ENGINE INSTALLATION AND TUNING TIPS

Performance engine durability is dependent on several supporting systems including the cooling system, fuel delivery system, ignition system and oiling system. If the support systems are not adequate, poor engine performance and possible engine failure could result.

OILING SYSTEM CONSIDERATIONS/ COMMON PROBLEMS

- Priming the oiling system before starting a new engine is crucial to engine life. This is important on initial start-up of a new engine and if a used engine has not been run for extended periods of time.
- Does the oil pan have adequate capacity? Most performance vehicles require a 7 qt. minimum capacity. All engines will benefit from increased oil pan capacity.
- Does the oil pan have proper oil control baffling for the vehicle's braking, acceleration and cornering capabilities? Road-race cars need oil control in four directions: braking, acceleration, LH cornering and RH cornering. Drag race cars need oil control in two directions: braking and acceleration. Baffles must be designed to keep oil over the pickup screen at all times.
- Is the pickup screen the proper distance from the bottom of the oil pan? If the oil pickup screen is too close to the bottom of the oil pan, it can cause cavitation. If it is too far away, it will cause the pump to draw air and minimize lubrication capacity. The pickup screen should be located .250" to .375" from the bottom of the pan. Does the design of the screen on the pickup tube create restrictions? We have seen some pickup tube screen designs that restrict oil flow as much as 75%. Wire mesh is good. Perforated metal is usually restrictive. Measure the wire size and calculate the flow area. Most aftermarket screens have less flow area than stock screens.
- If using a remote oil filter mount or oil cooler, make sure that all of the components are large enough to eliminate any restrictions to oil flow. Many Cobra replica kit cars use components that are too restrictive.
- Undersize oil lines commonly restrict oil flow.
- The more bends/turns in an oiling system, the more restrictions are created.
- Poorly designed remote filter mounts and adapters can create restrictions.
- Be sure that the oil cooler flows enough oil to meet the engine's requirements.
- Never reuse a used oil cooler. Debris gets trapped and cannot be cleaned out.
- Poorly designed oil filters can cause a restriction.
- Many oil systems only flow one way. Connecting the remote oil filter or oil cooler lines backwards can cause engine damage/failure.

IGNITION SYSTEM CONSIDERATIONS/ COMMON PROBLEMS

- The ignition system must deliver a properly timed spark. There are a lot of factors that determine when the spark should be delivered. The most common factors include: compression ratio, fuel quality, fuel octane rating, combustion chamber design, engine operating temperature, power adders such as NOS or supercharger, inlet air temp, altitude and load.
- Avoid too much or too little timing for your engine combination.
- Avoid hooking up the vacuum advance to intake manifold vacuum instead of ported vacuum.
- Avoid inductive crossfire created by improper plug wire routing. Separate plug wires on cylinders that fire in sequence.
- Improper timing can damage pistons, rod bearings, head gaskets and many other engine parts.
- Typical total mechanical advance timing at 4000 rpm for Ford Racing Performance Parts crate engines: 5.0L: 36º to 38º, 347/351: 34º to 36º, 392/460/514: 30º to 32º.

FUEL DELIVERY CONSIDERATIONS

- Size of fuel pump, size of fuel line, fuel pump placement, fuel filter placement, fuel filter size, injector size, fuel rail size, fuel pressure, jet size and baffling in the fuel tank.
- Does the fuel system maintain full pressure at peak engine horsepower in high gear?

Altitude, air temperature and fuel characteristics including quality, specific gravity and octane rating will affect your jetting requirements. Engine efficiency and Brake Specific Fuel Consumption (BSFC) also have an effect. Here are some examples of a Holley® 750 CFM 4V.

Octane	Temp.	Altitude	Jetting Front	Jetting Rear
94	80 F	0 ft.	81	86
Aviation 100LL	80 F	0 ft.	81	84
110 Race	80 F	0 ft.	78	83
94	80 F	3000 ft.	76	81
94	80 F	6000 ft.	73	77
94	40 F	0 ft.	84	89
94	120 F	0 ft.	78	83

As you can see by these examples, jet requirements can vary a lot depending on fuel, altitude and temperature. Oxygenated fuels are available in some states and can dramatically affect your jetting requirements. Make sure you get your jetting correct. Aviation fuel is lighter and will require richening an engine in relationship to its requirement with pump gas. We have found in the dyno testing of our crate engines that 1 point richer on air/fuel ratio equals only a few percent less power. Running an engine as lean as possible produces the best power but also increases combustion temperatures and the chances of engine damage.

