SUPER SIX MOTORSPORTS

Cyclone 3.5L EcoBoost, 3.5 Duratech and 3.7L Ti-VCT V6 Engine Tech

All 3 variants use the same forged crankshaft with 3.413" stroke. The difference is the bore, 3.64" for the 3.5/EcoBoost and 3.76" for the 3.7L version. All of the variants blocks are cast aluminum with floating cylinder walls and cast iron liners. None of the blocks use a closed deck. The FWD and RWD variants use different blocks, timing covers and accessory locations, which means that the blocks are not universally interchangeable. Seems that just about all of the parts now use a QR symbol.

All use the same powder metal connecting rod which includes a bushing on the pin end for a floating pin. The rod is shot peened for improved fatigue strength, has a decent cross-section and uses cap screws instead of through bolts. The rod shown on the left is a 96-04 3.8/4.2 powder metal rod, the Cyclone rod in the center and one of our favorite 351W forged I-beam rods on the right. Notice how the cross section of the Cyclone rod appears to be more like the 351W I-beam than the 3.8/4.2 rod which was much to weak for high performance applications. Only time, boost and nitrous will determine the durability and strength of the Cyclone rod, but since the EcoBoost engine has already been proven to provide exceptional durability in the 365-400 HP range with Ford's factory tuning expertise, we can expect adequate durability at power levels around 500 HP or so with upper rev limits at 6500-7000 or so as long as the tuning is on the money without detonation. The Cyclone rod is no light weight at over 630 grams, but at least most of that is in the big end where the rod could be lightened without weakening it. The small end of the rod is actually tapered which reduces the important weight up at the top of the cylinder, but the pin is thick walled and very heavy.

Compression ratios are 11:1 for the EcoBoost and 10.5:1 for the 3.5/3.7. 11:1 compression ratio for a turbo application is an exceptional accomplishment owed to unique technologies that are employed in EcoBoost which include unique piston crown details, direct fuel injection into the combustion chamber instead of the intake port, variable valve timing of both intake and exhaust cams and internal piston cooling. EcoBoost uses a unique cam driven mechanical fuel pump to raise the fuel pressure from 40 PSI to ~ 2200 PSI for direct injection. This high pressure mechanical pump is driven by a special lobe on the intake cam on the driver side cylinder head. The generic 3.5/3.7 use cast iron cams, that visually appear to be identical with exception of the lobe locations and the position teeth, and have identical engineering numbers. There is a tiny lasered part number below the QR symbol that may differentiate the intake and exhaust cams. EcoBoost uses what appears to be a billet steel intake cam with the special lobe for the high pressure fuel pump. We know of 2 generic 3.7 cast iron cams that have broken in two, so perhaps the EcoBoost billet intake cam was intended to add some strength due to the mechanical fuel pump.

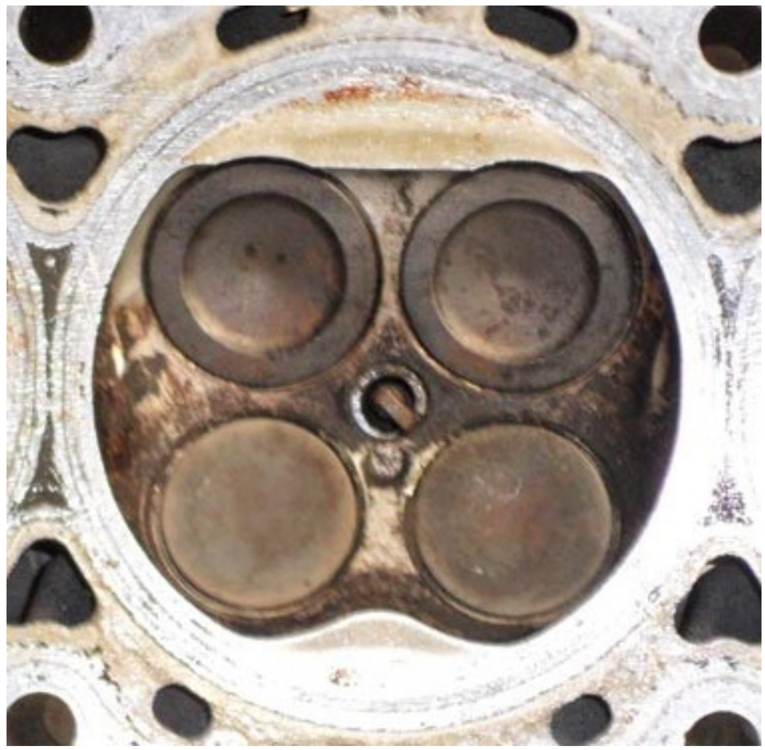
The pistons of the EcoBoost and the generic 3.5/3.7 are both hypereutectic and use anti-friction coated piston skirts, this has become the norm for modern production engines. The pistons are made with internal lightening pockets to reduce reciprocating weight and use modern thin, high performance rings with a Dykes or Napier-style 2nd ring. The pistons are light weight at 372 grams but the wrist pins are thick walled and pretty heavy at 119 grams. The EcoBoost piston combines a dome with dual intake valve reliefs and an internal dish, kinda looks like a toilet bowl seat, where the bowl is the target of the direct injection. The 3.7 piston uses a shallow flat topped domed design with 4 valve reliefs. We'll have to wait and see how well the stock 3.7 pistons hold up once the hot rodding begins with increased boost, superchargers, nitrous, etc but as we know, hypereutectic pistons in general don't tolerate even the smallest amount of tuning error, detonation, etc without catastrophic failure.

