Tuning the Lucas Distributor

What is covered:

This document will look at tuning the advance curve of Lucas distributors, 23D/25D and 43D/45D types in particular, but the principles and approaches used apply to any distributor with mechanical advance. The effect of changing spring rates and free lengths will be analyzed, design charts and examples will be presented.

What is not covered:

Repair and rebuild of these distributors is adequately covered elsewhere and won't be discussed here. Answers to the fundamental question of what advance curve your particular engine needs or how the curve should be changed to accommodate engine modifications should be sought elsewhere. One piece of advice that will be offered is that after doing quite a bit of study in this area one thing is apparent: anyone professing to know what curve is suitable for your particular engine formula, without doing dynamometer testing, is offering nothing more than an educated guess, or less. Buyer beware.

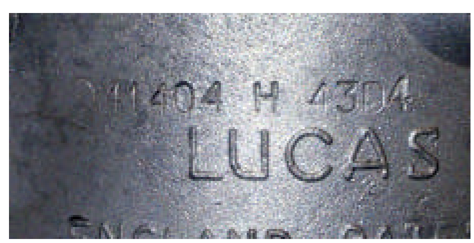
Background:

All Lucas distributors have identification numbers stamped on the side. These numbers include two important pieces of information: the service number and date of manufacture. A listing of service numbers is available[1] which includes the factory built-in advance curve, applications and other data. These data should also be included in the workshop manual for the vehicle on which you are working. The distributor manufacture date is in week/year format and can give a rough guide to the date of manufacture of the vehicle it came from.

Deciphering the codes:

40897 is the service number for the 25D4 used in early MGB's, 163 is the date code for 1st week of 1963

40819 is the 23D4 for all early Mini Cooper S models, this one manufactured 8th week of 1966

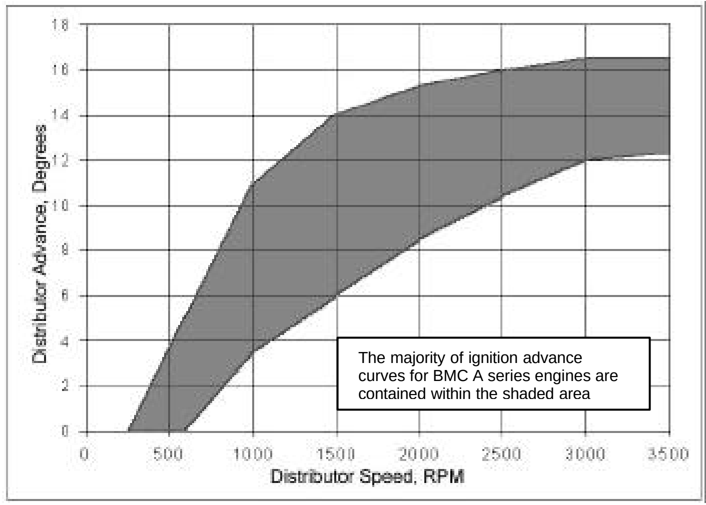


41404 is a 43D4 distributor for all Canadian Mini's from 1975-1980. The date code is outside the photo to the right

The service number suffix appears to distinguish changes in the production run

As you can imagine, there are thousands of different ignition advance curves, which makes sense considering there are hundreds of different engines each working under vastly different conditions.

However, studying advance curve data in the reference table reveals that all ignition advance curves have the same basic pattern, dictated by physics of the internal combustion engine: increasing advance with increasing engine speed. The reason for all the different curves, even within the same engine family, is discussed elsewhere[2]. If we look at all the advance curves for a family of engines, say the BMC A series, a bounding area can be drawn. A few things become clear when the detailed data is studied:



- There is no discernible trend based on engine size alone;
- Compression ratio, cam duration and intended fuel octane rating have the most influence on the curve;
- Virtually any engine in the family will operate with any advance curve in the group, although not at its optimum performance.

An engine does not know whether it is being serviced by a 25D, 23D, 45D distributor or one made by Hitachi or Bosch or even if it's electronic or points type, as long as the spark event is initiated at the right time.

Essentially, what is trying to be achieved by advancing the ignition spark as engine speed increases is to place the peak cylinder pressure point at 17º-20º ATDC. Most engines have a 10-fold increase in crank speed from idle to maximum, but air/fuel mixture burns at a relatively fixed rate. Thus, as engine speed increases, the mixture has to be ignited earlier. Placing the peak pressure point any earlier than the optimum point will either begin forcing the piston down the bore while the crank and rod are still lined up relatively straight, or earlier, which is characterized by engine knock. Any later than 20º ATDC will result in the pressure front chasing the piston down the bore and lost power. Engine knock can damage an engine, so factory advance curves are designed to be very conservative to avoid the situation and resulting warranty claims. Their thinking is that it is better to loose a bit of power than risk burning a piston.

