



## FOUR-CYLINDER ENGINE SECTION

### 1.6L OHV "KENT" ENGINE

Open-wheel racing enthusiasts associate this overhead valve design with the long-lived international Formula Ford series, the starting point for many professional drivers. Most of the combustion chamber is in a dished piston, where the mating cylinder head face is nearly flat. Production for European models (Cortina, Capri and Fiesta) is now phased out. Ford Racing sold numerous production-type parts for Formula Ford competition.

### 1.6L/1.8L/1.9L/2.0L SOHC "CVH" OR "SPI" ENGINES

The two-valve CVH (Canted Valve Hemispherical) engine was introduced with the 1981 Escort and later used in Focus. The layout is also called "Cam in head," because it resembles a classic overhead valve geometry. A single overhead camshaft lifts up hydraulic lash adjusters, linking individually mounted rocker arms to valves "canted" at angles relative to the cam axis, as well as front to rear, to match the shallow hemispherical chamber. Manufactured at Dearborn (Mich.) Engine Plant, it was replaced by the Duratec® HE engine family.

### 1.6L/1.8L/2.0L DOHC MAZDA® ENGINES

In the early 1990s, Mazda®-manufactured four-valve engines were shared with Ford applications. The 1.6L was introduced on 1991 Australian-made Mercury Capri (including a turbocharged variant), the 1.8L on 1991 Escort GT, and the 2.0L on the 1993 Probe. Ford Racing parts were not developed for this iron-block architecture, which was replaced by the Zetec® and eventually Duratec® I-4 engine families.

### 1.8L/2.0L DOHC "ZETEC®" ENGINES

Based on the CVH engine bore centers, this iron-block four-valve was developed for the 1994 Mondeo/Contour world car, and later shared with the Escort and Focus. Manufacturing sites were Cologne, Bridgend (Wales), and Chihuahua (Mexico). Launched with hydraulic bucket tappets, it was later converted to light-weight mechanical (solid) tappets. Ford Racing parts were developed with its Focus usage, including a 170 horsepower SVT Focus, the USAC® Ford Focus Midget Series, and SCCA F2000. The production Zetec® was superseded by the Duratec® I-4.

### 2.0L/2.3L/2.5L SOHC ENGINES

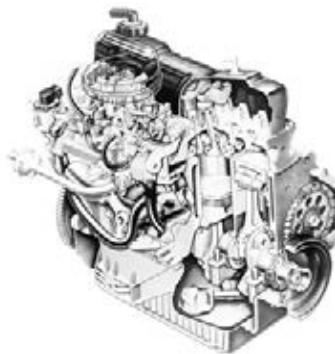
Ford's first North American metric engine featured a belt-driven overhead cam and finger-follower valve train, while retaining traditional cast iron block and head. The 2.3L SOHC was the base engine of numerous 1974-1997 models, including Mustang, Pinto, Fairmont, Ranger, and early Aerostar vans. A turbo version was launched with the new 1979 "Fox" Mustang, with a 2nd generation port-fuel-injected (PFI) turbo powering the 1983 Thunderbird Turbo Coupe, Mustang SVT, and later the Merkur® XR4Ti. A twin spark plug head with Ford's first coil-pack distributorless ignition was introduced on 1989 Ranger and 1991 Mustang models. The Ranger also offered a smaller bored 2.0L version in the mid-'80s; its last iteration was the stroked 2.5L 1998-2000 Ranger. Lima (Ohio) Engine Plant provided most production, supplemented by Taubate (Brazil). Ford Racing parts were



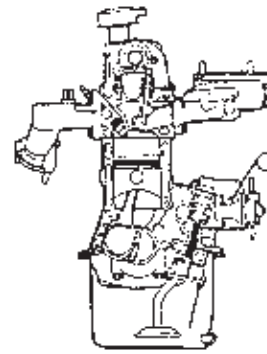
1.6L/1.9L CVH



2.3L OHC (Turbo-Intercooled)



2.3L/2.5L HSC



2.0L OHC

developed for the SOHC, including a partnership with Esslinger® Engineering for an aluminum cylinder head. Ongoing racing usage includes the SCCA F2000 series.

A European 2.0L SOHC was produced for 1971-1974 cars. While conceptually similar, it was dimensionally unique in terms of bore, stroke, bore spacing, block deck height, and crankshaft journal diameters.

### 2.2L 3V SOHC PROBE ENGINE

The 1989 Probe launched with a Mazda®-sourced overhead cam three valve (2 intake, 1 exhaust), in naturally aspirated and turbo versions. Ford Racing parts were not developed for the 2.2L.

### 2.3L/2.5L OHV "HSC" ENGINES

The 1984-1994 Tempo/Topaz 2.3L High Swirl Combustion (HSC) engine resembles Ford's classic cast iron push rod 200 cid I-6, with two cylinders removed. The 1986-1990 Taurus offered a 2.5L version, but most customers wisely chose an available V6.

### 1.1L/1.3L/1.6L DOHC "SIGMA" ENGINES

Ford's first aluminum block I-4 arrived with the 1997 Fiesta, internally designated as "Sigma." Primary design work was contracted to Yamaha, with original manufacturing in Valencia (Spain) and later at Bridgend (Wales) and Taubate (Brazil) plants. In this compact design, double overhead cams actuate mechanical bucket tappets. The 2011 Fiesta 1.6L is the first North American production application, with twin-independent variable cam timing (Ti-VCT) increasing fuel economy and power. The turbocharged "EcoBoost" variant provides up to

178 horsepower in North American Fusion and Escape applications. Ford Racing offers a growing number of parts, including key components for "B-Spec" race configuration.

### 2.0L/2.3L/2.5L DOHC ENGINES

Mazda® led initial design of this aluminum-block world engine, which replaced five other large four-cylinder engine families starting in 2001, with manufacturing in Mexico, Dearborn, Valencia (Spain), and China. Early North American applications included Ranger, Focus, Fusion, and Escape, with a specific late closing intake cam (Atkinson Cycle) on hybrid applications.

Dearborn Engine Plant is the exclusive source of the 2.0L gas-direct-injection (GDI) twin-independent variable cam timing (Ti-VCT) upgrade launched for the new 2012 Focus, developing 160 horsepower. Chihuahua and Valencia Engine Plants provide the 2.0L/2.5L intake-VCT engine, for North American Escape, Fusion, Fusion Hybrid, C-Max Hybrid, and Transit Connect.

