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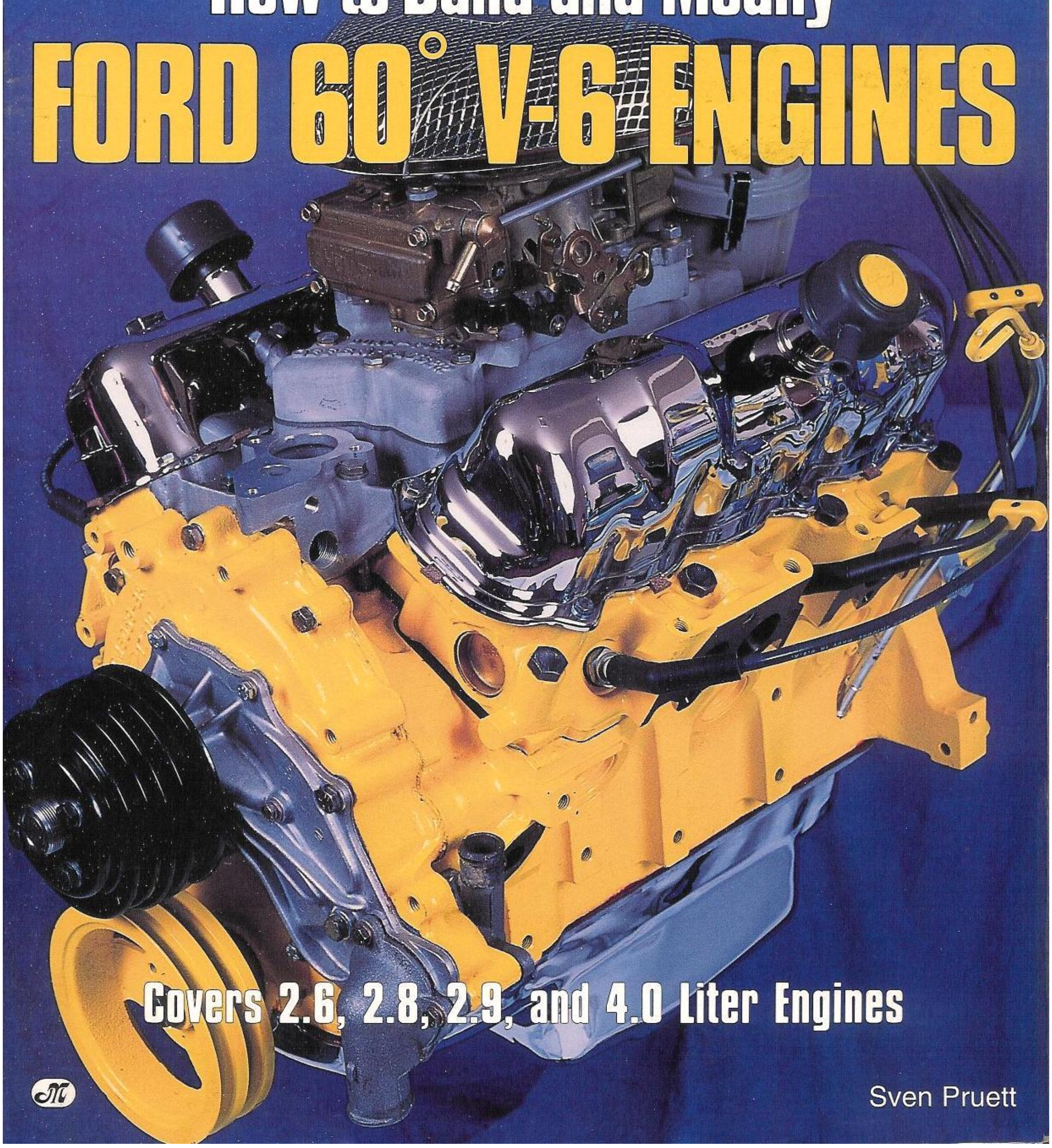
POWERPRO SERIES

How to Build and Modify FORD 60° V-6 ENGINES



Covers 2.6, 2.8, 2.9, and 4.0 Liter Engines

Sven Pruett

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How to Build and Modify FORD 60° V-6 ENGINES

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On the front cover: The horsepower of Ford's 60° V-6 is easily increased with straightforward modifications and careful assembly.
Steve Mohlenkamp

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About This Book

This book was written in an effort to provide the do-it-yourself engine builder with the information necessary to build a respectable Ford 60-degree V-6 performance engine. Therefore, every attempt has been made to avoid procedures and parts that are "exotic" or prohibitively expensive. It is the intent of this book to provide a detailed description of the modifications and procedures that are within the grasp of the average builder. The horsepower examples that are described within this book by no means represent the maximum power potential that is available from the Ford V-6. That was not the intention. The idea is to explore the potential of these engines while maintaining a high level of reliability, a reasonable cost level, and relative ease of construction. Readers will find that most of the areas of engine preparation that require very specialized and expensive procedures (like extensive cylinder head porting, stroking, and so on) have been avoided. These types of modifications are very often out of the grasp of most enthusiasts. In most cases, the average person who is looking for increased performance will draw the line before such modifications are required.

Dedication

It seems that when the time comes to express your appreciation for the enormous amount of support that you receive from loved ones during the production of such a work, you never seem to be able to quite convey just how much these very special people mean to you. However, at the risk of failing to accurately and completely express my gratitude, I am, at least, duty-bound to try.

This book is dedicated to my wonderful family without whose love, caring, patience, and support, this entire project would never have been possible.

To my wife, Mary, for your undying faith in me and precious love. To my son, Christopher, for your perpetual patience and understanding. To my beautiful twin daughters, Sibonet and Desireé, for showing me the meaning of the word "miracle." And last but not least to my parents, Bill and Anneliese, for the love, guidance, support, and the inspiration to press on . . . regardless. All my love to all of you.

—Sven,
January 1994

Acknowledgments

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Foreword

First, to the best of my knowledge, a book of this nature does not exist anywhere in the world. As a Ford V-6 enthusiast, you are well aware that almost every repair manual devoted to your particular vehicle includes an "engine repair section" or the like. However, these sections often involve only the most basic repair and rebuilding techniques. I have not yet seen a manual that was able to instruct an individual on how to *correct* the problem areas of these engines or how to significantly improve their performance potential without sacrificing reliability. In fact, in my experience, many of the techniques outlined in most of these publications are outdated or just plain wrong!

Second, the Ford V-6 is a unique engine. Although many standard building techniques can and should be incorporated, these engines are full of little peculiarities that require very special attention. Such "peculiarities" have to be identified through long hours studying the dynamics of these engines and through good old trial and error (read: trying stuff that eventually leaves you up to your outlet in oil-dry and busted parts, but wiser none the less). Many of you have probably already experienced at least a few of these annoying little gremlins, and I am sure you will agree that life would have been just fine had they never come around and introduced themselves. I hope that this book will help all who consult it to avoid at least 95 percent of these potential problems.

Finally, the definition of an enthusiast is: "One who possesses great or fervent interest or excitement." Perhaps a more useful and accurate definition of an automotive enthusiast would be: "One who knows a little about everything but not everything about anything." Of course we all know at least *one* exception.

As someone who is, or will soon be in possession of a Ford 60-degree V-6, you will soon find that you are unique among your peers. Although the performance potential of these little engines can be impressive, the performance parts scene is bleak at best. So, if you've gone so far as to buy this book, you are obviously dedicated to your project and you have the initiative to do it as well as you are able. And once your friends quit giving you the business about "that cute li'l Ford," I hope you will be happy with the end result of your project. Furthermore, if, after all of this, you still find it in yourself to walk out into the garage on a Saturday afternoon, fire up your finished project, and enjoy it for the day, then you are a true enthusiast, and it is for you that this book was written.

1

The Cylinder Block

For some strange reason, the cylinder block often seems to lack the consideration that such an important element of a performance engine deserves. A performance engine is very much like the human body. It inhales, exhales, and requires the proper nourishment. In addition, it requires a strong supporting structure so that it can perform its duties to its full potential. In humans, this is delegated to the skeleton. In a performance engine, the cylinder block is the skeleton. The demands imposed upon the engine block are much the same as those imposed on the human skeleton. The block must be strong and stable to offer sufficient support. And it must be conditioned so as to offer endurance and reliability. If a block is not prepared (conditioned) properly, the entire engine assembly is subject to potential failure.

Choosing a Block

Essentially, all the Ford V-6 60-degree engines share the same basic block design. They all incorporate four main bearing saddles and four cam bearing saddles, thus providing excellent lower end rigidity in most applications. Your available choices depend primarily on your intended direction. If you are a purist and are interested in absolute authenticity, then your decision is simple—stay with the engine that came in your car. However, if you are not bound by such ties, you have several options available to you

2.6 liter (automotive)

This engine is somewhat limited in its performance potential. If you are limited to this engine, plan on relatively conservative performance modifications. The 2.6 block is thin in certain critical areas thus giving it a "twisty" nature. If serious performance is your goal (200hp+), then step up to the 2.8 or 2.9 engine, otherwise you can expect to have problems with reliability. Consider also that the 2.6 engine has absolutely *no* provision for a hydraulic valvetrain. Consequently, if you really hate adjusting valves, then this engine is not for you. If you are relegated to the 2.6, keep the following things in mind when preparing the cylinder block. First, *do not* bore this block more than 0.030in over. A few past publications have advocated a larger overbore (up to 0.060in). This is *not* a good idea. The cylinder walls are relatively thin and any more than about a 0.030in overbore will result in piston ring sealing problems and overheating. Furthermore, the 2.6 engine suffers from rather extreme block flexure when overbored. This flexure can cause severe piston galling and eventual bearing failure due to the distortion created in the cylinder bores and bearing saddles. Second, *do not* remove more than 0.010 inch from the deck surface. Again, the decks are too thin and they have large water passages on the lower deck surfaces that are prone to leakage. Too much material removal will result in increased head gasket failures, a problem in stock 2.6 engines anyway. Because of these drawbacks, I recommend that at least the 2.8-liter automotive block be used if at all possible.

2.8 liter (automotive)

This engine is a good candidate for performance modification. This block benefits from several improvements that are the direct result of racing development in the European Group 2 touring car series. The advantages of this block include a significantly heavier overall casting with particular improvement in the main web and deck areas. These modifications virtually eliminate the block flexure problems associated with the 2.6-liter engine. A dramatic improvement in piston ring sealing, reduced piston galling, and better heat dissipation are just a few of the advantages to using this block for performance purposes. Another advantage is greater aftermarket parts availability compared to the 2.6. The 2.8-liter engines are also much more abundant than the 2.6. Capris, Pintos, Bobcats, and Mustangs, to name a few, were all equipped with the 2.8.

As with the 2.6, there are a few "maximums" that must not be exceeded when building the 2.8. First, the maximum allowable overbore is 0.040in. This much overbore should be avoided if at all possible. A more realistic overbore would be 0.030in. The decks will safely accept a 0.020in maximum cut, but I would take off only the minimum amount required to straighten each deck as it is full of water passages that reduce the overall deck integrity. This should be relatively easy as deck warpage is not a common problem. Lastly, this engine, like its 2.6 liter predecessor, has a mechanical valvetrain.

2.8 liter (truck)

This engine incorporates one significant change that makes it the best choice when building the 2.8: bigger cam bearings. This relatively minor change allows a bit more latitude when choosing a camshaft. Cam grinders have more room to play with larger base circle cams. Additionally, the larger (and stronger) cam reduces most of the "torsion bar" effect experienced in some extreme-duty 2.8 engines. Aside from the cam, however, this engine is essentially the same as the 2.8 automotive engine, and therefore all overbore and deck milling limits applied to the automotive 2.8 engine should be followed. These engines were available in Ranger pickups and Bronco IIs through 1986.

2.9 liter (truck)

Although the 2.9 resembles the 2.8 in appearance, it is significantly different in design. First, the 2.9 retains the large cam bearing configuration, but this engine uses a hydraulic valvetrain. This allows you to use some nice cam profiles, including some with roller lifters, to improve performance. Second, the camshaft drive has been converted to a more conventional chain drive instead of the usual two-gear drive used in all 2.6 and 2.8 engines. Third, the cylinder heads were completely redesigned, virtually eliminating the problems inherent in the 2.6 and 2.8 liter designs (more on this later). Finally, the 2.9 was only available as an electronically fuel-injected engine. Although carburetor conversions are being developed, nothing is commercially available to accomplish such a conversion. Therefore, the fuel injection system will have to be used in most applications. As with the 2.8, the overbore should be kept less than 0.040in and the deck milling less than 0.020in.

The 2.9 liter has many advantages. In fact, if your pockets are really deep, a set of four-valve Cosworth heads are available in Europe. All things said and done, the 2.9 truck engine should be a consideration for any engine expected to produce 235 or more horsepower.

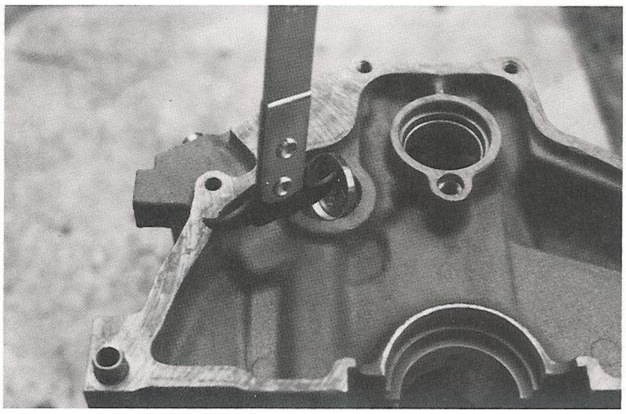
4.0 liter (truck)

With the introduction of the Ford Explorer came the latest evolution of the Ford V-6, the 4.0 liter. Built along the same lines as its earlier cousins, the 4.0 liter is visually very similar. But rest assured, that's where most of the similarity ends! The 4.0 liter enjoys numerous improvements including hydraulic roller camshaft, crank-fire ignition, and cubic inches. The 4.0 was designed as the standard engine for Ford's sport/utility vehicles and as an option in the Ranger.

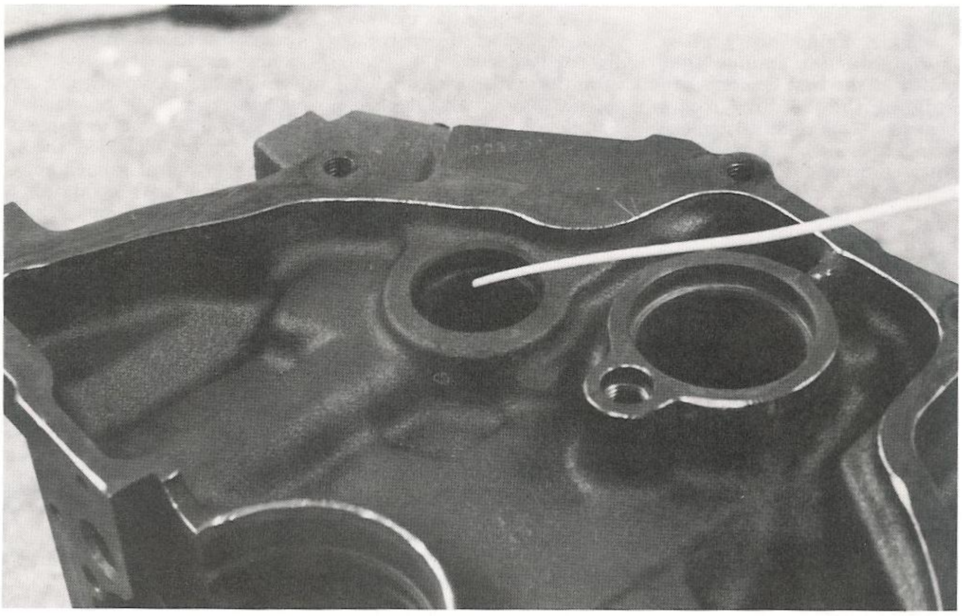
Unfortunately, the practicality for performance applications is rather limited at this time. In stock trim, the engine is dependent on a complicated electronics system, and the investment required to convert it to something more conventional (read "affordable") can quickly exceed the budget of the average performance enthusiast. In short, unless you have a considerable budget, don't expect to set very lofty performance goals or expectations. On the plus side, the 4.0 liter has a pretty good set of heads and, with a fair bit of work, could easily produce a reliable 200hp+ without requiring an enormous outlay of money. If you desire in excess of 230hp, however, expect a considerable increase in expense as the required performance components are both rare and expensive. Although the block was subject to significant weight reduction measures, the overall strength is still very good. This block will safely accept a 0.040in overbore and 0.020in of deck material removal. It appears that Ford intends to continue developing new versions of this platform, so the future may hold interesting things for the performance-minded.

