Plug Reading

The Bantam Racing Club Committee 1983

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Plug Chop!!

WHY?

Why do a plug chop? Two reasons: -

1. To try to read the results of the changes you have made to 'tune' the engine e.g., carb' settings, ignition timing, plug grade, compression ratio.

2. To try to read the engine conditions that are giving the current trouble e.g., high revving misfire, loss of top end power (or even the mid range version of these maladies), detonation etc.

HOW?

To perform or 'do' a plug chop is easy. To do it with safety (to yourself and others) takes a little more care and thought. The simple act of chopping the motor dead, at full bore (or whatever throttle opening you choose) is accomplished by first checking that the engine does stop when the throttle is shut (of course this should always be the case) then fit a new or freshly cleaned plug of the appropriate grade (more about which anon!) to the previously warmed up engine. Finally the engine can be brought up to racing temperature by driving it hard for a couple of laps, then on a full bore part of the circuit you simply shut the throttle and whip in the clutch both at the same instant so that the engine stops and the bike is free to coast to rest. It is at this point that your right hand (throttle hand) should be raised in the air to warn the following riders you are no longer driving your bike along but only coasting. Stay clear of the racing line and be prepared to stop and push if your coasting could cause those racing to change line.

WHERE?

A full bore part of the circuit we said that is easy to find at Snetterton, Cadwell and Llandow not so easy at Lydden or Brands short circuit:

Cadwell :- Down past the start and finish, having done your plug chop you can coast part way back up the hill to the paddock. If not on the last lap be sure you are on the outside line for the hairpin.

Llandow :- Paddock straight, dead easy.

Snetterton :- The long straight opposite the start and finish has a convenient run off area at the end of it. A long push back to the paddock? Not necessarily, if you carry a spare plug and spanner with you not on you, as, should the spanner be wedged between you and a strip of speeding tarmac, you will find spanners dig into you quicker than the tarmac very painful !!! A cyclists saddle pouch, an old tobacco pouch, pencil case stuck inside of the fairing is the usual ploy.

Lydden :- A burst of full bore in bottom rushing up the hill to the hairpin is the best I can manage there. The full bore in top rush down the hill from chesson's drift leads to the devils elbow and getting round there with the clutch in would be chancy, apart from the chaos you would create behind you with a bunch of fellow riders trying to guess where you are going to kiss the bank and doing their best not to join you.

Brands Hatch :- Going up the hill to Druids, you can then coast round the hairpin and down the hill, keeping to the right hand side of the track here to re-enter the paddock (centre of circuit) from the bottom bend.

WHEN ?

As previously stated when you are trying to 'tune' an engine or when you are trying to cure a power-sapping problem.

You will find you can be far more objective at a race circuit on a practice day than when you have the pressures of a race day influencing your judgment. Your efforts are more likely to be rewarded with success on a practice day, plus you can get more 'plug chops' on a practice day, therefore you can wring more changes, your testing can follow a logical order without so much temptation to skip vital steps and arrive at the wrong conclusion. Having said that a lot of useful checks are done during pre race practice and if you have tried a weaker jet for a race, then a 'plug chop' on the coming in lap could show the need to go even weaker or warn that you only just got away with it or more likely show that by going weaker you are generating more heat and over heating the plug therefore need to change to a 'colder grade of plug.

ABOUT SPARK PLUGS

Reading the plug is a misleading term to start with you will be attempting to 'read' the combustion chamber. To be precise the operating conditions inside the combustion chamber by removing part of that combustion chamber (what should be the hottest part) for a close examination

.

The first thing you have to learn is that there are some important differences in spark plug threaded ends, which are four diameters and lengths. Most plugs thread diameter is 14 mm, but Honda for example uses 10-mm plugs in small displacement engines and 12-mm spark plugs in all the 4's . There also are 18-mm plugs seen only rarely in motor cycle applications.

Because the differences in thread diameters are so large, few people get into trouble through trying to stuff a 14-mm plug into a 12-mm hole or vice-versa. The same definitely is not true of the plugs threaded lengths, or reach. Setting aside for the moment the small variations created by use of an inch based standard in a mostly metric world, there are just four nominal reach dimensions 3/8", 1/2", 7/16" and 3/4". These dimensions are followed by engine makers in the depths they give to plug holes, the idea being that the lower end of the plug face, should be flush with the surface of the combustion chamber.

People do make mistakes with plug reach, using 3/4" plugs in 1/2" depth holes is the most common error, and one fraught with unpleasant consequences. One of the disasters you can have from using a long reach plug in a short reach hole is purely mechanical in nature. In time the exposed plug threads inside the combustion chamber may become filled with hard baked deposits. If that happens you will find it almost impossible to remove the plug without also removing the plug hole threads. Reversing this kind of mistake, using a plug reach too short for the hole, lets deposits fill the plug holes exposed threads and may cause difficulties when you try to install the correct reach plug.

The worst and most immediate problem created by an over-long plug in an engine is that the exposed threads absorb a terrific amount of heat from the combustion process. This raises the plug nose temperature and may take them up high enough to make the side electrode act as a glow plug. What then happens is you have the white hot electrode firing the mixture far too early like an over advanced spark timing but worse because the early ignition causes yet higher combustion chamber temperatures which cause even earlier ignition, and so a runaway condition which if you are lucky will burn the plug but most likely will wreck the engine.

