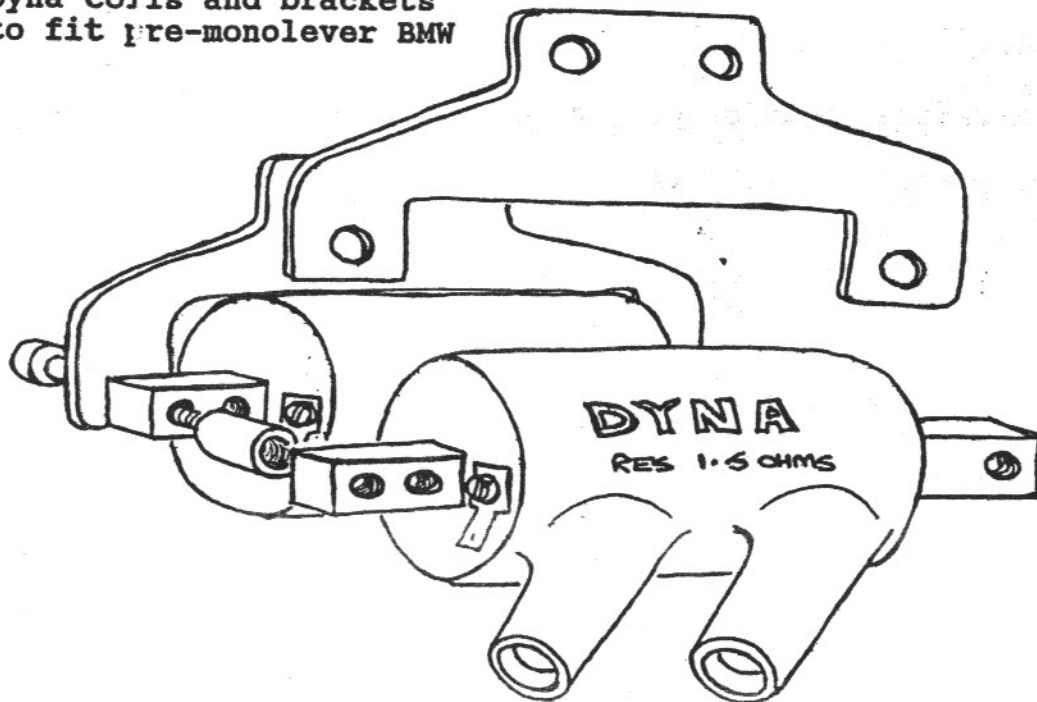
This modification, while not difficult, does require that you- or a friend- have access to a suitable machine tool etc; the machining is a normal enough procedure, as is the subsequent

setting up of the engine. If in doubt, ask!

Ignition Coils:

The heart of this modification is the ignition system, which requires the use of two double-ended coils, operating in series. For this reason the use of 6 volt coils is obviously essential. A pair of 12 volt coils (Such as are used on the current range of twins) will not operate satisfactorily in parallel, and even if they would, the current requirements of such a pair would cripple most ignition systems!

Dyna Coils and brackets
to fit pre-monolever BMW



The best source for the necessary (American) "Dyna" coils is Harman Services, where Dyna coils (Colour coded BROWN) may be obtained for £70 per pair. Brackets are an extra £25, but can easily be manufactured from thin steel plate. The use of double-ended Honda coils (eg: CB200 etc) is not recommended, as their insulation has been known to break down when used to produce the voltage which is possible with the BMW electronic ignition system.

The Dyna coils have a primary winding resistance of 1.5 Ohms, and therefore draw slightly less current than the post-1981 originals; should they be fitted to a pre-81 model, however, it would be necessary to use an electronic ignition system in order to protect the contact breaker points from excess current. If your BMW is already fitted with electronic ignition, you will not require an additional "Ignition Booster" such as Luftmeister like to sell with their very expensive dual ignition kit.

Adjustments:

Having installed the necessary hardware, we will therefore have to weaken the mixture, the need for which will be obvious, and also retard the ignition timing; as the combustion process will now take (Roughly) half as long as was previously the case, the effective ignition timing will be greatly advanced, and the setting will therefore require to be retarded in order to obtain

optimum engine characteristics. Failure to do so will result in a higher idle speed, with general roughness, lower power output, and higher fuel consumption... this is undoubtedly how tales that twin plugging is ineffective are started.

