Testing your Ignition with an Oscilloscope.

AUTOMOBILE ENGINE TUNING IS a grossly misused and misunderstood operation. To many it implies some esoteric knowledge or ability — of listening to an engine and somehow deducing that the ignition must be advanced — or the mixture strength richened a bit on the front carburettor.

In reality it consists almost entirely of ensuring that ignition and carburetion is adjusted to the vehicle manufacturer's specifications.

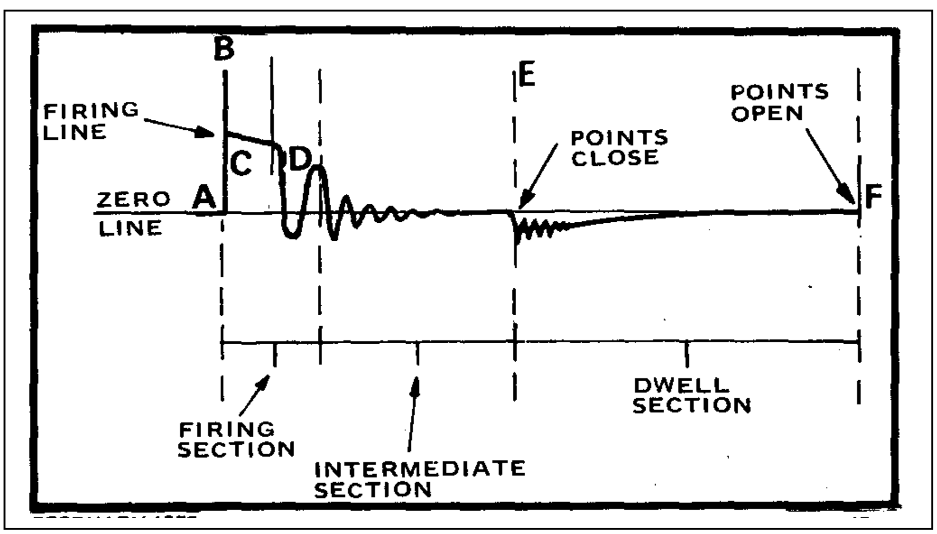
No more — no less.

But to do this it is virtually essential to use at least some basic instrumentation; a dwell meter, a tachometer, a good exhaust gas analyser — and preferably an ignition analyser.

Many car enthusiasts have at least a tacho/dwell meter — but few have access to an ignition analyser for such devices are costly indeed. Nevertheless if a few limitations are accepted virtually any standard oscilloscope can be used as an ignition analyser simply by making a couple of very simple capacitive probes — which can be as simple as clothes pegs and a few square inches of aluminium foil.

An ignition analyser displays waveforms from the primary or secondary side of the vehicle's ignition system. Surprisingly perhaps, this waveform provides information, not only about the ignition system in general but also about carburetion, and a number of mechanical conditions.

The analyser can do this because the voltage required to fire a petrol/air mixture in an engine is affected by many different variables including air-fuel ratio, cylinder compression, ignition timing, ignition polarity, spark plug gap and condition etc, etc.



THE SECONDARY WAVEFORM

The simple waveform shown is a typical secondary waveform that is derived from the secondary (or high voltage) side of the ignition system. This waveform is the one most commonly used since phenomena occuring in the primary side of the system will be reflected through the coil windings and appear in the secondary pattern.

Point A: is the instant at which the contact points open thus causing the magnetic field to collapse through the coil's primary winding. A very high voltage is thus generated in the secondary winding and this continues to rise — until a spark jumps across the distributor rotor gap and the spark plug gap (point B). The voltage at which this occurs is known as the 'ionization' or the 'firing' voltage and may be anywhere between 5 kV and 1 5 kV depending on the factors outlined above.

Points C—D: after a very short time the voltage drops substantially but the arc is maintained (point C). The subsequent section from point C to point D is known as the spark line and when viewed on a 'scope the amount by which this line slopes away from the horizontal is directly related to resistance in the plug and coil ht leads (ignition suppression). A slope of 300 or so is OK — if it's more than that then - it's worth checking lead resistance with an ohmeter. The total resistance between the centre terminal of the coil and the centre electrode of the plug should not exceed about 20k assuming the rotor gap is shorted out of course! Actual resistance is not critical but anything more than 30k may cause problems. Resistance over 50k almost certainly will.