Even a single plug thread exposed in the combustion chamber will raise electrode temperatures quite markedly. That could be a real problem as plughole depths are not held to close tolerances, and the almost universal adoption of crushable plug washers gives the user a chance to compound the errors by over tightening when fitting a new plug. most spark plug manufacturer answer to the problem, is to leave an unthreaded relief at the lower end of the plug thread. the relief also serves as a pilot guiding a plug straight into the hole. Finally the relief accommodates differences between manufacturers interpretation of reach dimensions and tolerances. Lodge plugs do not as yet have this relief but they fit a solid copper washer in place of the crushable one, this can be re-annealed (softened) by heating uniformly to red heat and quenching in water.

Matters of thread length and diameter resolved, you can still get into trouble with a spark plug property called ‘heat range’. All conventional plugs, whatever the application have to stay hot enough to burn away deposits (oil, carbon etc.) that otherwise would short-circuit the spark, and that places the lower limit for temperature at about 370°C (700°F). There are multiple upper limits for plug temperature sulphurous fuel elements begin chemical erosion of the electrodes above 590°C (1100°F), oxidation of the nickel-alloy electrodes begins at 870°C - 980°C (1600°F - 1800°F) and at some point (which depends on compression ratio, mixture, throttle setting , etc.) the electrodes will be hot enough to cause pre-ignition. So to be safe, plug temperatures must be held between 370°C and 540°C (700°F and 1000°F) over the whole range of operating conditions.

Engines vary enormously, as do the operating conditions riders subject them to (some manage to keep the throttle open nearly all of the race) . So plugs themselves have to be given equally varied thermal characteristics. This is done by varying the length of the path taken by heat as it travels from the very hot centre electrode and insulator nose to the relatively cool areas around the body’s threads and washer. Plugs with long insulator nose which leads heat high into the plug body before it turns back toward the cooler cylinder are ‘hot’ or ‘soft’. Short nosed plugs with a shorter heat path are ‘cold’ or ‘hard’. Unfortunately the old-fashioned terms ‘hard’ or ‘soft’ plugs are being replaced by the American-ism ‘cold’ or ‘hot’ plugs. It must be remembered that the engine puts heat into the plug not the reverse. A ‘hot’ plug does not make an engine run hotter , neither does a ‘cold’ plug make it run cooler. The old-fashioned terms were more descriptive, you need a ‘harder plug to withstand conditions in a hotter running engine whilst a ‘softer’ plug could survive in a cooler running engine. Whatever ‘terms’ are used, the whole object is to match the thermal characteristics of the plug and engine so that the electrode temperature will stay between 370°C and 540°C
(1000°F and 1000°F) over the whole range of operating conditions.

The most common result of these confusions is to use a plug grade a bit ‘colder’ than is needed:

1. Because it is safer (you are not likely to burn or melt a ‘too cold’ plug).

2. One’s own engine is most likely to need the ‘coldest’ plug available (because of that ‘super pipe’ ; high compression ratio, advanced ignition; or simply the hard rider!);

3. “you only need a hotter plug to stop it oiling”.

All three reasons or assumptions are most likely to be wrong!!! Or should it be said? they are the wrong way to arrive at the plug heat grade for a given rider/engine combination.

Knowing which plugs are ‘hotter’ or ‘cooler’ than the ones you are presently have in your bike it is easy if you stick to the same brand. Nearly all the worlds plug makers use a number-based code to designate heat range in which the higher number mean colder plugs. Champion' do the opposite in the main but not always and sometimes have double digit numbers and sometimes single digits. Bosch's three digit numbers are a hold over from the early days when plugs were rated for engines' ' indicated mean effective pressure'. But combustion chamber pressure alone soon proved inadequate, for it was found that the thermal load on a plug, also depended on the spark timing, cylinder head cooling and even on the floe of mixture into the cylinder . These factors greatly complicated the business of assigning plug thermal ratings. Each plug maker has his own method of testing his design and assigning its thermal rating or 'grade', he will also test other manufacturer products and produce an equivalent chart. These cross-brand conversions are not exact, they only show the nearest equivalent. Stick with one brand and avoid troubles with reach.

There is more to spark plugs than just thread diameter and reach and heat range. The plug 'nose' configuration I.E., the arrangement of the electrodes, the ground (earth) electrode connected to the plug body or threaded part, the centre electrode should be found sticking out of the centre porcelain. One very useful variation of the standard spark plug has its insulator nose and electrodes extended from its metal shell. The projected configuration moves the spark gap further into the combustion chamber, which tends to improve efficiency by reducing the flame travel distance and making the combustion process more regular. there is a more important benefit the projected nose plug provides, in many engines what effectively is a broader heat range than you get with the conventional flush nose type. The projected nose is more directly exposed to the fire in the combustion chamber, and quickly comes up to temperature high enough to burn away fouling deposits after ignition occurs. Then during the subsequent inlet phase the swirling air-fuel mixture cools the plug's exposed tip. In this fashion the higher temperatures existing at full-throttle operating conditions are to some extent compensated by the greater volume of cooling air, the net effect is to make the projected-nose better able to cope with the conflicting demands of traffic and motorway riding for road bikes, and tight twisty sections and long straights in racing.

It should be evident that the projected nose plug's effectiveness depends on the pattern of incoming mixture flow. Four stroke engines often have intake ports angled to promote turbulence. If the plug positioned directly in the path of the intake flow there will be a large amount of heat removed from the plug's tip by this direct air cooling and that is just what you get in most four stroke motor cycle engines. Two stroke engines can benefit from projected-nose plug's fouling resistance which they get simply from the length of their insulator (it is a long way from the centre electrode back up to the metal plug body). However the two stroke's incoming charge doesn't always do a good cooling job on the plug and you will have to be very cautious in using a projected nose plug in your two-stroke racer.