Cylinder Head Machining:

The spectacular part of this modification, the cylinder head machining, is pretty straightforward; the finning on the lower side of the head must first be cut away, in order to expose the outside of the combustion chamber wall. Drill lines of small holes close together, and break out small pieces of fin, before finishing off with a rotary burr in a power drill. Take great care not to drill into the chamber wall by drilling below the level behind the fins, or to cut away the fins around the pushrod tubes.

Mark the location of the lower plug on the inside of the chamber, using the upper plug's dimensions from the centre of the chamber, and from each valve seat; an old plug, minus the side electrode, may be fitted to provide an accurate datum.

With the head set at 45 degrees on the drill table, and the centre lines of the stud holes square with the table edge, the pilot hole is bored from the inside. It is, of course, now too late to change your mind about the entire project, as you watch your machine's vitals being transformed into drillings!

The head is now reversed, and the hole realigned on the pilot drill, which is then replaced by a 3/4 inch diameter end mill, to cut away the remains of the fin roots, and to provide the necessary flat area for the spark plug to seal against. For this operation it is necessary that you have access to a slow speed drilling machine—a vertical mill is ideal—or the tool will jump and chatter, possibly damaging the head; 30 to 60 rpm is ample.

The end mill should have an arbour at its centre, of the same diameter as the pilot drill, so eliminating any tendency for it to jump or chatter, and preventing the tool from wandering into the pushrod tubes. The metal thickness at this point is some 3/4", so while it is not critical, no more metal should be removed than is necessary to form a good sealing area. (Approx. 1/8" at one edge)

Without disturbing the position of the head, the pilot hole is now enlarged to the required tapping size, tapped, and the top thread bevelled. The head may now be removed from the machine, and the plug fitted; the excess thread below the plug should be measured and carefully removed, in order to eliminate the formation of a potential 'Hot Spot', by use of a hand scraper or small end mill.

Sounds simple, doesn't it? Fellow S.W. Section member Pete Jackson and I machined my R100 heads during a long lunch hour, with no problems but mutual apprehension!

Spark Plugs:

We had long debated the question of plug size, and finally decided on the standard 14mm diameter, as the necessary tap was readily available. We were very careful to position the new plug exactly opposite the original, and were therefore most distressed

to discover that, in spite of all our care, the spark plug socket spanner fouled one of the pushrod tubes! We had failed to realise that these tubes are not displaced symmetrically about the centre of the head... the lower plugs were correctly sited, and all that was necessary was to reduce the thickness of the socket.

In view of the generally critical dimensions, however, I would strongly recommend anyone contemplating this modification to use 12mm spark plugs; the use of 10mm plugs is not to be recommended, as, in our particular application, they are said to be prone to premature fouling problems.

Should you, however, wish to use the larger size, short (1/2") reach plugs of Bosch W5-6-7 grades are readily available, with the suffix code AC. The appropriate 12mm short reach plugs are the NGK D6-7-8- range, with suffix code HA.

Suitable taps will be readily available from your local cutting tool wholesaler; the Second Cut tap only is required. The 12 X 1.25mm tapping size is 10.8mm, while 14 X 1.25mm users will require 12.8mm. Expect to pay around £9 for a tap, and £4 for a tapping drill.

Connecting the Coils:

The Dyna coils will, with the brackets supplied, fit directly to any twin except the later types which use a single double-ended coil; on these models it will be necessary to mount the second coil above the air filter, in the space reserved for extra relays.

The primary sides of the coils are connected in exactly the same manner as the originals, using the connectors supplied, and do not require to be of any particular polarity, as the two sparks produced by each coil must be of opposite polarities regardless. The front HT outlets are best connected to the upper plugs, the rear outlets supplying the lower plugs via cables routed along the uppers, and secured to a rubber-lined clip mounted on the rear rocker cover stud.

The cables will connect to the coils via the standard straight connectors, but for a neater job use right-angled connectors, with waterproof plastic caps, from an old Lucas (Mini) distributor... the Prince of Darkness has some uses!

The best type of leads for use with the lower plugs, however, is to be found at your local VeeWee discount VW spares agent, in the form of Bosch silicone rubber plug leads, with their tightly fitting rubber caps, which are of the fit and forget type! These are available in a vast range of lengths, with straight or angled ends, at very modest cost.