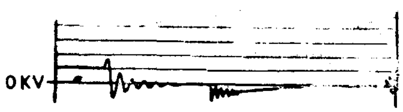
Point D: the section immediately following the end of the spark line (point D) should be a series of diminishing oscillations. These should appear as our illustration. If there are no oscillations — or just one or two — then it's a safe bet that there's a shorted turn in the coil. It may not have broken down completely yet but it's a safe bet it shortly will. (See also below).

Point E: is where the contact breaker points close. It is essential that there is a gap between the last oscillation of the preceding section and point E for otherwise the diminishing coil energy will be fed into the now closed points thus preventing the coil re-building its magnetic field for the next cycle of ignition.

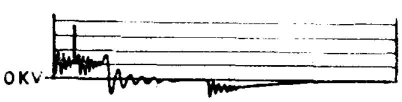
A great deal may be learnt by studying point E carefully, point misalignment, point bounce, burnt points etc may be spotted at this part of the waveform. The correct waveform at point E should be a short downward line followed by six or so diminishing oscillations.

Point F: magnetic energy will now build up in the coil until Point F. This is in effect the same point as our previous point A but in the next firing sequence. The section from points E to F is known as the dwell section and should occupy roughly the proportion of the total, waveform as shown in our main drawing. Dwell is adjusted by varying the contact breaker gap and should be set using a dwell meter.

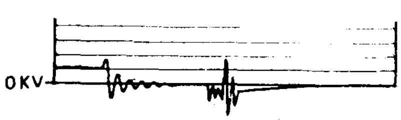
CONTACT POINT INDICATIONS



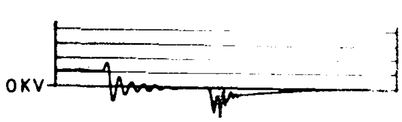
Unusual point opening signal (note hash extreme right of picture) burnt or arcing points.



Spike on spark line. Point arcing caused by faulty capacitor.



Points bouncing probably caused by weak closing spring.



Points misaligned – or dirty.

SPECIFIC INDICATIONS

Firing waveforms should be observed with the engine warm and running at about 1000 rpm--that is about 400 rpm higher than normal tickover speed.

Check each section of each firing sequence slowly and carefully. The various figures shown in this article indicate how specific faults will show up.

FIRING LINE

All firing lines should be of roughly equal height. If any plug is 10-15% or more higher than the rest, connect a jumper lead to earth and short out at the plug terminal. If the firing line now decreases the fault lies within that cylinder — either a faulty plug or unusually weak mixture (probably caused by a leaking inlet manifold gasket). If the firing line does not decrease there is a partial open circuit in the associated plug lead or that lead is not making firm contact with the connector within the distributor cap.

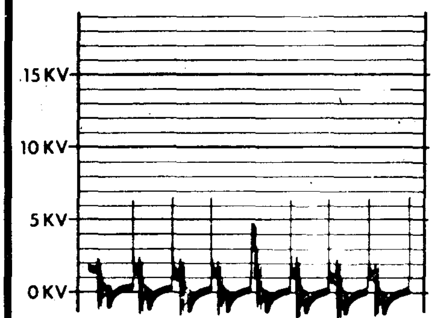
If the firing lines are unequal on a multi-carburettored engine check to see if the lines which are higher correspond to those cylinders fed by one common carburettor. If so it is probable that the mixture from the carburettors is unbalanced. A further but less common fault that may be spotted this way is an eccentric distributor cap — the gap between rotor and distributor contacts being wider on one side than the other.

At some time during the check ‘snap’ the throttle wide open momentarily, meanwhile watching the firing lines. They should all rise by about the same amount. If one or more lines rise substantially higher than the others then there is an open circuit plug lead or resistor, a wide plug gap or badly deteriorated plug electrode.