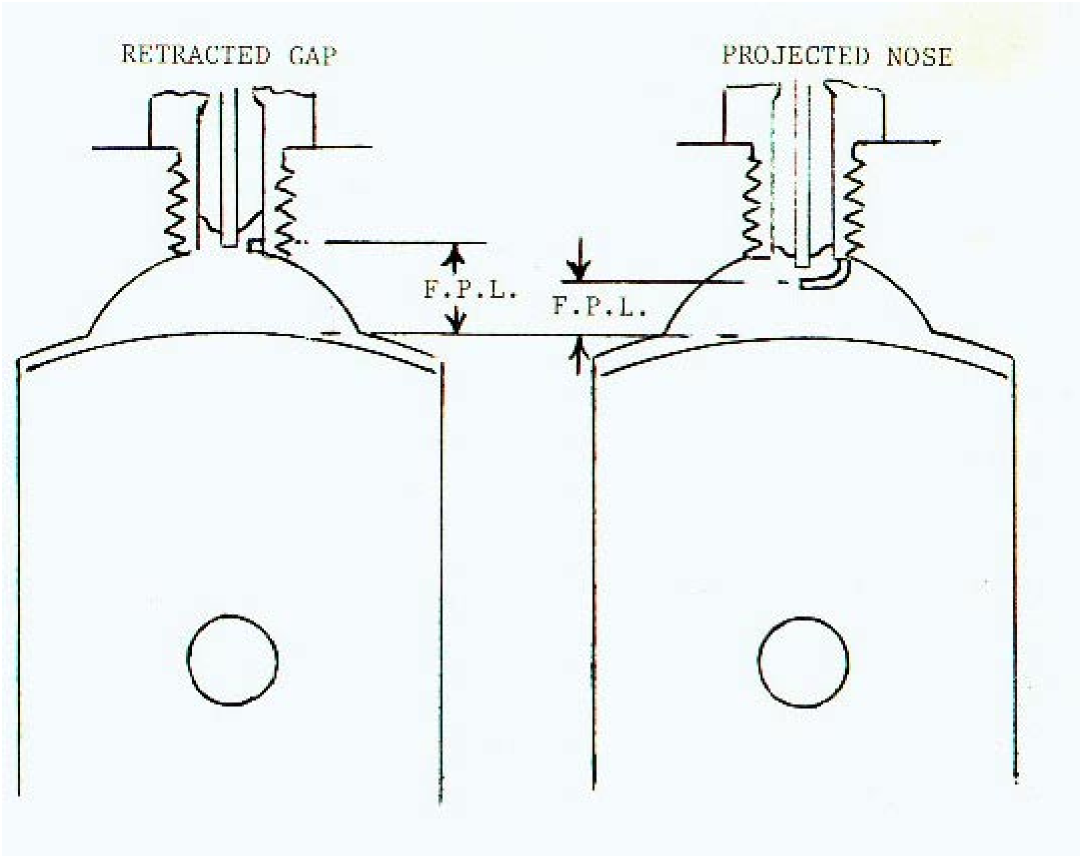
Limited plug/piston clearance in certain racing engines has prompted plug makers to create the retracted gap configuration. Champion inadvertently did every one a great disservice by labeling its retracted gap design as a 'R' plug, people thought the letter meant "racing" and used 'R' series in all kinds of high-performance applications where they were not particularly the best choice. Even if an 'R' plug's heat range (all are very cold) is right it's gap placement lights the flame back up in the hole and the combustion process never is quite as regular as it should be. The retracted-gap plug exists only because some engines present a clearance problem, it never was intended for use where conventional or projected nose plugs can be fitted.

Motor cycle ignition systems are the weak sister of the world's spark generators. Bikes therefore need all the ignition help you can give them, which brings us to yet another useful group of special spark plugs, those with precious metal electrodes. Conventional plugs have thick blunt electrodes made of an alloy that is mostly iron with a little nickel added to lend resistance to erosion. Special electrode plugs have a ground electrode made of ordinary nickel-iron alloy, but a centre electrode of something much more costly - platinum, silver or gold-palladium. Bosch still favor platinum, Champion ND and NGK offer plugs with electrodes in materials ranging from silver to tungsten. Gold-palladium seems to be the alloy tat offers the best price/performance advantage.

Platinum and gold-palladium alloys can survive the combustion chamber environment as very small wires and in that rests they're great advantage. Electrons leap away from the tip of a small diameter sharp edged wire far more willingly than from one that's fatter and rounded. So the fine wire plug requires less voltage to form a spark than one with conventional electrodes, and the difference becomes increasingly biased in the fine-wire's favour as hours in service accumulate and erosion blunts the iron alloy electrodes. There are of course drawbacks to precious metal plugs. They are more expensive and they are very sensitive to excessive ignition advance. The overheating you get with too much spark advance affects the plug's centre electrodes before it can be detected elsewhere in an engine, and when subjected to this kind of mistreatment fine wire electrodes simply melt. Mick warns - an engine detonating sufficient to start melting the centre electrode, precious metal or nickel/iron, cannot run for long (1 or 2 laps) before it will melt/hole the piston. The melting/glowing electrode will quickly move detonation into pre-ignition.

