RACECAR's Formula Ford Test

Living With

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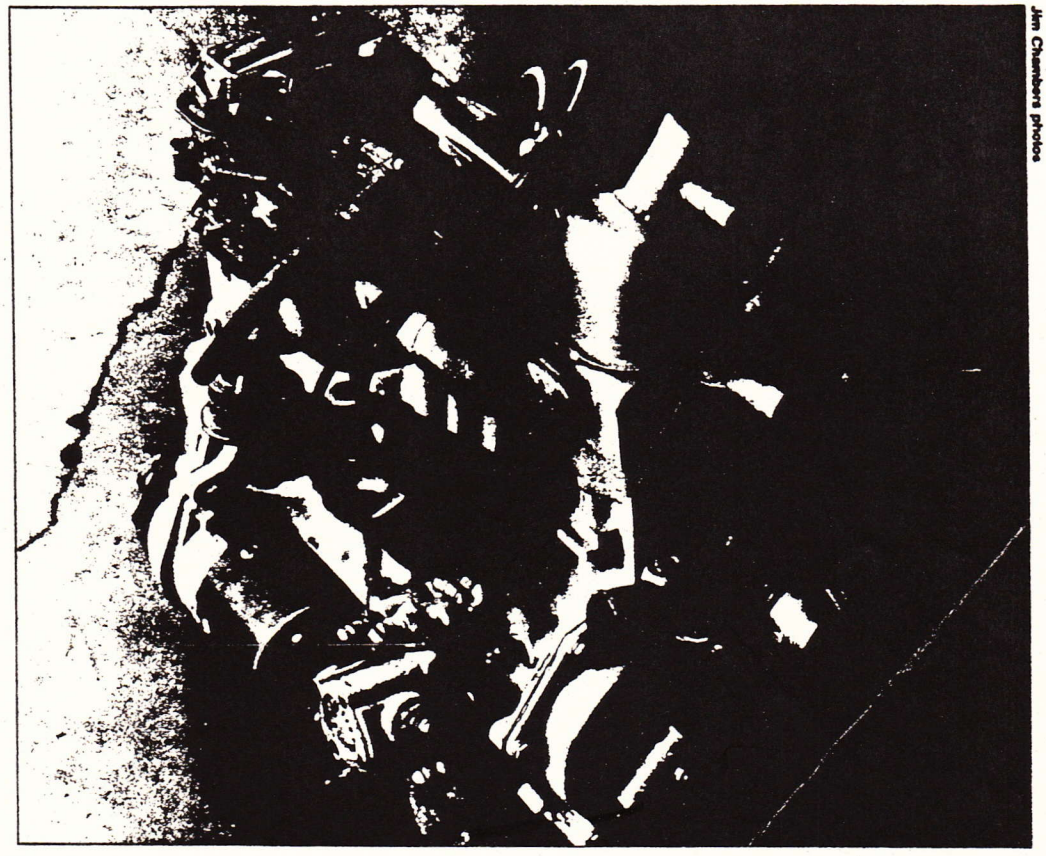
Automotive Development



Jim Chambers photos

Since the introduction of Formula Ford into the United States in 1968, thousands of drivers have tried their skills in the cockpits of these sleek racing cars. Some have moved up to Formula One and others have dropped out of racing altogether, but still Formula Ford has remained the most popular class in the amateur ranks. Much of the success of this single-seater class can be attributed to the reliability of the four cylinder Pinto/Cortina engine on which the Formula is based. Despite the existence of such classes as Formula Junior and Formula Vee, it was not until the introduction of the Formula Ford that American racers had available a real racecar that could be driven repeatedly without breaking. Finally, the average racer could spend enough hours on the track to learn how to really drive these little missiles. They did, too, all over the country, resulting in the biggest fields and the most competitive racing ever seen.

Your Engine

The very reliability of the Ford engine, however, brings its own problem: it can be so badly tuned that it may be down on power by 15 to 20 per cent, yet it is so strong that it keeps on running. Any respectable racing engine would melt a piston if it were run as far off normal conditions as many FF engines are, not just for a single race, but sometimes year after year.

If you really want to be successful in your racing endeavors, however, it helps to have the elements you can control squarely on your side. A well-tuned engine is a good place to start, so let's take a minute here to define tuning. Tuning includes all of the adjustments possible (ignition timing, spark plug heat range, carburetor jets, etc.) with your engine hardware, but does not include changing the major components (i.e. cylinder heads, exhaust system, etc.).

Despite a wealth of available information on FF engines, the sheer number of participants has provided an ample breeding ground for self-perpetuating rumors that are not based on a proper understanding of the facts. Typical ones include: "The best shift point on my engine is 6800, but I usually run it to 7200"; "Fred Schwartz picked up 11.3 per cent more power with this new outer space oil additive"; "Put three drops of this in your gas tank and don't tell anybody"; "George picked up 300 rpm by heat treating his crankshaft." Bad information is obviously easy enough to get, but how about good information?