The cylinder heads are paired, there are specific left hand and right cylinder heads that cannot be interchanged. The heads are clearly marked in several locations and even include alloy identification markings! The intake port volume is 194cc, the exhaust port is 83cc and the combustion chamber is 59cc. The 3.5 and 3.7 do not use the same cylinder heads and the heads do not interchange. The EcoBoost cylinder head is also different from the generic 3.5 and 3.7 cylinder heads with regards to direct injection and the exhaust flange bolt patterns The combustion chamber is shaped differently and of course the presence of the hole for the fuel injector. In that regard, EcoBoost fuel injectors are located below the intake ports. Each head uses a master cam cap which holds the electronic controllers which vary intake and exhaust cam position via oil pressure. The cam phasers are mounted on the front end of each cam with a single bolt (conventionally threaded by the way) that is tightened to a torque value that would make even King Kong envious. The cam phasers are also indexed to the cam with a small pin. Plenty of leverage is needed here and thankfully the cams have wrenching surfaces in several places. The cams rotate in the clockwise direction on both heads. The timing chain directly drives the intake cam on each head and the exhaust cams are driven indirectly from the intake cams by secondary chains which each have their own hydraulic tensioners. Each of the minor intake and exhaust cam caps are identified by number and direction, but there is no convention which identifies them by head, this has several connotations, so until it is determined what the tolerances are, plan to segregate cam caps by cylinder head. The master cap represents #1 and #5, #2-4 on the exhaust side from front to back, and #6-8 on the intake side from front to back. Like most modern engines, MLS head gaskets are used, 4-layer construction, .050" thick.

As might be expected, the exhaust manifolds are different as well and the EcoBoost exhaust manifolds do not fit on the 3.5/3.7 heads due to the differing bolt patterns.

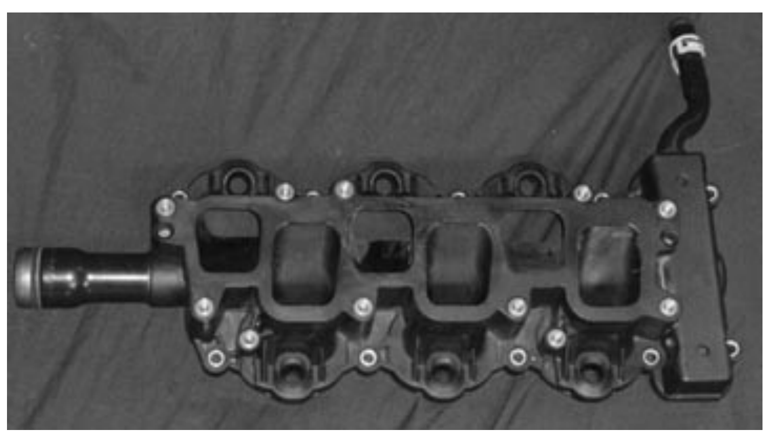
Unlike the valvetrain of the new Coyote 5.0 engine which uses hydraulic lash adjusters and cam followers, the valvetrain of the generic 3.5/3.7 and EcoBoost uses what Ford calls "Direct Actuating Mechanical Buckets". This type of system has been used on motorcycles for ages and other automotive applications such as Toyota 2JZ-GTE after being pioneered by Cosworth many years ago. You can liken this to a pushrod engine comparison as the difference between a hydraulic lifter and a solid lifter. Just like a solid lifter valvetrain operates with a certain amount of lash or clearance, so does direct actuation operate with lash or clearance between the cam lobe and the upper surface of the bucket. Without the hydraulics of a lash adjuster and without the weight of the follower, the Cyclone valvetrain should exhibit better high RPM stability than the Coyote 5.0! The lobe contact surface of the bucket is highly polished. The buckets are computer matched at time of assembly, probably as a means to accept very minor tolerances on the depth of the valve job because the lash values, i.e. cam to bucket clearances, are very tight. This means that the buckets must be treated as shims that are specific for each and every valve. The buckets must be segregated by exact location with respect to the individual valves and seats or else it might be nearly impossible to achieve the desired lash without extensive reiterative assembly, measurement, disassembly, etc until all 24 buckets are in the correct location. We're going to miss the user-friendliness of a hydraulic roller follower valvetrain. Typical intake valve lash is .009-.010" intake and .015-.016" exhaust as measured with a feeler gage. Net intake valve lift is approximately 0.385", net exhaust valve lift is approximately 0.360". The intake and exhaust valves are very small, with 5.5mm stems and tiny single groove locks with small, lightweight retainers. The exhaust valve even includes an undercut stem at the head. The valve sizes are 1.45" intake and 1.22" exhaust. The valve springs are typically very small, with an installed height approximately 1.52". We say approximately because its near impossible to measure with the springs so deep in the tiny recessed spring pockets. We have not measured spring rates at the installed height because a very low load spring force gage is required, the seat loads are probably in the 60 pound range.