Finally, some manufacturers market "auxiliary gap" or "booster gap" plugs, they have an air gap built into the core between the H.T. wire connection at the top (outside) of the plug and the centre electrode. Conductor deposits on a plug's insulator nose tend to bleed off the spark coils electrical potential (voltage) as it is building up to spark level strength. If so much energy is allowed to leak away, firing will not occur and the plug will be "fouled". Mechanics discovered this trick, of holding the plug lead slightly away from the plug terminal, to clear lightly fouled plugs and plug manufacturers have included it into some designs they now market. The air gap works like a switch keeping plug and coil disconnected until the ignition system's voltage rises high enough to fire the plug even though some will leak away on the fouling deposits on the insulator. Such fast voltage rise time simulate the characteristics of capacitor discharge ignition systems and offer no advantage at all when used in conjunction with capacitor discharge ignition (CDI).

It is helpful to know about these different plug configurations if you are doing your own maintenance and tuning work, and it is essential that you know how to "read" plugs if you are dealing with high performance engines, whether factory or do-it-yourself. The 'know how' can only be gained with experience so of course there is no substitute for going and having a go. You should now be able to avoid the most destructive combinations of mistakes. We have already seen three assumptions resulting in too 'cold' or 'hard' a plug being used, a belief it will help fend off that old devil detonation is another one.. Try to use too cold plug and very likely you will have to jet down for a lean mixture to avoid plug fouling and as you lean an engine's air/fuel mixture down near the roughly 14.5:1 chemically correct level it becomes extremely detonation-prone. Excessive spark advance is even worse in its ability to produce detonation and when combined with a lean mixture it’s enough to quickly destroy an engine.



When changing from retracted gap to projected nose configuration (or vice versa) in a relatively low head shape, the change to the Flame Path Length (FPL) can be a high proportion of the FPL therefore necessitating a change to ignition timing (in this case retarding, 0.1mm?).

COMBUSTION PROCESS

Before delving into 'plug reading' we have to have a common understanding of the combustion process, the following dictionary definitions of terms used, and the graphical descriptions are an attempt to this end.

DICTIONARY DEFINITIONS

COMBUSTION (COMB)
Burning. A chemical reaction or a complex chemical reaction in which a substance combines with oxygen producing heat, light, flame and pressure through confinement.

IGNITION (IGN)
The action of setting fire to something. Initiating combustion by raising the temperature of the reactants to the ignition temperature. Particularly the means of firing the combustive mixture in an Internal Combustion engine by an electric spark.

FLAME (F)
The glowing mass of gas produced during combustion.

FLAME FRONT (FF)
The outside surface of the above glowing mass of gas as it spreads through the combustion mixture.

DETONATION (DET)
Extremely rapid combustion which takes place within a high velocity shock wave. Also used loosely, but incorrectly, to describe the combustion reaction, which occurs during 'knocking' or 'pinking' in an internal combustion engine.

SHOCK WAVE (SW)
A very narrow region of high pressure and temperature in which airflow changes from sub-sonic to super-sonic.(This does not mean that a Bantam that detonates is super-sonic).

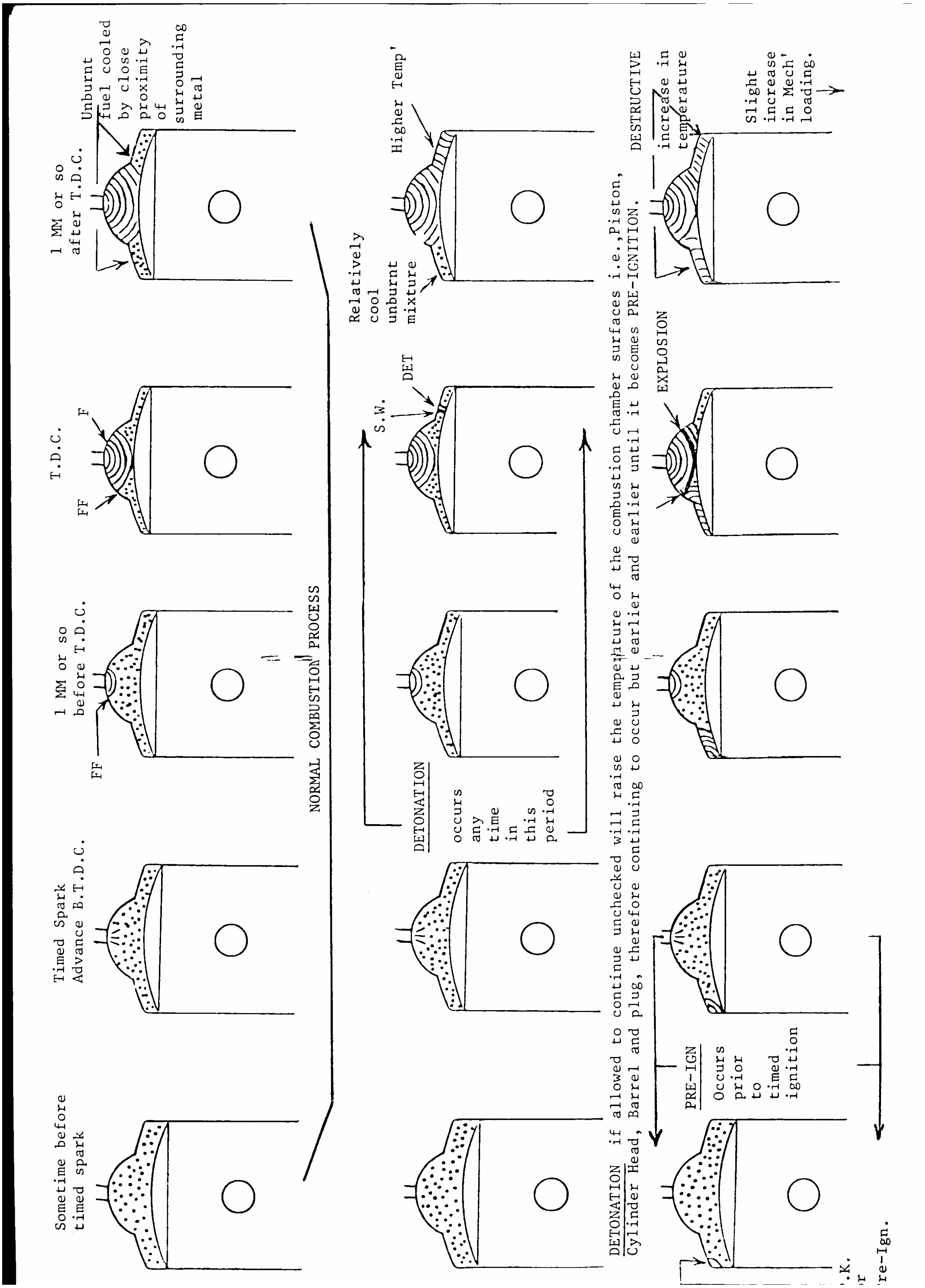
PINKING AND KNOCKING (P.K)
In the internal combustion engine (petrol). Violent explosions in the cylinder due to the mixture reaching ignition temperature prior to the mechanically timed ignition, often due to over compression of the air and petrol vapour before sparking.