COMMON PROBLEMS WITH FUEL DELIVERY SYSTEMS

- Do not mount an EFI electric fuel pump so it has to draw fuel from the tank. This creates negative pressure in the fuel line allowing the fuel to boil at a lower temperature.
- The pump must be mounted in the tank or in a location so that it is gravity fed.
- If the fuel rail is too small and you have large injectors, this can create a pulse in the fuel rail allowing fuel starvation on some cylinders.
- Fuel should be pushed through the fuel filter. Pulling fuel through a filter can cause cavitation. If a filter is to be used on the inlet of a rail-mounted fuel pump, a filter rating of 160 microns MINIMUM should be used.
- It takes approx. 1/2 lb of gasoline to support 1 hp. This is commonly referred to as a .5 BSFC. You should always err in the safe direction of larger when sizing your injectors and fuel pump.

COOLING SYSTEM CONSIDERATIONS/ COMMON PROBLEMS

- Higher horsepower requires more cooling capacity.
- When the fill point of the cooling system is not the highest point, air pockets are created. The air pockets then create hot spots, and the hot spots promote improper combustion, which can cause engine failure.
- Improper pulley size makes the fan and water pump turn too slow or too fast. Production water pumps are normally run at 20% over engine speed and do not perform well over 5000 engine rpm. Underdrive pulleys generally reduce water pump speed to 85% of engine rpm and may not provide enough water flow to cool the engine.
- The radiator must have enough area to dissipate the heat being generated by the engine.
- If the fan size is too small, it will not move enough air across the radiator so it can properly dissipate the heat being generated. Fan shrouds increase the effectiveness of the fan significantly.
- Radiator location can affect airflow through the radiator at different vehicle speeds.

FLYWHEEL, CONVERTER AND TRANSMISSION PROBLEMS

- Installing the wrong flywheel for the balance factor of the engine will cause vibration and eventually damage the engine.
- Wrong length input shaft or "stack-up height" can force the crank forward, damaging the engine thrust bearing.
- Improperly installing the torque converter can force the crank forward, damaging the engine thrust bearing. This is most commonly caused by improperly locating the torque convertor drain plug in the flexplate.
- If the torque converter balloons, it can force the crank forward, damaging the engine thrust bearing and the transmission. Most high-performance torque converters have anti-ballooning features.
- Damage to the thrust bearing can happen in seconds!

MISCELLANEOUS PROBLEMS THAT CAN DAMAGE AN ENGINE

- Dropping nuts, bolts, washers or foreign materials down the intake. We have seen this more than once.
- Reusing an intake off an engine that had broken parts in a cylinder. The parts can get bounced up into the intake manifold, carburetor or air cleaner (pieces of piston or piston rings, etc.). When you put your used intake on your new engine and start it, the pieces are drawn in and damage your engine.
- Bead-blasting an EFI intake. You will NEVER get all of the blasting media out. When the engine is started, it draws the blasting media into the cylinders, destroying the engine.
- Improperly torquing fasteners when installing new parts to your engine. Over-torquing of the intake manifold bolts to the cylinder head on 302 and 351W engines can cause head gasket sealing problems.
- Installing distributor gears at the incorrect height, or using gears made of the wrong material. We have seen this a lot on remanufactured distributors as well as popular aftermarket manufacturers of distributor assemblies. Use cast iron gears for cast iron flat tappet cams, and steel gears for steel hydraulic roller cams.

ENGINE DYNAMOMETER TESTING BASICS

TYPES OF ENGINE DYNAMOMETERS

There are many types of dynamometers for testing engines: Water Brake, Eddy-Current, Electric...just to name a few. Depending on availability and engine application, Ford Racing utilizes any of those mentioned. The basic function of each of these dynamometers (referred to as dynos from this point forward) is the same. Each applies a different method to absorb the energy output of the engine. The engine output is measured as torque (work) and power is calculated. The energy produced by the engine is absorbed by the dyno and eventually dissipated as heat. Dynos measure this engine output over a range of engine conditions that vary with speed and load. Temperature, pressures, air/fuel ratio, water, oil, fuel and airflow measurements are elements of the test cell. The accurate measurement of these parameters is just as vital to good testing as the dyno itself. The test cell that houses a dyno can vary widely. Conditioned airflow, exhaust evacuation and fuel delivery must be adequate for the power level of the engine tested. Shortfalls in any of these areas can impact the integrity of the test.

Ford Racing tests our crate engine offerings on any of the above-mentioned types of dynos. The type depends on test cell availability and type of engine application (street, sealed circle track, etc.). The engine is directly coupled to the dyno via a prop shaft. This type of testing yields brake power and torque. Test results are brake, horsepower and brake torque because measurements are taken directly from the crankshaft output.