Disassembling the Short Block

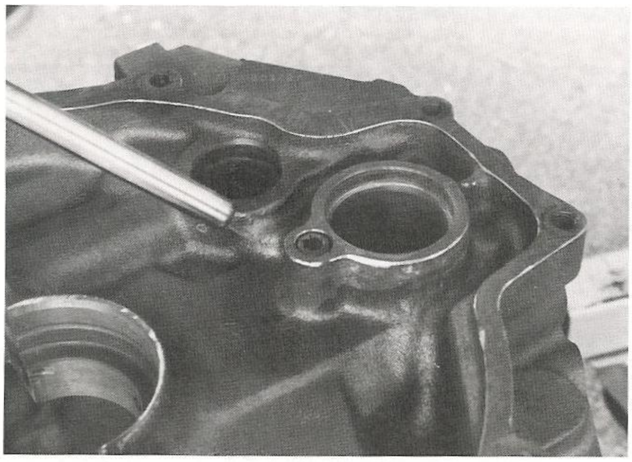
The thing to remember when disassembling your short block is to keep everything organized. As



Freeze plug removal can be considerably easier if you use a hook-type seal puller to help with the extraction.



Take great care when removing the rear freeze plug so that the seating lip will not be damaged. Never drive either the freeze plug or the cam core plug into the block to remove.



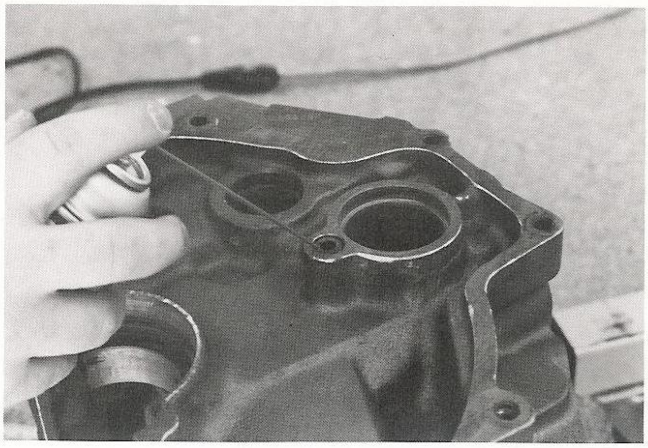
To help remove the rear oil gallery plug, use a propane torch to heat the area around the plug to loosen the factory sealing adhesive.

you remove each component you should mark it and its respective fasteners. Keep any reusable fasteners and small parts organized so that when the time comes, you will remember where they go. Old butter tubs and coffee cans work wonderfully when organizing your fasteners. Mark the lid with the appropriate information and store all of the containers in a safe place. Make sure that they don't get mixed up with other containers that belong to another project.

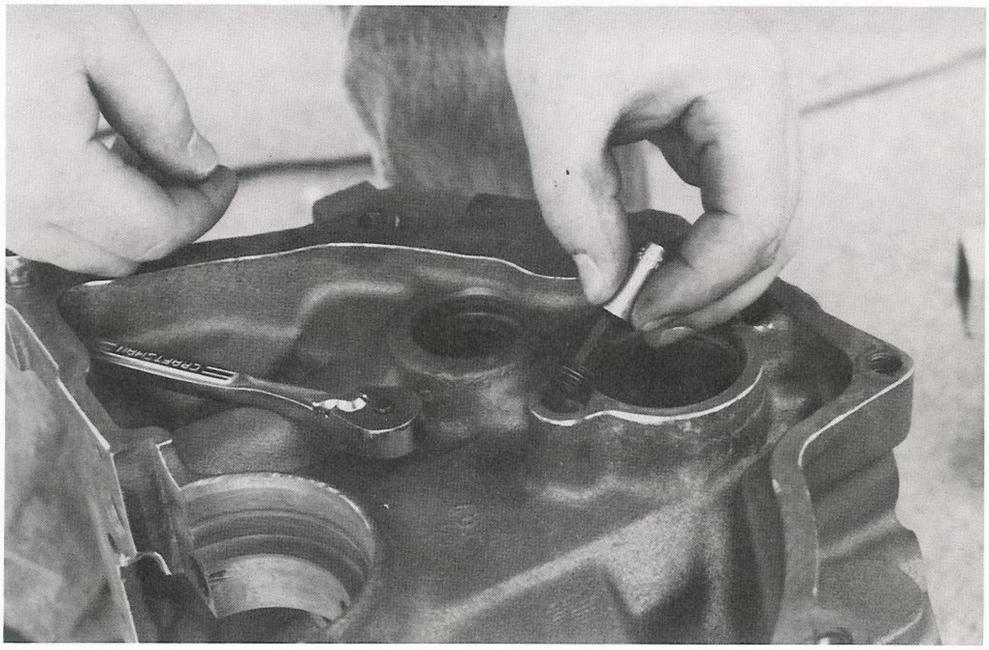
Before any work can begin, you must strip the block of everything. However, before you turn a single nut, you must mark all of the rods and main caps if they are not so marked from the factory. Each rod (both halves) should be marked according to its respective cylinder number. Main caps should be marked according to their location in the block starting from front to back (most main caps are already marked from the factory). Once this is done, remove the piston/rod assemblies and the crankshaft, coat them with WD-40, and store them in individual plastic bags.

Remove all of the freeze plugs and oil gallery plugs. Take care when removing the two plugs at the rear of the block. Don't drive them into the block, as you could cause damage. Instead, you should pull them with a slide hammer or a hook-type seal puller. When removing the oil galley plugs, make sure you mark them so that they can be reinstalled in the same holes from which they were removed.

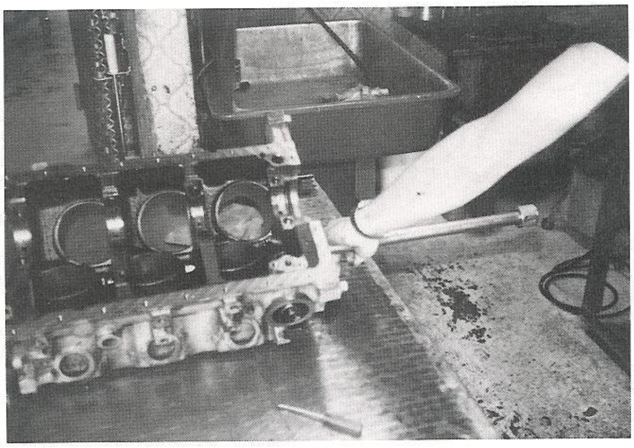
Finally, all of the cam bearings must be removed. Unless you have the proper tooling and



While the plug is still hot, spray the thread area with penetrating lubricant. Be very careful, as the lubricant can catch fire if the block is hot enough.



The oil gallery plug should unscrew fairly easily using a ratchet-driven hex key.



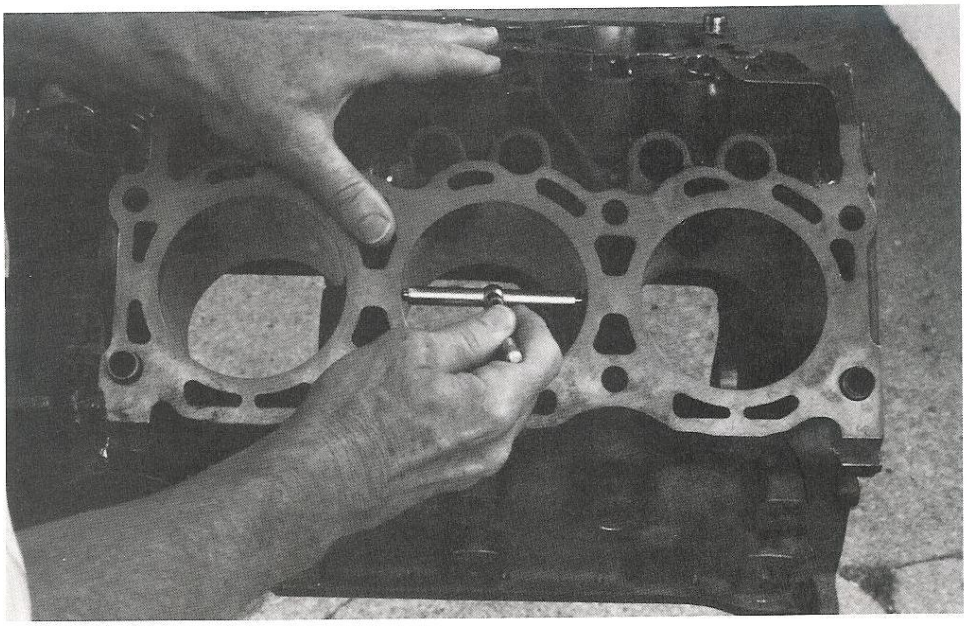
Removing the cam bearings requires special tooling. Leave this job to a qualified and properly equipped machine shop.

know how to use it, let a machine shop perform this task. Once the block has been completely stripped of its parts, the real work can begin.

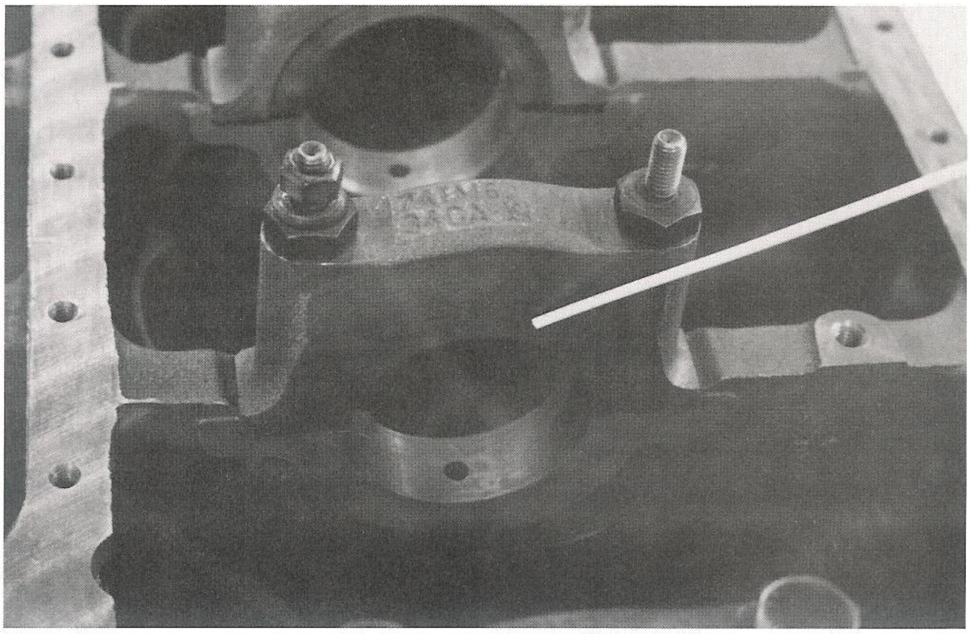
Cleaning and Preliminary Inspection

The first order of business is to establish the "rebuildability" of the engine. This begins by determining if the cylinders have been overbored. Ideally, you should start with a block with a standard bore. Using a vernier caliper and snap gage or a cylinder bore gage, measure just below the cylinder ridge so that you can get an accurate reading. If the block has been bored more than 0.020in, stop where you are and go find another one.

If you are blessed with a standard bore block, it is time to



An accurate cylinder bore measurement is essential in determining if your block will be a good candidate for a performance rebuild.



Once the block has been stripped, check for "bluing" around the main bearing bores. Bluing is a sign of bearing failure and if your block shows signs of it, you should consider using another block.

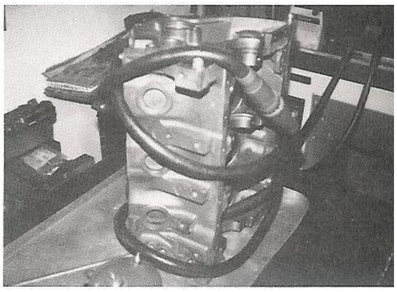
determine the amount of wear in the cylinders. This is best measured with a dial bore gage, though a snap gage and micrometer are also acceptable. Take this measurement in the ridge area as this is the part of the cylinder that wears the most. This area should be 0.015in *smaller* than the intended overbore size. For example, if the standard bore is 3.660in and you would like to have it bored 0.030in over (to 3.690in), the ridge area must measure 3.675in or less. If the bore is acceptable, visually inspect all of the head bolt and main cap bolt holes for pulled or stripped threads.

If everything checks out, take the block to the machine shop and have it "hot tanked." Hot tanking is a generic term used to describe the caustic cleaning process used by many machine shops. Follow the hot tank cleaning with a jet-spray cleaning process. Jet cleaning is a much faster process than most hot tanks and is especially useful following the various block machining processes.

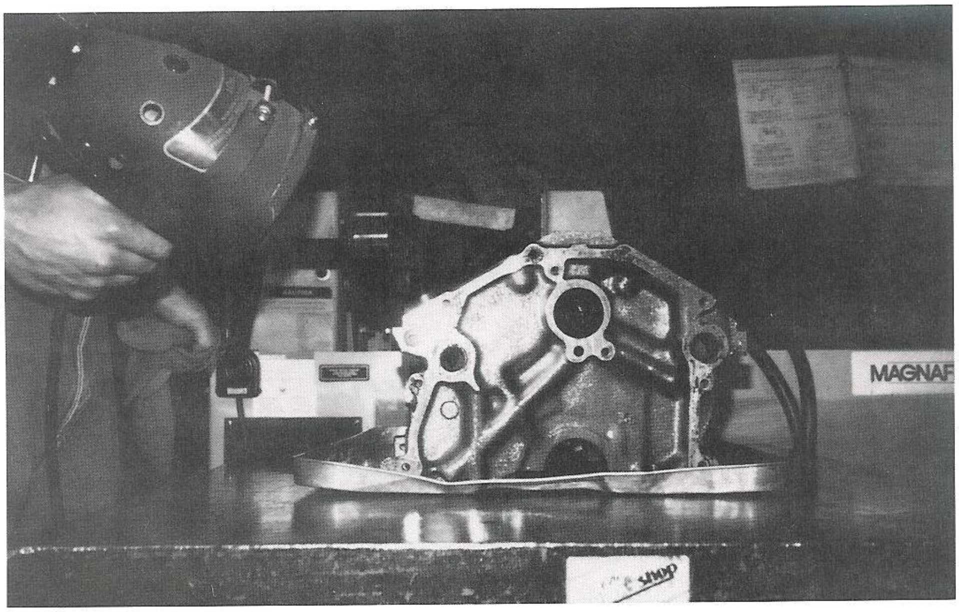
Crack Inspection

Now that the block has been thoroughly cleaned, a careful visual inspection for cracks is mandatory. Cracks will most often be found in the lifter valley, cylinders bores, between cylinders, external water jackets, and main bearing webs. Do not limit your checking to these areas alone. Use a strong shop light to inspect all areas of the entire block.

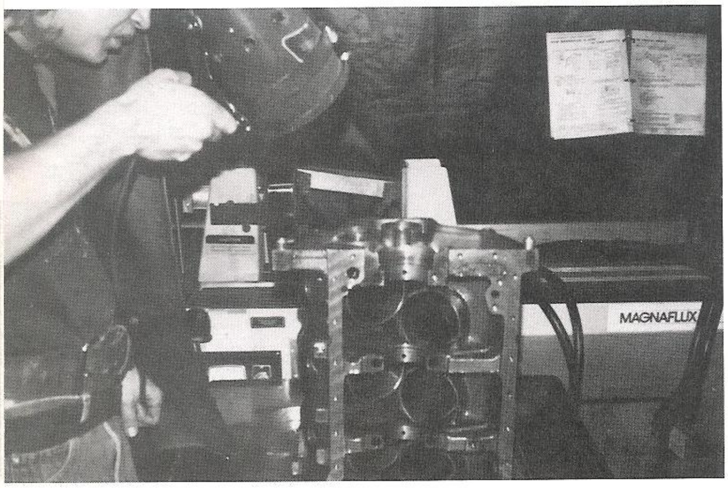
If no cracks are apparent, take the block to the machine shop and have it Magnafluxed. Magnaflux is a crack detection process whereby the entire block is magnetized and then sprinkled with a magnetic powder. Since a crack causes a disrup-



The Magnaflux process begins by magnetizing the block using heavy gauge cables and lots of current.