Pre-Modification Work:

Prior to the twin-plugging it is essential that the machine is in optimum condition - overhaul the carburettors, replacing the needles and needle jets, which wear due to the combination of carburettor vibration and the non-positive method of needle mounting. That these components were in need of replacement on my R100 was amply demonstrated by an immediate 5mpg improvement in fuel consumption... routine replacement at around 35,000 miles would appear to be a good idea.

1981 R100 Installation:

My R100, otherwise known as Herman the German, was therefore back in optimum condition, running up to 90mph on quarter throttle, and 110 on half -quite an improvement over standard, and due only to the use of the next to lowest needle position, and advancing the ignition timing by 4 degrees. (One tooth pitch on the flywheel starter ring gear.)

Initial Running:

For initial tests, the carburettor settings were maintained, and the ignition timing retarded from the maker's setting, by use of the TDC mark ('OT') in place of the low speed mark ('S') - a shift of 4 degrees.

On starting, my initial impression was that the engine idled much smoother than before, and could be slowed to 500 rpm, which had never previously been possible. Throttle response was much crisper, and the engine was smoother throughout the range; rather like my R45, in fact, but with twice the power! Performance was about the same as before the conversion, so the next obvious step was to retard the ignition a further 4 degrees.

This procedure resulted in an improved performance level, of 5mph on both the established quarter and half throttle speeds; this total ignition retard of 8 degrees appeared to be the optimum figure. The carburettor needles were then dropped to their lowest position, producing a further improvement, and a somewhat unreal feeling of power and smoothness... and this in an engine which had always been regarded as being particularly smooth!

Coil Failure:

Before I had the chance to take accurate performance or fuel consumption figures, I was brought down to earth in no uncertain way-the engine stopped! Roadside investigation revealed that the primary winding of one coil had become open-circuited; it was the work of a moment (Well, almost) to connect the upper HT cables of each cylinder to the good coil, substitute a 1.5 ohm, 50 watt wirewound resistor for the failed unit, and reset the ignition timing to the usual position, before we were on our way again. A failure of this type should be most unusual, Dyna coils being renowned for reliability... such is life.

Continued Running:

The great day finally arrived, when my replacement Dyna coils finally arrived from California- no charge was made, even though the warranty period had been exceeded by several months. Herman the German was reconnected to all four plugs, and, with the ignition timing retarded by eight degrees, I restarted the evaluation process which had been brought to an untimely end when one of the original coils had failed.

Everything seemed to be as I remembered it- generally smoother, with a definite improvement in mid-range response, and slightly darker tailpipe deposits indicating that rather more of the available fuel was being burnt. I was, however, now aware of a definite power loss below two thousand rpm or so. Further retarding of the ignition accentuated the problem, which did not clear until the timing was advanced by four degrees, the low

speed setting then coinciding with TDC. Overall performance, on my commuting route to Bath, was, however, below the level attained with the standard system... there was clearly a problem.

Effect of Compression Ratio:

Dual ignition systems on higher compression engines had not produced this syndrome; The effect of the low (8.2:1) compression ratio of my R100 would be that the combustion process, once initiated, would take longer to complete than would be the case with an equivalent high compression engine.

In my case, this meant that if the timing were sufficiently retarded to provide maximum power at higher speeds, it was too retarded to provide the same benefit at lower speeds, when the centrifugal advance unit had not fully operated. Under these circumstances, where the ignition was taking place after TDC, the combustion process could not reach maximum pressure until after the crankshaft had passed its point of optimum leverage.

In the case of a higher compression engine, the more rapid combustion process would take place within a smaller crank angle, permitting the point of maximum pressure cylinder pressure to coincide more closely to the point of optimum leverage.

Modifications to Advance Unit:

I therefore reverted to the standard system, but will eventually modify the advance unit to reduce the travel of the bobweights by some 20%, which will provide standard timing at low speeds, but reduce the advance at higher speeds to give optimum engine characteristics.

1980 R100T Installation:

Meanwhile, Pete had also machined a pair of heads for Howard Truscott's R100T, which became the subject of a 'Plan B' installation. As an experiment, we made the initial start without retarding the ignition, and were rewarded by an explosion which blew off both the left hand carburettor and its associated half of the air filter casing! After retarding by four degrees, Howard conducted a test run, and pronounced himself to be greatly pleased; we then dropped the needles fully, the results of which pleased him even more! The optimum ignition timing was found to be at a total of 8 degrees retarded from standard (ie: a static timing of 4°ATDC)

Not being given to particularly gentle riding, it was a little difficult to pin Howard down on fuel consumption, although his impressions agreed with mine that his engine had gained a good 'Edge' of performance, particularly in the mid speed range, and was generally nicer to use.