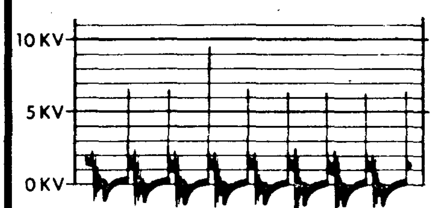
One or more lines staying lower than normal indicates spark plug breakdown or insulation breakdown in the circuit’ concerned.

SNAP THROTTLE INDICATIONS

All lines should rise but remain even.



One line breaks up. Insulation break down — probably spark plug fouling. Extreme cases will show similar signal under normal steady running.



One line rises above rest. Wide plug gap, partial break in suppression resistor, plug lead etc.

COIL OUTPUT AND INSULATION TEST

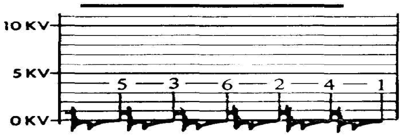
While the engine is running disconnect a plug lead and observe the firing pattern for that cylinder. The firing line should rise to about two to three times its previous level (to about 20 kV) and should extend below the base line by about half the upward distance.

If the firing line is short or intermittent — or if the lower section does not appear — then there is an insulation breakdown in the distributor cap, plug leads, rotor or coil.

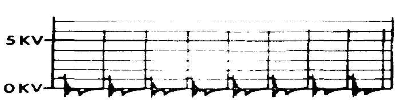
COIL AND CAPACITOR

A series of diminishing oscillations should be observed at point D in the waveform. If these do not appear, or are truncated, there is either a shorted or crossed turn in the coil — or the capacitor is breaking down.

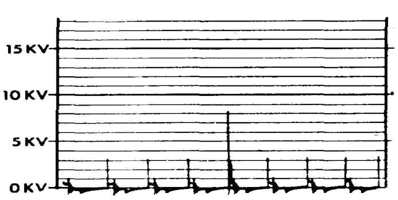
FIRING LINE INDICATIONS



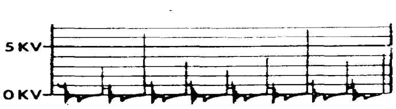
Normal pattern:
Note that the firing line for cyl. 1 appears at the extreme end of the trace. The remaining cylinders then appear in engine firing sequence.



Firing lines even but high:
Excess plug gaps, rotor gap, break in coil ht lead, mixture too lean ignition retarded.



Firing line high on ONE cylinder:
Break in plug lead, broken electrode in spark plug. To test short plug — if line drops, problem is within cylinder.



Firing lines uneven:
Break in plug leads, worn plugs, burnt distributor cap contacts, uneven air/fuel mixture.

BREAKER POINTS

Point E on the main waveform. The drawings accompanying this article show various fault indications. Note however that faulty point action may also show up at the point opening position (A). Check breaker point action with the engine running at all speeds. Weak or incorrect breaker springs cause the points to bounce is readily seen on the scope

COIL

With very few exceptions — notably on some Citroens — the high voltage side of a vehicle’s ignition system is designed to have positive earth — regardless of overall vehicle battery polarity.

The reason for this is that electrons are emitted more readily from a hot surface than a cold one so as a spark plug centre electrode always runs hundreds of degrees hotter than the side electrode the ignition system is devised so that a negative potential is, applied to the centre electrode.

If this polarity is reversed, the plug will require an extra 5 kV or more to fire it — and that voltage may not be available from the coil under heavy load — or when rurming at light throttle at high speed (remember a weak mixture needs a higher voltage to ignite it than a rich one).

If you are checking polarity on a specialist ignition analyser then the polarity is correct if the pattern is as shown in the illustrations in this article. If you are checking it with a standard scope (with no inverting device) then the pattern should be upside down if polarity is correct. (See below for full explanation).

Polarity is corrected simply by reversing the coil terminals. (Incorrect polarity is usually caused by a mechanic replacing a coil intended for a negative earth vehicle with a coil meant for a positive earth vehicle — or vice-versa. It may also, but less probably, be caused by an incorrectly manufactured coil, or less likely, by the vehicle's polarity being accidentally reversed by the battery being connected the wrong way round).