Once the block has been covered with the indicator, a special high-intensity lamp is used to inspect the block for cracks. Here the technician is checking the deck surfaces for any signs of crack formation.

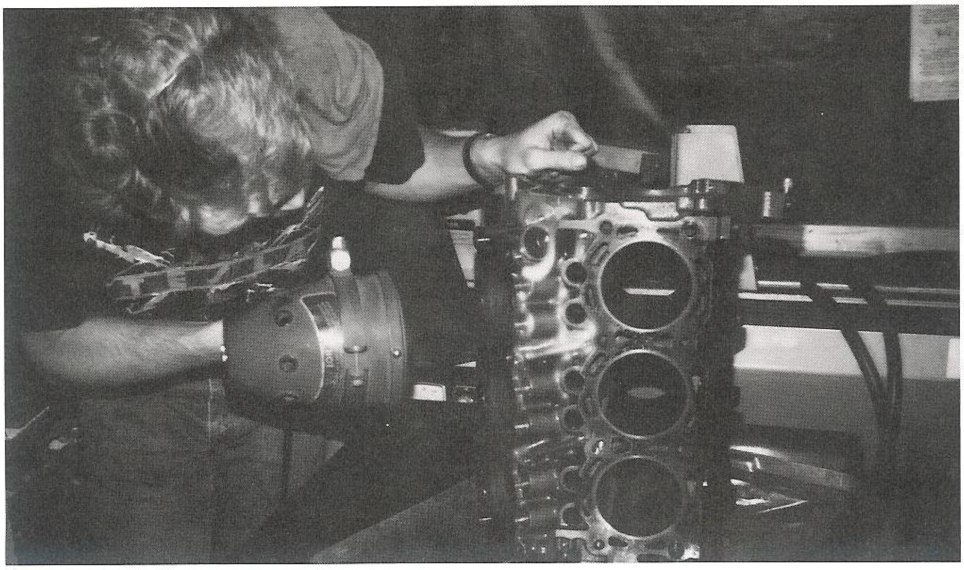


Here, the technician inspects the web area of the rear main bearing and the area surrounding the freeze plug.

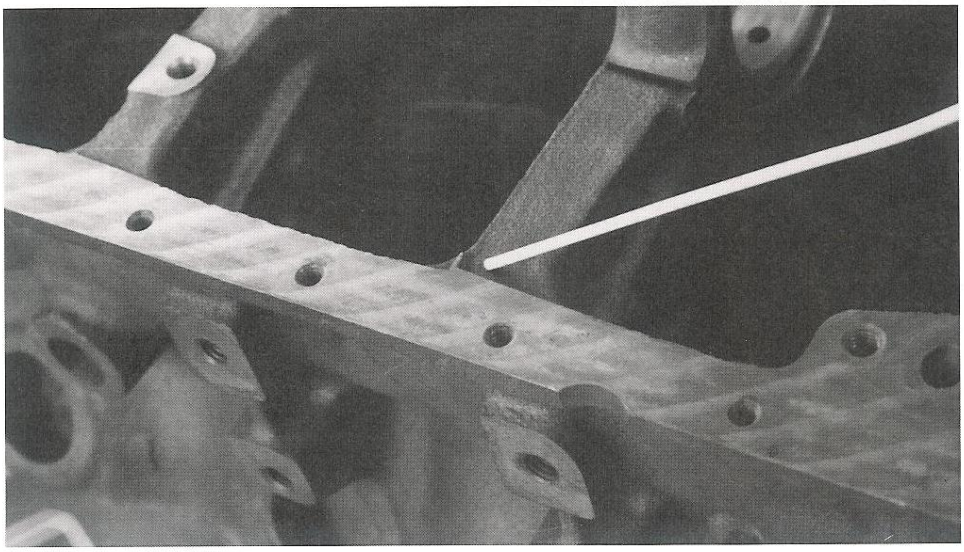
tion in the magnetic field, the powder collects along the crack allowing the inspector to easily see it. If for any reason the Magnaflux test is inconclusive, have the block pressure tested as a backup.

Deburring

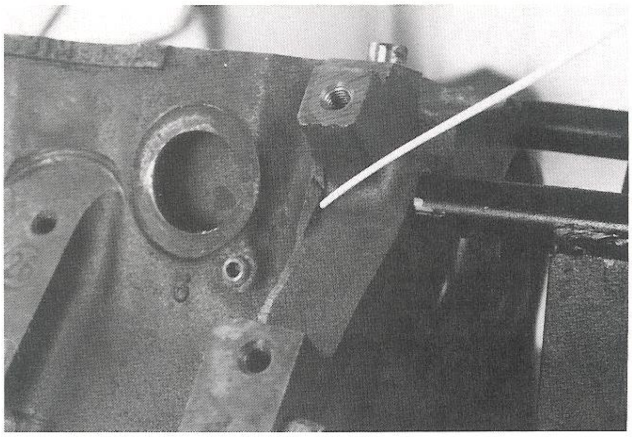
The purpose of deburring the block is to reduce the number of areas where cracks could start and to help reduce the possibility of casting flash becoming dislodged and ruining the engine. Proper deburring requires that all sharp edges be smoothed on both the inside and outside of the block. This does not mean that every edge should be radiused. It simply means that these edges should be given a mild chamfer. Don't overdo it. Be sure to chamfer all oil drains in the block. Don't forget to deburr



Another area that is prone to cracking is the lifter valley area. Make sure that the machine shop is very thorough about its crack inspection procedures.



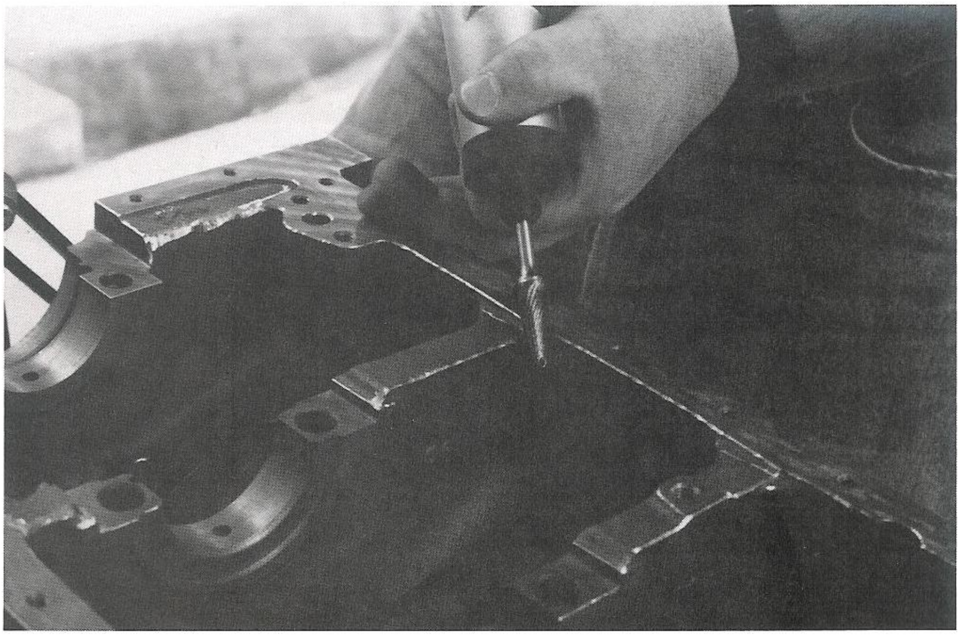
When deburring a block, look for pieces of casting flash inside the block. This little piece is just dying to chip off and wreak havoc on anything it can get its paws on inside the engine.



Casting flash and sharp edges should also be removed from the outside of the block. This helps eliminate the possibility of crack formations on the block exterior.

the oil return holes in the cam gallery. This is made easier by using a long, tapered drift to knock off any large pieces of slag, however you must take extreme care not to damage the block.

Many people recommend polishing the lifter valley to improve oil drainback. I do not recommend this procedure on street-performance engines for two reasons. First, the uneven texture of the cast iron has a greater surface area than it does if it is polished. This rough surface helps improve heat dissipation. Second, the relatively small amount of oil that is pumped to the top of this particular engine doesn't present much of a problem with respect to windage, so I don't believe this large amount

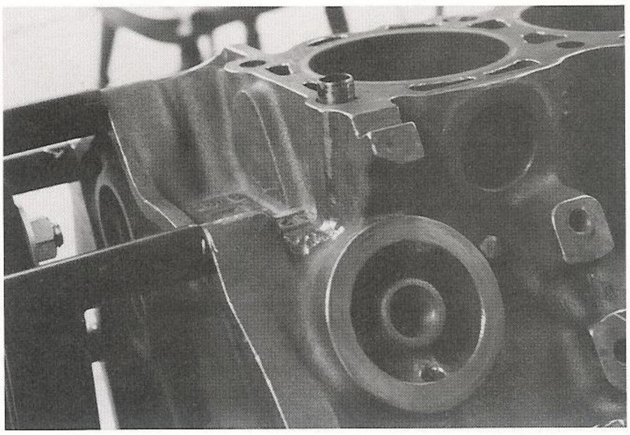


A light chamfer should be given to all of the sharp edges inside the block. It is not advisable to radius these areas, tempting as it may be.

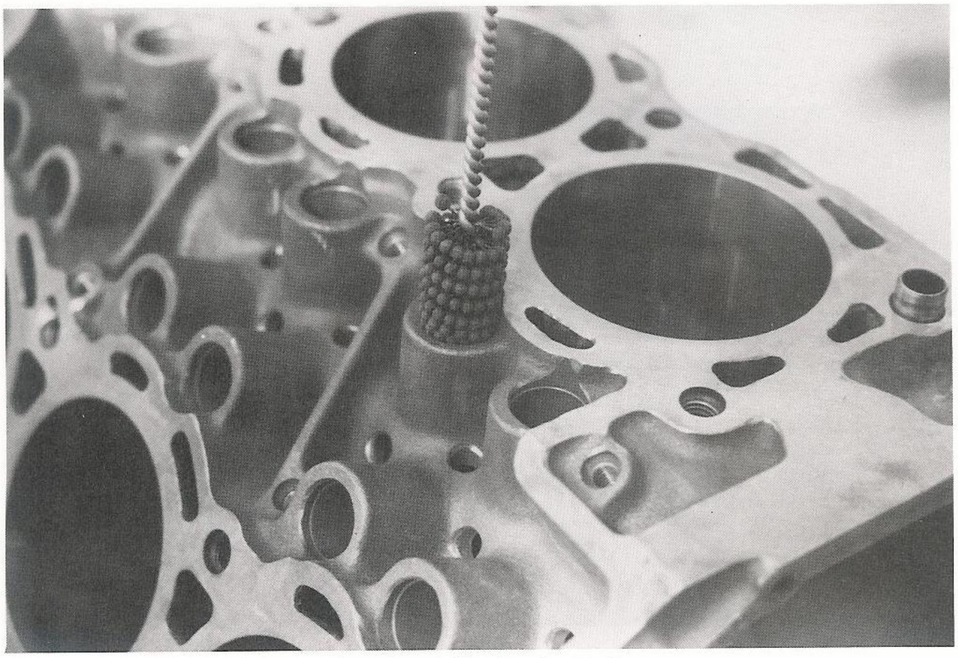
of work provides any significant advantage.

Using a small "flex-type" brake cylinder hone, lightly hone each lifter bore to break any glaze that may be present and to condition the lifter bore for the installation of the new lifters.

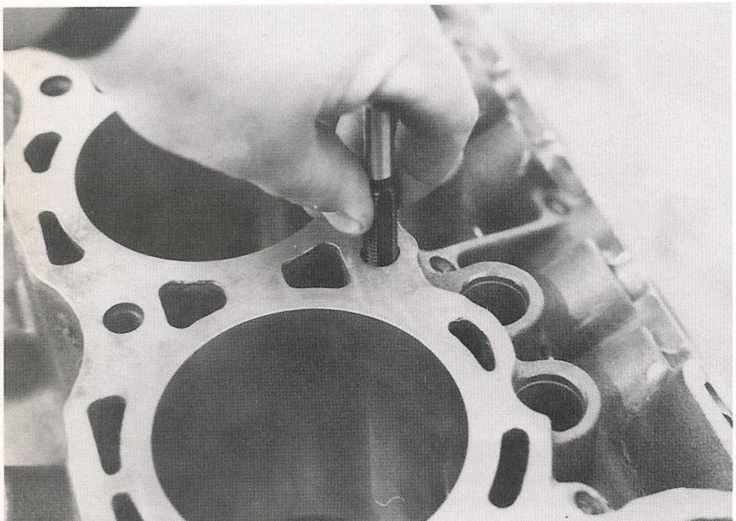
The final step in deburring involves chasing all of the threaded holes with a tap. Using a light oil and a sharp, correctly sized bottoming tap, chase each threaded hole using hand pressure only. Thread chasing is done to clean the threads of any foreign material. Therefore, absolutely no material should be removed from any of the threads. Once this is done, all of the holes should be chamfered using an 82-degree chamfering bit.



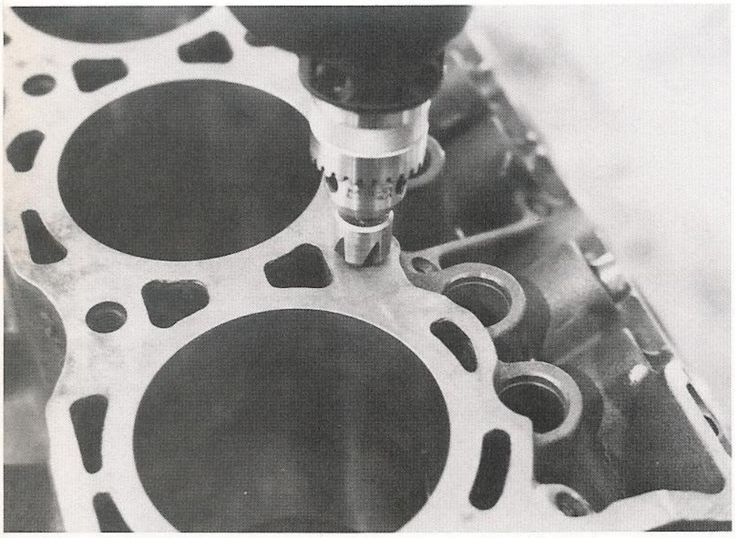
The block exterior edges should receive the same chamfering process as the block interior edges. You will probably find deburring the exterior of the block to be much more time consuming than the interior deburring process.



Once you have knocked down all of the sharp edges around the block, run a properly sized flex-hone through each lifter bore to smooth and deburr it.



Each and every bolt hole must be chased following the deburring procedure. Remember to use a sharp tap lubricated with a light cutting oil such as WD-40. Only turn the tap by hand, never with a wrench.



Follow up the thread-chasing procedure by lightly chamfering each head bolt hole using an 82-degree chamfering bit.

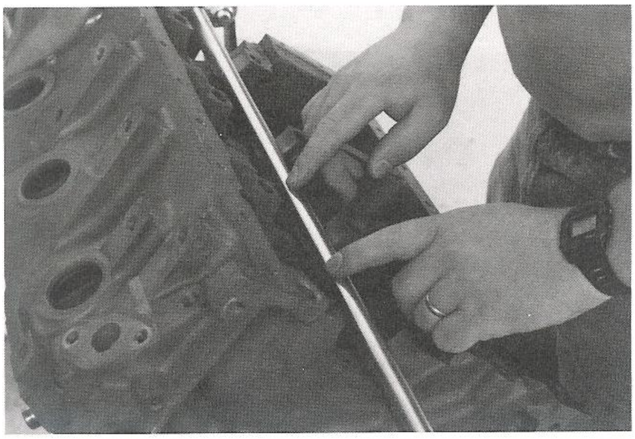
Machining the Block

All machining operations should be done by a qualified machine shop. However, it is important that you understand the purpose of each operation that will be performed on your block. Also, I will make a few recommendations to help guarantee that your money is well spent. Keep a notepad close at hand throughout this section.