Reference books such as the Cortina or Pinto 1600 manual can give you the basic dimension, tolerance, torque and fit information on the major engine parts. Another useful book is the *Formula Ford Scrutineer's Manual* by Frank Schultheis. This handy reference shows you what every part in the engine should look like as well as what parts and modifications are legal for Formula Ford. Another good reference book is the *High Performance and Racing Heat Range Chart and Tuning Guide* which is free from the Champion Spark Plug Company, P.O. Box 910, Toledo, OH 43601. This book provides a list and comparison of spark plugs suitable for FF and has a fine section on engine and spark plug analysis.

The Engine Dynamometer. It is very important to establish the fact right here that the use of a dyno is not essential to produce a competitive FF engine. Many good engines have been built and tuned without use of the dyno, and they did not get properly tuned by magic. The only reasonable alternative to the use of the dyno is track testing, about which I will say more later.

The engine dyno is a wonderfully versatile tool for testing and tuning an engine, but like all tools it is capable of misuse. At this point, we should distinguish the difference between a chassis dyno and an engine dyno. There are many chassis dyno installations scattered across the US and these are terrific devices for tuning up your tow car but are virtually useless for tuning an FF engine. This is due to their inability to control coolant and lubricant temperatures and variable slippage between the tires and the load cell rollers. The chassis dyno is just not exact enough for our needs.

The engine dyno, on the other hand, is nothing but a large brake which will restrict the engine to any chosen speed while the throttle is kept wide open. The force required to hold the engine at the chosen speed is measured and the horsepower developed by the engine is calculated. The resolution of most engine dynos is very good (changes in output of one half of one percent can be reliably measured) and it is obvious that with patience and a series of cut and dry tuning changes, an engine can eventually be brought to its best tuning combination.

One of the more puzzling aspects of the dyno to many is the seeming variation in dyno numbers from one installation to another. I recall watching on the Atlanta straight as a 102 hp Ford blew off another Ford dynoed at 112 hp! Both engines were carefully tuned, but on different dynos. The calibration of an engine dyno depends on the fundamental units of mass, length and time, all of which can be measured quite precisely, therefore all dynos should read the same. Right? Wrong. Although the actual calibration of a dyno can be done with great precision, not all operators do so. Also, differences in dyno construction and operator technique introduce even more variability.

The bottom line in choosing a dyno is to make sure that a lot of Formula Fords have been run on it. Presumably, if the operator has a reasonable amount of Ford experience, he can get the job done fairly quickly without charging down too many blind alleys.

The next step is to consult with the operator as to what consitutes a reasonable test schedule. Lists of test possibilities abound: exhaust systems, synthetic oils, oil pressure vs. power, adustments of this and that. Consult with the operator. He has probably seen many of these tests before and can help you sort your test schedule into an attainable set of primary and secondary goals.

When your engine goes on the dyno, it will be started and run under light load and observed for trouble areas as it warms up. If a retorquing or other minor adjustment is needed, it will normally be done after the engine has reached operating temperature. If the engine has new piston rings, the load will now be regulated to let the engine produce about one quarter of full power until the rings have adequately seated. The time required for this may be only a few minutes, but may be as long as three or four hours. There will be several indications when the rings are properly seated: the amount of vapor passed by the crankcase vent will be markedly reduced, cylinder leakage figures will decrease and then remain constant and piston tops and spark plugs will appear dry and oil free.

At this point, the engine will be ready for full-power tuning. The first runs will be tentative and cautious with frequent examination of spark plugs. These will probably be followed by a few full power runs to establish an approximate ignition timing. Carburetion changes come next, with fuel flow measurements to calculate Brake Specific Fuel Consumption (BSFC). BSFC is a measurement of the fuel required to produce one horsepower and is an indicator of engine efficiency. Every engine type has a fairly narrow range of BSFC where it runs best and BSFC can be a valuable aid to tuning. If the BSFC numbers are larger than normal, this usually indicates that the mixture is too rich and vice versa. Of course, to make this more complicated, the BSFC may be high at one end of the RPM range and low at the other end, necessitating a bit of maneuvering with the main jets, air jets and emulsion tubes in which a compromise mixture may result. When the mixture has been trimmed to the desired BSFC, then you will probably need to go back for some fine tuning on ignition timing and possibly some alternative spark plugs.