A Valencia-built Gas Turbo Direct Injection (GTDI) version launched for the European Mondeo. In the 2012 Ford Explorer and Edge, the GTDI enables up to 30 miles per (U.S.) gallon highway, for fuel economy leadership. Other versions are used in the Falcon (Australia), as well as Land Rover® and Volvo® applications. For 2013, Fusion, Escape, Taurus, Focus ST, and even Lincoln MKT limo applications are added, with 240-247 horsepower. As a result, this engine architecture is offered in every North American vehicle platform except Fiesta and full-sized trucks.



## V6 SECTION

### 2.0L/2.5L/3.0L DOHC 4V “DURATEC®” ENGINE

The small engine compartment of the 1994 Contour (Mondeo in Europe) required a compact design, with a short forged steel crank and rear-mounted cam-driven water pump. An aluminum block casting process was licensed from Cosworth®, which rotates the sand mold during metal solidification to improve quality. Subsequent applications included Taurus, Cougar, Escape, Mazda® MPV, Mazda® 6, Freestyle, 500, and Fusion. Initial concept design work was contracting to Porsche® Engineering, resulting in a full main bearing girdle similar to the Porsche® 928 V8. Roller finger follower (RFF) aluminum cylinder heads resemble the 4.6L 4V, although more compact. The 199x SVT Contour tuned the 2.5L to 200 horsepower, with Extrude-Hone cylinder heads improving airflow. Low-profile mechanical bucket tappet heads were developed for the 3.0L Jaguar® S-Type/Lincoln LS packages, and later applied to the All-Wheel-Drive X-Type in 2.0L (European sales), 2.5L, and 3.0L variants. 2010-2012 versions were upgraded with variable cam timing (VCT) and identified internally as the “D30 Pl.” Aftermarket V6 applications have included the turbocharged Noble® sports car from South Africa. Aston Martin’s® 6.0L V12 is based on this architecture.

### 2.5L DOHC 4V PROBE ENGINE

The 1993 Probe used this all-aluminum Mazda® design, shared with the Mazda® 626 and further developed for the Mazda® Millenia’s Lysholm® supercharged Miller-cycle. Mazda® replaced this engine family with Ford-designed V6s.

### 2.8L/2.9L/4.0L OHV/SOHC 2V “COLOGNE” ENGINE

Ford of Germany developed a 1961 1.2L OHV 60-degree V-4 to a 2.8L/2.9L V6 for North American Capri, Bronco II, Mustang II, Ranger, and Merkur® Scorpio® sales, then expanded it to 4.0L for the 1991 Explorer. The original push rod layout was converted to modular-style single overhead cam 2V heads for 1997 Explorer and 2001 Ranger, using a jackshaft in original block camshaft bore to drive the right-hand cam chain from the rear, and the left-hand cam chain from the front. A main bearing bridge, structural oil pan, and second order balance shaft were offered for improved NVH. Mustang and Land Rover® applications were added starting in 2004. Ford Racing sells parts for 2005-2010 Mustang.

### 3.0L OHV 2V “VULCAN” ENGINE

A traditional cast iron block and head-push rod design introduced for 1986 Taurus, the Lima (Ohio)-produced Vulcan was later used in Ranger, Tempo, Aerostar, Windstar, and the first-generation Probe.

### 3.0L/3.3L SOHC 2V “VILLAGER” ENGINE

Nissan® contributed this iron block engine to the Mercury Villager and Nissan® Quest minivan joint-venture project.

### 3.0L/3.2L DOHC 4V “SHO” ENGINES

The Yamaha®-designed and built 3.0L SHO

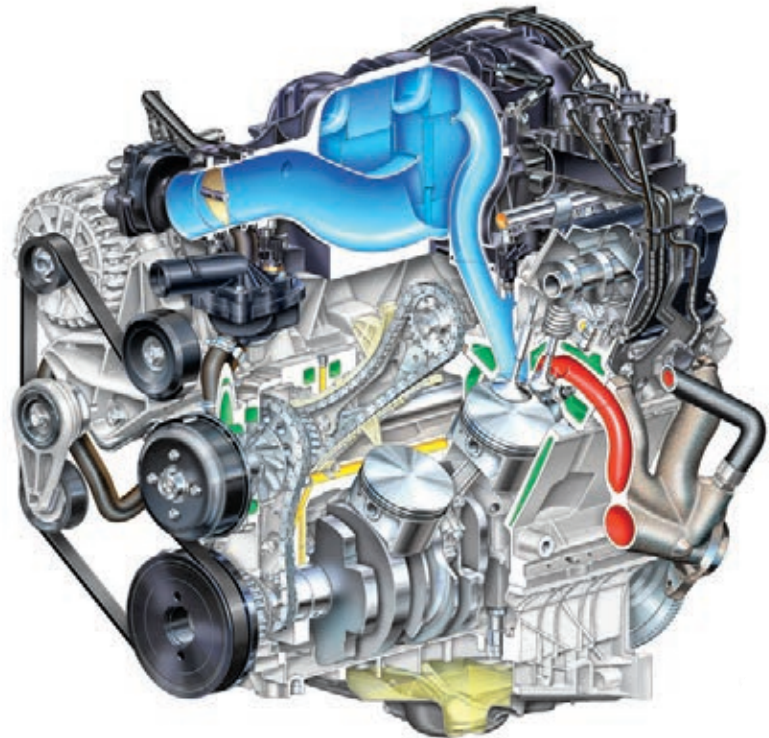
(Super High Output) program was initiated for a late-'80s Ford SVT mid-engined sports car, code named GN34. When the GN34 was cancelled, the engine was picked up for the 1988-1995 Taurus SHO. 3.0L versions used a five-speed manual; the 3.2L version was used in a later automatic transmission application. The high-revving SHO V6 used a cast iron block and 4V heads with bucket tappets.

### 3.5L/3.7L DOHC 4V “DURATEC® 35” and “DURATEC® 37” ENGINES

Code named “Cyclone” in development, this all-aluminum design uses a deep-skirt die-cast block with cast-in liners, six-bolt main bearing caps, forged steel crank, and mechanical bucket tappet heads. Launched from Lima Engine Plant for the 2007 Edge, it is now used in all of Ford’s North American mid-/large-sized front-wheel drive vehicles, typically coupled to the new 6F transmission. Lincoln and Mazda® applications increased bore size for 3.7L displacement, with Mazda® engine manufacturing localized in Hiroshima.

Cleveland-built “EcoBoost” Gas (twin) turbo direct injected (GTDI) 3.5L versions premiered in 2010 for the All-Wheel-Drive Taurus SHO, Flex, plus Lincoln MKT and MKS. With 365 horsepower, this engine provides V8 performance without the associated fuel-economy or vehicle-packaging compromises. For 2013, Explorer Sport applications are added.