Align Honing

Since all major cylinder block machining operations are indexed from the crankshaft bore centerline, the first thing that you must determine is the condition of the main bearing bores. If the mains are not the proper diameter and are not properly aligned, there is no possible way to produce an engine that is "square to the world." In many cases, it only takes a few thousandths of an inch of misalignment in the bearing centerlines or a bearing bore that is slightly out of specification to spell disaster. Therefore, before you spend one dime on machine work, you must first measure each main bearing bore and check to see that all of the mains are on a common centerline.

Main bearing alignment is the first item that must be verified. This dimension is not easy to establish without the use of some rather specialized (yet simple) equipment, so this procedure is best left to the machine shop. Essentially, checking main bearing alignment requires the use of a precision-ground warp gage. A warp gage is basically a 3/4in rod that is ground to very close tolerances and hardened to maintain durability and accuracy. The bar is positioned in the main bearing saddles and is rocked back and forth slightly to ensure that it is correctly installed. Once this is accomplished, feeler gages are used to determine if the bearings are properly aligned. A good block will show no more than 0.001in of

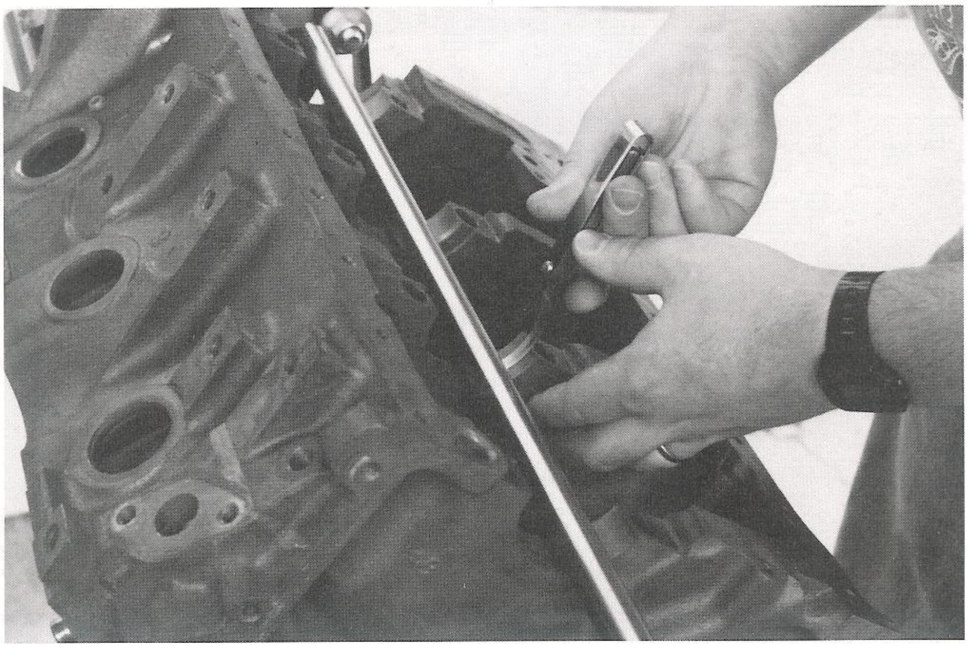


Use a warp gauge to check the main bearing alignment prior to any machining. Here, the builder aligns the warp gauge in the bearing saddles by rocking the gauge back and forth.

deviation across all of the bearing saddles. If your block is in excess of this tolerance, it will require machining to restore the proper bearing alignment. If the bearing alignment falls within these specifications, the next step is to check the bore diameters.

Measuring the main bearing bores can be accomplished in many ways. The easiest method is to use a set of snap gages and a micrometer. However, a dial bore gage is probably the best tool for the job. Each bore should be measured on its vertical axis, about 80–90 degrees from the parting line. In all cases (2.6, 2.8, 2.9, and 4.0 liter), the bearing bores should be between 2.3866in and 2.3874in in diameter.

Align honing is a machining process used to return the main

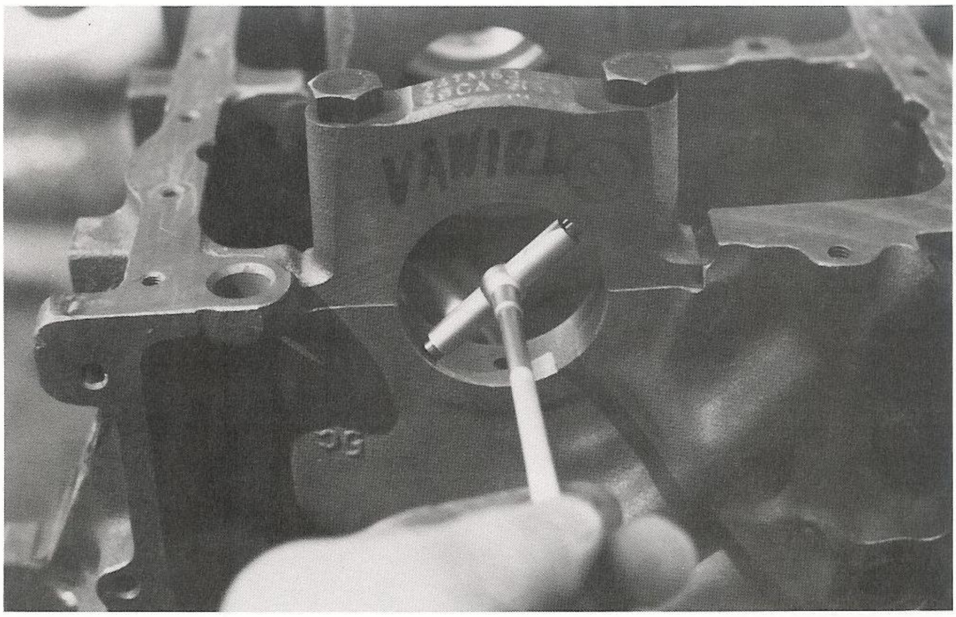


With the warp gauge accurately centered in the bearing saddles, the bearing bore alignment is checked using a feeler gauge.

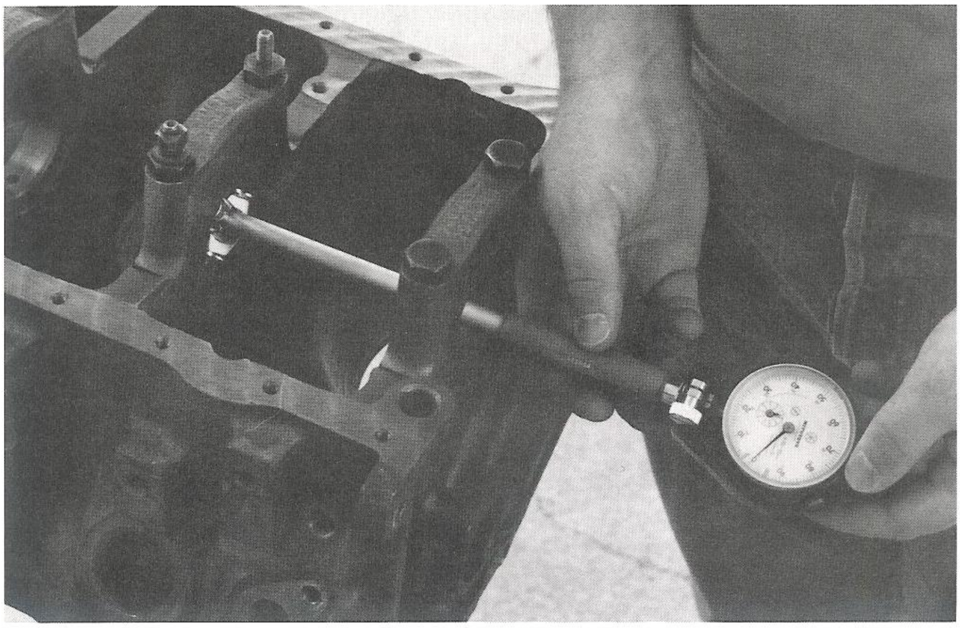
bearing bore diameters to their proper ID, and to correct any main bearing alignment errors. In short, the align honing process involves removing a small amount of material from the clamping surface of each main cap, creating a bearing bore that is slightly smaller in its vertical plane than the original. Then the bores are simultaneously honed to reestablish the proper bearing bore diameters. Reducing the bearing bore diameters maximizes bearing "crush" and improves the heat transfer out of the bearings and into the block. Please note that I do not recommend this procedure unless it is absolutely necessary based on the main bearing measurements. If any of the bearing bore dimensions are out of specification, then you should have your block align honed. You cannot achieve optimum bearing clearances unless the main bearing bores are properly finished.

Many people use the align boring method to achieve the proper bearing bore diameters and alignment. I do not recommend this process for two reasons. First, it relies heavily on the skill of the machine operator and his familiarity with the machine. If the operator has had a bad day, not only is your day ruined but so is your entire project. Second, there is a greater chance that the camshaft and crankshaft centers will be changed in relation to each other due to the greater possibility of error by the operator. This makes proper timing gear/chain adjustment nearly impossible. Do yourself a favor: if your engine requires main bearing machining, stick to align honing.

Once again, the objective of align honing is to achieve the smallest acceptable main bearing bore diameter recommended by the *bearing manufacturer,* not the factory, and to establish a common bearing bore centerline. This will require a full set of bearings. The bearings should be the exact size and brand that will be used in the final assembly. When ordering bearings, be sure to get all of the critical dimensions recommended by the manufacturer. When you take the block to the machine shop, be sure to include the actual fasteners (studs/bolts) that will be used in the final assembly. This is critical to the accuracy of the honing job because studs distort the surrounding material differently



Main bearing bore diameter can be checked with snap gauges and a micrometer. Since the main bearing oil hole is on the vertical centerline of the bore, measurements will have to be taken at several locations on both sides of the oil hole.



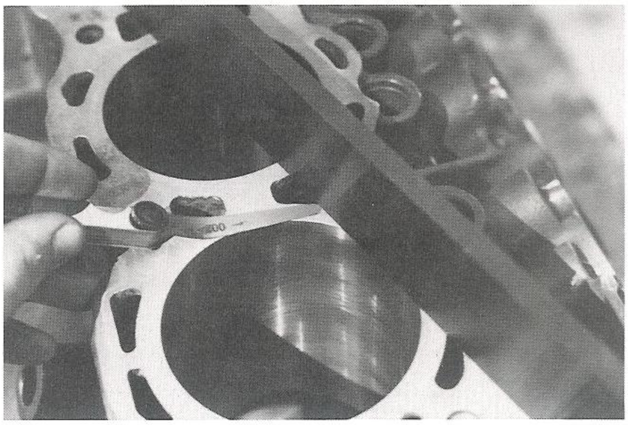
A dial bore gauge measures the bearing bores with extreme accuracy. Although this is an expensive piece of equipment for the average engine builder, it is preferred by the vast majority of professional engine builders.

than bolts do. The fasteners that you should include are main cap studs/bolts and all washers that are associated with these fasteners. Tell the machine shop to set up the bearing bores slightly on the "tight" side so that bearing crush is maximized.

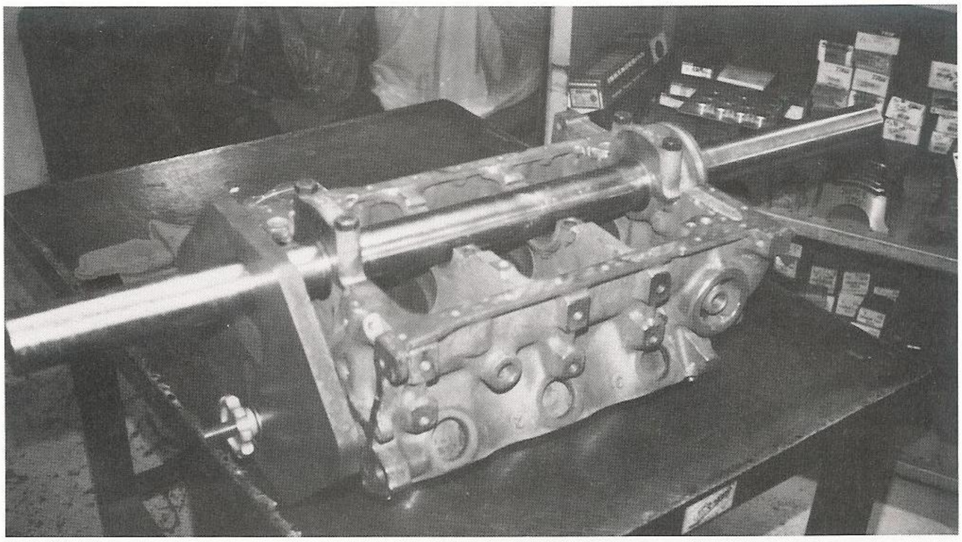
It is very important to let the machine shop do all of the prep work associated with align honing. Main cap and block preparation is delicate and critical. One mistake could result in catastrophic bearing failure, so leave this job to a professional. Once this procedure has been completed, you can feel confident that the block is ready to produce maximum power and reliability.

Decking

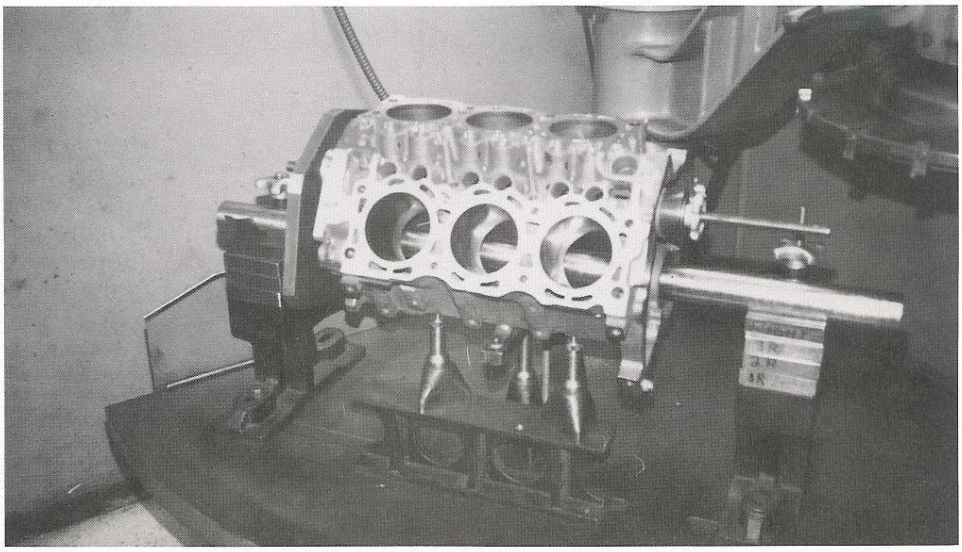
Decking the block should always follow the align honing pro-



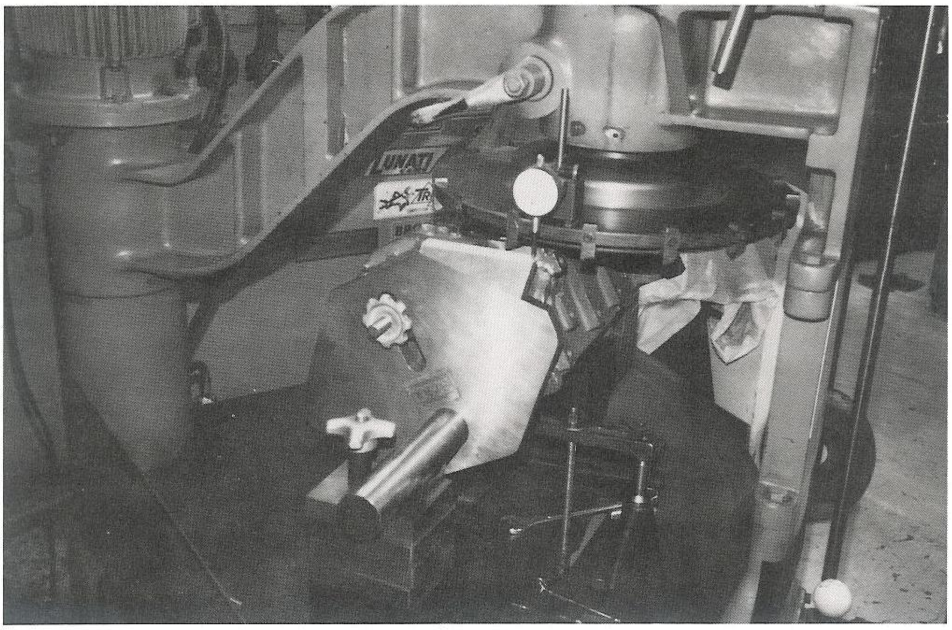
Prior to having the block decked, you should determine the amount of deck warp that is present by using a precision straightedge and a set of feeler gauges. If the deck is warped less than 0.002in in any plane, it will probably only need to be slightly trimmed to ensure that the decks are precisely indexed.