EXPLOSION (EXP)
A violent and rapid increase of pressure in a confined space. May be caused by an external source of energy (e.g., heat) or by a couple of other causes, which need not concern or confuse us.

(T.D.C.).

Top dead centre of crankshaft rotation therefore highest position of piston up the bore.

(B.T.D.C.)
Before top dead centre.


Sometime before timed spark
Timed Spark Advance B.T.D.C.
FF
1 MM or so before T.D.C.
FF
T.D.C.
F
1 MM or so after T.D.C.
Unburnt fuel cooled by close proximity of surrounding metal
NORMAL COMBUSTION PROCESS
DETONATION occurs any time in this period
S.W.
DET
Relatively cool unburnt mixture
Higher Temp'
DETONATION if allowed to continue unchecked will raise the temperature of the combustion chamber surfaces i.e.,Piston, Cylinder Head, Barrel and plug, therefore continuing to occur but earlier and earlier until it becomes PRE-IGNITION.
PRE-IGN Occurs prior to timed ignition
EXPLOSION
DESTRUCTIVE increase in temperature
Slight increase in Mech' loading.

COMBUSTION DIAGRAM TEXT

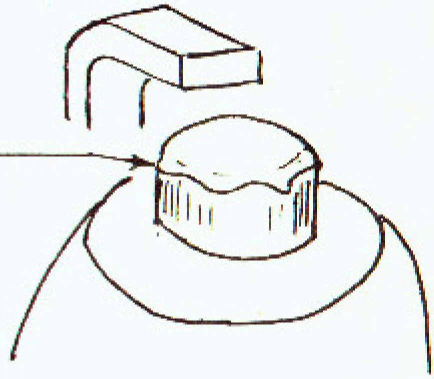
Most people who have had some experience with racing bikes (especially those with 2 strokes) know that detonation is a piston killer. Few really know the phenomenon, for what it is, a too sudden ending to the normal combustion process. You may imagine that the ignition spark causes an engine's mixture to explode, but it actually burns. There is a small bubble of flame formed around the spark gap when ignition occurs, this bubble expands - its surface becoming a bit ragged by combustion chamber turbulence - until all of the mixture is burning. This process begins slowly but quickly gathers speed because mixture beyond the flame front is being heated by compression and radiation to temperatures even nearer to the fuel vapour's ignition temperature. When the initial spark is correctly timed the spreading flame bubble will have almost completely filled the combustion chamber as the piston reaches top dead centre, and most of the burning will have been completed by the time the piston has moved just a millimeter or two down the power stroke. The final phase of this process can be shifted from simple burning into a violent detonation of the last fraction of the whole mixture charge. Starting the fire too early will produce detonation, as it gives the mixture out in the chambers far corners time enough to reach explosion level temperature. A slight lean mixture detonates at a lower temperature. Slight over compression raises the temperature of the whole mixture charge. It is all a function of ignition timing, mixture, and compression ratio in any given engine, and spark plug heat range plays absolutely no part in it.

PLUG READING

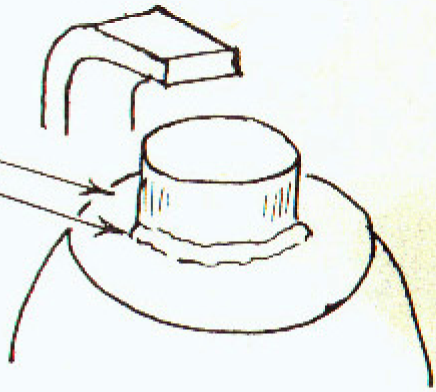
Your engine's spark plug does not cause detonation but it can tell you when and why the phenomenon has occurred. Moreover the spark plug can tell you with remarkable precision how much spark advance and what jetting your engine needs. Those are the things you can 'read' in a spark plug and all that is written there will be revealed clearly when the heat range is set right.