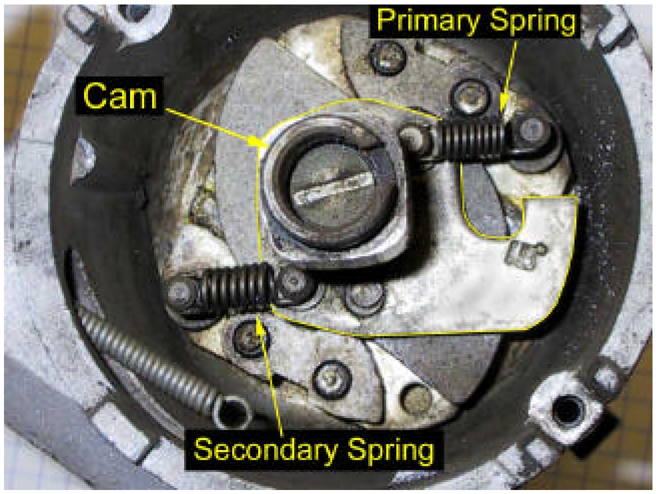
Factory ignition curves are an approximation, at best, at the time of manufacture. Manufacturers can never anticipate all conditions under which a vehicle will be operating, except in general terms and they most certainly could not anticipate that it would still be operating 30 or 40 years later. Thus, if any changes have been made to the engine to increase volumetric efficiency, or even if the fuel is not the same as intended, the stock advance curve is no longer optimal.

A look inside:

This is the area of focus for this document. After removing the breaker plate you will see:

- The cam with a stamped maximum mechanical advance figure
- Two small springs, the primary spring being the smaller, or weaker of the two.

These parts, plus a vacuum advance diaphragm if fitted, are the only parts that differ between any two service numbers in the same distributor family. As engine tuners, this is advantageous for us because with a change of the cam and two small springs any distributor can be made to deliver any desired advance curve. Under the cam are the bob weights that fly out under centrifugal forces and cause the cam to advance. It should be noted that all the advance weights are the same throughout a distributor family so they cannot be changed to affect the advance curve.



Curve tuning: the cam

The cam performs two functions:

- Open and close breaker points
- Limit the maximum mechanical advance.

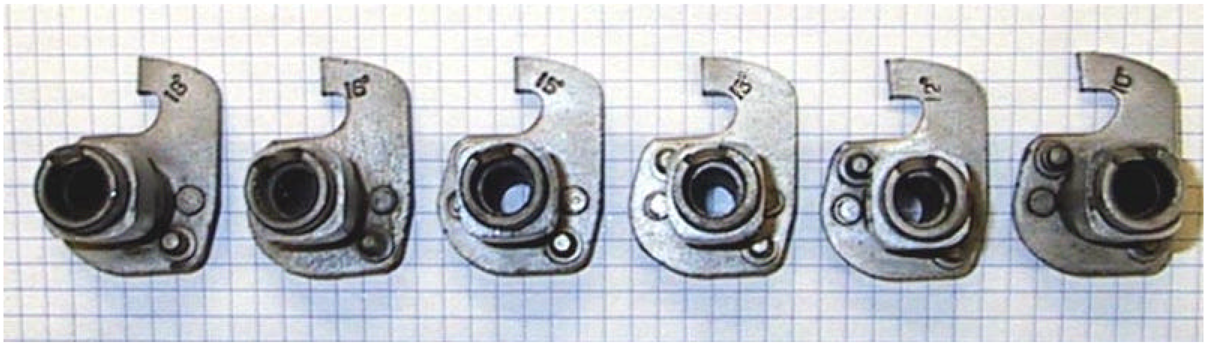
There are two types of cam profile, symmetric and asymmetric, but this is virtually irrelevant now because breaker points should not be used unless there is some overriding reason to do so. Aftermarket electronic kits should be installed to eliminate breaker points whenever possible.