Machining the block using the BHJ Blok-Tru fixture is without question the best way to get the block "square to the world." As you can see, the fixture indexes off of the main and cam bearing bores, ensuring complete accuracy.



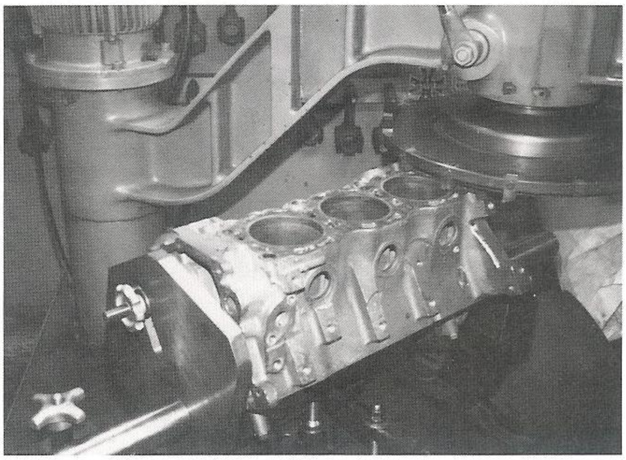
Once the Blok-Tru fixture is in place on the block, the assembly is placed in the mill and leveled.



Notice the aluminum wedge placed atop the fixture. This wedge is used to adapt the fixture, which is designed for 90-degree engines, to a 60-degree configuration.

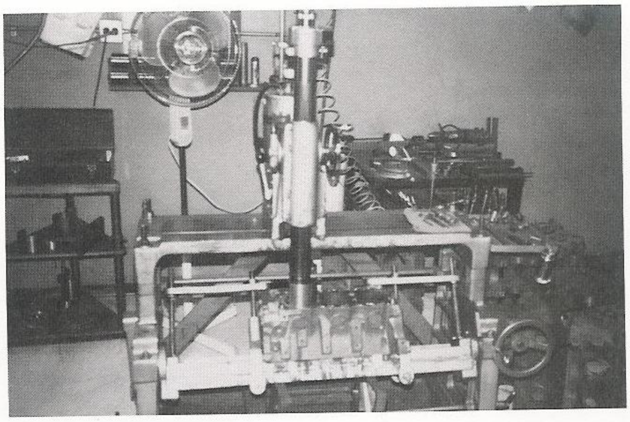
cedure. This process ensures that the deck surfaces are exactly parallel to the crankshaft, that they are exactly 60 degrees apart, and establishes exactly equal deck heights. I believe that the only way to ensure the accuracy of all of these dimensions is by using the BHJ Blok-Tru fixture. This fixture allows the machinist to square the block, index it, and establish the proper deck height all in one machining operation. It is essential that these dimensions be correct, because you can't order the correct pistons unless they are absolutely accurate. I believe that decking is also an essential part of properly building a Ford V-6 for performance.

All decking operations should be done on a mill, not a surface grinder. The mill cutters produce a rougher finish than a grinder

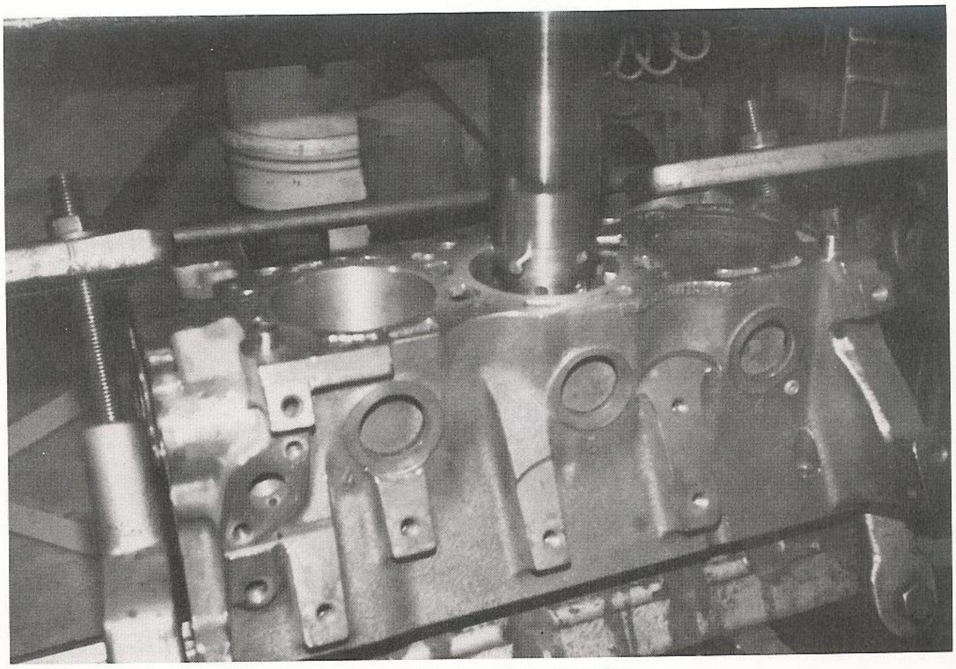


The block is decked only enough to square things up and equalize the deck heights. Make sure that the machine shop uses a mill cutter to do the decking, not a surface grinder.

can, which will significantly reduce head gasket failures by giving the gasket a surface that it can "bite into." Keep in mind that it is best to remove the least amount of material possible to square up the decks. This ensures that the most amount of material is left in the deck area to provide the best support to the upper portion of the block. Remember that the 2.6 liter block should not be decked more than 0.010in and the 2.8, 2.9, and 4.0 liter blocks should be decked no more than 0.020in. Once the deck height has been finalized, record this dimension for future reference. The final step in the decking process is to lightly chamfer all of the head bolt holes with a 60 degree chamfering tool.



Once the block has been machined square, you can be assured that it can be bored exactly perpendicular to the crankshaft and deck surfaces.



Each cylinder is bored to within.0.006–0.008in of the final size. This will allow enough room for the hone to establish the final bore dimension and finish.

Boring and Honing

The last machining process involved in block preparation is the cylinder boring and honing procedure. It is critical that this procedure is done properly to ensure that the cylinders are properly sized, located, perfectly round, and properly finished. The following section contains several specifics that should be incorporated in the preparation of your Ford V-6. I recommend that you follow them closely.

I believe that it is absolutely necessary to have a full set of finished pistons on hand before the block is bored. It is possible to rough bore the cylinders if the required overbore is known, however the final honing *must* be done with the proper pistons on hand.

Boring

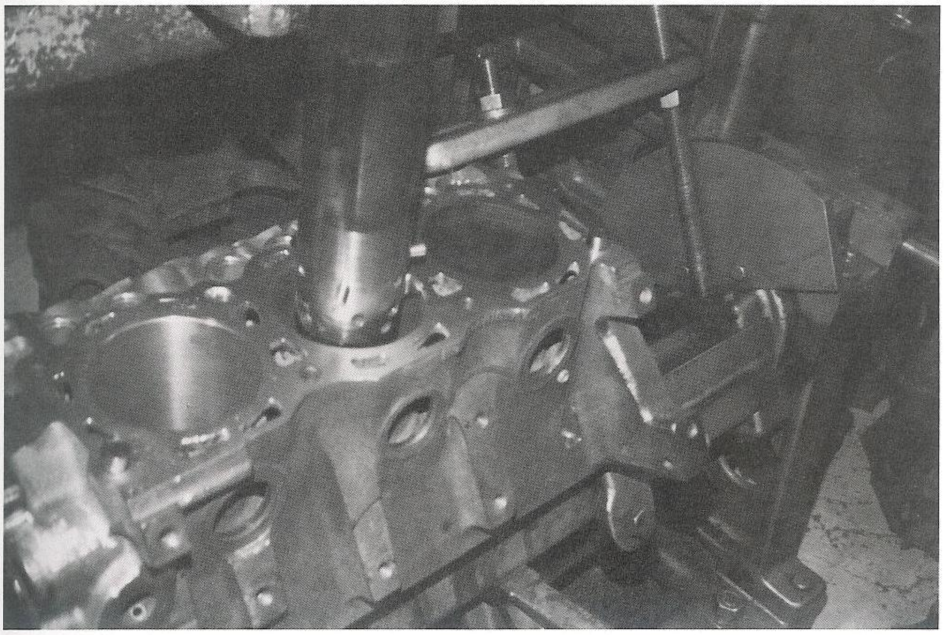
The cylinders should be bored on a machine that indexes off of the crankshaft bores. This will ensure that the bores are exactly perpendicular to the crankshaft. However, if the decks have already been trued to the crankshaft bore, a boring bar that indexes off of the finished deck will work just fine. During all boring operations, all of the main bearing caps should be installed using the proper fasteners.

Once the aforementioned items have been taken care of, the cylinders should be bored to within about 0.006 to 0.008in of the final bore size.

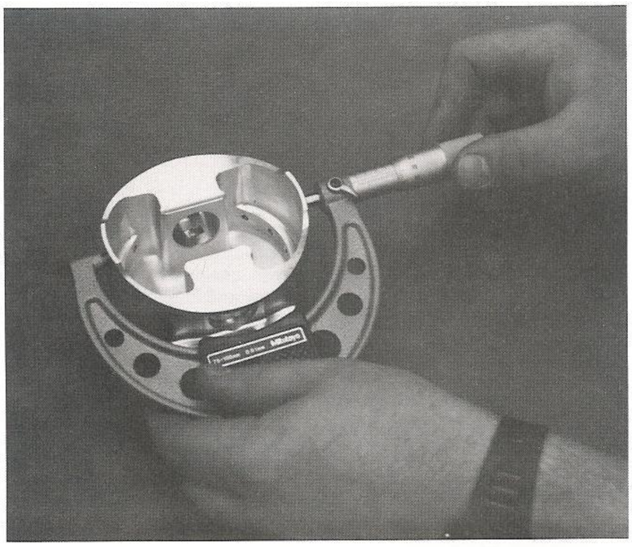
After the final boring is complete, the cylinder bore top edges should be chamfered. This chamfer should be 60 degrees and between 0.030 and 0.040in wide. This will prevent the piston rings from catching on the cylinder bore during installation and it will eliminate potential detonation problems associated with a sharp top edge.

Honing

Each cylinder bore must be honed to fit each individual piston. Before honing begins, each piston should be accurately measured and marked with its respective diameter. The piston diameter should be measured according to the manufacturer's recommendations. You should be able to measure each piston diameter to the nearest 0.0001 inch. Record each piston's diameter on the dome of the piston with an indelible marker. At the



Once each cylinder has been bored, the boring bar is offset slightly and the top edge of each cylinder is given a mild 60-degree chamfer.



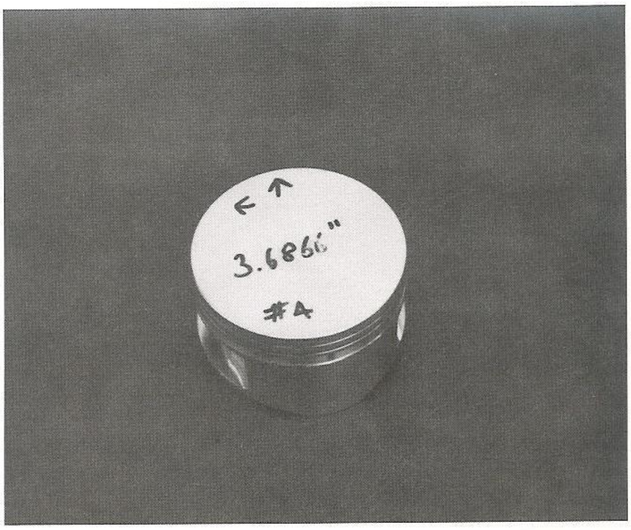
Prior to the final honing procedure, each piston must be accurately measured to establish the proper finished bore size for each piston.

same time, each piston should be mated to its respective bore. You should number each piston according to its respective cylinder. To find the final bore diameter for each cylinder, add the piston manufacturer's recommended clearance (0.0065 inch for example) to each respective piston diameter. This will equal the proper finished bore diameter for that piston. Record the finished bore diameter on the deck surface beside each respective bore.

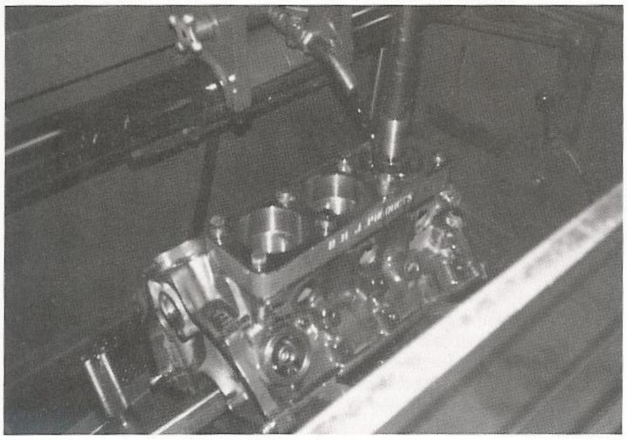
All honing should be done on a Sunnen CK-10 automatic power honing machine. This is the only machine that should be used, so accept nothing else. The final finish on the cylinder bores should be achieved with a Sunnen JHU-820 stone (400 grit). The bore should be as smooth as possible. A smooth bore finish is best for quick seating and tight sealing of moly rings. Always use torque plates during all of the honing procedures. I prefer the "R" series torque plates manufactured by BHJ Products. The top edges of each cylinder should be finished by lightly polishing the radius with 400-grit wet-or-dry sandpaper. Finally, deburr the bottom of the cylinder bores using 400-grit wet-or-dry sandpaper.

Cleaning

Following the machining processes, the block should once again be cleaned in a jet wash cabinet. Once the jet washing process is complete, you should thoroughly wash the block by hand to remove any debris missed by the jet wash. Cleaning the cylinder block will require particular attention to detail. If the block is not absolutely spotless, small pieces of trash will certainly make their way into the oiling system and wreak havoc on those nicely finished and expensive parts. My best advice is to take your time and be thorough to an extreme.



As each piston is measured, it is a good idea to mark the piston diameter on the dome while, at the same time, indicating the proper cylinder number and direction of installation.

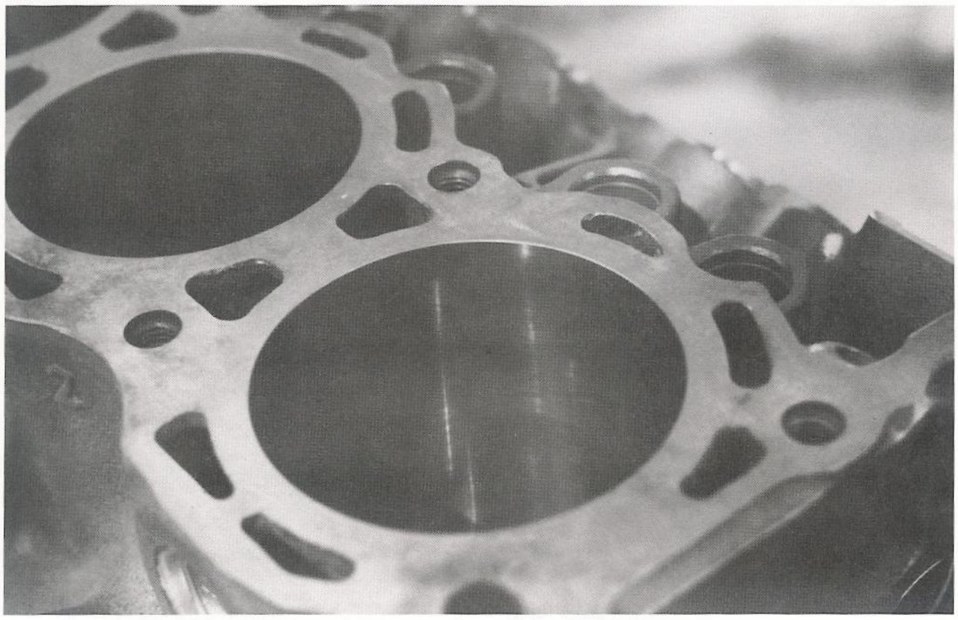


All honing should be done with a torque plate bolted to the deck surface. This is a BHJ Products "R" model plate for use on the 2.8- and 2.9-liter engines. Each cylinder is carefully checked several times throughout the honing procedure. Most good machine shops can hit the final bore size within 0.0005in or less.