The intake and exhaust ports are very straight, oval shaped, 194cc intake volume, 83cc exhaust, the combustion chambers are very shallow 59cc with shrouded intake valves. 3.5/3.7 head shown here. Both intake and exhaust ports display protrusions on the roof which provide extra material at the bottom of the deep valve spring pockets. Elimination of these protrusions on the roof of the port will help flow in a big way, we'll have to find out if this impacts long term durability or not, a crack here would hard to diagnose and be difficult to repair.



The Cosworth-style 4-valve heads flow a lot of air, over 300 CFM and the flow numbers easily exceed conventional style ports of similar volume and achieve flow rates that we'd never achieve with the 3.8's split-port heads. This is BIG, means there is so much more potential in the Cyclone with these air flow rates.

There is an important consideration to remember in the various intake manifolds. Since EcoBoost employs direct injection, the fuel injectors are located directly in the cylinder heads, which means the EcoBoost intake manifolds are generally one-piece intakes without provisions for fuel injectors, which means that they cannot be swapped onto the naturally aspirated versions. Since the naturally aspirated engines are not direct injected, their intake manifolds are generally two-piece intakes with the fuel injectors located in the lower intake manifold. In other words, the intake manifolds and heads must correspond based on presence or absence of injectors and the injector locations. The intake manifolds, heads and pistons are not interchangeable between naturally aspirated and EcoBoost applications. Driver side valve cover, fuel rails, high pressure direct injection fuel system, etc are also non-interchangeable.



The plastic lower intake manifold of the 3.7 begs for porting to provide a better transition from the square cross section of the runner to the oval shape at the flange surface and to reduce the protrusion at the fuel injector bung. We've also flowed the stock and ported generic 3.5/3.7 intake. What we learned is that the stock lower intake results in a typical 21% flow loss and porting completely eliminates that loss. We have not flow tested the upper intake. Considering how ugly it is, it's a great design, large plenum volume, bellmouthed openings and tapered runners. While it performs well at stock power levels, its kinda ugly and will be a compromise on a high performance stroker or forced induction application. For this reason, we're working on the development of a prototype sheetmetal upper intake for power adder applications.

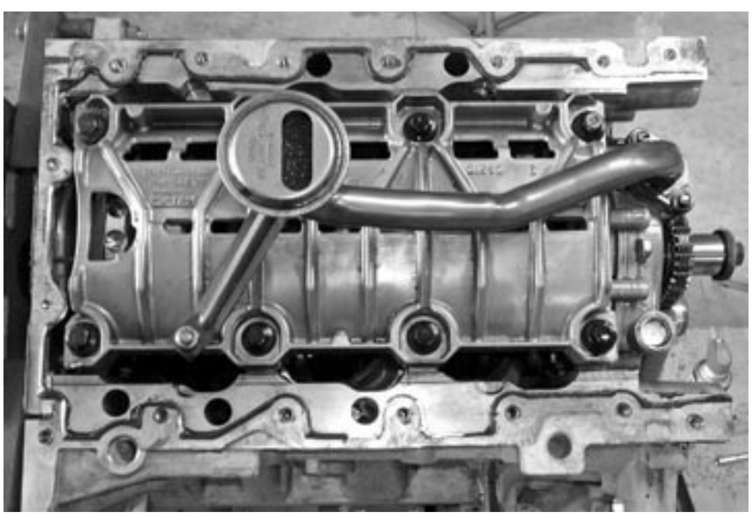
The 3.5 uses an aluminum lower intake manifold with equal sized ports but of similar shape, again, porting will be beneficial and yield a better transition to the oval intake port shape in the cylinder head. The 3.5 aluminum lower intake manifolds have different bolt and coolant transfer ports and will not interchange with the 3.7 lower intakes.