Three areas can be manipulated to change an advance curve:

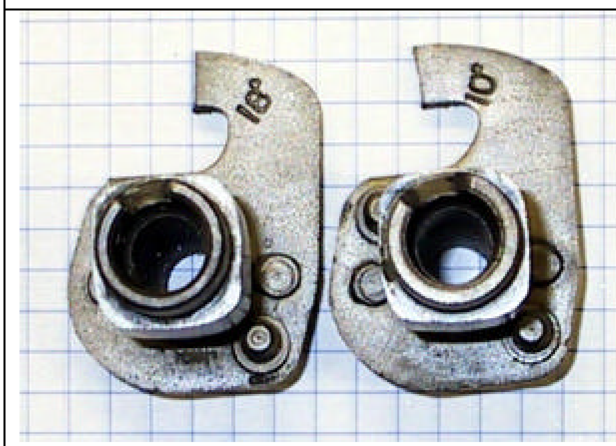
- **Spring free length**
- **Spring rate**
- **Maximum advance**

This means that the difference between any 2 distributors of the same family (23D/25D or 43D/45D) is 2 springs and the length of the cam arm.

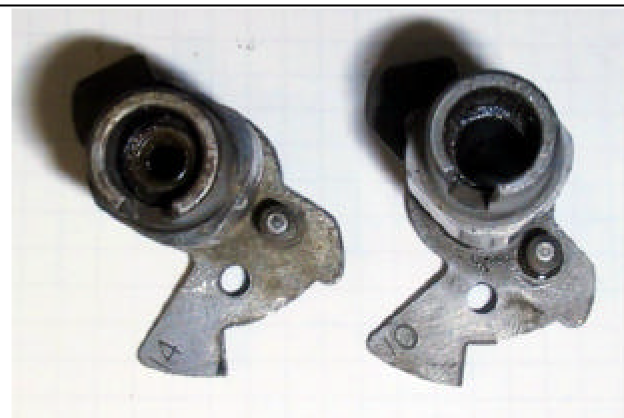
More important to this discussion is the maximum mechanical advance the cam will allow. The number of degrees the cam will advance is stamped on the arm. The difference between any two cams is the length of the arm; the lower the advance figure, the longer the arm. Obviously if a different maximum advance figure is desired the cam arm can be ground down to deliver more advance, or an extension welded on to limit the advance.



A group of 23D/25D cams ranging from 18º to 10º



18º and 10º cams, note the length of the arm



14º and 10º cams for the 43D/45D family

The first step in tuning an advance curve is to determine the maximum ignition advance the engine can tolerate, and subtract from that figure the initial static advance. The distributor mechanical advance will be ½ that figure. For guidance on this determination, see Hammill's *How to Build and Power Tune Distributor-Type Ignition Systems*[3].

EXAMPLE: 1275 A series engine with 270º camshaft, modified head, HIF6 carb, extractor exhaust ie the standard 'formula' street performance engine.

Initial static advance (crank): 10º BTDC
Maximum dynamic advance (crank) 36º BTDC

(36º-10º)/2=13º therefore, a cam with 13º mechanical advance is required

How the distributor advances between static and maximum is governed by the advance springs.

Curve tuning: spring rate and free length

This is the area of most mystery and misinformation in the entire engine compartment. However, it needn't be that way because with the application of a sensible amount of science any advance curve can be plugged into a distributor just by knowing the properties of the springs being installed. These properties can be calculated just by measuring a few key properties of springs, namely:

- Spring material (when in doubt, assume standard spring steel)
- Wire diameter;
- Body diameter;
- Number of coils;
- Free length between end loops

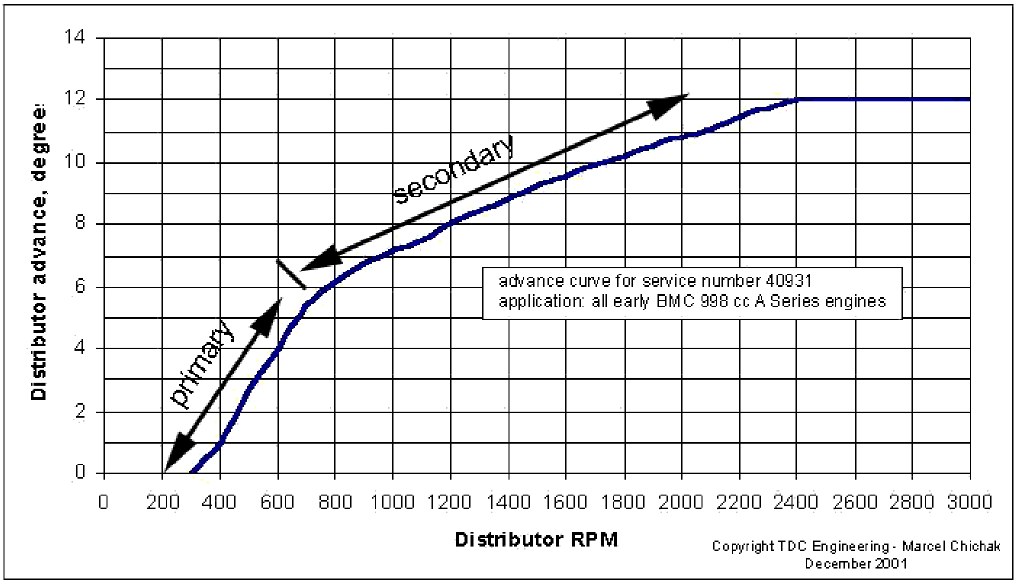
These measurements can be plugged into a standard extension spring force formula, or a convenient program such as the one supplied by Southern Spring[4], to calculate the needed properties.