Before you begin cleaning the block, have the following essential supplies on hand:

- Liquid laundry detergent
- 2gal (or larger) bucket
- Small bottle brushes (gun cleaning brushes)
- Large bottle brush (diameter of bore or larger)
- Stainless solder brush
- Toothbrush (stiff)
- WD-40 (at least two large cans)
- Paper towels (three rolls)
- High pressure sprayer (car wash)
- Degreasing solvent
- automatic transmission fluid (ATF) (about 2qt)
- Compressed air

Begin cleaning your block by securing it firmly in the back of a pickup and carting it to your nearest car wash. I recommend



The optimum bore finish is achieved using a Sunnen JHU-820 400-grit stone to create a cross-hatch pattern of 30 degrees. A smooth bore finish is critical to proper ring seal.

that you take a few things with you: an engine stand, WD-40, two 30gal trash bags, a pocket full of quarters, and a friend. At the car wash, mount the block on the engine stand. This will make rotating the engine easy and it will keep it off the ground (where all of the grunge is). Once the engine is secured, insert the proper amount of coinage into the car wash and start blastin'. You should do the first few washings with the "soap" function of the car wash. Blast every crevice that can possibly get wet. Keep in mind, the more thoroughly you clean the block now, the easier it will be to finish the job later. Finish the blast-cleaning by using the "rinse" function. This should be a clear water rinse not a "wax rinse." You should rinse the block no less than three times with the clear water rinse. Be sure that your friend is armed with the WD-40 *before* you have completed the third rinse. As soon as the final rinse is through, completely soak the entire block with WD-40, paying particular attention to the cylinder bores, oil galleries, and the main bearing and cam bearing bores. The water displacing quality of WD-40 should effectively drive the water away from these critical areas. Remember, it is not possible to use too much WD-40. Once you are sure that every area of the block has been thoroughly coated with WD-40, place two trash bags over the block and dismount it from the engine stand. Secure the block in the back of the vehicle and take it home.

Once you get home, make a bucket of rich soapy water using liquid laundry detergent. Unload the block and mount it on the engine stand once again. Thoroughly scour the block inside and out using the cleaning brushes soaked in degreasing solvent to clean all crevices (especially around the pan rail area). Use the gun cleaning brushes to clean the oil galleries. Do not touch the bores with these brushes as they can damage the crosshatch finish.

Now, using the soapy water and the same brushes you just used, repeat the entire cleaning process as just described.

The last step is to scrub the cylinder walls with paper towels soaked in clean soapy water. Do not use cloth to scrub the bores as they deposit too much lint. Continue washing the bores until no dirt appears on the paper towels. Rinse the block using large amounts of clean water. Immediately following the rinse, thoroughly coat the block in WD-40. The water should bead as if the block had been freshly waxed. Now use compressed air to blow-dry all areas of the block. This should eliminate the remainder of the water. Resoak the block in WD-40.

The best way to check your work is to use the "fingertip test." Basically, you know you've done a good job if you can run your finger around any part of the block and see no deposits on your fingertip. If your block passes this test, congratulations! Unfortunately, you are not done.

Even though the cylinder bores may seem clean, all kinds of little nasties are still left in the pores of the cylinder walls. To remove these deposits, soak several paper towels in ATF and thoroughly scrub the cylinder walls. You will notice black deposits on the first few towels. This indicates that the surface of the cylinders have trapped a large amount of debris. Do one cylinder at a time, changing paper towels often. You know that the bore is clean when no deposits appear on a freshly soaked paper towel. Once all of the cylinders have been cleaned, wash the block using a fresh bucket of clean, soapy water. Rinse the block and coat it with WD-40. Blow-dry the block using compressed air, recoat with WD-40, place the block in a plastic bag, and store it in a safe place.

Internal Block Painting

Over the past fifteen years or so, painting the interior surfaces of the cylinder block became very popular among certain engine builders. The idea was to provide a smooth surface on the interior of the block to optimize oil drainback. I am sure that there are still those who advocate painting cylinder block interiors, but I'm not one of them. I have seen more than one of these "painted" engines expire because the paint that was supposed to be doing all the good ended up flaking off. This, in turn, plugged up the oiling system, causing catastrophic bearing failure. I just don't think that it's possible to get an engine clean enough to ensure proper paint adhesion in all areas. Furthermore, the so-called benefits of block painting may not be benefits at all. The rough interior surface of the block actually has more surface area than a smoothly polished (or painted) surface. This larger surface area allows the oil to remove more heat from the block, providing a significant amount of additional cooling. These 60-degree V-6 engines need all of the help they can get when it comes to cooling. I strongly recommend that you don't paint the interior block surfaces.

The Crankshaft and Connecting Rods

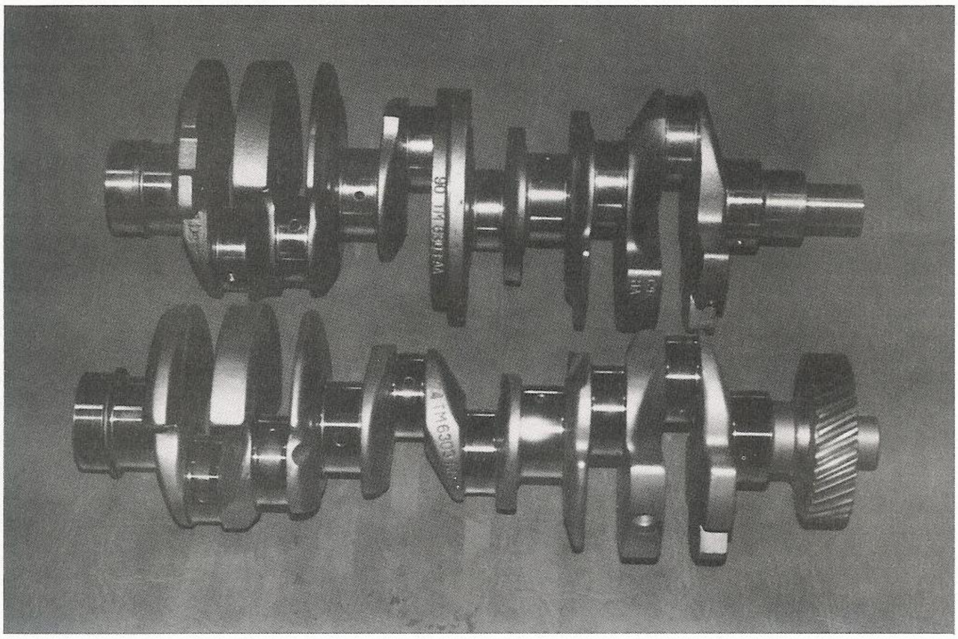
2

The Crankshaft

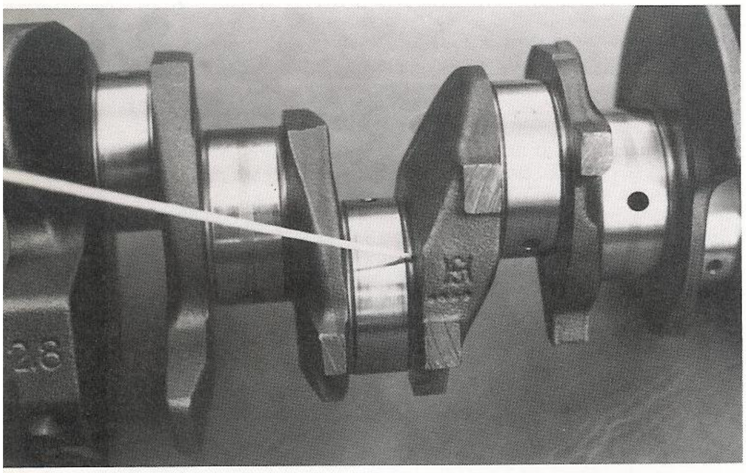
The crankshaft is undoubtedly one of the most frequently ignored components in the engine assembly. All too often I see folks spend lots of time and effort on so many little details and then turn right around and throw in a garbage crankshaft. Soon (very soon) they find themselves surveying the remains of what started out as a really good idea. Now, when I use the term "garbage" crank, I don't just mean one that is bent or gouged. I include most "catalog" cranks as well. Catalog cranks are those pieces of business that you would get from the local in-'n-out auto parts store's "rebuilt engine" catalog. I have yet to see one of these that could even remotely be considered for even a stock rebuild. Luckily, there is a fairly large surplus of used engines out there and, therefore, usable cranks. You will be glad to know that there is no magic to preparing a V-6 crankshaft, but good attention to detail is important. If you don't make the crank happy, it certainly won't make you happy.

Choices

Choosing a crankshaft for your project is, relatively straight forward. However, as a prerequisite, it is important that you have a good idea as to the approximate power level and rpm at which the engine will operate. Once you



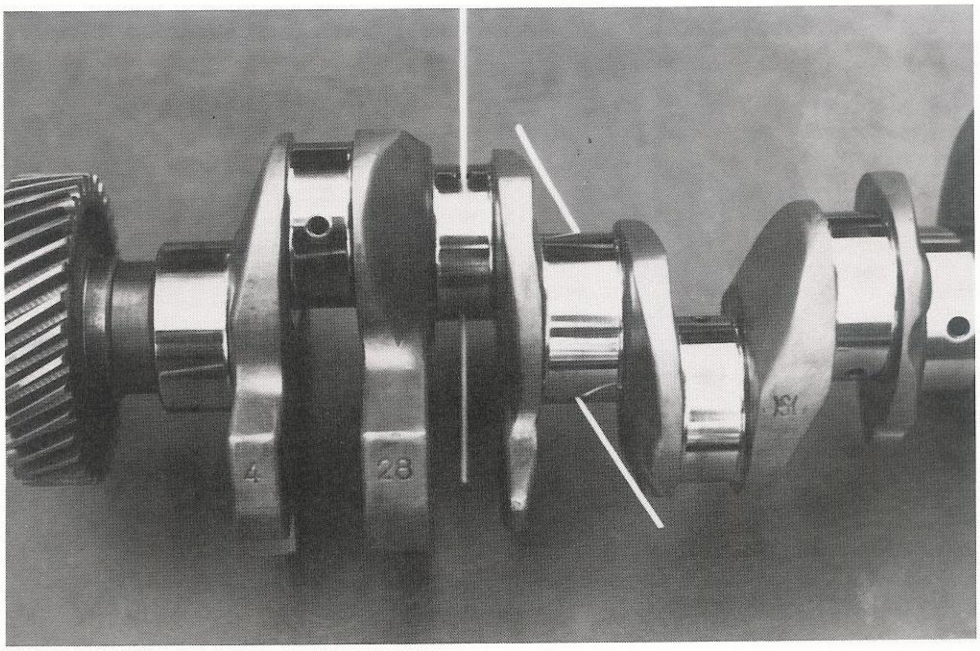
A comparison of a production 4.0-liter crankshaft (top) and an early 2.8-liter crankshaft shows that crankshaft design has evolved very little over almost twenty years. The most obvious difference is the addition of a center counterweight to the later 4.0-liter crank.



The more desirable truck crankshafts have generous rolled fillets on both the main and rod journals.

have this information in hand, keep in mind the following recommendations when making your crankshaft selection.

- For 2.6-liter engines, the only crankshaft available is the stock casting.
- For 2.8-liter engines that are expected to produce less than 210hp and will be operated at a maximum of 6000rpm, you can use the automotive crankshaft (identified by a casting number beginning with a 74TM).
- For 2.8-liter engines that are expected to produce in excess of 210hp and will likely be operated in excess of 6000rpm, you should use the truck crankshaft (identified by a casting number beginning with an 84TM). The truck cranks have the advantage of rolled fillets, making them stronger in the main and rod



A nice feature of some of the smaller displacement Ford V-6 crankshafts is factory cross-drilling. This is especially desirable in extreme duty engines as it helps to eliminate bearing failures due to oil starvation.

journal areas.

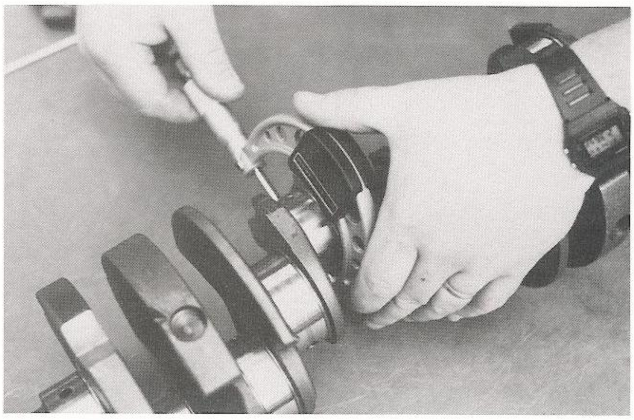
- 2.9 and 4.0 liter engines must use the stock casting as no other factory options exist (Cosworth 2.9-liter engine notwithstanding).

In truth, all of the stock V-6 crankshafts are very impressive. The material used for these cranks is a cast nodular iron. The term "nodular" refers to the concentration of carbon pockets that exist throughout the casting. Additionally, the crank incorporates four main bearings, with thrust loads handled by the number three main, and is also a "six-throw" (one throw per rod). The following guidelines will help you ensure that you'll have no problems with the crankshaft.

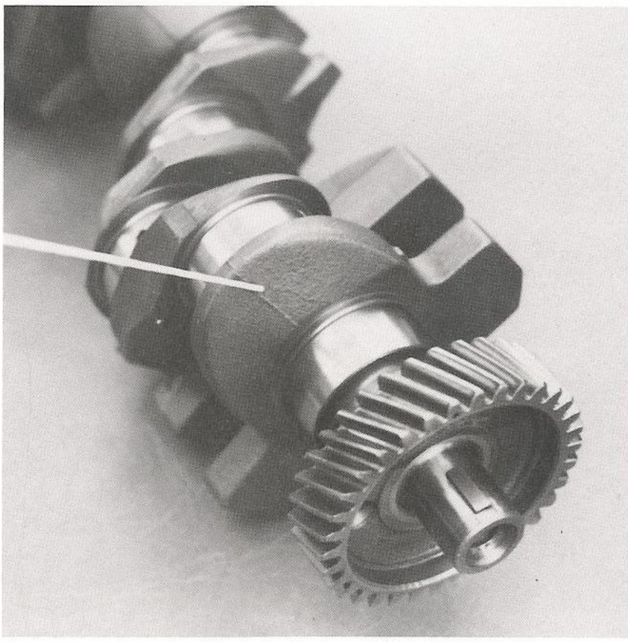
Inspection

The first order of business is to find out if the crankshaft you have is a good one. Start by giving the crank a thorough visual inspection. Look for evidence of a spun bearing, usually accompanied by shiny blue "heat marks" on the journal. Second, look for gouges or signs of bearing metal impregnated in the journal surface. Check for any signs of previ-

A good way to find out if a crank has been ground undersize is to inspect the back of a rod and main bearing shell. If undersized bearings have been installed, they will be marked with the appropriate amount of undersize. As indicated in this photo, this bearing is 0.25mm undersized (about 0.0098in).



If your crank passes a thorough visual inspection, the next step is to measure each journal to determine if the crankshaft has been ground undersize.



When inspecting a used crankshaft for the first time, look very carefully for signs of heat marks on the main and rod journal areas.