Twin-independent variable cam timing (Ti-VCT) was added for the first rear-wheel-drive usage, achieving 305 horsepower for the 2011 3.7L Mustang — more than three times base Mustang



output from 20 years prior, and equaling SVT Cobra output from only 10 years prior. The 2011 F-150 added the same base engine, plus a rear-wheel-drive Ti-VCT version of the 3.5L EcoBoost, achieving a 22 mile-per-gallon (U.S.) highway rating and 365 hp. These F-150 V6s will be shared with the North American-produced rear-wheel-drive Transit announced for 2013 production. The Ti-VCT upgrade has also migrated to normally aspirated (non-turbo) front-wheel drive 2011 Flex/MKX, 2012 Explorer, 2013 Taurus, Flex, MKS, MKT, and MKZ

Look for this engine in even more applications and Ford Racing parts in the future.

### 3.8L/3.9L/4.2L OHV 2V “ESSEX” ENGINES

Named for the Essex (Ontario) Engine Plant, the 1982 3.8L used a 90-degree bank angle, like a V8, for numerous rear-wheel-drive car applications. Front-wheel-drive applications started with the 1988 Taurus/Sable and Continental, then the 1994 Windstar. A first-order balance shaft was added to select applications beginning in 1988. The 1989-1995 Thunderbird SC (Super Coupe) added a 90 cu. in. Eaton® Roots-style intercooled supercharger.

Split-port cylinder heads were introduced with the 1996 Windstar, and then in all 4.2L applications. The 95 mm stroke (vs. 86 for the 3.8L) 4.2L was launched in the 1997 F-150 and Econoline, replacing the 4.9L I-6. A two mm-stroke increase created the “new” 3.9L from the 3.8L in 2004. 3.8L/3.9L usage in the 1994-2004 Mustang resulted in some aftermarket performance parts.





## SMALL BLOCK V8 289/302/351W/351C/351M/400

### SIX WAYS TO BUILD A WINNER

Ford manufactured millions of small block V8s, and Ford Racing parts are available for many of them. You have a choice of six engines to modify (eight if you count two high-performance BOSS versions). So, you've got great flexibility working for you, whether you begin with a complete engine assembly or a bare block. All have four-inch bores, but there are differences that affect parts interchange, for example, the water passages described on page 86. Here's a brief description of Ford small blocks.

### 289/302

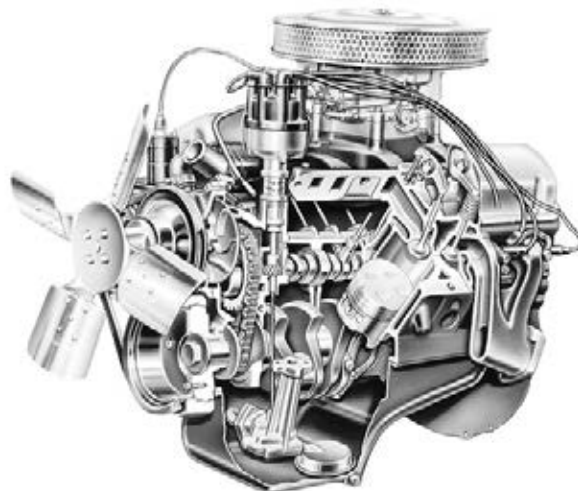
The 289 was produced from 1963 through 1968, and the 302 from 1968 to 2001. They're very similar, except for stroke. Of special interest is the 289 4V high-performance engine (1963-1967) with mechanical camshaft, threaded rocker arm stud (adjustable) and a recessed spring seat. Most other 289/302 (1968-1976) engines use a press-in stud. 1978 and later 302 engines use a modified pedestal. Many 289/302 parts fit earlier 221/260 engines (which had smaller bores). They also had less metal around the bores, so you can't overbore to come up with a 289. The 1985 model Mustang GT introduced a new high-output 302 with roller tappet camshaft. Electronic fuel injection was added in 1986.

### 302 BOSS

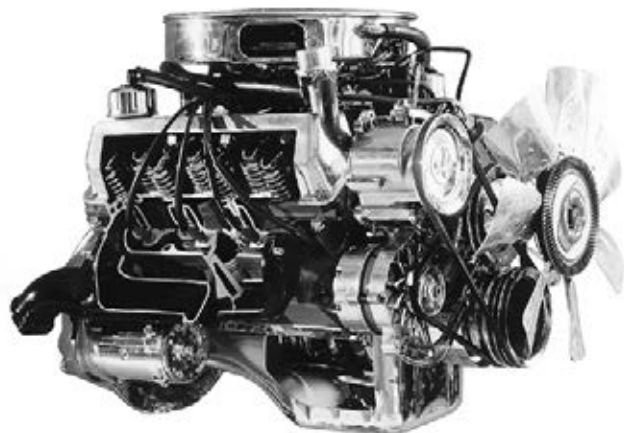
This is certainly one of Ford's all-time super engines. The 302 BOSS (1969-1970) proved to be very competitive in 5-liter TransAm racing. It featured big breathing heads with canted valves, mechanical cam, stamped rocker arms with a threaded adjustable stud, push rod guide plates, forged crankshaft, 4-bolt main caps (#2, #3 and #4 journals), beefy con rod with spot-face for .375" bolt and forged pistons.

### 351W (WINDSOR)

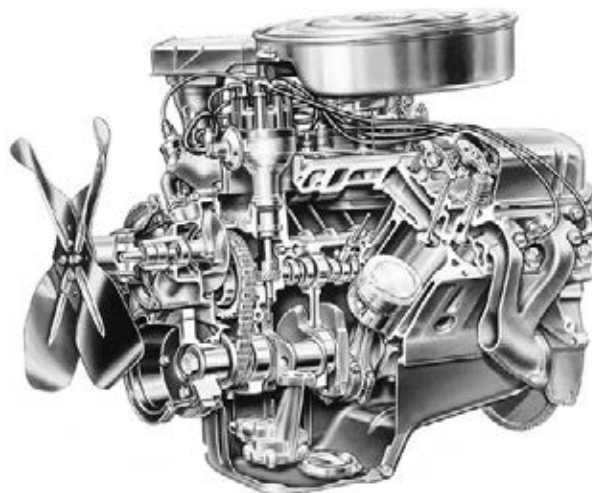
The Windsor Engine Plant builds this engine; hence the name. Normally, this isn't important. But another engine, the 351C (for Cleveland Engine Plant), has the same displacement. That's about all they have in common. So, it's always important to differentiate between the two. The 351W is a beefier block than the 289/302, but has the same bore spacing (4.38") and bore diameter (4.00"), so heads retrofit. A higher deck height requires a unique intake manifold. Main journals (3.00") are larger than the 289/302 (2.25"). Camshafts interchange, but the 351W has a different firing order: 1-3-7-2-6-5-4-8 vs. 1-5-4-2-6-3-7-8 for the 289/302, except 1982 and later 302 HO which use the 351W firing order. The 351W has been used from 1969 to 1998. In 1994 the cylinder block was modified to accept a hydraulic roller camshaft for the F-150 truck. The 1995 Cobra "R" Mustang used a 351W engine that was very similar to the Lightning engine. The Modular engines eventually replaced the 351W.