The key properties of the advance springs, which dictate the shape of the advance curve, are:

- Primary spring rate (#/in or N/mm)
- Primary spring initial tension (# or N)
- Secondary spring rate
- Secondary spring free length

Tools
To measure spring properties you will need precision measuring instruments like a micrometer or calipers

How each of these properties shape the advance curve is best shown using a typical measured advance curve.



This graph shows that the primary spring controls the lower advance curve by:

- Holding the cam from advancing below a certain RPM;
- Returning the advance mechanism to the zero advance position;
- Linearly advancing the cam until the secondary spring engages.

Any advance curve can be plugged into any distributor just by manipulating the springs and cam arm length. Any distributor from any manufacturer can be made to deliver the advance curve an engine needs, thus there is no advantage, or magic, to having a distributor made by Accel, Piper or Aldon.

The secondary spring controls the upper advance curve by:

- Engaging at a predetermined RPM and lowering the rate of advance;
- Linearly advancing the cam until the advance stop is encountered.

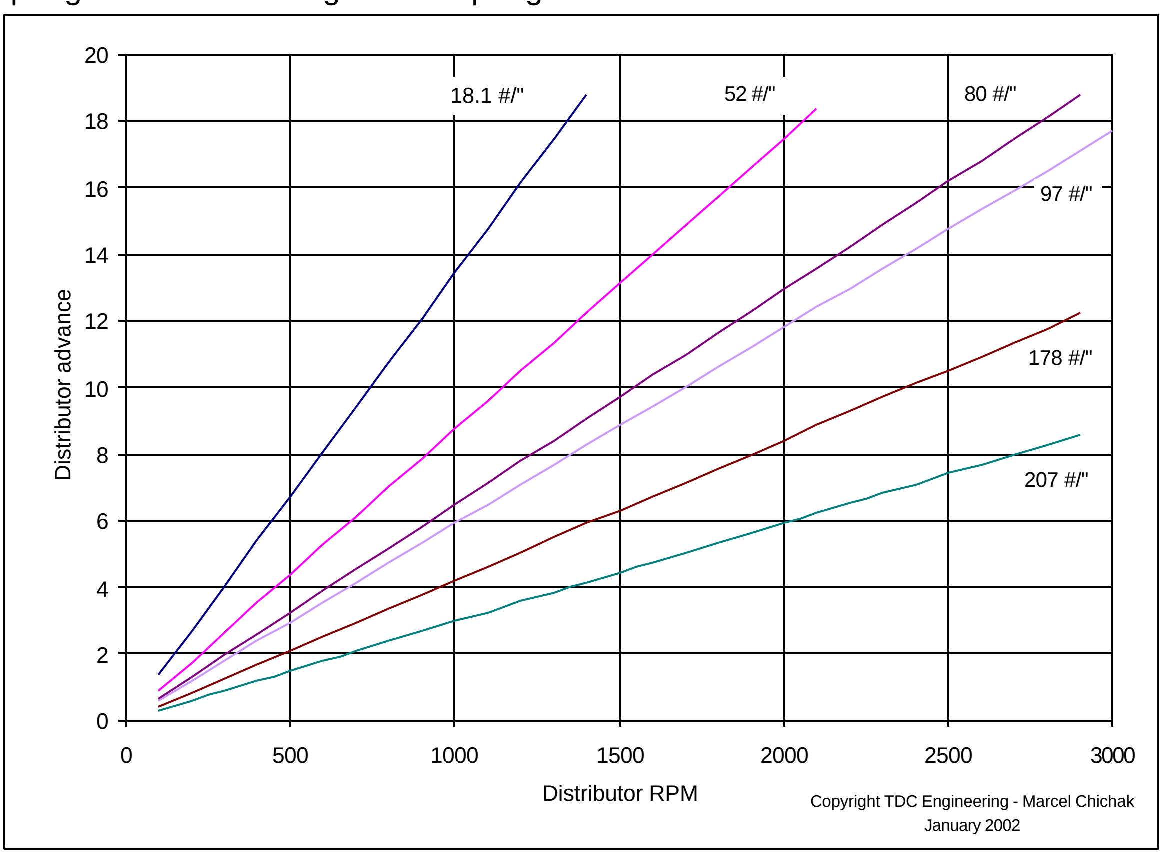
It also shows that:

- Stroboscopic timing of the engine at idle is in the steepest portion of the curve so to attain any degree of accuracy in the setting it must be done when the distributor is in a zero advance state (below 300 distributor RPM or 600 crank RPM in the example shown), or when it is at the advance stop (above 4800 crank RPM).
- The curve changes shape as the secondary spring engages, 700 RPM in this example.