The R100T did not produce the trade-off of top and bottom end power which was noticed on my R100; it is one of the higher compression BMW twins, at 9.5:1.

Use of 1981-Type Air Filter:

These pleasant characteristics were further enhanced by the fitting of a post-1981 type of air filter assembly, which, while not so 'classic' as the all-metal pattern, is able to extend the carburettor intake pipes to double their original length, and to

provide them with a large plenum chamber from which to breathe. The effect of this on the engine's low speed torque was such that Howard found it possible to negotiate a certain mini roundabout, previously regarded as a second gear requirement, in third! A very cost-effective modification.

In addition to the air filter casings, it is also necessary to obtain the crankcase breather pipes, the correct intake elbows for a similar 1981 model, and also the complete choke mechanism (From clutch lever assembly to levers and springs on the carburettors)

When fitting the 1981 choke mechanism to a pre-81 type of carburettor, an anchorage will have to be provided for the return springs; Carefully file away the rib around the throttle cable adjuster, to fit a 6mm washer below the adjuster locknut. A 1mm hole drilled at the edge of the washer will provide a suitable anchorage.

Remember that there are at least two different sizes of intake trumpets for this type of air filter! These trumpets are of a "tuned" volume, and should not be modified in any way; a recent test of a modified R100GS in an American magazine recorded a large loss of low down power and torque after holes had been drilled in the sides of the trumpets.

Comparative Performance:

The journey to the 1989 FIM Rallye provided a good example of what a dual ignition system can do; as usual, I was mounted on Herman the Trusty Twin, in standard, but carefully adjusted condition, while Howard was running happily on the 'Plan B' twin plug system. My fuel consumption worked out at a little over 60 mpg, some journeys returning high sixties, and the occasional 70 mpg day...pretty much as usual.

Howard was travelling in company with the Hotel Group, all of whom were K100-mounted, and given to pretty rapid progress; in such company he would have previously returned no more than 55 mpg, but this year was able to cover anything from 65 to 74 miles per gallon... he generally used 20% less fuel than his riding companions, who had previously used slightly less than Howard!

The only problem which was encountered was one of a slight hesitation on initially opening the throttles at high altitude when climbing passes such as the Col du Tourmalet and Col d'Iseran, both of which are over eight thousand feet high- this was later cured by use of larger (50cc) pilot jets.

Use of Fuel Additive & Octane Requirement:

In spite of the twin plugging, Howard was still experiencing some pinking, even though he was using four-star fuel; after much thought, a chance conversation introduced me to the use of a fuel additive, which was claimed to reduce pinking, and provide lubrication for the valve seats, top piston ring, and upper bore in place of amount of tetraethyl lead which is no longer provided in the fuel.

In the absence of lead, other octane-boosting additives, such as benzine and ethanol, are added to the basic petrol. Being of a volatile nature, these additives tend to evaporate, and in so doing combine to produce compounds which are not conducive to

good combustion, promoting the growth of carbon deposits at a far greater rate than has been common since the mid fifties.

The effect of these carbon deposits is to reduce cooling of the compressed charge, due to the insulation effect of the build up within the combustion chamber; this increased temperature increases the tendency for spontaneous detonation. This effect, combined with a reduction in the efficiency of cylinder filling caused by deposits on the back of the inlet valve head, increases the octane requirement over that of a new, and therefore clean engine.

The stated octane requirement of an engine is actually a mean figure, which takes into account usage-related increases such as these. Regular use of the additive, it is claimed, should maintain the octane requirement at the 'New Engine' figure by removal of these deposits, in addition to reducing bore and valve wear during the combustion period.

The additive, known as Formula One Octane Booster, is available in 500cc dispenser bottles, which will treat 400 litres of fuel, at around £65 per twelve-bottle case from:

G.T. Autochemilube, Lower Cherwell Street,
Banbury, Oxfordshire OX16 8AY
(Tel: 0295-56466)

In the interests of science, we dosed one tankful with the Miracle Additive, and, over the following two hundred miles or so, the pinking gradually faded away... Encouraged by this, Howard then added a gallon of unleaded to his reserve supply; the engine ran normally, and soon demonstrated its ability to consume such basic fuel without problems. With long-term ownership in mind, however, the use of four-star fuel is preferred by both of us, even with the additive, in order to extend the life of both bore and valves.