289 Hi-Per



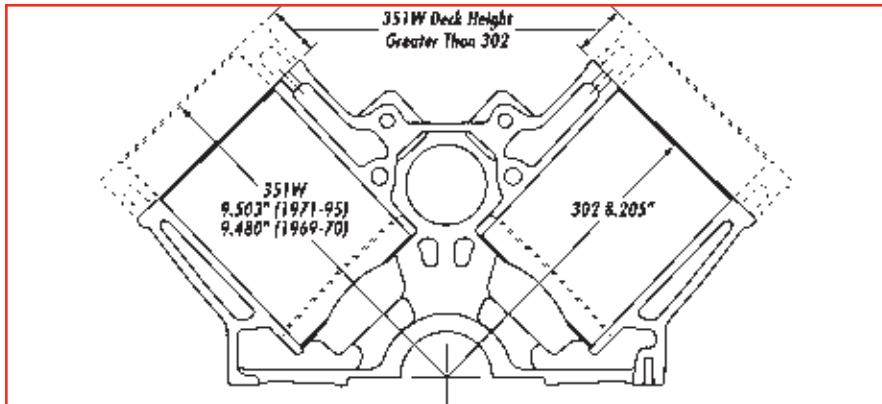
302 BOSS



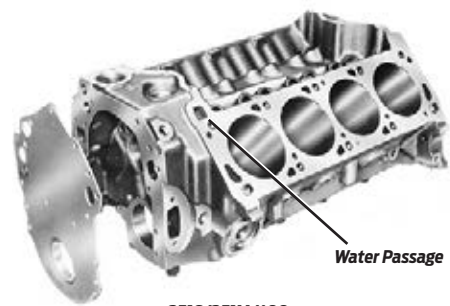
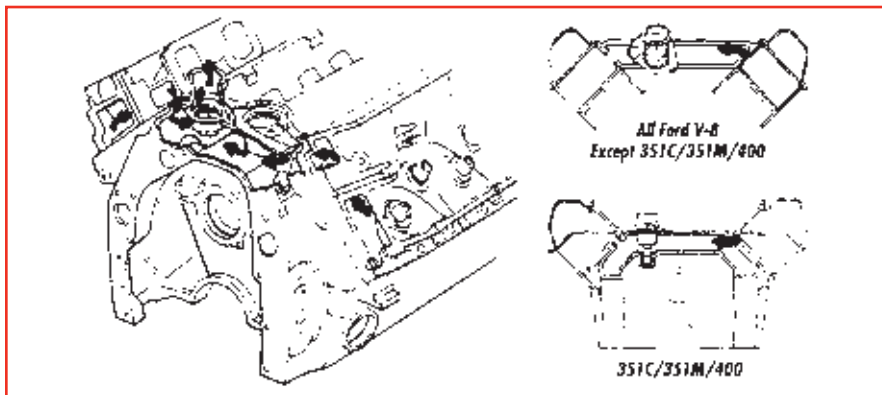
351W



## SMALL BLOCK V8



289/302/351W



351C/351M/400

Water Passage

### 351C (CLEVELAND)

The 351C entered the scene in 1970 and was produced until 1974. It has canted valves with multi-groove keepers, hydraulic cam and pedestal-mounted rocker arms with "sled" fulcrum seats that are retained with cap bolts. Heads for 2V induction have open chambers with rounded ports, while 4V heads have "quench" combustion chambers with larger rounded intake and exhaust ports. A 351C Cobra Jet appeared in 1971 with 4-bolt main caps, which was carried over in 1972 as the 351C-4V with open chamber heads.

### 351C BOSS

The 351C BOSS also appeared in 1971. It had 4-bolt main caps and the 4V-type quench chamber head with pedestals machined to accept a 302 BOSS-type valve train and mechanical cam. The con rod featured a 180,000 psi .375" bolt. In 1972, open chamber heads were used with a flat-top piston, and the name changed to 351C HO.

### 351M (MODIFIED) AND 400

The 351M and 400 are similar in design to the 351C, but there are subtle differences. Both the 351M and 400 blocks are 1.100" taller and have larger main journal diameters. Engine mounts are unique. Bellhousing pattern is the 429/460 design.

### WINDSOR VS. CLEVELAND WATER PASSAGES

289/302/351W engines use a front cover, and water exits the intake manifold face of the cylinder head through the intake manifold to radiator. 351C/351M/400 engines do not use a front cover. The block is extended and covered with a flat stamping. Water exits the combustion face of the head and into the block, and then to the radiator. Windsor and Cleveland heads physically interchange, but some modification is required to accommodate the differences in water passages. See above for details.

### FORD RACING 302/351 FORD RACING WATER PASSAGES

Several different water passage hole patterns have been used on 302 Ford Racing and 351 Ford Racing cylinder blocks and heads since their introduction. Engine assemblers should lay the head gasket on the block and the cylinder head (with front of the gasket toward the front of the engine) to make sure there is a path for coolant flow from the block into the head. In some cases, holes may have to be drilled in the block or head, or punched in the gasket.

### FORD RACING 302/351 "FORD RACING" ENGINE BLOCKS

Ford Racing has designed several "Ford Racing" blocks for maximum performance competition. They're designed for small block engine builders who want to use existing 302/351C or 351W components. 302/351 Ford Racing engines constructed with Ford Racing block and Ford Racing cylinder heads are not available as complete assemblies.

When ordering parts, consider these key points:

- 302 Ford Racing Block (M-6010-R302)—can be used with all 289/302/302 BOSS applications.
- 351 Ford Racing Blocks (M-6010-E351 thru M-6010-W351)—can be used with all production 351W applications, except those relating to crankshaft main bearing diameter. The 351 Ford Racing block is machined for the smaller 351C-type bearings. Ford Racing crankshafts feature the smaller 351C main journals that are compatible with these blocks. The block is available in two deck heights (9.500" and 9.200"), so either Windsor or Cleveland components can be used topside. Requires 289/302/351W-type camshaft.
- If 302/351 Ford Racing heads are used on 302/351 Ford Racing blocks, the Ford Racing-type intake manifolds are required.