Water Brake dynos absorb energy by pumping water through various orifices. Speed and load are controlled through a feedback loop of inlet and outlet valves. Water Brake dynos are typically capable of absorbing very high engine outputs and rpm.

Eddy-Current dynos rotate a disc through a magnetic field. This magnetic field can be varied in strength to control the rpm of the disc. These dynos are desirable for engine development due to very good rpm control.

Electric dynos rotate a generator to absorb engine output; this yields an electric output that can be accurately measured. Typically, Electric dynos can be used to spin a non-firing engine and measure pumping losses and friction. Those types of losses are difficult to ascertain in conventional dyno testing.

METHODS OF TESTING

Once the engine is installed in a test cell, and all desired operating parameters are instrumented, testing can begin. The dyno is capable of absorbing an infinite number of operating conditions ranging from idle to WOT (wide open throttle) and idle rpm to rpm's beyond peak horsepower. In cases where the dyno is operated manually, the operator will set the rpm value via a controller. The operator then opens the throttle via a throttle actuator and applies load to the dyno. As the throttle is opened further, the dyno will control the rpm to the set point and the load will increase until full throttle is reached. Many types of testing exist for evaluating engine performance. Crate engine testing consists of power development, durability, idle stability, etc.

POWER TESTING

Methods for performing power tests or power runs vary by dyno facility and engine application. Acceleration tests (sometimes referred to as ramp tests) are controlled completely by dyno software through the dyno controller and throttle actuator. The rpm and transient times are programmed by the operator and, once set, the controller takes the engine through the test. These tests typically do not let the engine stabilize at any given speed and data is collected throughout the ramp. For example: The test would begin at idle. Slowly, the throttle will be opened and rpm controlled to the first chosen rpm test point. Eventually the throttle will reach WOT. From then, the rpm will increase at a given rate of rpm/time until the maximum test rpm is reached. Test data is recorded throughout the entire run. Finally the controller will close the throttle and return the engine to idle.

Another method of power testing is the step method. This can be controlled manually or by an automated test where the dyno software controls the engine operation. The dyno controller is set to the first rpm test point and the throttle actuator is slowly opened to the full throttle point. The controller will maintain the rpm of the engine to the set point. In the manual mode, the operator will observe the data until stable and then record. In automated mode, the dyno will hold the throttle and rpm for a set period of time and automatically record the data. In either case, this testing provides good steady readings and makes for good repeatable runs. The above procedure will be repeated for all desired rpm test points.

Results of power testing are used in the design of crate engine packages and for marketing/sales. For further information on interpreting results, see article on "Correction Factors, Observed and Corrected Horsepower and Torque."

DURABILITY TESTING

Durability testing varies by engine application and configuration. The type of engine and where it will be used can influence the type of durability testing greatly. For example, durability testing criteria for a sealed circle track crate engine will be determined by minimum and maximum track conditions. Durability testing for a street application crate engine will be determined by peak torque and horsepower for the given components. Testing conditions are typically WOT or high-load conditions and variable rpm to cover as wide of a range as possible. In short, durability testing criteria vary, but the goal is the same. The goal is to produce an accelerated wear condition that exceeds the normal application of the engine as designed.

CORRECTION FACTORS, OBSERVED AND CORRECTED HORSEPOWER AND TORQUE

THE NEED FOR CORRECTED TEST RESULTS

The main reason for a correction factor is the ability to compare testing performed under different atmospheric conditions. The correction factor will contain a temperature, barometric pressure and an efficiency percentage. The temperature and barometric pressure have significant impact on the performance of an engine. Also, to a lesser degree, humidity can affect the performance. Some dyno facilities have controlled atmospheric chambers to condition air to a desired temperature, humidity and barometric pressure. These test cells are very sophisticated and usually booked with production, emission, cold start and hot test work. The test cells with these chambers can easily cost several hundred thousand.

Considering these challenges, it becomes evident that there is a need to be able to test engines under observed operating conditions and correct the results to a standard set of conditions.

SOME DEFINITIONS

Observed Operating Conditions are measured near the entry of the carburetor or inlet air system of the engine. These conditions include inlet air temperature, wet bulb temperature and actual barometric pressure.

Observed Torque is the measured torque value while the engine is running. It typically uses a calibrated load cell. This load cell measures the work the engine is doing in real time. The observed torque value is then used in calculating the observed horsepower value.

Observed Horsepower represents how fast the work (generated by the engine) is being done. This is calculated by the following formula: (observed torque * rpm)/5252.

Observed Barometric Pressure is atmospheric pressure measured near the engine air inlet.

Observed Inlet Air Temperature is self-explanatory.