Back to the crankshaft, it is indeed a forging as has been reported by the media, but it's a twisted type, not as good as a non twist forging, but at least we have a forged crank now. And its made from 4130 alloy steel. Its internally or neutral balanced and also fully counterweighted like the later 3.8's, 4.0's and 4.2s. The counterweight machining is much rougher than it should be for best fatigue life in high performance/high RPM applications, but with polishing and shot peening the crank should prove to be exceptional. The leading and trailing edges of the counterweights can be contoured to improve the windage. The crank snout does not use a keyway, but instead uses a pin to align the crank timing gear, however, the harmonic balancer is attached solely by interference fit, there is no key or pin securing the harmonic balancer/crank pulley. The rod and main journals are undercut, a big rolled radius would have been better for strength and durability. Main and rod oil holes are slightly chamfered. The flywheel bolt pattern uses 8 bolts. Overall, the crank is a big improvement over the cast iron cranks used previously in 3.8's, 4.2's and 4.0's.

The bottom end uses a cast aluminum structural windage tray that also acts as a main cap girdle if you think the cross bolted 6-bolt main caps, as beefy as they appear, need the help of a structural aluminum windage tray. Also of interest is the large diameter of the oil pump pickup/screen assembly, should ensure more than adequate supply of oil to the pump.

The 3.7 in the Mustang and F-150 uses cast iron exhaust manifolds that are thin and flat, carrying the shape of the oval exhaust ports to the collector. Although the volume of the exhaust manifolds seems small, its shaped nicely with regards to exhaust flow. No doubt that short tube and long tube headers should both offer a marked improvement, especially with our ported heads with their enormously improved exhaust port, better headers will be real important.
For anyone interested in engine swaps, here are the rough overall dimensions of the 3.5/3.7 and EcoBoost. For the 3.5, width at valve covers: 25", Height: 30.5", Length (not including accessories): 22-23". The overall height of the EcoBoost is slightly less than the generic version: 27", but the EcoBoost is wider at the turbos: 31", with the turbos located 9" above the bottom of the oil pan.

The block is very stout, cast aluminum alloy with contemporary architecture aimed at improving strength, durability and performance. High strength and light weight, the block only weighs about 70 pounds and employs robust 6-bolt billet steel main caps, cast-in piston oil squirters and a deep



skirt. Like other modern engines, the Cyclone uses a removable rear main seal cover plate and a structural rear sump cast aluminum oil pan. The cylinders feature cast-in liners and are fully floating at the top of the block.

Cam Phasers: The cam phasers are quite heavy and unfortunately pretty complicated with overlapping internal oil passages in the rotor, internal spring-loaded locks, metallic oil seals, etc. Oil pressure unlocks the phasers which allows them to be phased in the desired directions by oil pressure as a function of load, RPM, etc. The intake phasers advance the retarded timing, the exhaust phasers retard the advanced timing. Tuners can create a "ghost" cam effect by allowing a certain amount of overlap to occur between the valve timing events. So far, the "Ghost" cam tunes can deliver the intended lopey cam sound With respect to the intake phaser, capture marks on the stator show the maximum cam timing range is right at 40-44 degrees and this correlates with some of the factory cam tuning data we've seen which shows the range to be 45 degrees of retard on the intake side. These phasers are what allows these engines to make good power at higher RPMs but also allow improved fuel mileage in the lower cruising RPM ranges and the typical low speed driving RPM ranges by cranking in large amounts of retarded intake cam timing to minimize pumping losses to improve fuel efficiency. Taking a close look inside an exhaust cam phaser, shows that the exhaust cams are operating in a range of about 25 degrees of advance, again that's right in line with the factory stock cam timing phasing range which is 20 degrees maximum. We were hoping that the Cyclone's cam phasers were similar to the Coyotes, but unfortunately, the 3.7's phasers are quite different from the Coyote's. This means that 3.7-specific limiters or pahser deletes would be required. If one were prone to eliminating the heavy phasers.

It turns out that forced induction has not been kind to the 3.7 stock hypereutectic pistons which have proven to be failure prone at low and intermediate boost levels, mainly on the driver side of the engine. These pistons use a relatively thin top ring land and the top ring uses a tight ring end gap typically .011-.012". Combined together, these factors contribute to catastrophic piston failure when under boost. They tend to break out a large segment of the 2nd ring land on the intake valve side of the piston. The cure is the use of our forged pistons with generous top ring land thickness and proper, for forced induction application, ring end gaps in the .021" range.