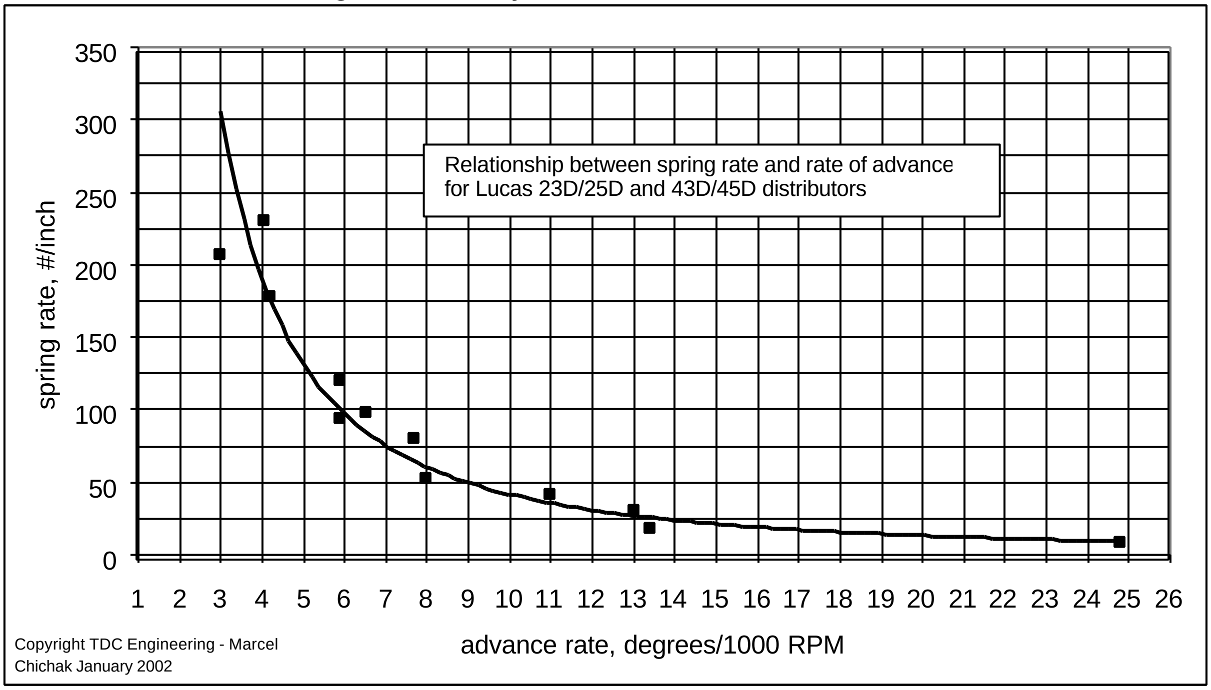
Because the primary spring is in control of the lower end of the advance curve, it must be in tension under static conditions. The secondary spring must be loose to allow the primary spring to work and produce the characteristic advance curve with two different rates of advance as shown. Of course, the primary spring is still working as the secondary spring engages and continues to do so right up to the point where the cam arm hits the stop. Therefore, the shape of the advance curve after the secondary spring engages reflects the combined spring rates. In the above example the primary spring rate is 15 #/" and the secondary rate is 210 #/" so the effective rate of the upper portion is 225 #/".

As can be seen, the spring rate changes the slope of the curve. The example shows the primary spring advances 6º from 300 to 700 RPM or a slope of 15º/1000 RPM and the secondary takes over and advances a further 6º from 700 to 2400 RPM or 3.5º/1000 RPM.

By testing, the relationship between spring rate, in lb/inch or N/mm, and rate of advance, in degrees/RPM can be derived. A series of tests were setup with a 25D4 distributor equipped with an 18º cam and a very weak primary spring so that its rate would be negligible compared to the secondary rate. The only change made between tests was the secondary spring that varied in both spring rate and free length. The result of this series of tests is shown below which shows only the secondary spring rate. While the data shows a logical trend for lower slopes with higher spring rates, it also shows a fair bit of variability. This may be due to variations in material properties or just loss of spring rate due to the age of the springs used in this series of tests.