At this point, the engine should be close to the right basic tuning and a careful examination of the data from the dyno is in order. If the power peak occurs in the right rpm range and the power produced is clearly competitive, this information should be reflected in the data. We can then make the following conclusions: First, the engine is oil and watertight and has been fully run in. Following installation on the chassis, it will not need any special treatment. It has been tuned to the best possible combination and comparing the corrected power numbers with other engines run on this dyno indicated that the power is quite good (power figures are normally corrected to a set of standard atmospheric conditions for the purpose of comparing engines).

We also know where the power is and how to gear the car. If the power falls sharply above 6400 rpm, it is evidently important to gear high enough to avoid running the engine there. On many tracks, it may be possible to gear for splits of 800 rpm or less. If this is the case, then a shift point of 6300 will keep the engine in the best power band.

Despite some of these problem-solving capabilities of the dyno, we still have two general problem areas which the dyno ignores—transient conditions and g loading. Diagnosis and solutions to either problem have to come about through track testing. For example, let's assume that you have installed your freshly dyno-tuned engine in your chassis and are trying it out for the first time. Unfortunately, the engine is a dog and won't get out of the slow corners at all. Bad dyno tuning? Not necessarily. The problem is most likely a bad accelerator pump diaphragm or a mis-sized accelerator pump jet.

What about a condition where the engine runs fairly during initial track testing, but

when you try to go fast, it fouls all four spark plugs and pumps oil out of all the breathers in a steady stream. Is it broken piston rings? More than likely the problem is an oil pan with marginal oil scavenging (a broken or roughly prepared windage tray perhaps) which was acceptable on the dyno but which will not handle any serious side g loads.

How about an engine that is a world beater on the dyno, but shoots ducks in every left hand turn? The problem could be a motor mount that flexes enough to let the distributor touch the chassis. As you can see, the dyno is not the ultimate problem solver, but can be a very useful tool if understood properly.

The alternative to the dyno is on-track testing, an endeavor which bears fruits proportionately to the amount of organization put into it. Although track testing has the obvious disadvantages of physical danger, inconvenience and uncontrolled variables, it does have the strong benefit of testing the car as a whole and can be designed with chassis and driver development.

The primary instruments involved here are located in the car with the most important being the tachometer. Before hitting the track, make sure your tach has been properly calibrated (most speedometer shops can do this at a nominal fee). The secondary instruments (oil pressure, oil temperature, water temperature) are normally adequate, but if your car does not have an oil temperature gauge, you should consider installing one.

Before you take your first lap make sure that a reasonable gearset is installed and that the ignition timing is set at 38-40 degrees BTDC (before top dead center). Then, do one slow lap and bring it in. Take the time to thoroughly inspect the engine and all associated plumbing and correct any fluid leaks or loose parts. Finally, remove and carefully inspect all four spark plugs. What you should see is a reasonably rich condition with some signs of light oiling (this assumes that the piston rings are newly installed and not seated). FF engines have been successfully run with spark plugs ranging from N-55G (very cold) to N-64Y (fairly hot), but for the purpose of seating the piston rings we can use something in the middle such as an N-60Y gapped at .032 of an inch. If at any time these plugs show excessive heat, immediately install a cooler plug.

Now try two or three slow laps (not over 4000 rpm) and repeat the inspection process. These first few laps are the most critical since if there is a serious problem with the piston rings, it will show up *very* quickly. If all is well, continue lapping at 4000 rpm or less as the temperatures start to come up. A fair amount of heat is produced as the rings seat and the water temperature may rise up to 200 degrees or more. If this happens, come into the pits and wait for the car to cool down (this is a fine opportunity to inspect the engine and plugs).

Assuming that all is going well, however, continue motoring at 4000 rpm with frequent motor inspections. If you have installed cold plugs and they show signs of heat then your fuel mixture is too lean. You can correct this by going least two sizes larger on the main jets. Very soon your piston rings will start to seat and the coolant temperature will drop and the plugs start to look somewhat normal. When this happens, try running the engine through the gears a few times with a 5600 rpm shift point.

If all of the plugs are relatively free of oil, you are ready to try some mixture adjustments.

Regap the plugs to .025 of an inch and run the car down the longest straight at about 5600 rpm. Cut clean, coast into the pits and check the plugs. Frequently, plugs number two and three will appear to be richer than the others, but this can be ignored. Simply change the main jets as necessary until this test shows only moderate richness and then attempt full speed runs down the same straight followed by a clean shut off and plug reading. The purpose of this exercise is to bring the air correction jets into the right range bearing in mind that increasing air jet size will lean the mixture at the top end. If you have that difficulty, with signs of excessive heat, go one step colder until the plugs are right.

What about ignition timing? Most FF engines will run best with a total timing between 37 and 41 degrees before TDC, so set the timing at the lower end of this range and use your stopwatch to time the car from 5200 to 6200 rpm in top gear. Advance the timing and try again until you have the best setting, but check the plugs frequently as you do this as you may need a colder plug. At this point, you should have a reasonably well-tuned engine.