Carbon Growth:

The rate at which modern fuels, particularly the Unleaded type, promote the growth of carbon deposits was dramatically illustrated when Don Rolling installed dual plug ignition on his R100RT—after only 25,000 miles, the carbon in the valve recesses of the pistons was well polished, where it had been touching the valves... could this be the basic cause, in conjunction with regular over-revving, of valves being dropped?

Starting Problems & Plug Hygiene:

With some years of experience in these systems we have learnt that it is essential to maintain all four plugs in operation, as the loss of one plug by a short circuit due to external tracking or internal fouling will cause an eight degree retard in the effective ignition timing of the affected cylinder, as it would thereby be converted back to single plug ignition! With such a difference in timing between the cylinders starting is very problematical, the engine appearing to be oversensitive to use of the choke, yet requiring its use.

The answer to these problems is therefore to ensure that the lower plug caps make a good seal with the insulators of the plugs—NGK manufacture such caps for 12mm plugs, but they can be difficult to obtain, and Bosch manufacture suitably long leads

for cars, with rubber plug caps which are probably better still.

It is also essential to use the correct (ie:Standard) grade of plugs, in order to avoid fouling. In general, pay great attention to the hygiene of your spark plugs, particularly the lower ones.

Should you then have any problems, use normal logical diagnostic procedures, and do not be convinced that the basic cause is the use of dual plug ignition- if it were that bad, we would have had aircraft falling out of the sky for years!

Further Development:

Even higher levels of economy are probably possible, as we did not experiment on Howard's machine by reducing the main jets from their original 160 to 155; Although listed by Bing, the 155 size is not available from BMW, as it has never been used by them. The original 2.66 needle jets are, apparently, the weakest size practicable. Should you not demand the ultimate in throttle response, or travel over high passes, the original 45cc pilot jets will usually suffice.

General Comments:

In spite of my particular problem, the basic concept of dual-plug ignition has been vindicated, given that one has a sufficiently high compression ratio - three other South-West Section members have since adopted this system, using Dyna coils, with great success.

The main advantages of the system have been proven- the ability to use modern four star, or even unleaded fuel in the older high compression engines without pinking, and an appreciable improvement in fuel consumption, with definite gains in mid range get-up-and-go and general smoothness.

Skeptics will ask why BMW do not use a twin plug system, as they must be aware of the deficiencies in their engines; the main answer is probably one of cost, as one extra coil, plug leads, and plugs, multiplied by the number of twins built every year, does add up to quite an impressive total! As most of the production is for fleet buyers, who are not particularly sensitive about obtaining maximum efficiency, but are concerned with costs, any deviation from the established design is not deemed to be absolutely necessary.

In reply to the obvious question of 'Is it really worth it?' I would say 'Yes' to owners of high compression machines who either do not wish to be bound to the use of an additive, or wish for a little extra from their engines.

If your main requirement is the ability to use unleaded fuel, or what passes for four-star these days, the best answer is probably the regular use of a fuel additive; should you then be caught without, your engine will be in sufficiently clean condition to tolerate the fuel.

To users of low compression machines such as my own, I would have to admit that it is not really worth the trouble, when one considers the gains in both performance and fuel economy to be made by sympathetic adjustment, which really transforms the overall character of the engine... during the return from the 1989 FIM Rallye, when we really had to go some in order to make

the ferry, after one of our number was suddenly taken ill, Roy Booth told me that Herman was the best- performing twin he had ever ridden in company with on his K75S- such an accolade, and all for no expense! (He was, in fact, so impressed that he bought an R100RS!)

The dual plug system, does, however, add a definite edge to the overall performance, and is worth the trouble to those who do not mind (or even enjoy!) having to take a little more trouble than is required of our higher-compression brethren...

Dual plug ignition does, however, work satisfactorily on the smaller low compression models, such as the later R80 engines, which due to their smaller bore have a more compact combustion chamber, and therefore have a shorter combustion period than a 'Thousand' of the same compression ratio.