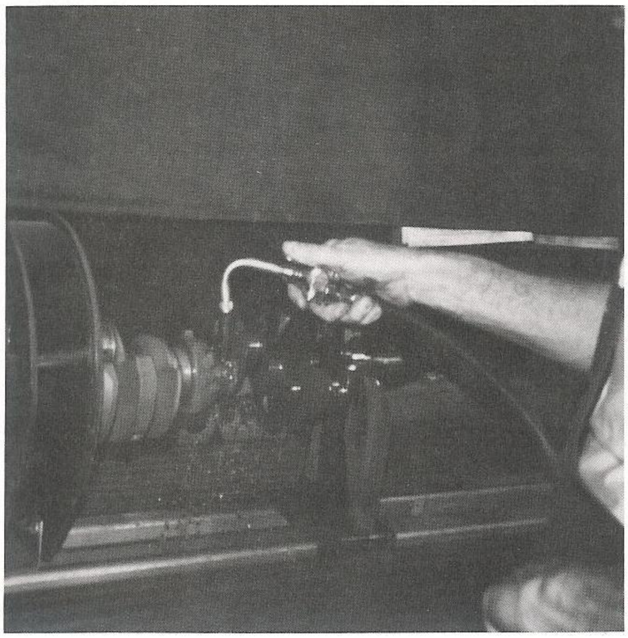
A dial indicator is used to check the crank for straightness as it is turned in a pair of precision v-blocks.

ous welding or chroming. And finally, check for any visible cracks. If you find any of these wear signs, then figure out what you are going to do with your brand new, extra-heavy-duty wheel chock. If the crank looks good, measure the main and rod journals to determine if the crank has been ground undersized. Most often, if a crank has been ground, the appropriate grind numbers will be stamped on one of the counterweights. But measure it to confirm the dimensions. If you find that the crank has been ground, I recommend that you find another one. The rule of thumb is to start with a standard size crank.

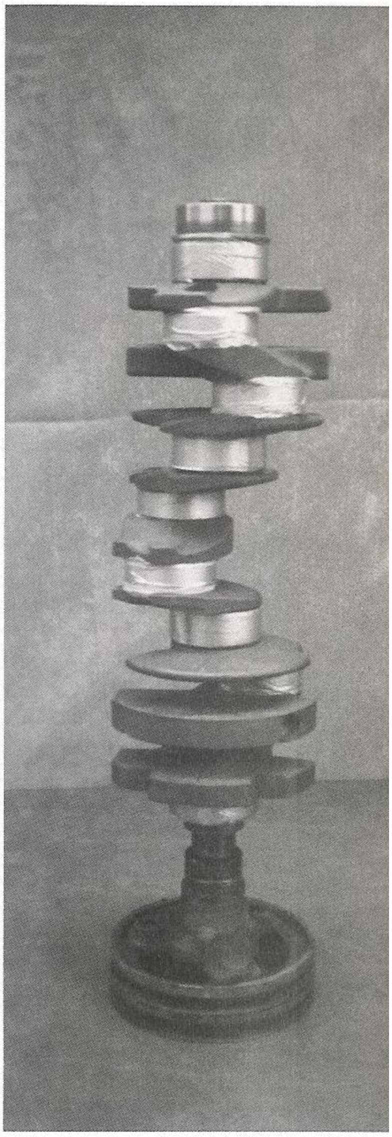
Cleaning and Deburring

The crankshaft preparation procedure should always begin with a thorough hot tank or jet spray caustic cleaning. Once again, I believe jet spray cleaning to be superior to the old hot tank method. The idea is to completely degrease the crank and remove any accumulations of varnish or carbon that may impede the crack inspection process to follow. Once the crank has been cleaned, it's off to the crank shop for the Magnaflux (Magnaglo fluid) crack inspection procedure. This procedure is an absolute necessity when it comes to proper crankshaft preparation. Make sure that the crank shop that will be checking the crank for cracks is not using the conventional Magnaflux powder method. This process does not perform the same function as the Magnaglo process and will often not indicate small (yet potentially fatal) cracks in the crank. If the crank turns out to be free of cracks, then the work of deburring can begin.

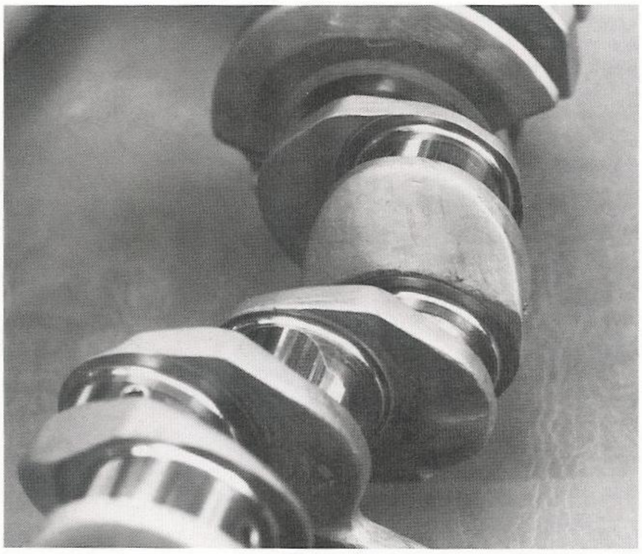
Crankshafts are deburred for the same reasons as the block and the rods. The purpose is to reduce the number of possible starting points for crack formation and to reduce the chance of errant flakes of material falling into the oil and destroying the engine. Before any grinding begins, all of the main and crank pin journals must be protected to avoid damage during the grinding process. I find that one of the best ways to do this is to cut "collars" from 2in schedule 40 PVC pipe and place them around each journal. Wrap each collar with enough duct tape so that the tape is slightly higher than the machined thrust faces on the journals. Use a body grinder or a small handheld grinder and a fine grit disc to do the primary grinding on the crankshaft. The goal is not to remove material too quickly, but to remove all of the parting lines and casting flash that may exist on the crankshaft. Do not try to "knife edge" the crank. Once the crank has been completely deburred, the next step is shot peening. This is done to compress the unmachined surfaces of the crank providing a more dense surface structure to reduce the formation of cracks. I prefer the peening method using #230 steel shot to achieve an Almen "A" arc height of 0.012–0.015in, but whatever process your crank shop uses will probably be sufficient. The most important thing to remember is not to peen the journals, snout, or sealing areas of the crankshaft. It is



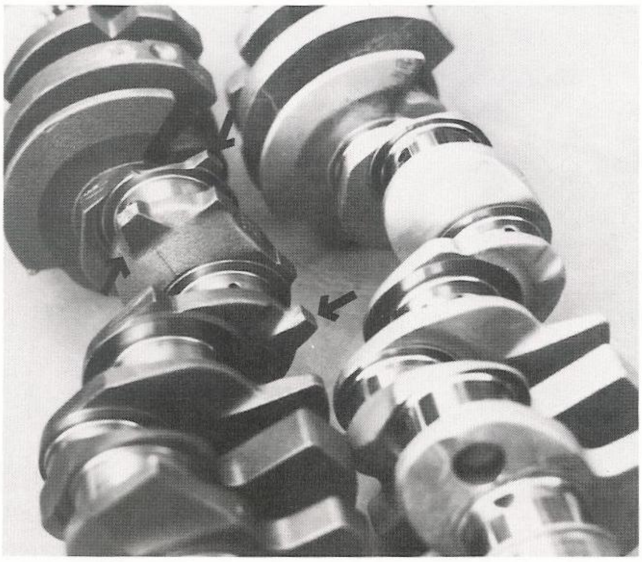
The Magnaflux crack detection process begins by magnetizing the crankshaft. After the crankshaft is fully magnetized, a magnetic fluid solution (Magnaglo) is poured over the entire crankshaft. This fluid is much more "crack-seeking" than the magnetic powder and is the preferred medium to use when inspecting crankshafts. A special high-intensity inspection light is then used to inspect the crank for cracks while it is still fully wet with indicator.



A good way to protect the journals from damage during the deburring process is to place rings of PVC pipe around each one and then tape each journal until the level of tape is even with the cheeks of the journals.



Shot peening will leave a nice even texture on all of the surfaces. Furthermore, the compressed surface is now much stronger and crack resistant than before.



This picture illustrates the rather significant amount of material removal involved in deburring. Notice the absence of the indicated bosses on the finished crank (right).

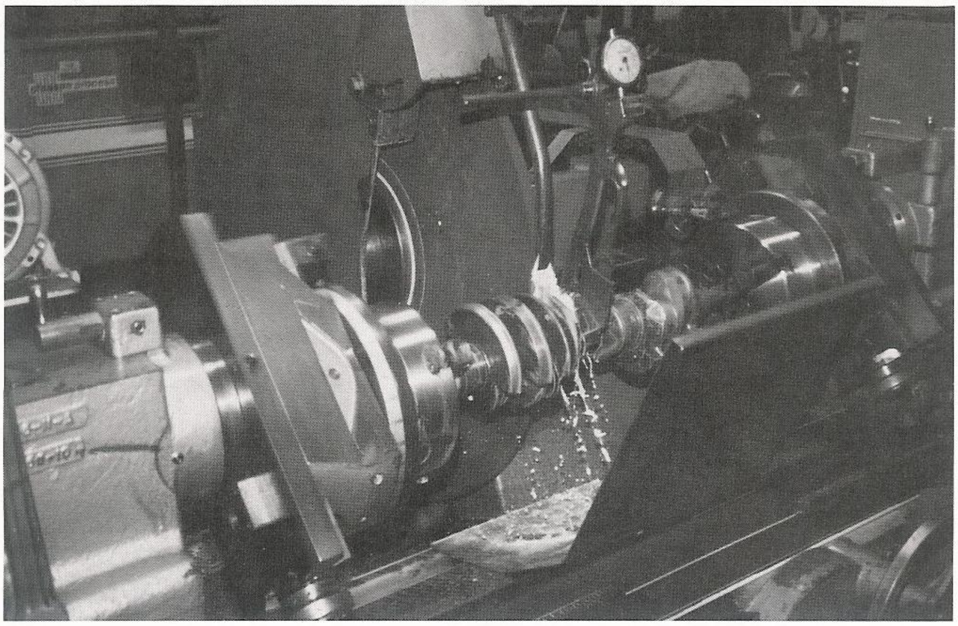
not a bad idea to leave the protection collars on the crank during this procedure.

Grinding

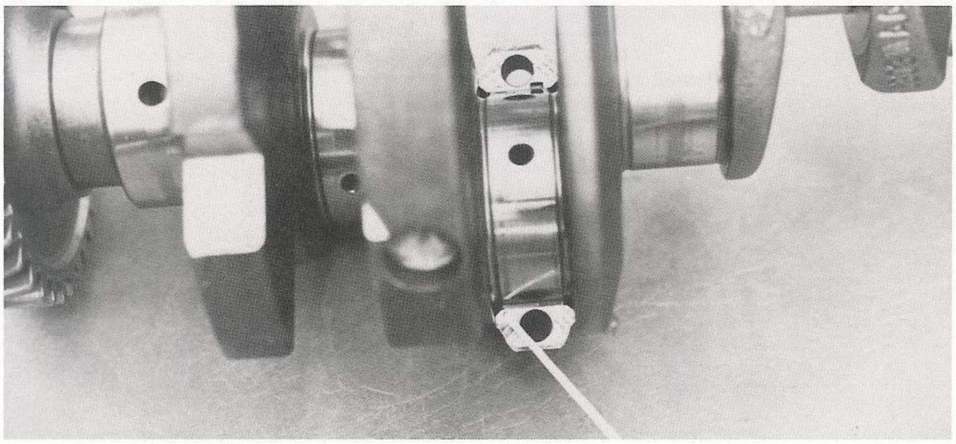
The next step in crankshaft preparation is grinding the shaft to the proper size. This is the most critical operation during the entire process so it is imperative that everything be done just right. I highly recommend that you research the market very carefully before choosing a crankshaft grinding shop. Additionally, I believe that it is absolutely necessary to have a full set of finished rods and a new (properly sized) bearing set available before any grinding is performed. It is not a bad idea to clamp a new rod bearing into a finished rod and take it to the crank shop with the crank. Also, you will want to install a main bearing (preferably the #3 main) into the block. Torque the bolts to the proper specification and measure the bearing inner diameter using a dial bore gage. If you do not have such a gage, take the time to haul the block to the crank shop with everything else.

Although the stock crankshaft is very durable, I recommend that under no circumstances should a Ford V-6 crankshaft be ground more than 0.010in undersize. Again, if the crank has standard dimensions when you start and it passes all of the aforementioned criteria, 0.010in should allow plenty of room for the crank grinder to grind, index, and stroke equalize the crank.

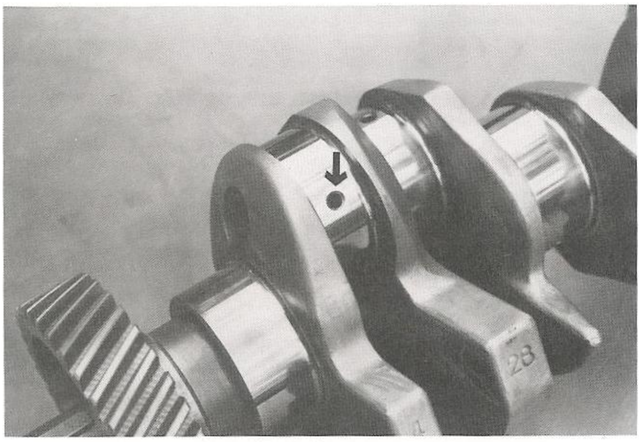
Indexing and stroke equalizing are very important. Indexing ensures that the crank throw separation is exactly 30 degrees. Stroke equalizing is pretty self-explanatory. Each crank throw is ground so that the stroke length is equal from throw to throw. Believe it or not, it is not uncommon to find stock cranks with throw indexing that varies as



Grinding the crank to size is a very delicate and critical process in crankshaft preparation. During the grinding process, all of the stoke lengths must be equalized and each throw should be indexed.



Each journal should have a generous radius ground into the fillet area. This will ensure that the crank will offer optimum strength and rigidity.

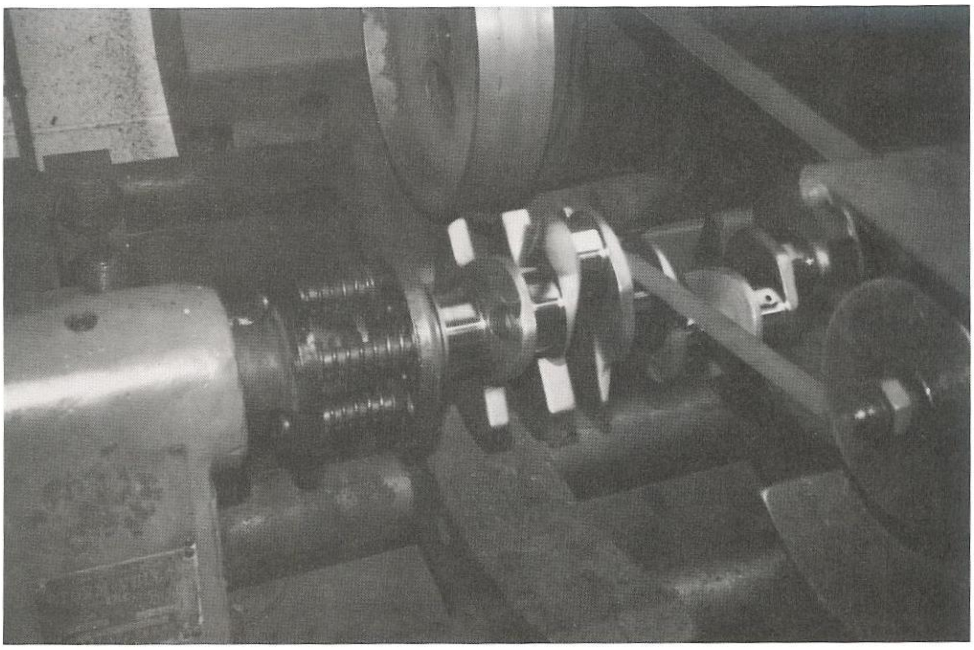


All of the oil holes in the crank should be chamfered following the grinding operation. It is best to have a crank shop do this as it has special tools that will ensure no damage to the freshly ground journals.