Changing the data around to express spring rate as a function of advance rate the following chart was produced. More data points are required to confidently draw a design line, but with a limited range of spring rates available for testing, the line shown will have to remain as a guideline only.



Primary Spring Initial Tension

When extension springs are wound, they have a certain amount of built in stress left within them that causes the beginning of their load-elongation relationship to be non-linear. In consequence, the spring does not begin to elongate until a certain load, or tension, is applied to it. This initial tension is not something that is very significant in primary springs and it's not a factor in curve design. Where it has to be accounted for is in testing of the distributor. You will notice that all distributor curve specifications are given as 'deceleration'* tests, which gets around the problem.

Secondary Spring Free length

As you can see from the typical advance curve shown above, the primary spring is in full control until the secondary spring engages. The point of engagement is determined by the free length of the secondary spring. Since there is a linear relationship between cam advance and the distance between the spring mount posts, the point of

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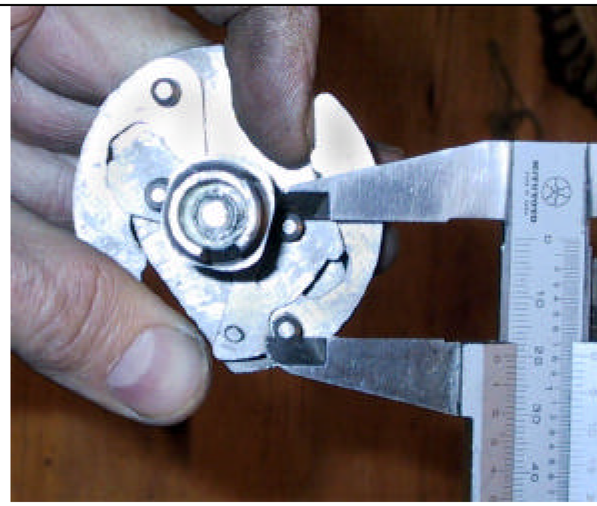
* The correct term is acceleration which has either a +ve or –ve sign. In fact, in this case, acceleration, the change of speed with time, is not relevant: the advance is read at various fixed speeds during the test.

engagement, and thus the advance position, can be determined. By measuring the distance between the posts at both extremes, this simple relationship can be determined.

Measure between the spring posts with the cam in the zero advance position – 0.665" in this case



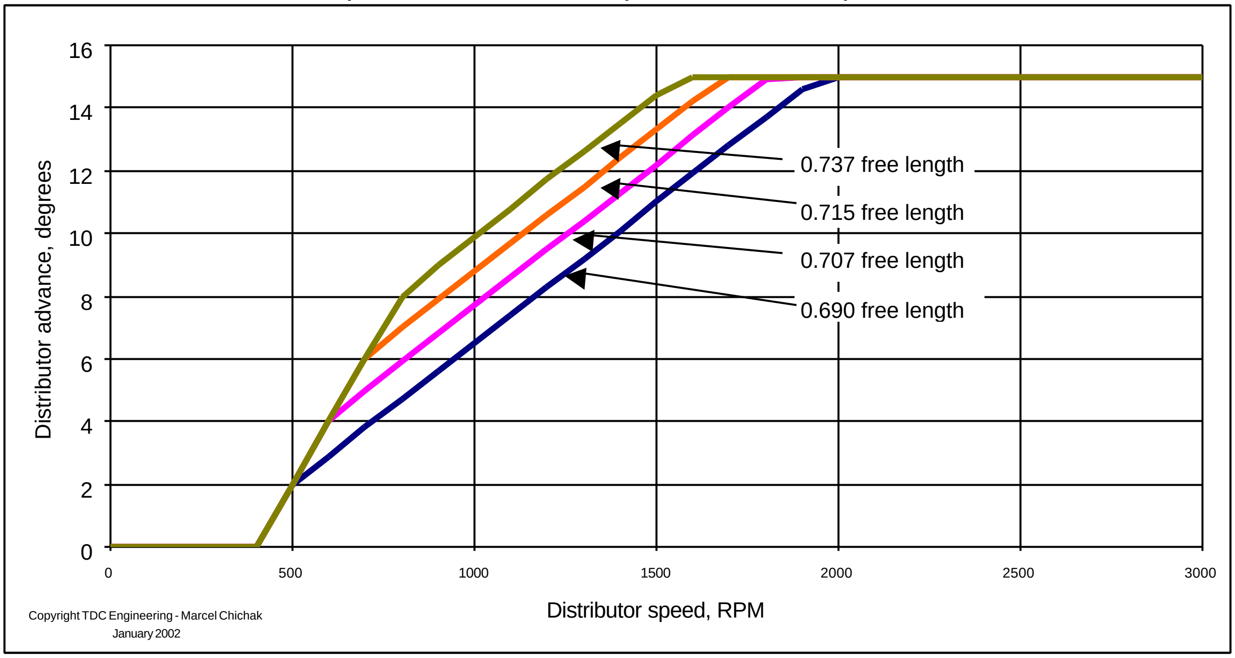
measure same dimension with the cam in the full advance position - 0.785"