Wet Bulb Temperature is the temperature achieved by evaporating water into the observed inlet air. This is accomplished by using a wick with one end in a vessel containing water and the other connected to a thermometer or thermocouple. This reading is used in calculating vapor pressure, humidity and, ultimately, correction factor.

Corrected Torque is the measured torque times the correction factor.

Corrected Horsepower is the measured horsepower times the correction factor.

Corrected Barometric Pressure is the observed barometric pressure minus the corrected vapor pressure.

Standard Barometric Pressure is stated in the definition of the correction factor.

Load Cell is an electronic device capable of measuring force.

Brake Horsepower is useful power determined from the engine (no other powertrain losses); can be observed or corrected.

BASIC ENGINE PERFORMANCE AND ATMOSPHERIC CONDITIONS

Engines utilize fuel and air, and apply a form of combustion to convert the power stored in fuel into usable work. The air contains oxygen; this is the element that supports the combustion process. Cool dry air contains more oxygen molecules within a constant volume and pressure. As barometric pressure increases, additional oxygen molecules are present (maintaining a constant volume).

For example, if an engine was tested on a cool January day where the barometric pressure was relatively high, observed engine performance will be better than the same engine tested on a hot, muggy August day when a storm was coming in. Also, engine tests performed in higher altitudes have lower observed barometric pressure and engine performance is lower.

CORRECTION FACTORS

Several correction factors exist and this article will deal with two of them.

(1) SAE J1349, June 1990 Data corrected to 77º F and 29.31 in Hg 85% efficiency.

(2) SAE J607, Data corrected to 60º F and 29.92 in Hg.

SAE J1349

This formula utilizes the observed inlet air temperature and wet bulb readings to calculate saturated, current and corrected vapor pressure. The corrected vapor pressure is subtracted from the observed barometric pressure. It is subtracted because this pressure is due to water vapor in the air. This yields corrected barometric pressure.

The conditions for correction are 77º F and barometric pressure of 29.31 inches of mercury. Once the corrected barometric pressure is calculated and the observed inlet air temperature is known, those values are plugged into the following formula. The correction factor formula is:

C.F. = 1.18 #[(29.31/Corrected Barometric Pressure) * {(Observed Inlet Air Temp+460)/(537)} ^.5]-.18

SAE J607

This formula utilizes the observed inlet air temperature and wet bulb readings to calculate saturated, current and corrected vapor pressure. The corrected vapor pressure is subtracted from the observed barometric pressure. It is subtracted because the pressure is due to water vapor in the air. This yields corrected barometric pressure. The conditions for correction are 60º F and barometric pressure of 29.92 inches of mercury. Once the corrected barometric pressure is calculated and the observed inlet air temperature is known, those values are plugged into the following formula. The correction factor formula is:

C.F. = [(29.92/Corrected Barometric Pressure) ^1.2 * {(Observed Inlet Air Temp+460)/(520)} ^.6]

SUMMARY

Once a correction factor is calculated, the observed numbers are multiplied by it. These are the “corrected values.” Undoubtedly, the best scenario is to test under the exact same conditions each time. If that is not achievable, a good rule of thumb is that engines corrected to the SAE J607 standard will yield corrected torque and power numbers approximately 4% higher than those corrected to SAE J1349. Unfortunately, SAE J607 conditions are not very realistic. The most commonly accepted standard is the SAE J1349. This corrects to a more practical set of atmospheric conditions and utilizes coefficients to compensate for an 85% mechanical efficiency. Please note temperature is converted Rankine degrees in both formulas.

FYI about Ford Racing catalog torque and horsepower ratings

Ford Racing push rod crate engines are rated at STP-corrected operating conditions. This correction factor is actually SAE J607, and also referred to as “Racer Corrected.” Simply speaking, the STP correction factor takes the ambient conditions and corrects the observed data to 60º F, a barometric pressure of 29.93" of mercury and no correction for vapor pressure. This correction factor is used by most dyno shops because it yields the highest numbers to advertise.

Ford Racing Modular crate engines are rated at “SAE” corrected operating conditions. This correction factor is SAE J1349, and typically referred as just “SAE.” This correction factor is used by automotive manufacturers to rate torque and power for new vehicles. This correction factor adjusts the ambient operating conditions and corrects the observed data to 77º F, barometric pressure of 29.31" of mercury and compensates for corrected vapor pressure. Some of Ford Racing's Modular crate engines are direct vehicle replacement engines, and since these engines/vehicles are originally advertised with SAE-corrected numbers, they also are advertised in the catalog with SAE numbers. This keeps the engines' torque and power ratings consistent with O.E. advertised numbers.