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FERRARI 12-CYLINDER TUNING - THEORY AND APPLICATION

by Tom Meadows

With the upcoming events in Monterey, many of you are putting a fresh tune on your 12-cylinderFerrari or just checking many of the more basic adjustments prior to the week's events.

Tuning a 12-cylinder engine can be a daunting task even for the most experienced mechanic. There is now a vast amount of information on the web about the process, and much of the information often seems to be conflicting or may simply not be complete enough in its presentation. I am going to address here the method I use to fully tune a 12-cylinder engine, and also some very basic tests and adjustments to bring a well tuned motor up to its full potential. The process is laid out for the carbureted Ferrari 12-cylinder engines with both two and four cams. Although much of it will apply to the sixes and eights as well, in many ways they are a completely different breed of engine to tune.

There are two ways to approach tuning the Ferrari 12-cylinderengine: The first is to simply apply years of tuning practice and follow your own practical experience. There are two problems with this both for the average owner, and many shop mechanics as well. The first is that the opportunities to develop this level of experience are limited due to the scarcity of these cars, and the second is that you will inevitably run into a problem that your experience alone cannot solve.

The solution that I apply is to blend my own experience with solid theoretical tuning principles. My theories are based on 34 years of experience with tuning virtually every kind of car or motorcycle made, my university level education in mechanical engineering, thermodynamics and physics, and my daily ongoing research into modern technical developments in the automotive world.

One of my favorite maxims is: "The difference between theory and application is that in theory there is none". This means that theoreticians seldom have to deal with the real world, and theories must be continuously tested with application to prove their worth.

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When I looked at my first 12-cylinder Ferrari motor I admit to having been utterly confused as to how it all worked. Out of this confusion came the realization that I had to simplify how I perceived the multiple carburetors, distributors and cylinders. What I concluded is that the Ferrari 12s are two six-cylinder engines on a common crankshaft. This was easily tested by disconnecting one distributor and noting that the car could still start, idle, and be driven on only one bank, albeit with a very low level of performance. I have seen on several occasions customers that brought their car in running on only one bank of cylinders and completely unaware of it. Their main complaint was of poor performance. One of the strengths of the 12-cylinder design is that even in poor tune the engine can still pull very smoothly with even torque application and this can be very deceptive when trying to evaluate its state of tune.

As soon as you split your perception of the motor into its being two six-cylinder engines, many tuning problems are simplified. If you have an imbalance on either bank whether it be due to unmatched cam or ignition timing, compression or carburetion flow, then you have two motors that have their power pulses working at odds with each other, resulting in a power loss. If you pick one bank of six cylinders, tune it to its maximum potential, and carefully match the tune of the other bank to be identical, then both sides of the motor will work in harmony putting out maximum horsepower.

I delight in going to car shows and listening to all the twelves and their varying states of tune. When both banks are in perfect matching tune, there is an audible depth and harmony to the exhaust note that is instantly identifiable to the trained ear. The British will refer to a motor as having gone "On Song" when it has this particular note .

Here is the process I follow to put a Ferrari twelve as close to perfect tune as possible, with maximum efficiency and running "On Song". The process consists of six parts: (1) Establishing a performance baseline (2) Testing the compression (3) Timing the camshafts (4) Calibrating the ignition (5) Synchronizing the carburetors (6) Comparing the newly tuned motor's performance with the baseline. The sequence of the process here is very critical and doing it in any other order will be counterproductive and provide poor results.

The first step is to warm the car up, grab a passenger with a stop watch and take it out on the open road in order to perform three acceleration tests back to back. Standing start drag strip type tests are hard to repeat consistently and are influenced too much by variations in the driver's technique. To provide a less driver influenced test, take the car up to 40 mph in third gear and cruise at a steady speed. Have the passenger start the stopwatch when you give it full throttle and stop it when the speedometer reads 70 mph, 80 mph being preferable, but not legal in most states. Take the average of the three times and you now have a baseline to evaluate the performance gains or loss from any changes you make in the car. You should also maintain very accurate fuel mileage figures over the prior months as this is the best indicator of the thermal efficiency and overall tune of the motor.