MIXTURE STRENGTH

This section is intended for the lucky man who has access to an exhaust gas analyser and tachometer as well as a scope.

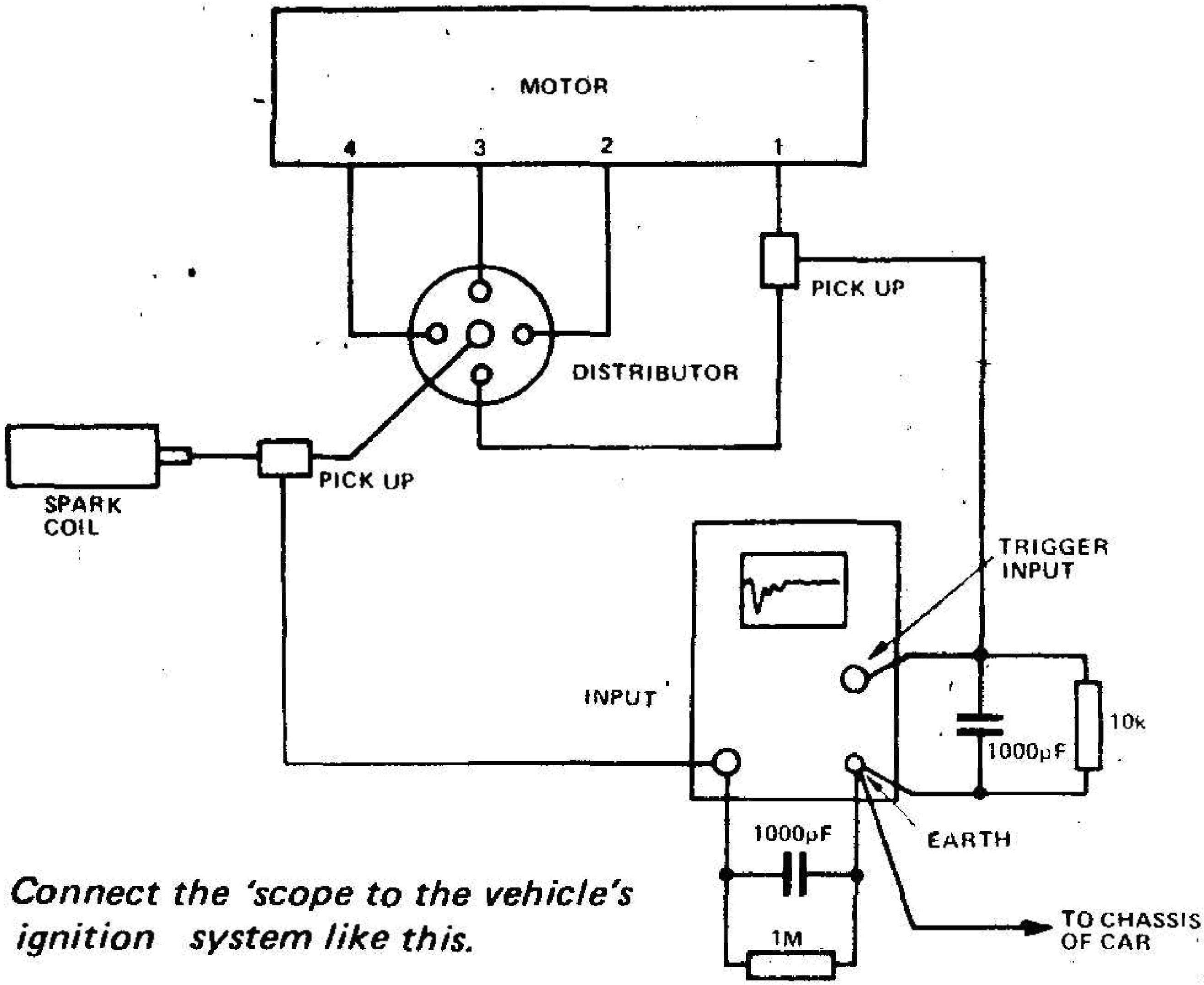
If cylinder compression pressures are identical, plugs in good order and evenly gap1ied, and plug leads and distributor in good order — then any significant difference in firing line heights will almost certainly be caused by differing mixture strength from one cylinder to another.