The difference between these two values, 0.785-0.665 = 0.120" divided by the maximum advance of 15° (although 10° is shown, the stop has been ground down to give more advance) gives 125°/inch. With a secondary spring free length of 0.700, it will engage at (.700"-.665")* 125°/inch = 4.4°

It should be noted that the Lucas distributor is not exactly a precision assembled piece of equipment; there is a small variation in the positioning of spring posts. Take a distance measurement between posts on the cam arm side and opposite side and use whichever pair is most beneficial. If a cam is changed to give more or less mechanical advance, the position of the post positions will not be exactly the same as they were before, so the break point in the advance curve will be at a subtly different place. After changing anything on the distributor, check the curve.

Exactly how the secondary spring free length affects the advance curve is best shown in the following example, the tests for which were done on a specially modified distributor with vernier adjustable spring posts. What this graph shows is that the spring rates do not change, only the point at which the slope breaks, so the net effect is for the secondary spring to engage later and allow the cam to hit the stop earlier in the rev range.

If you look closely at the example below, you will see that all the curves go through a couple of common points: 2° at 500 RPM and 15° at 2000 RPM. These points coincide with the points where the dynamic timing is commonly set on an engine: at a 1000 RPM idle or at 4000 RPM with the distributor fully advanced. The timing light would not distinguish between these different curves, which illustrates the potential error of blindly trusting a single-point ignition timing calibration. Although all the curves would be set at the same static advance position, there's 4° (8° on the crank) difference between them.



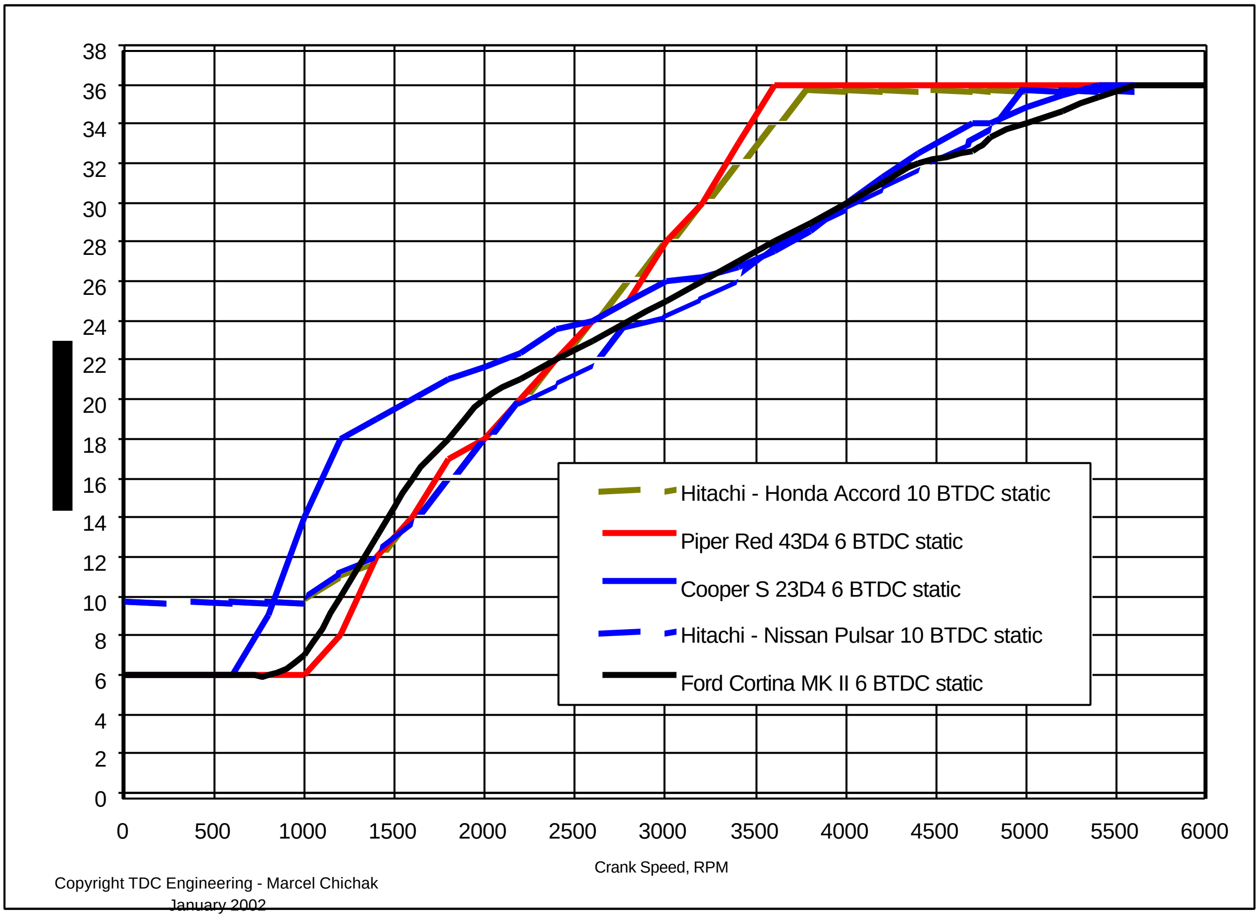
Because an ideal advance curve must place the peak pressure point in the narrow 17º-20º ATDC range, there isn't 8° of room in which to play. If a lower curve is correct, a secondary spring that's too long will cause knock, whereas if a higher curve were correct, a short secondary spring would result in lost power.