## 4.6L/5.4L V8, 6.8L V10, AND 5.0L “MODULAR”

The Modular engine design focuses on low-friction, best-in-class sealing, long-term durability, and increased bottom-end stiffness for reduced noise/vibration/harshness. Common features are deep-skirt block with cross-bolting, chain-driven overhead camshafts, direct-mounted accessories (air-conditioning compressor, power steering pump, and alternator), valley-mounted water pump, fully counterweighted crankshaft with cross-drilled oil feeds, powdered-metal connecting rods, steel camshafts, and aluminum heads with low-friction roller finger follower valve train. The head bolts extend past the cylinder bores into the bearing webs, reducing bore distortion and providing a better seal of the steel head gaskets. A specific description of each type follows.

### 4.6L SOHC 2V/3V

The 4.6L SOHC (2V) was introduced for the 1991 Lincoln Town Car followed by the 1992 Crown Victoria and 1994 Thunderbird. Made primarily at the Romeo (Mich.) Engine Plant, it is the basis for all modular engines, replacing the classic 5.0L (302 cid) OHV. The original block is cast iron with a nodular iron crankshaft. Cylinder heads use in-line valve design with one intake and one exhaust valve per cylinder. Spark plugs are angled inboard, towards the top of the engine, for improved serviceability. A press-fit piston pin was used for initial car applications, and replaced by floating pins by 2002.

4.6L 2V truck applications started with the 1996 F-150. With the high demand for V8 engines, production was soon shared between Windsor and Romeo. Windsor-built 4.6L engines use a Windsor-machined cast iron block, sharing a bearing-cap design with the 5.4L, and a mix of Windsor- (8-bolt flange) or Romeo- (6-bolt flange) machined crankshafts.

For 1996 model year, the Mustang GT moved from the 5.0L Cleveland-made to a Romeo-made 4.6L 2V. Production moved to Windsor for the freshened 1999 Mustang, piloting the “Performance Improved” (PI) heads and cams with 260 horsepower. All Romeo 4.6L 2V applications migrated to the PI design for 2001 models, allowing Mustang GT engine production to return to Romeo. The 2001 model Mustang “Bullitt” featured intake, throttle body, and exhaust changes for a 265 horsepower rating.

The 2002-2005 Explorer combined the aluminum block (see 4.6L 4V) with 2V heads; this combination was also used briefly by the Expedition SUV. Initial production used cylinder heads specially machined on the block face for an added O-ring seal around the block’s oil feed; a subsequent head-gasket upgrade enabled regular head usage. Aluminum-block castings switched in-cycle from Windsor-sourced

(Cosworth® process) to Nemak®-Monterrey® sand castings, with lower bulkheads strengthened by chilling during solidification.

The 2005 4.6L 3V Mustang GT combined this Romeo-machined aluminum block with the 5.4L’s 3V cylinder heads, variable cam timing (VCT), and high-flow oil pump, for 300 horsepower. Early 2005 models were assembled at Essex Engine Plant until December 2004, when production was shifted to Romeo, but the design was unaffected by this change. The 2005-2006 Mustang GTs have a block-mounted “cold side” thermostat, where the 2007-2010 models are re-plumbed to the more conventional “hot side” thermostat on the cylinder head crossover. Cam covers were made of magnesium for 2005-2006 models, then switched to aluminum for 2007-2008, then reverted back to lighter magnesium. The Mustang alternator is equipped with a one-way clutch pulley to reduce audible belt chirp in fast shifts on 2005-2010 manual transmission and 2005-2008 auto transmission applications.

To hit 315 horsepower in the 2007-2008 Mustang Bullitt, Ford Racing’s air induction and exhaust changes were combined with a retuned crankshaft damper, enabling higher peak engine speed. Similar changes were applied to the 319 horsepower 2007 Shelby GT. The freshened 2010



Mustang GT also achieves a 315 horsepower rating with intake, exhaust, and calibration changes. 4.6L 3V truck applications, using the cast iron block and a long-runner intake manifold with single-bore throttle body, arrived for 2006-2010 Explorer and 2009-2010 F-150.

### 4.6L DOHC 4V

The Romeo-made 4.6L DOHC was first introduced in the 286 horsepower 1993 Lincoln Mark VIII. The Teksid®-cast (Italy) aluminum block includes four bolt main bearing caps; also cross-bolted for added support. Chains borrowed from the 4.6L 2V connect the crank to the intake cams, which use short secondary chains to drive the exhaust cams. A high-flow oil pump, select-fit main bearings and floating piston pins improve NVH and oil pressure robustness. Electronically controlled and vacuum-actuated Intake Manifold Runner Control (IMRC) allowed one set of the cylinder head’s dual intake ports to be throttled closed, and then opened for peak power; a system upgraded to fully electronic control for 1995 model on-board-diagnostic (OBD) emissions requirements.

The 1995 Lincoln Continental 4.6L 4V was the modular V8’s first and only front-wheel-drive application, using a unique Windsor-cast (Cosworth® process) aluminum block. To protect transmission durability, the engine was detuned





## 4.6L/5.4L V8 AND 5.8L “MODULAR”

via late-intake valve closing, a fuel-economy technique later applied to Toyota and Ford hybrid engines. The transverse-engine vehicle packaging created the legacy of this application: 100 mm bore centers and tight bore offset used for all 4.6L/5.4L/6.8L engines

The 1996 Mustang SVT Cobra increased 4V performance to 305 horsepower with cylinder head intake-port revisions and a new side-entry intake manifold. Durability enhancements included a fully counterweighted steel forged crankshaft for the higher engine speeds with a manual transmission, in addition to a crankcase windage tray, handling-baffled oil pan, and a patented full-flow oil cooler. Power rating increased to 320 horsepower in 1999, with “tumbleport” cylinder heads enabling deletion of the Intake Manifold Runner control. Unfortunately, production variations resulted in inconsistent peak-power performance, requiring customer exhaust system component retrofits and a production hiatus for 2000 model year. The Cobra was relaunched for 2001 model year, with intake manifold improvements supporting better robustness to the 315 horsepower rating. The Cobra also migrated in-cycle from the Teksid®-cast to Windsor-cast aluminum block; function was unaffected.

An Eaton® Roots-style supercharger was added for the 390 horsepower 2003-2004 SVT Mustang Cobra, code named “Terminator.” Because of the high cylinder pressures, Romeo’s aluminum block was replaced with the 2V’s cast iron block.