Only one question remains: where is the real power peak? Using third gear, establish and record the time to accelerate through 200 rpm increments using starting points from 5200 to 6200 rpm. To avoid the action of the accelerator pump, start each run at a considerably lower speed. Evaluation of this data will allow you to gear the car over the center of the best power points.

Trouble shooting. If all of this is done with care, you will have a nicely run-in, well-tuned engine which is ready to go racing, but what if difficulties crop up along the way?

Overheating is one of the most common problems and it will cause irreversible piston and ring damage very quickly. It is also a difficult problem to diagnose since it can be caused by the engine, the chassis or both. First, check ignition timing and spark plug condition, since either severe advance or retard can cause this problem. If in doubt, set the timing at 38 degrees BTDC and also verify the accuracy of the TDC (top dead center) mark as well as you can by looking in the number one plug hole. Although very lean mixtures will cause overheating, this is relatively rare and is immediately obvious from the spark plug condition. Often, tuners will try to correct overheating by going to a purposely rich mixture. My experience with this has been that it only produces a rich-running, off-power engine which continues to overheat. If these basic diagnostics have not produced a cause for the problem, then you should suspect a bad head gasket.

Use a torque wrench to check the tightness of the head bolts and if any loose ones are found, resist the temptation to simply retighten them. If the head gasket is leaking, it will almost always have to be replaced. A compression or leakage test will also help to locate a head gasket problem, particularly the leakage test. The famous shade tree mechanic's test of running the engine with the radiator cap off and watching for exhaust fumes in the water never seems to work for me, but I keep on trying.

If you should find a burn head gasket, the cure is to replace it, but treat the engine with suspicion since the cause may be a warped head or block. If you have more than one head gasket failure with the engine, it is obviously trying to tell you something and that is, "Take me home, I'm sick."

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if the gasket seems good, then the problem may be due to the water pump drive or the chassis (insufficient radiator or bad location). The only reasonable way to drive an FF water pump is with a cogged belt which can never slip. Despite this, there are still a few driven by vee belts (it might be slipping, but how can you tell?).

A bad radiator is another potential problem and the easiest test for it is to take it to your local radiator shop for testing and repair as necessary. The matter of size and location is more difficult. Talk to the other owners of your marque and see if you can make any sense from their experience. Many chassis built across the Atlantic are not up to our summer climate and require modification.

Next to overheating, the most common serious problem in Ford engines is low oil pressure. Although this is sometimes aggravated by chassis conditions such as a clogged oil filter, it is most frequently an engine problem caused by either a worn out oil pump or excessive main bearing clearance. The construction and working clearances of the gear rotor pump internals are covered nicely in all of the Pinto and Cortina manuals so I won't say anything more except that the problem is usually main bearing clearance. The genesis of the ailment usually lies with some well-meaning machine shop fellow who sees a few marks on your crankshaft journals and decides to polish them out.

The optimum main bearing clearances are about .0015 to .0018 of an inch, but clearances of up to .0022 are usually all right. Beyond this, the best Ford oil pumps just cannot provide the volume to maintain 50 psi with hot oil. These clearances are fairly tight by V8 standards and thus your well-meaning friend may give you a nice, loose free-running engine which unfortunately won't hold oil pressure. The only real cure for the problem is to grind the crankshaft to the next undersize and hope that no one tries to help you out by providing a little extra clearance.

Oil additives? I haven't seen any that solve the problem. Put the car back on the trailer and fix it right.

Misfiring is always a disheartening event, but the cause is usually electrical. The FoMoCo distributor is only a marginal piece of equipment which is prone to shaft wear and rotor fit troubles. Normally, the first thing to check is rotor fit on the shaft and rotor-to-cap interference. If the rotor has hit the cap, forcefully wiggle the shaft from side to side. If it moves freely, the best cure is to replace the distributor, but if the shaft fit is still good, rotor and cap replacement will usually solve the problem.

About half of the new rotors will not fit the shaft very snugly, but this can be cured temporarily with a paper shim between the rotor and shaft. If the distributor checks out all right in these areas, then the condenser, ignition coil, switches and miscellaneous wiring should be scrutinized and replaced if suspect.

Fortunately, the Weber carburetor used on FF engines is an extremely reliable device which rarely goes wrong, but it will require frequent servicing to remove grit from the air jets and emulsion tubes. In severe cases, this grit will block the air jets and cause the mixture to go to a full rich condition at high engine speeds with considerable loss of power. It will continue to run smoothly but will feel very flat and sluggish. A quick look at the plugs should help you to isolate the problem.

Other on-track problems? There are lots of them such as the miserable Lucas starter. . . but let's save that for another day.