EXAMPLE IGNITION CURVES

Armed with the knowledge of what gives an ignition curve its shape, it's time to look at a few different stock curves. The next example can be broken down into two groups centered around the Piper 'Red' distributor based on a Lucas 43D4, and the Cooper S 23D4. The data is presented as engine RPM vs. crankshaft advance to show how the different curves look when they are all set to a particular maximum advance, 36° in this case.

The Piper 'Red' is marketed as being correct for heavily modified BMC A Series engines as a more or less universal application, regardless of engine specification. Plotted beside it is the curve from a stock Hitachi distributor from a mid-80's Honda Accord. At anything more than 1500 RPM the curves differ by no more than 2° which can be considered nearly identical allowing for the level of accuracy in reading the data from the distributor machine and repeatability of the instrument itself. One thing to notice is that the Hitachi and Piper both use equal weight springs and therefore do not have a break in the curve. Piper used two weak springs giving an equivalent rate of 11.5°/1000

RPM or about 40 #/” springs with a 15° cam. To replicate the Piper curve, the same rate springs and a 15° cam could be used in a 43D4 (or 45D4 if a vacuum unit is needed) or a very light primary spring and a 40#/” secondary with the free length the same as the post spacing. Of course, one could also adapt the Hitachi for use in a BMC A series and use it in its standard form[5].



The second group includes the Cooper S, a Hitachi curve from a mid-80’s Nissan Pulsar and a curve from a 1969 Ford Cortina GT Motorcraft distributor. Again, above 1500 RPM the Hitachi and Motorcraft curves are nearly identical as is the Cooper S curve above 3000 RPM. To change the Lucas curve to match the Hitachi or Ford, the primary spring would have to be changed from 10 #/” to 25 #/”, decreasing the rate from 22°/1000 RPM to 15°/1000 RPM. The secondary spring would have to be changed from 270 lb/” to 125 lb/”, increasing the rate from 4.7°/1000 RPM to 5.1°/1000 RPM. The break in spring rate is needed about 8° after the start of advance, or 4° distributor advance, consequently, if the distributor being worked on is the one in the example above, the free length would be 0.707”±.

Why the advance curve for the Nissan overhead cam 1600 cc aluminum engine should be similar in any way to that for the Ford 1600 cc iron engine with a flat head and Huron chamber-in-bowl pistons is something that needs considerable thought. But, exactly why Piper figures that the ignition advance curve that is suitable for a Honda overhead cam, 1700 cc aluminum engine is also suitable for ANY modified pushrod iron head and block engine of displacement varying from 1 litre to 1.4 litre is beyond explanation.

What is clear is that ignition advance curves are simple to change and assuming the correct advance curve is known, it is easily obtained. It should also be clear that an existing curve should not be trusted to either be correct for the application at hand, or that the distributor is delivering it accurately. Each distributor should be checked through its full range of operation so that a single-point calibration setting, when it is in the engine, will deliver the intended results.

By shedding light on this subject it is hoped that more tuners will take responsibility for ensuring the advance curve in their distributor is optimized for the application and this responsibility is not entrusted to anonymous mass producing accessory marketers who offer nothing more than a 90 day guarantee that the product supplied will function as assembled.

References:

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