The new Terminator left a gap in the Mustang line-up, going down to the 260 horsepower 4.6L 2V Mustang GT, so the original SVT Cobra engine was revised for the 305 horsepower 2003-2004 Mustang Mach1 feature car, including a working shaker hood scoop mounted to the engine and available automatic transmission (with cast crankshaft). 2003-2005 Lincoln Aviator and 2003-2004 Mercury Marauder also featured this base engine. Early 2003- and 2005-model production used the NemaK®-Monterrey® cast aluminum block; later 2003 and 2004 production used the Windsor-made (Cosworth® process) aluminum castings.

Ford Racing’s 5.0L Cammer crate engine is based on a bored version of the 4.6L 4V. There are other ways to this iconic displacement: Some 5.0L short blocks have been created with only stroke increase, and others have combined bore and stroke increase.

### 5.4L SOHC 2V/3V

To replace the 5.8L OHV, a longer stroke version of the 4.6L was developed for 1996 F-150. The 5.4L’s undersquare geometry creates challenges, such as higher piston speeds and less stiff crank geometry. To maintain good NVH and durability, numerous changes were made to beef up the original 4.6L, such as a forged steel heat-treated crank with eight-bolt flange, stronger head casting material, and redesigned tight main bearing cap alignment dowels. Longer stroke and connecting rods drove a higher block deck height. Select fit main bearings and floating piston pins were adopted from the 4.6L 4V. A high-strength cast iron crank was developed for 2V Econoline applications.

Cylinder head layout, port design, and camshaft timing have been tied to the 4.6L development. The 1996 two-valve original swirl port was upgraded to the Performance Improved (PI) port and camshaft in 1999 for F-150 and Expedition. F-250/F-350 Super Duty and Econoline followed in 2000.

300 horsepower arrived in 2003, with the three-valve cylinder head for Falcon (Australia) and the redesigned 2004 model F-150, and came to Expedition and F-Series Super Duty applications for 2005. The truck intakes used a Charge Motion Control Valve (CMCV) port throttle, similar to the original 4.6 4V IMRC, to shroud the two intake ports. This CMCV was deleted for 2009 5.4L models, with slight chamber changes restoring in-cylinder motion. The three-valve layout drives tight packaging of the centrally mounted spark plug, so a special long-reach plug design was developed; this plug design migrated to a smaller diameter (12 mm cylinder head thread) in early 2008.

Originally branded “Triton” for F-Series, E-Series, and Expedition applications, the 5.4L is most associated with Windsor Engine Plant, but engine assembly and machining have also been supplemented by the Essex Engine Plant nearby.

For performance applications, the 1999 F-150 SVT Lighting used a 360 horsepower 5.4L 2V with an Eaton® Roots-style supercharger, upgraded to 380 horsepower for 2001-2004 models, with a detuned version offered in the 2002 Harley-Davidson® edition F-150. The 2007-2008 F-150 Harley-Davidson® edition was also offered with a retrofitted Roots-style supercharger. Of course, Ford Racing offers many performance parts for all of the 5.4Ls.

### 5.4L/5.8L DOHC 4V

The combination of Romeo 4V cylinder heads and the Windsor 5.4L bottom end began with the limited production 2000 SVT Cobra R, hand-assembled at Ford’s Engine Manufacturing





## 4.6L/5.4L V8 AND 5.8L “MODULAR”

Development Operations. New “Cobra R” cylinder head castings incorporated open intake ports. A standard Windsor steel crank was rebalanced for higher-strength connecting rods.

For the next 5.4L 4V application – 1999 to 2004 Lincoln Navigator – regular Romeo 4.6L 4V heads, with smaller tumble ports (see 4.6L 4V), were used to optimize drivability and emissions. A long runner intake targeted low-end torque and mid-range performance, and controlled active communication valve across an intake balance tube.

Ford Performance Vehicles (FPV), an Australian joint venture of Ford and Prodrive Engineering, adopted the 5.4L 4V for the 2004 Falcon and Falcon Ute, using a mix a North American- and Australian-sourced components. 2009 models were developed to over 425 horsepower.

The Ford GT mid-engined super car combined a new aluminum block with Cobra R cylinder heads, using a special compact cam drive, a production-based steel crankshaft rebalanced for unique connecting rods, a belt-driven external oil pump, and Lysholm® supercharger. The Romeo Engine Plant Niche Assembly Line even attached each dry sump oil tank for testing, then shipped it strapped to the engine for vehicle installation. While the GT production ended in 2006, Ford Racing continues to offer performance components.

For the 2007 model year, 5.4L 4V supercharged usage shifted to the Mustang Shelby Cobra GT500, with a cast iron Windsor truck-based block, Roots blower, and conventional oil pan. Horsepower has grown from 500, to 540 (2010 model with dual-knock sensors), 550 (2011 with plasma spray-bored linerless aluminum block),

and 662 (2013 model bored to 93.4 mm for 5.8L displacement, plus larger supercharger with higher boost pressure). Ford Racing offers numerous supercharger, intake, exhaust, and calibration options for even more performance

### 6.8L SOHC 2V/3V

The 5.4L added two cylinders for the 1997 6.8L Econoline, with a cylinder head-mounted balance shaft and steel split-pin crankshaft for even firing. The Windsor-made 6.8L also replaced the big block 7.0/7.5L in Super Duty (F-250, F-350) and Motorhome applications. All 2V applications utilized the PI cylinder head starting in 2000.

The three valve upgraded performance to over 350 horsepower for 2005 Super Duty and Motorhome chassis. The 6.8L 3V head is similar to the 5.4L 3V. The 3V also employs a dual-mode intake manifold with an electrically actuated long-short runner control (LSRC) valve. The 6.8L’s cam-driven balance shaft precludes Variable Cam Timing, since the balance shaft must remain in phase with the crankshaft.

Ford Power Products offers 6.8Ls modified for compressed natural gas (CNG) generator usage, large hybrid gas/electric buses, and a supercharged version for hydrogen-powered buses.



## OTHER V8 ARCHITECTURES

### 3.4L DOHC 4V “SHO” ENGINE

Yamaha® produced this all-aluminum V8 for 1996 Taurus SHO, as a replacement for the 3.0L/3.2L SHO V6. Its 60-degree design improves the crash crush zone in front-wheel-drive vehicles, but requires an internal balance shaft. The architecture was the basis for the 2006 Volvo® V8 (XC90, S80).