How do you know when you have chosen the right heat range? it is easy, a spark plug should be getting hot enough to keep its insulator nose completely clean, with all deposits burnt away but not so hot that its electrodes show signs of serious overheating. These are things to look for on a new plug or freshly cleaned (light vapour blast) one, which has been subjected to a few minutes of hard running. After many miles of service insulators acquire a coating of fuel deposits, with some colouration from oil in 2 stroke applications and there will be some erosion of the electrodes even when everything is normal. Don't try to read old spark plugs, even expert's find that difficult they will have had the sharp edges of their electrodes eroded away. A fairly new plug with its electrode corners still intact freshly cleaned by a light vapour blast (not a wire brush) as done by some proprietary plug cleaners can be used to good effect. A new plug will present unmuddled information about what is happening inside an engine, and give you a complete picture after just a few minutes of hard running. At least they will if they are running hot enough and that should be hot enough to keep the insulator clean.

And not so hot that the centre electrode starts to melt, under a magnifying glass it can look like the icing running off the cake.

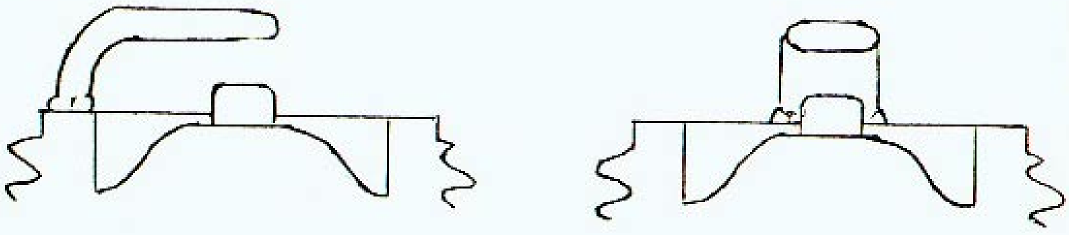


Bistering on the ceramic insulator nose and boiling of the cement are two other indications of overheating.



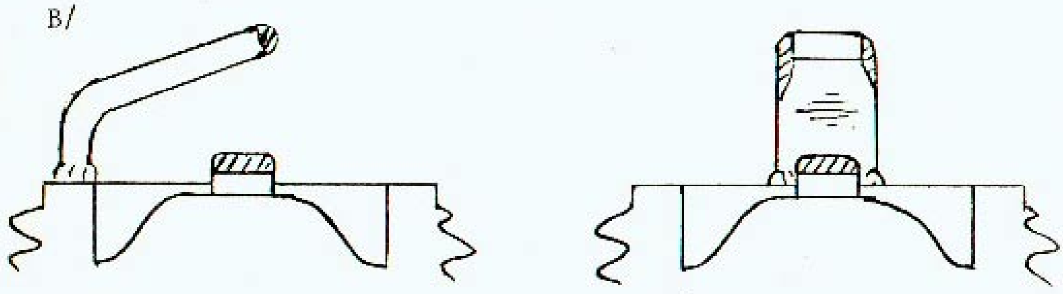
The edges of slightly eroded plugs A/ can be renewed as illustrated below:-

A/



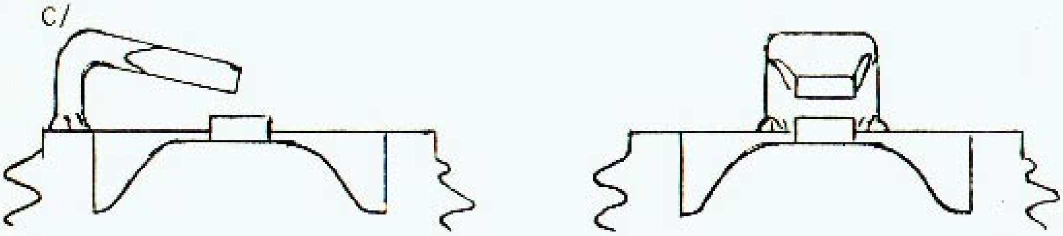
Bend the earth electrode up out of the way (light vapour blast at this stage) remove the rounded corners (shaded area in B/) carefully with a sharp file:

B/



Bend the earth electrode back down to correct gap as in C/:

C/



WARNING over zealous vapour blasing can blast all of the centre electrode cement away, it can also ruin precious metal centre electrodes.

COMPRESSION RATIO (C.R).

So far so good, the experts have thus far been of one accord. Now we have to prove Compression Ratio, Ignition Advance and Mixture Strength, our experts are not in the same agreement. Taking compression ratio first Gordon Jennings prefers not to mention C.R but recommends 135-165 P.S.I. cranking pressure. Of our resident ace's George Harris was the one out of step with the majority in quoting C.R. in terms of the geometric value i.e. calculating using the full stroke of the piston and not the remaining part of the stroke after the exhaust port has closed. George recommends the following maximum C.R.'s:-

Air cooled Bantam - 13:1
Typical air cooled alumininium Barrel - 14:1
water cooled Barrel - 15:1

Mick Scutt says:-

"on this point it seems that it may be better to use geometric values as a guide. I have checked up on a few engines (Bantam) and it seems that those that have higher exhaust timings generally have lower C.R.'s, probably because they are breathing better. The ratio's are calculated using all the stroke they are all between 12and 13 to one although the spread of values is much greater when calculated from exhaust port closing. I would go along with George on this an recommend an absolute maximum of 13:1 preferably less to start with"

Both George and Mick disagree with Dave Hunters recommendations:-

125cc with good cylinder filling - 7.8:1 (i.e. 96(Exhaust 9.1cc trapped volume giving geometric C.R. 14.6:1)

125cc Bantam with normal 3 port transfer system 8.8:1 (i.e., 86(Exhaust 9.25 cc trapped volume giving geometric C.R. 14.3:1)

An ex Bantam racer, now a development Engineer with a 100 cc Kart engine manufacturer points out, that the 100 cc engines use excessively high C.R's of around 11:1 from exhaust closing. The poor cylinder filling they have to have in spreading the power from 6,000 rpm to 16,000 rpm, (no gearboxes!) they not only can get away with these high C.R's indeed have to use them to achieve their relatively modest 15 B.H.P.