The voltage required to fire a rich mixture is substantially less than for a weak mixture: for instance a 12:1 ratio may need 3 to 4kV — whilst a 15:1 ratio may need 7 to 9 kV (typically). Thus even quite small differences in mixture strengths will be reflected quite dramatically in firing line height.

The only accurate way to adjust mixture strength is as follows:

Connect a tachometer to the engine and adjust slow running to 1000 rpm. Without looking at the gas analyser adjust mixture strengths so as to produce the highest tickover speed whilst maintaining the firing lines at an even height. if necessary reduce the tickover speed to keep it around 1000 RPM. Finally richen the mixture a shade until tickover speed drops by about 50rpm.

Then and only then – look at the gas analyzer. You should now have a reading somewhere between 14:1 and 15:1. If you haven't then there's something wrong with the carburetion system – an air leak in the induction manifold: incorrect float chamber level: blocked slow running jet or something.



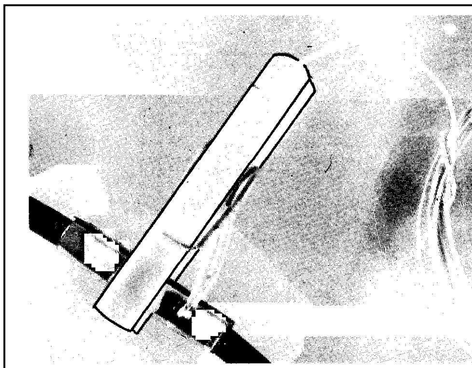
Connect the 'scope to the vehicle's ignition system like this.

CONNECTING THE SCOPE.

A motor vehicle's ignition system produces output voltages varying from 3kV to 20kV or more. These high voltages must be reduced to a workable level before coupling into an oscilloscope.

The simplest way of doing this is via a resistive voltage divider - however a capacitive divider will work equally well (we are dealing with ac signals) and is simpler to connect.

We can make one of the capacitors by wrapping a piece of Alfoil - about 50mm long - around the required lead and connecting this foil to the scope. A more professional approach is to glue a short length of split tube to a clothes-peg - as shown in the accompanying photograph. This will have a capacitance of about lpF - not much but ample for the massive signals we are sampling.



A simple pick-off can be made by glueing short lengths of split metal tube to a clothes peg.

A second capacitor of about l000pF should be connected as shown. The capacitive divider thus formed divides the input signal by about 1000:1 thus reducing the input signal to a workable 3 - 20 volts. A 1M resistor should be connected across the l000pF capacitor to provide a dc load.

The technique in use: Place the lpF capacitor over the main lead from the coil to the distributor and connect it to the 'Y' input of the scope.

If the scope has a trigger input, this may be used to lock in the ignition signal. Just make up a second capacitive pick-up and place this around number 1 plug lead. Once again use a l000pF capacitor as a divider but bridge this capacitor with a 10k resistor - not 1M as previously.

Start the motor and adjust the 'Y' gain and timebase frequency to give four (Or SIX or eight) complete firing sequences across the screen. The first complete pattern will be number 1 cylinder and the rest will follow in the engine firing order.

All waveforms may be superimposed by expanding the trace and triggering via the X input.

If the scope does not have a trigger input, synchronization is slightly harder to achieve. Number 1 cylinder may be identified simply by shorting out that cylinder momentarily.

When the scope is connected as described above, the ignition waveform will appear inverted relative to that seen on a commercially produced ignition analyser - and the waveforms shown in this article. It is surprisingly easy to adapt to an inverted picture, however, if this is found to be a problem, it can be remedied simply by coupling the signals into the scope via a simple 1:1 transformer. Details will vary from one scope to another but all that is basically needed is two coils of wire taped together. It may be necessary to reduce the l000pF capacitor(s) to 470pF. Just connect the secondary to give the correct picture.

If possible, arrange to calibrate the scope's vertical axis so that the magnitude of the signals may be measured. This is best done simply by taking average indications from several vehicles and 'calibrating' by transferring data from the graphs in this article. The result may not be accurate, but only a rough guide is required.