### 3.9L DOHC 4V ENGINE

Lima Engine Plant adopted the Jaguar® AJ 4.0L V8 architecture for the 2000-2005 Lincoln LS and 2002-2005 Thunderbird. This compact architecture used direct-acting mechanical bucket tappets, and a full main bearing bedplate replacing separate main bearing caps with a structural oil sump. A unique air-assisted fuel-injection system was added to optimize emissions, controlled by a 3-way idle-air by-pass valve. Another emissions feature was “Precision cooling,” with

minimized water-jacket cross-sectional areas to increase the fluid velocity in the jackets, thereby increasing heat transfer. 2003-2006 models added electronic throttle control and variable-intake valve timing, with more conventional fuel injection, achieving 280 horsepower.

### 6.2L SOHC 2V “BOSS” ENGINE

The SVT Raptor F-150, unveiled at the 2008 SEMA® Show, introduced the new two-valve 6.2L with twin spark plugs and variable cam timing. Built at Romeo Engine Plant, its 115 mm bore centers enables bigger valves for better breathing than the Modular V8. The 6.2L has also replaced the 5.4L and most 6.8L engines in F-250/F-350 Super Duty applications. Ford Racing developed a pre-production engine for the 2008 Baja 1000 and experimental-class drag racing. Look for this new cast iron block engine in other future applications, along with Ford Racing components.





## 5.0L DOHC 4V "Ti-VCT" ENGINE

2011-2013 MY 5.0L 4 VALVE V8 ENGINE

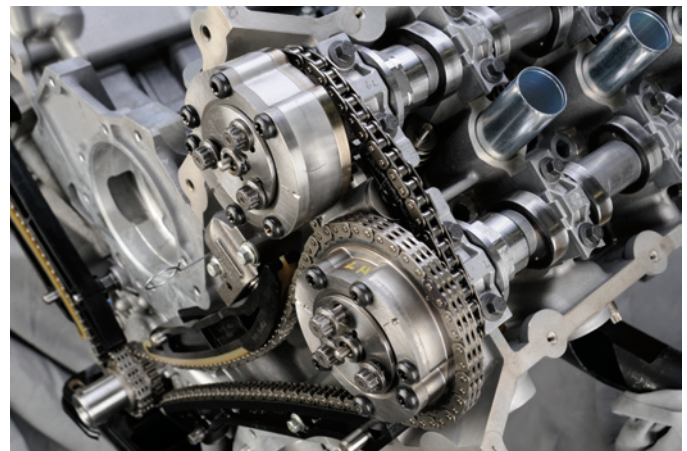
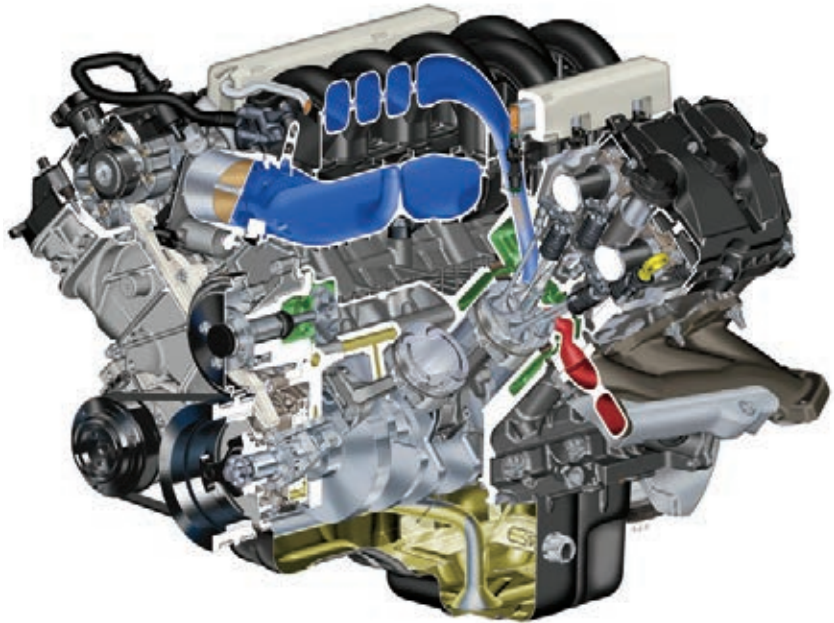
Several major Modular 4V upgrades programs were initiated starting in the late '90s, but then shelved. Major issues were high costs of implementing a new design, while existing V8s were enjoying high demand. As a result, other strategies for fuel economy and performance improvement were prioritized, such as 6-speed automatic transmissions. By mid-2007, these factors had changed. With lower demand for large SUVs, modern V8 manufacturing capacity was idled and available for conversion to a new design. In addition, Mustang needed a competitive, affordable, and efficient response to new Chevrolet and Dodge pony cars, which would offer V8s a third larger than the 4.6L. And Ford's new strategy for fuel economy leadership meant F-150 needed a reduced displacement line-up, plus aluminum blocks to spearhead major vehicle weight reductions. The response was internally code named "Coyote," an homage to the historic high-output V8s campaigned by A.J. Foyt.

The 4.6L architecture supported increasing bore from 90.2 to 92.2 and stroke from 90 to 92.8, while retaining the basic architecture (e.g., bore spacing, block deck height, bearing sizes) that enabled major machining and assembly line re-use. The power increase from the resulting 4951cc displacement alone would be only about 25 horsepower, so to reach the Mustang's 400 horsepower target, specific output would also need to leap – from less than 70 hp per liter, to over 80.

Major airflow improvements were the focus for power-density gains, both leveraging new

technology and challenging former Modular design constraints. Airflow improvements began with major cylinder head port improvements. While prior Modular V8s required access to head bolts with camshafts and valvetrain pre-assembled to the cylinder head, the 5.0L moved camshafts over the head bolts, creating more room for optimal intake and exhaust ports. Compact roller finger followers and hydraulic lash adjusters, supplied by INA, were another enabler for optimized parts and increased valve lift (12 mm intake, 11 mm exhaust). Twin-

independent variable camshaft timing (Ti-VCT) allowed separate phasing adjustment of intake and exhaust cams, for smooth idle and fuel economy, but available quick response at high rpm. The Borg-Warner® cam-torque-actuated VCT phasers borrowed components and concepts from both the new 6.2L V8 and latest 3.0L V6, with reduced complexity compared to prior oil-pressure actuated designs. Throttle body position and intake airflow was optimized by moving the alternator down from the block valley to the side of the block, all enabled by







corporation of electric power steering in place of a separate belt-driven pump. For Mustang, stainless steel welded headers are added to optimize power and torque, while fitting within the tight engine compartment. Even the dipstick was moved, to go directly through the cylinder head, to avoid a compromising exhaust-manifold runner routing.