Allow the car to cool down, remove the spark plugs, identify them as to which cylinder they originated from and perform a compression test. A compression test, just like the road performance test, must be 100% repeatable. This requires an accurate compression tester that has never left your sight. I have seen more than one motor that incorrectly passed or failed a compression test due to a faulty gauge. Buy a good one, store it carefully, don't drop it and never, ever loan it out.

Many compression gauges can also give an incorrect reading because the owner has replaced the little Schrader valve in the gauge with one from an inner tube. The correct Schrader valve for a compression tester uses a special type of rubber seal to deal with the gasoline fumes and also to deal with the much higher pressures encountered in an automotive engine. Correct valve stems for compression gauges can be obtained from Snap-On or MAC tool distributors.

Valid compression tests are done with the engine either fully warm or fully cold, and as long as you are consistent with your choice of methods your results will be repeatable. I prefer to do it cold simply to

avoid burning my hands. A warm test will usually give slightly higher readings, but not appreciably so.

Prior to the starting the compression test I use a bungie cord to hold all the throttles open to their maximum opening. Not doing this can result in a lower overall reading due to the blockage of air flow to the cylinders. It is important to have a fully charged battery and sound starter motor to perform these tests with.

Generally an engine will reach maximum compression after seven compression strokes for each cylinder. This is the point that the needle on the gauge stops moving and full compression is reached. Any number between seven and ten will work as long as you always use that same number of compression strokes in your test. Do not neglect to ground the ignition system or remove power to it, as failure to do so can damage the coils or ignition modules. I prefer to attach a small jumper lead from the center coil terminal to ground as I have found this to be easiest and most reliable.

If you have an assistant, crank the motor so you can watch the gauge as the pressure builds with each stroke. Some motors will build pressure slowly and evenly while a really strong motor will jump to 90 psi on the first stroke and hit its maximum within three more strokes. The general range of numbers should be between 140 psi and 175 psi. Under 130 psi in any cylinder and the performance will start to suffer and make tuning very difficult. Note the numbers from each cylinder and compare them with the spark plug from that cylinder. Reading spark plugs is a very high art indeed, but in general if you get a low compression reading you will find the plug from that cylinder to be oil fouled from mechanical wear, or if sooty and gas fouled, indicative of a tuning problem.

Many mechanics and owners prefer a leak-down test but there are several drawbacks to this method. First it can be quite difficult to get the motor on exactly TDC, and if you are a degree or two off you will get low readings due to piston rock or movement at the top of its arc. Doing this properly on all twelve cylinders can be very time consuming. Secondly this test is usually done around 100 psi or so which is much lower than the cranking pressure. The main strength of the leak down test is that it will clearly tell you if the leakage is in the rings or the valves, simply by listening for the hiss of leaking air coming from the tailpipe or carburetors. This can be very useful diagnostic information.

Next in the sequence is to time the camshafts. If you look at the Ferrari 12 without ignition or carburetion, it is simply an air pump with the quantity of air movement being governed by when the valves open or close. Cam timing is what controls and governs this quantity and it is the most critical mechanical relationship between matching the performance of the two engine banks.

Cam timing is usually bypassed by the owner/mechanic due to its complexities, and also by shops if the owner is unwilling to bear the extra expense. It is absolutely the single most common loss of performance in the twelves due to cam chain wear or misadjustment over the years. If you are serious about the tuning process, take all the time required to make it absolutely perfect. In all cases it is best to dismount the engine for the process, although it can be properly done in the chassis as well. If you choose to time the motor's cams in the chassis, this process can be greatly simplified by the use of a laptop computer with a remote camera head. This allows you to remotely monitor the degree wheel as you turn the motor and observe the dial indicator on the valve at the same time as the motor is rotated.

The correct process of proper cam timing is quite complex and would easily cover a dozen pages of text, and there are many pitfalls awaiting someone new to the process. The sequence of mechanical processes is readily available in factory manuals, on the web, and also from any cam regrinder or manufacturer

The Ferrari factory in some cases supplies cam timing information using marks on the flywheel, but these can be incorrect if the flywheel has been replaced. The majority of the carbureted twelves have what many think are timing marks engraved on the camshafts, with these marks being aligned with marks on the cam caps to complete the cam timing process. It is critical to understand that these marks are only assembly marks, which is to say they will allow the motor to be initially started without damage, but are not accurate enough for final tuning.