So how does one 'read' the effectiveness of a particular engine's C.R. the best guidance I have seen comes from Mick Scutt:-

"If the compression ratio of an engine is too high then it will suffer from persistent detonation and overheating problems that cannot be overcome by retarding the ignition or by richening the mixture.

Excessive retarding or richening reduces power output dramatically but a lower C.R. than optimum will cause only a minor loss in power.

The optimum ratio for an engine can only be found by experiment but it is not worth putting great deals of effort into this as the gains are really very small when approaching the optimum.

The C.R. should not be experimented with until an engine is running reliable so that small changes are easily noticed. It is all too easy to raise the ratio to just over the optimum so that any other small changes to the engine or fuel will bring on the overheating troubles.”

IGNITION ADVANCE

It is impossible to separate the question of ignition advance from the primary evidence of the plug overheating, which is most strongly shown on the centre electrode. If you inspect this electrodes tip with a magnifying glass (x5 or x10) and see that it’s edges are being rounded by erosion and melting, then you know there is overheating. You should also have a close look at the tip of the ground electrode, checking for the same symptoms. Finally inspect the condition of the insulator, which should be white but with a surface texture similar to its new state, a porous grainy appearance is evidence of overheating. If signs of overheating are confined mostly to the centre electrode, it is a safe bet you are using too much ignition advance. retard the timing in small (0.004” or 0.1 mm) increments and as you get close to the optimum you will find two things happening, first the plug will be running colder. Second the centre electrode will begin to acquire a film of fuel deposits extending out from the insulators nose towards its tip.

The fuel film is what you watch when making fine adjustments in ignition advance. In an engine that has been given just a few degrees excessive advance (as most have) the fuel film will only extend outward along part of the centre electrodes exposed length ending abruptly a couple of millimeters from the tip. The portion remaining will not be filmed over simply because it has been hot enough to burn away the fuel salts dusted over the rest of the electrode. You will have the correct spark advance when the centre electrodes fuel film continues right to within a hairs breadth of the tip. There are a couple of points to be observed in this matter. An over retarded ignition timing will not show except as absence of any evidence pointing to too much advance. Also a spark itself will blast spots in the electrodes fuel film, when there is enough combustion turbulence to blow the spark sideways into a curved path you will get a cleared area on one side of the electrode. This lopsided spark blush should not be mistaken for the more sharply defined ring associated with the electrodes tip overheating produced by excessive spark advance.

Having arrived at the optimum ignition timing or just on the safe side of it, you should check that the heat range of the plug is still suited to the engines operating temperatures.

MIXTURE STRENGTH

Gordon Jennings and our experts are at odds on how to arrive at this one, or should it be said they reserve judgment on some of Jenning’s more controversial prognosis.

Before looking at the provocative ideas from across the Atlantic, it would be best to study George’s easier to follow guidance :-

“Mixture Strength like most 2-stroke parameters, is a very complex subject if dealt with in depth.

Yes, theoretically there is a correct air/fuel ratio, which should give maximum power , but in practice this will depend on many other variables such as mixture mixing efficiency, degree of dilution with exhaust gases remnants etc. Further more , a variation from an otherwise optimum mixture strength may be necessary depending on barrel cooling efficiency, breathing efficiency, ignition advance and compression ratio.

Assuming a “basically good engine” with sensible C.R. ignition advance and plug grade, the overriding consideration is to jet to just avoid excessive piston crown temperature at full bore, and this will again depend on the cooling efficiency (extent of Barrel/head finning, whether water cooled by thero-syphon or pump etc.) otherwise you may well have a motor which will develop maximum power for a lap or two but will never finish a race! This is particularly true of an air cooled Bantam which has relatively scant finning and an iron barrel to compound the issue.

My personal advise is to standardize on a particular plug grade (suggest N80G for air cooled Bantams and N82G for water cooled versions, avoid extreme cold or extreme hot grades of plug) and establish a definite relationship between plug and condition of the piston crown after a series of full bore plug chops. You will then have a firm datum from which to work when reading the plug only. The end face of the plug (threaded end) and the insulator nose will give a good indication of plug (and hence piston crown) operating temperature, and as long as you are jetted to be just, but absolutely clear of any top end “wooliness”, there is little practical benefit in jetting significantly weaker.

Piston crown condition after a full bore chop should be typically cool black or dark brown around all of the squish area except that portion nearest the exhaust port and centre of the piston crown, which should be medium/light brown.

Although very slight tinkle may be acceptable (though still undesirable) on acceleration, on full bore ensure there is no audible or visual signs of detonation i.e., piston and cylinder head should be devoid of any signs of light sand blasted appearance in any areas. (Bear in mind excessive ignition advance or too high a C.R. can cause detonation as ell as too weak a mixture).”