On the bottom end, the 4.6L crank pin was shifted for more stroke, with conventional straight-thru oil hole drilling replacing the 4.6L/5.4L's complex cross-drilling. The crank's front nose is revised for a dual-accessory belt. A rear-mounted stamped crank sensor wheel, again based on 6.2L and 3.5L, replaced the front-mounted pulse wheel for a more stable signal. While "Modular" from this manufacturing perspective, the new 5.0L would literally recast the basic modular block design for internal oil and coolant routing, resulting in virtually no potential for component mix and match with older modular engines. The crankcase casting was also strengthened around the main bearing bulkheads, while also opening up more internal breather area around the crank for reduced pumping losses.

Developing 412 horsepower (SAE Net) at 6500 rpm, the 5.0L 2011 Mustang GT zings up to 7000 rpm. For higher volume F-150 truck applications, the 5.0L was retuned to optimize fuel economy and torque, with less aggressive intake cams, unique pistons, and cast exhaust manifolds, resulting in 360 horsepower.

## BOSS 302

The BOSS 302 engine is based on the 5.0 DOHC 4V "Ti-VCT" engine with upgraded parts.

Some of the BOSS-specific parts contributing to the BOSS 302 V8's output and durability include:

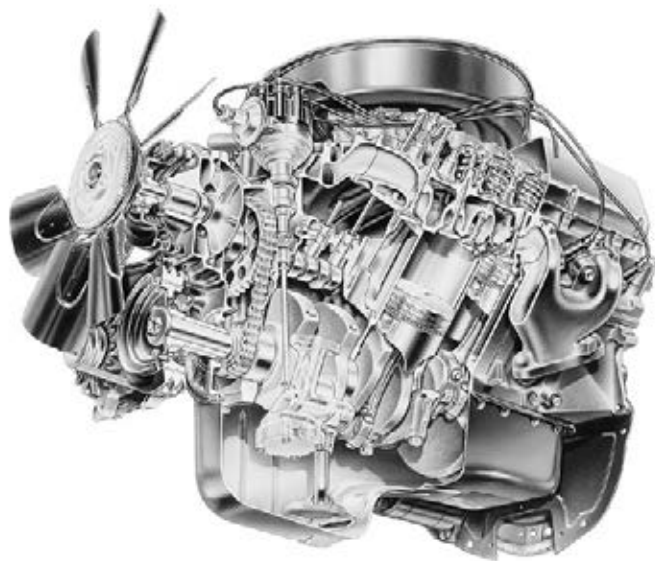
- Revised composite intake system with shorter runners, inspired by Daytona® Prototype racing engines, for high-rpm breathing
- Forged aluminum pistons and upgraded sinter-forged connecting rods for improved strength, needed for the higher combustion pressures and engine speeds
- New high-strength aluminum-alloy cylinder heads with fully CNC-machined ports and chambers for exceptional high-rpm airflow without sacrificing low-speed torque
- Lightened valve train components to provide excellent dynamic performance up to speeds well above the engine redline
- Sodium-filled exhaust valves for improved heat dissipation
- Race-specification crankshaft main and rod bearings for higher load capability and improved high-speed durability
- 5W50 full-synthetic oil with engine oil cooler for improved oil pressure and longer-lasting lubrication during extreme racing conditions
- Revised oil pan baffling for improved oil control under racing conditions and during cornering loads greater than 1.0 g
- 2012-2013 Ford Mustang BOSS 302 engine delivers 444 horsepower and 380 lb-ft of torque without the aid of forced induction

Contrary to normal engine development protocol, the first batch of durability test engines weren't installed in an engine dyno. Instead, thanks to a request from Ford Racing, they went straight to the track.

Ford Racing challenged the BOSS engine team to give them the first available BOSS 302 engines for the January Daytona® race. They got the engines 12 weeks later, and the team prepped five BOSS 302R cars for the January race. It was a fantastic opportunity to be able to get full-on race experience with the engine so early in the program.

Using race telemetry, the BOSS team has been able to gather on-track data to help optimize engine calibrations, oil-pan designs and cooling. In order to engage in virtual racing whenever they needed, the team used the telemetry data to re-create a hot lap at Daytona® on the dyno back in Dearborn, allowing further fine-tuning.

Every BOSS 302 Mustang owner will benefit from their contributions to the program.



## 429/429CJ/429SCJ/429 BOSS/460

During The Golden Age of Muscle, high-performance versions of 429/460 engines flashed on the scene like a firefly. The glow was brief—from 1969 to 1971. The memory lingers on. All of those cubic inches! Never again available directly from the factory ready for competition. Luckily, engines and pieces are still around. There are several ways to go, depending on the performance level you want, be it simply a Bracket Drag Racer, or something more potent, like an offshore power boat, big torquing engine for truck pulls or a Pro Stock drag machine. Here's a brief description of production engines to give you an idea of part interchangeability and general performance level.

### 429/460

The 429 "Thunder Jet" was introduced in 1968. It's your basic passenger car "wedge" engine design with hydraulic cam, 2-bolt main caps and either 2V or 4V carburetor. Cast iron "rail" rocker arms are mounted on non-adjustable, positive stop studs (1968-1972). 1973 and later 429/460 engines use pedestal-mount rocker arms. The 460 is a stroked version of the 429. With modifications, these engines can be used for most competition, except offshore boats or with a supercharger.

### 429CJ (COBRA JET)

Take a base 429, then add a hotter hydraulic cam, larger CFM carburetor, heads with bigger ports and valves, plus a few other items and you have a 429CJ. 1970 engines had 2-bolt mains; 1971 models 4-bolts. Engines built before 11/1/1969 use an adjustable, non-positive stop rocker arm stud, so a mechanical cam is easily installed.

### 429SCJ (SUPER COBRA JET)

Now, we're talking about an engine you can modify for serious competition. The 429SCJ has 4-bolt main caps (#2, #3 and #4 journals), mechanical cam, adjustable non-positive stop rocker arm studs, stamped rocker arms and push rod guide plates. The pistons are forged aluminum and con rod bolt seats are spot faced. As with the CJ, production ended in 1971.

### 429 BOSS

This is an all-out competition design with aluminum heads and hemi combustion chambers (technically, they're "crescent-shaped"). The first few hundred in 1969 for NASCAR® competition were called "S" engines; the later street version is a "T" engine. "T" engine con rods are spot faced for a .375" bolt and hex nut. "S" engine con rods are beefier, 0.056" shorter, have wider bearing journals and use a .5" bolt with 12-point nut.