Assumptions are critical to the tuning process and to assume the cam timing is correct when it has not been measured will affect every other part of the tuning process. You can tune your motor without checking the cam timing, but if any problems arise, this will introduce a very serious unknown into your assumptions. If you do not have service records documenting the cam timing on your motor, take the time and ensure that it is correct.

Here are some very basic rules of cam timing that are independent of the actual mechanical process and which are quite important to observe: (1) You must have accurate timing specifications to begin with, ideally from factory sources. (2) Your process has to be one hundred percent repeatable within +/- one degree. (3) It takes at least three identical tests to guarantee repeatability. (4) Each bank must be identically matched.

Document the cam timing of the motor as you found it, and document all the numbers of its final timing to the factory specs. This is important in the event the cams have been reground and the factory numbers will not work for optimum performance. If it runs worse after the cam timing you will at least have the original numbers to use as a baseline for correction.

Once the cams are timed, re-do the road performance test and note any gains or losses in performance. Repeat the compression test and note the results. Cam timing at engine cranking speeds has a relatively small effect on cranking compression. When you add fuel, ignition, high rpms and the resulting increases in gas velocity, significant gains from proper cam timing are realized.

Next is to bring the ignition up to factory specification. With two distributors and two sets of points in each unit, there is much room for error due to maladjustment and normal wear. I chose to specialize in Ferrari ignition service due to their complexity and the resultant rewards from proper assembly and calibration.

The plug wires are the first thing to check and this can be done with basic ohmmeter tests. In general, spark plug wires should have about 1000 ohms resistance per linear foot and more than 3000 ohms per foot requires replacement. I have pulled wires off cars in regular service and found resistances as high as 200,000 ohms in any given wire. Just because it runs does not mean it is running well. Make sure the plug connectors are properly attached and the retaining screws at the distributor cap terminals are tight, and the rotor and cap terminals are free of oxidation or deposits

Over the years, many of these cars have been fitted with Fiat 124 rotors with the 8mm tip width due to cost. It is very important, due to Marelli's use of a non-advancing rotor design, to install a correct 11mm tip width rotor. I have seen running motors with one of each type of rotor installed. Check to see that yours are the correct tip width and that they match.

The condensers can be tested for capacitance and leakage but most owners opt for simple replacement of these parts in lieu of

testing. Be advised that Ferrari used several different capacitors on the various motors with values, in units of micro farads, ranging from .17 mfd to .29 mfd. The capacitor value is stamped on the bottom of factory condensers. The .29 mfd are the most common. Most of the reproduction capacitors I have found vary quite widely in capacitance. While this will not create any significant running problems it does reduce point life and provides a less than optimum spark.

Many owners have successfully phased the points sets in each distributor while on the car with good results. It takes quite a bit longer than doing it on the bench with a distributor tester, but with lots of patience it can be done. Phasing of the points alone is only a part of the complete process, as the advance curve of each distributor must also be matched to the other.

Again this can be done on the car but requires quite a lot of time and patience. Matching the advance curves within the factory spec of +/- one degree is at the heart of tuning a motor for perfect smoothness. A distributor tester is the best way to do this, and many Ferrari owners have purchased their own machines to do to his work.

The factory has on several Ferrari 12-cylinder engines used a single distributor with a twelve contact cap, which solved the problem of having to synchronize the advance curves, but introduced a new problem, which is the internal arcing between the now more closely spaced connectors in the distributor cap, and the bi-level rotor.

It usually will require three sets of plugs to tune a motor; the first set is used for start up and preliminary carb tuning, the second set is for final mixture adjustment and the last set is for delivery to the customer. Plugs can be cleaned by media blasting but dollar for dollar nothing beats a brand new spark plug at this point in tuning. I prefer NGK Iridium plugs for everything I tune but at $8 each, many owners will opt for Bosch Platinums with either single or dual electrodes, which are my second choice. Don't forget a very light coating of anti-seize on the plug threads, and to securely tighten the plug cap on the top of the plugs and torque them to 18 foot lbs. Always torque spark plugs, as I was recently told by George Clark, a retired AC spark plug factory representative and Lamborghini and Bizarrini owner.