Mick Scutt would add at this point :-

“If the piston or the head has a light carbon coating on the crown then mild detonation will cause small specks of carbon to be blasted away particularly at the outer edge of the squish area. (the sandblasted effect George mentions is generally quite serious).”

And now, something to make the more experienced tuners sit up and take notice. If you don’t agree with it, don’t knock it, try it !

A lot of amateur tuners, some of whom are fairly successful, will look at some plug freshly removed from a two-stroke motor and offer advice based on the colour of the oil deposits on the insulator nose. In fact if the plug is hot enough there will not be any colour and if there is, that still has nothing to do with air/fuel mixture. If you think about it you will realise that the only colour you can get from an air/fuel mixture is black the colour of soot, which is not brown or tan or magenta or any colour other than black. If your engine mixture is too rich, the sooty evidence will present on the spark plug's insulator, in a very particular area.

you will not find soot out near the insulator on a plug that is running hot enough to keep itself from fouling because the temperature will be too high to let soot collect. The insulator is much cooler deep inside the plug body and coolest where it contacts the metal shell, which is precisely where you "read" the mixture strength... Look far inside a plug where its insulator joins the metal shell and what you will see there, if your engine's mixture is too rich is a ring of soot. If this ring continues outward along the insulator to a width of even a millimeter you can be sure the mixture is rich enough to be safe, and too rich for maximum output. In most engines, best performance is achieved when the mixture contains only enough excess fuel to make just a wisp of a "mixture ring" on the plug insulator. Air-cooled two-stroke engines often will respond favorably to a slightly richer mixture, which provides a measure of "liquid cooling". Some four-stroke engines give best power when the mixture is leaned down to such an extent that the last trace of soot deep inside the plug disappears.

Never try to jet too close to a best power mixture until after you have taken care of spark advance. As previously noted, the air/fuel ratio that yields maximum power is only a shade richer than the one that is most detonation prone. Fortunately the plug will tell you when there has been even slight detonation inside your engine. The signs to look for are pepper-like black specks on the insulator nose and tiny balls of aluminium concentrated around the centre electrode tip. Severe detonation will blast a lot of aluminium off the piston crown and give the plug a Grey coating - which is a portent of death for the engine. A few engines will just show a trace of detonation when jetted and timed for maximum power, but that never produces anything more than a few minuscule spots of aluminium gathered on the centre electrode's sharp edges. If you see more aluminium and an extensive peppering evident on your plug, you are indeed in trouble.

It cannot be stressed too strongly the need to give ignition timing your closest attention, because excessive spark lead is the most frequent cause of detonation. You cannot stop advance produced detonation with a cold "hard" spark plug nor with anything but a wildly over rich mixture. To high a compression ratio is another frequent cause of detonation, brought about accidentally by a change of components, crank rod or piston, or change in the breathing efficiency of the engine. A compression ratio that has worked well with no detonation, can be too high if a better expansion chamber or better shaped ports or a combination of both or a bigger carb introduced, and they trap more air/fuel mixture in the combustion chamber, (better breathing). You will have more air/fuel mixture in the same volume therefore achieving an effective greater compression and generating more heat in the process, so to capitalise on the better breathing you would have to lower the compression ratio. Air leaks between the carburettor and the final combustion volume will make a nonsense of mixture strength checks you may be making. On a two-stroke, this means inlet track, crankcases, cylinder head and exhaust port. Leak testing the whole system at 10-12 P.S.I. with a leak rate of better than 1 lb. in four minutes, is really worthwhile.

To sum up the clutch and throttle adjustments have to be spot on so that the rider can perform or learn to perform, good reliable "plug chops". Organise a "practice day" if a lot of sorting, or a lot of learning has to be done. Select a plug brand to use; the precious metal centre electrode, projected nose type is a good, easy to read, configuration to use in a modern racing two-stroke.

The plug grade is the first variable to grapple with and the foregoing recommendations could start you in the right ball court. An understanding of the best heat ranges should be sought early, If only to recognise an over heating plug that can carry no more evidence than that.

Ideally you want to sort compression ratio, ignition timing and mixture strength, in that order, but unfortunately it is not as easy as that, as these three variables are so inter-related.

The recommendations on page XX show how even proven experts disagree. Therefore it is difficult to get the compression ratio right first time.

Maintaining the manufacturers design compression ratio has got to be the right place to start when dealing with production racers. Maintaining all cylinders at the same compression ratio is the right starting point when dealing with multi-cylinder racing engines.

The ease of setting the spark advance correctly can depend on ignition system you are using. Remember contact breaker points can wear (therefore altering the timing) very quickly. Electronic systems that depend on the alignment of two lines can be checked or calibrated by strobe. Beware not to depend on strobing at 2-3000 RPM. ; they must be checked at, or near the operating speed as they can have a self-advancing ability inbuilt but not apparent.

with so many different carburetors being successfully used now, a close study of your particular one has to be made to thoroughly understand which adjustment richens or weakens which part of the throttle opening. Page XX recommendations are the best starting point, but if attempting to find the “mixture ring” remember a few minutes / 1-2 miles on a new or freshly cleaned plug is all you can afford before other things confuse the issue.

Confirmation of your interpretation of the plug reading by consulting the piston crown must be made when learning. Experienced tuners will readily consult the piston crown, if in doubt. It is not an altogether easy trick to “read a plug” with so many things to remember all at the same time, but it is a pretty effective one when you get it right

MIXTURE RING