Environmental Friendliness:

As a properly adjusted dual plug ignition system will burn a much greater proportion of the available fuel/air mixture, less total fuel is required to be provided. The resultant exhaust gas will therefore contain a far lower level of unburnt hydrocarbons. Some reports claim levels to be so low as to be almost zero. It will be possible to run the engine on unleaded fuel, even if it is a high compression model, and if combined with regular use of a fuel additive, valve seat wear will be negligible.

Ignition Timing and Carburettor Adjustments:

As a starting point for ignition timing, begin with the static timing retarded by 4° (ie: at TDC) - on the "OT" mark, and work from there; R100 models seem to prefer a little more advance (up to an additional 4°) while the R80 is usually happy at TDC.

It is worth the trouble to set the engine in its optimum standard condition, in order to establish its best steady speed at $\frac{1}{2}$ and $\frac{3}{4}$ throttle, and fuel consumption over particular routes, such as a motorway and a good "B" road - you will then be able to assess the benefit of each adjustment, and the entire project.

DUAL PLUG IGNITION - CARBURETTOR SETTINGS				
MODEL	MAIN JET	NEEDLE JET	NEEDLE	PILOT JET
R80 Monolever	130	2.66	2	45
R80/7 (55bhp)	140	2.68	2	50
R100T	160	2.66	1	45/50
R100RS/RT(1981)	160	2.66	2	45
R100RS ('78)	160	2.68	1	45
R100 (1981)	160	2.66	1	45

ADJUSTMENTS: For greater details of carburettor and ignition timing adjustments, with the associated maintenance requirements, see South West Section Technical Bulletins Nos. 2 and 3 - Boxer Servicing and Bing CV Carburettors.

TURBULENCE: As previously described, the production of turbulence in the combustion chamber is highly desirable, in order to present a rapidly rotating mass of fuel/air mixture to the relatively slowly advancing flame front. This ensures that a greater proportion of the mixture is consumed than would be the case with a low turbulence design.

The most popular method of introducing turbulence is the use of an appropriate cylinder head and piston design, which has been common practise in automobile engines for many years. Motorcycle engines have generally been confined to use of the basic hemispherical combustion chamber, which was originally designed in the very early years of the century. One of the earliest designs was the 1904 Peugeot, which was the first engine to feature a DOHC layout with hemispherical combustion chambers.

The basic hemisphere was a far better design for the production of power than any of its contemporaries, due to the excellent breathing properties conferred by its ability to house a pair of inclined valves which could not be accommodated within the diameter of the bore if mounted vertically.

However, as the piston reaches TDC in such a basic design, it merely compresses the mixture in a linear fashion, which even with a central spark plug cannot guarantee complete combustion, particularly in the case of large bore designs. In spite of this deficiency, the design has been very popular on high performance engines for many years, on both motorcycles and cars (Notably the XK series Jaguar engine, which has powered vehicles as diverse as the original XK120 in 1949, and the current Scorpion light tank!

The XK series engine, in capacities from 2.4 to 4.2 litres, suffers from the same lack of turbulence as the larger BMW twins, and, in race trim for the "C" and "D" Type Le Mans winners, was equipped with a dual plug ignition system. More recently the venerable Alfa Romeo 2 litre four cylinder engine has been provided with a "Twin Spark" ignition system to obtain the same benefits which will be provided to a BMW twin.

Design for Turbulence: Turbulence is generally produced by a design which suddenly changes the shape of the combustion space as the piston approaches TDC, so forcing the mixture into sudden motion as it is finally compressed.

The usual means of promoting turbulence in a hemispherical chamber is by the introduction of parallel "Squish" bands around the edges of the piston and chamber, which, as the piston reaches TDC, force the mixture out of the Squish band (Usually about 30 "Thou" deep) and into the smaller combustion chamber. Squish bands were introduced on the 1978 Boxers, but were discontinued the following year to reduce emissions of unburnt hydrocarbons, (The thin Squish band inhibits combustion in that area) before reappearing in 1981.

Modern automotive practice usually involves the use of "Wedge" chambers (Originally used on large American cars of the fifties) surrounded by a Squish band; mixture is therefore forced into the chamber, the shape of which promotes a swirling motion. While this design can produce almost as much power as a hemispherical head, it also produces about 10% more torque. It was not popular in Europe for many years, as our older small bore engines restricted the size of the valves which could be accommodated across the bore.