With sound compression, properly timed cams and a calibrated ignition system, it is time to adjust the carburetors. Let me state here for the record that there is no magic or mythology to tuning carburetors. It is pure science and applied physics. Every carburetion problem can be diagnosed by scientific methodology and understanding the physics of the airflow involved. Eduardo Weber was an absolute genius at this level of engineering science, and your goal, as a tuner, is to bring the carburetors as close as possible to the original design level he created.

At this point you will perform some simple physical examinations of the carburetor's physical condition. Very gently turn the mixture screws in until they stop and document exactly how many turns they are out from the closed position. In general they should about one to one and a half turns out, and you should note the drop in idle as you move the mixture screw to the fully closed position. Observe its response or lack of response as you do this and note it.

Next, open the throttles slowly, and carefully observe that all of the accelerator pumps squirt a solid identical stream of fuel into the venturis. Perform the same test opening the throttles quickly and compare the results. Note any variations or uneveness in flow for future repair. If you have to open the throttle more than three times during this test, re-pressurize the fuel system with the electric pump to keep the float bowl levels at the same position. Due to heat and over tightening, it is common for the carburetors to have warped bases causing air leaks. With the motor idling, spray a small quantity of carburetor cleaner around the bases to check for air leaks. If they are leaking there will be a noticeable change in idle speed. Any change, either large or small, indicates an air leak at the carburetor base and will require machining or other attention. Realize that any flammable fluid you use for this can be ignited from ignition leakage or exhaust heat and may cause an engine fire, so keep a Halon fire extinguisher handy.

These simple physical tests will tell you if you need to overhaul the carburetors or perform other repairs. Removing the tops of the carbs is advisable at this point to check the float levels and inspect for dirt, debris, and general internal condition.

If the carbs are in proper physical condition it is now time to synchronize them. This is the one area that is the source of many hours of discussion and disagreement among mechanics, and I like to think that the proper application of theory based on science and physics is the correct approach.

The point of synchronization is to match idle circuit air flow to each cylinder's need, and to match the mid range and full throttle airflow so all carburetors are the same. These are two separate processes and I am going to describe the four main approaches to their synchronization, their strengths and weakness and my own approach.

The most common approach, and the one the older Ferrari manuals describe, is to use a flow synchronization tool (synchrometer) to measure the airflow in each venturi. Some tuners, usually of the British persuasion,will use a small piece of hose to listen to each venturi to obtain similar results. Both methods work and require a fair amount of skill to properly implement. The weakness in the synchrometer approach is that the presence of the airflow meter over the venturi will richen the mixture on that cylinder changing its airflow. Secondly you can only check one cylinder at a time, which introduces another level of measurement error.

The ideal method for setting the idle mixtures is to use an exhaust gas analyzer. All shops that do smog work will have one and any shop that works on post-1972 emission certified Ferraris should have one as well. Many manuals recommend disconnecting the carburetors and tuning the motor on a single carburetor at a time to set the idles. This does work, but the simple fact is that with training any good mechanic can hear the difference in each idle mixture screw adjustment with all the carburetors connected and operating. Make small adjustments of 1/8 turn or less and pause a bit before going on, to give the motor time to respond to the new setting.

The ideal method for setting airflow both at idle and above is to fit the intake manifolds with vacuum taps for each venturi, and connect them to a 12 gang vacuum gauge. Dial type vacuum gauges fluctuate too much to be of value here, in addition to requiring twelve of them. Some shops still use mercury filled vacuum gauges and these provide the most stable reading, and also allow you to compare all 12 cylinders at once.

The mercury gauges have two significant drawbacks, the first being that if you snap the throttles shut rapidly, you can suck the mercury right out of the tubes into the running motor which creates a fine silvery dust cloud behind the car. Don't ask how I know this. The second problem is that mercury has been declared bomb-making material by Homeland Security and is no longer legally available to the public. I have a friend who recently e-mailed a company to obtain some mercury for his vacuum gauges and was subsequently contacted by Homeland Security both by mail and phone regarding

his request for prices and need for mercury.

There are several alternatives to mercury gauges including the types that use a metal slug to go up and down in the tube, or electronic transducers which convert the vacuum signal to an electronic signal. These are typically designed for two or four cylinder motorcycles. Adapting these gauges to a 12-cylinderengine is quite feasible, but will take the purchase of multiple units and a lot of time to assemble and calibrate properly.

If you don't have access to any of these methods or the experience to use them, there is a very bulletproof method that has always given me excellent results. I remove all the linkage rods and set them to equal lengths. I back off all the idle speed screws until the throttles are fully closed. I adjust each of the idle speed screws until it just barely starts to open the throttle plate, and then adjust the overall linkage up to open all the carburetors simultaneously. Turn the mixture screws one-and-one-half turns out from the closed position. If you have even compression and sound carbs this will work quite well. This is a very basic and totally mechanical approach and will usually provide a good idle and strong running. It is an excellent starting point to begin tuning from or to use after a fresh engine overhaul.

The last note of importance here is that downdraft Webers used on most Ferraris are adjustable for balancing side to side airflow, which has to be checked and adjusted. The mechanical method described above will work well with carburetors that have not had their factory balance settings changed, or that have been properly adjusted for side to side airflow.

With the carburetion synchronized the tuning is complete and ready for road testing. These cars respond well to tuning and you should find a significant difference in the measured acceleration time and fuel mileage. One reason for using the 40 to 70mph test is that it accurately measures the mid range performance, which is where you will spend the majority of your time driving the car.

There are some definite correlations between fuel mileage, thermal efficiency and horsepower. If your fuel mileage increases from your tuning efforts there will be a proportionate increase in horsepower, and while the correlation may not be directly linear it is readily measurable and very real.

Whether you apply any of these methods to tune your own motor or simply study them to further your knowledge, keep in mind that the approach to science and methodology used here is typical of what it takes in every aspect of Ferrari repair to keep your car running well and as close to factory levels of performance as possible.

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500 FERRARI CONTRE LE CANCER

By Marc Sonnery

Arguably the fastest growing Ferrari event in Europe in recent memory, the 15th edition of the sport et collection gathering at Le Vigeant circuit was too intriguing to miss. A great part of its success is to be attributed to its fund raising towards leading edge cancer research in the nearby CHU hospital in Poitiers. Having started as 50 Ferraris against cancer the number this year, a decade and a half later it has grown tenfold, a major success and indeed there is no comparable event in the Ferrari universe. Through 2008 a total of 1,440,000 Euros had been donated.

The track is situated in a picturesque and bucolic part of western France near the pretty town of l'Isle Jourdain on the edge of the river Vienne, with its famous viaduct (built for a long gone steam railroad), flowered bridge and smiling natives, their friendliness matching that of the organizers, the perfect recipe for a relaxed, convivial atmosphere.

The circuit itself, located a few minutes away, was built in 1990. It is 3.757km long, very green, nicely laid out and now ranks as one of the highest standard tracks among France's 51 circuits in terms of safety amenities with a very smooth surface, large gravel traps and expansive pitlane and garages.

Almost immediately upon arriving I had a long chat with none other than David Piper, a repeat participant who likes the track, describing it as quite easy to learn, not one of the fastest but fast enough, satisfying, you see about 150mph in the 250LM and 330P2 he had brought along.

This year the target was 500 Ferraris and 512 were actually entered despite the economy. It seems practically all showed up though as ever some arrived late while others left early but event organizer Jean Pierre Doury confirmed on Saturday evening, Sunday morning the peak quantity was as expected. Doury, who started it all when he nearly lost a friend to leukemia, built the event with relentless drive year after year to its current success with the extensive help of former and current club Ferrari France presidents Didier Griffe and Peter Mann.

This was achieved despite uncooperative weather, in fact only Saturday afternoon and Sunday morning were rain free. The nature of the event made it resilient and vast numbers showed up. It even