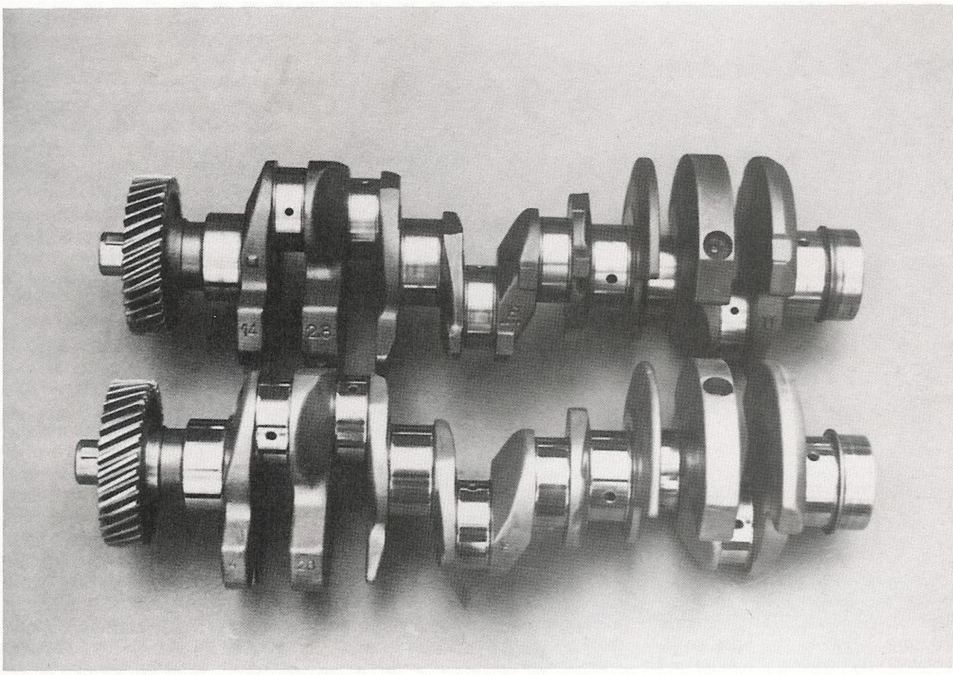
much as 4 degrees and stroke lengths that vary as much as 0.020in.

Radiusing the crank is yet another important task. All bearing journals should have the largest possible radius between the journal and the crank cheeks. Most V-6 crank failures that I have seen happen right in that area. Radiusing adds a considerable amount of strength to the crankshaft and is critical to reliability. The best advice that I can give is to provide the grinder with a fully assembled rod and bearing combination so that he can determine the maximum amount of radius that can be safely ground into the crank.

While the crank is at the machine shop, have the machinist chamfer all of the oil holes in



Polishing is the final step in the grinding procedure. This creates the perfect finish on each journal so that the bearings will enjoy a long life.



The finished crank (bottom) is visually much different from the stock example. Notice the smooth, clean surfaces and the highly polished bearing surfaces.

the crankshaft. Do not do it yourself. Although chamfering slightly improves oiling efficiency, the main purpose is to help prevent cracks from forming in the oil holes.

Polishing

The final crankshaft preparation step is polishing. The first thing that I must mention is that polishing is not used to finish the bearing clearances. The purpose of polishing is to smooth out any tiny imperfections that may have been left by the grinding process so no bearing damage will occur. This has become standard procedure in the industry and should not be something that you need to request, but it doesn't hurt to double-check. If the crank should require any touch-up to the polished surfaces due to nicks from measuring the crank or during mock-up, lightly polish the surface using 600-grit wet-or-dry sandpaper soaked in kerosene. Once the crankshaft has been fully finished, wash it thoroughly in a rich soap and water solution making sure to clean all oil passages with a bore brush. Rinse it with large quantities of clear water and immediately coat it with large amounts of WD-40, paying particular attention to the oil passages. Once all of the water is displaced, place the crankshaft in a plastic garbage bag and store it in a safe, dry place.

Heat Treating and Chroming

Heat treating is optional in a performance (nonracing) application. If your crankshaft was not ground more that 0.010in undersized, then the factory heat treating should still be sufficient. However, if the crankshaft is to see any racing use, heat treating is a necessity. The only heat treating process that I find acceptable is Nitriding. Nitriding can increase the fatigue strength of the crankshaft up to 80 percent, reduce wear up to 30 percent, and significantly reduce crack formation.

Some builders recommend chroming a crankshaft after grinding. I have found that chroming a crank is potentially more trouble than it is worth. Chroming can hide cracks that may be beginning or may already exist. Additionally, if not applied properly, the chrome may flake off and spell disaster for your engine. I do not recommend that any Ford V-6 crank be chromed, period.

Bearing Choices

Most people give little thought to the bearings that go into their engines. After all, a side-by-side comparison of most engine bearings will show little or no difference in appearance. Unfortunately, the appearance of the bearings gives practically no useful information as to the bearing quality or its performance. Factors such as bearing embeddability, material load capacity, and heat transfer capability cannot be determined visually. Therefore, considerable "real-world" testing is the only true way to determine the quality of an engine bearing. I believe the best available engine bearings for the Ford V-6 are the Michigan 77s, commonly known as Clevite 77s. These bearings have proven extremely reliable in both street-performance and racing applications.

Ford 60-degree V-6 engines impose some unique demands on their engine bearings. This is especially true of the 4.0-liter versions. When the Ford engineers set out to design the 4.0-liter platform, they chose to continue using the same crankshaft and main bearings that were used in the smaller 2.8- and 2.9-liter engines. Since the internal components used in the 4.0 liter are considerably more massive, the bearing loads are proportionally increased. In what seems to be a direct compromise, the engineers also chose to use aluminum-backed main bearings to support the crankshaft (presumably as a cost saving measure). One would suspect these bearings to be somewhat questionable in terms of reliability, and rightly so. I have found that under no circumstances should an aluminum-backed main or rod bearing be used in any Ford V-6. Aluminum simply does not offer sufficient strength to maintain the proper bearing shape during severe use and can result in a "spun" bearing. I have found that the aluminum-backed bearings will actually "roll-up" under high load conditions (not good). Suffice it to say, steel-backed, Michigan 77 bearings are the only way to go. To aid in the selection of the proper Michigan 77 bearings, a chart has been included in this chapter. All of the listed bearings are a "tri-metal" construction, using the Clevite 77 material, and should provide ultimate reliability in any Ford V-6 application.

Clearances

Most stock Ford V-6 engines have main and rod bearing clearances that are too tight for performance applications. However, since every engine that is destined for a performance application is going to undergo the aforementioned crankshaft preparation, the clearances can be corrected to offer optimum performance and reliability. Because all of the Ford 60-degree V-6s use essentially the same main and rod bearings, the clearances for these bearings will be consistent in all engines. Research has shown that the optimum bearing

Ford 60-degree V-6 Engine Bearings

Engine Type	Rod Bearings	Main Bearings	Cam Bearings
2.6 liter 1972–73	CB-723-P CB-723-P-10	MS-860-P MS-860-P-10	SH-1386-S
2.8 liter Auto 1974–79	CB-723-P CB-723-P-10	MS-1692-P MS-1692-P-10	SH-1386-S
2.8 liter Truck 1983–86	CB-723-P CB-723-P-10	MS-860-P MS-860-P-10	SH-1390-S
2.9 liter 1986–92	CB-723-P CB-723-P-10	MS-860-P MS-860-P-10	SH-1390-S
4.0 liter 1989–	CB-723-P CB-723-P-10	MS-860-P MS-860-P-10	SH-1441-S

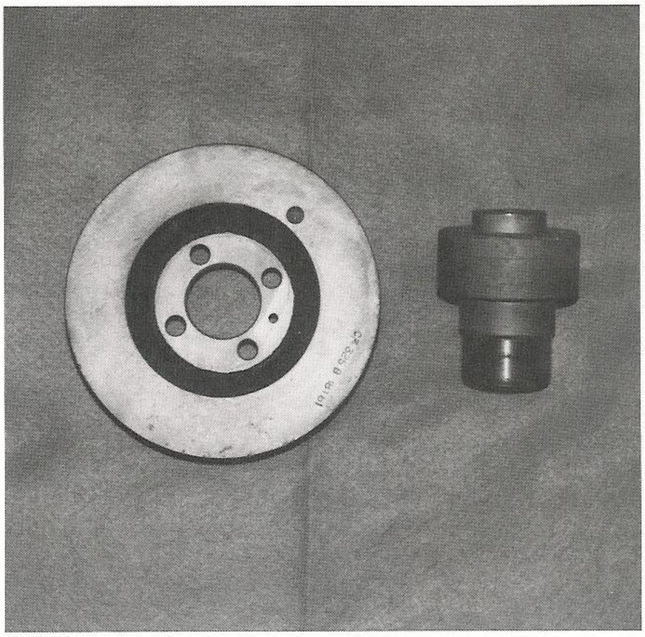
Note:
A) All "P" and "S" bearings are standard sizes.
B) All "P-10" bearings are 0.010in oversized.
C) "P-10" main bearings have 0.004in oversize thrust bearing length (except 2.8 Auto 1974–79 and 4.0 Truck 1989–).

clearance for the main and rod bearings in all Ford 60-degree V-6 engines is 0.0020–0.0025in. Although the cam bearing diameters are not consistent among the Ford V-6 engines, the cam bearing clearances are the same among all of the engines. The cam bearings should provide 0.0015–0.002in clearance. Finally, the crankshaft should be provided with 0.004–0.008in end clearance and the connecting rod side clearance should range between 0.006in and 0.011in. These bearing clearances will provide excellent oil flow through the bearings resulting in a cooler, more wear-resistant environment.

Crankshaft Dampers

You should consider some sort of crankshaft damper if you expect to operate your engine regularly in excess of 5500–6000rpm. Over the years, several different kinds of crank dampers have been used on the Ford V-6. Most of them were solid cast iron and did very little to dampen anything. For a brief period in the mid-1970s, some 2.8-liter engines were equipped with a true vibration damper. These units had an elastomeric ring just like those fitted to the small-block Ford engines. These dampers are worth finding. They are fairly rare, so if you can find more than one, you should snag them, pronto. If you plan to fit one of these units to a truck block, you will need a special spacer, which is available from Vanir Technologies. Be sure to get the accompanying timing pointers so that you won't get the wrong readings when you time your engine.

Another option is to have one of the many performance damper manufacturers make a unit that will duplicate the physical dimensions of the original damper that came with your engine. At worst, this will probably set you back a few hundred dollars but I think it is a wise investment on any engine that will regularly see 6000+ rpm.



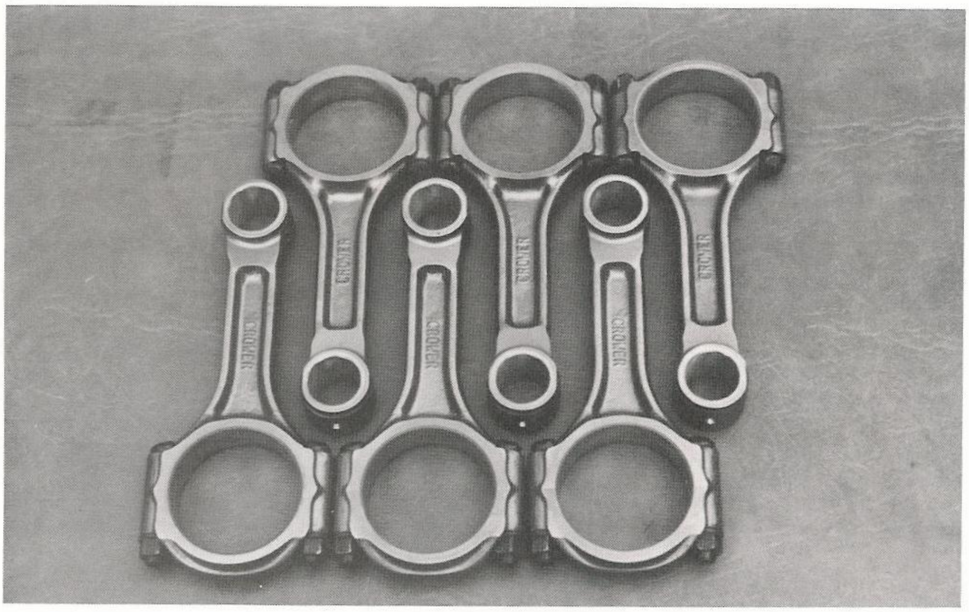
Some early 2.8-liter V-6 engines were equipped with true elastomeric vibration dampers. These are fairly rare and a good addition to any high-rpm performance V-6.

Connecting Rods

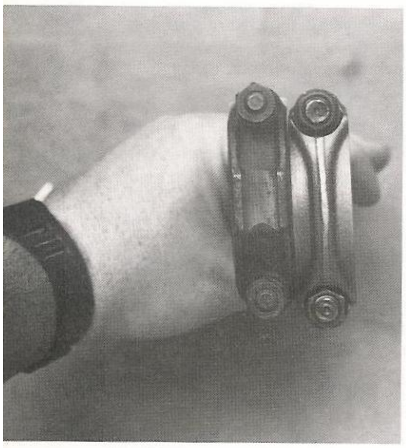
Rod selection for the Ford V-6 is simple compared to some of the other components involved in a performance buildup. The deciding factor is the intended application of the engine. You must ask yourself how often the engine will be run to top rpm and how long it will stay there. Basically, if stop light sprints are your bag, you probably don't need to be too concerned about a set of trick rods, but if you are really serious about performance, custom rods are a necessity.

The stock rods really aren't bad pieces. They are made of forged steel, with generous amounts of material around the big end and in the beam area. An interesting feature of the stock rods is an oil hole that squirts a stream of oil directly at the cylinder wall. This feature is a carryover from the engine's industrial V-4 ancestors. If properly prepared, these rods can be used successfully in engines producing up to 180hp.

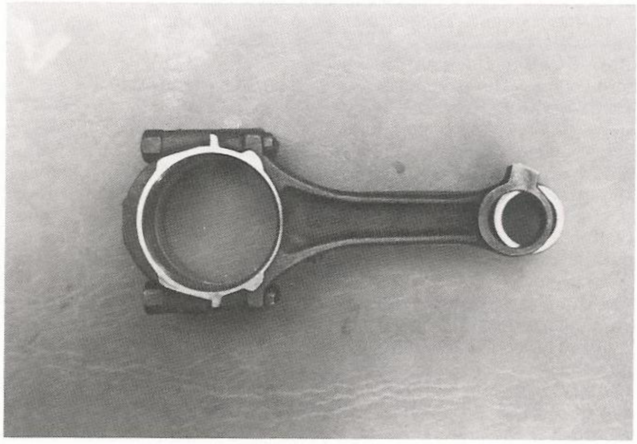
The best choice, however, is a set of custom rods forged from 4340 nickel-chromium-molybdenum steel. I have had great success with the custom rods manufactured by Crower Equipment Company. Contrary to popular belief, these custom rods end up being only slightly more expensive than a fully prepared set of stock rods. I believe that custom forged rods are an absolute necessity in high performance (200+hp), off road, or in any supercharged or turbocharged ap-



Custom forged connecting rods like these Crower units are an excellent addition to serious performance engines. This long rod set—available through Vanir Technologies—offers a 2:1 rod-to-stroke ratio and was installed in our project engine.



The Crower rods' strength becomes very evident in the rod cap area. As you can see, there is a large amount of extra material around the caps.



This photo shows the difference in length between a stock 2.8-liter rod and the Crower/Vanir rods used in our project engine.

plication where peak boost will exceed 7psi. A nice attribute of the Crower rods is that they are available in longer rod lengths allowing much nicer rod/stroke ratios. If you really want the ultimate in quality and reliability, custom forged connecting rods are the way to go.

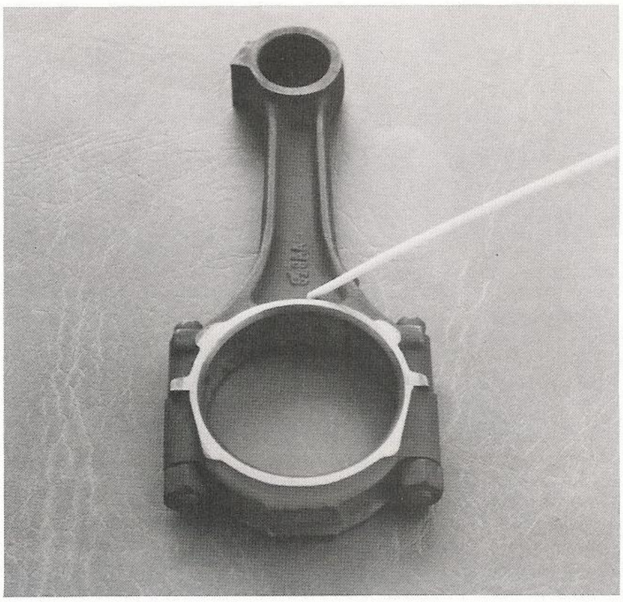
Inspection and Preparation (Stock Rods)

Obviously, the first thing that you need to determine is whether the rods that you have are worth the effort or if they would be better suited as doorstops. Check to see if there is any sign of "bluing" at the big end of the rod. This heat signature is an indication that the rod has been overheated, most likely due to a "spun" bearing. Another indicator of serious trouble is a heavy deposit of carbon around the big end. In either case, the rod should be discarded.

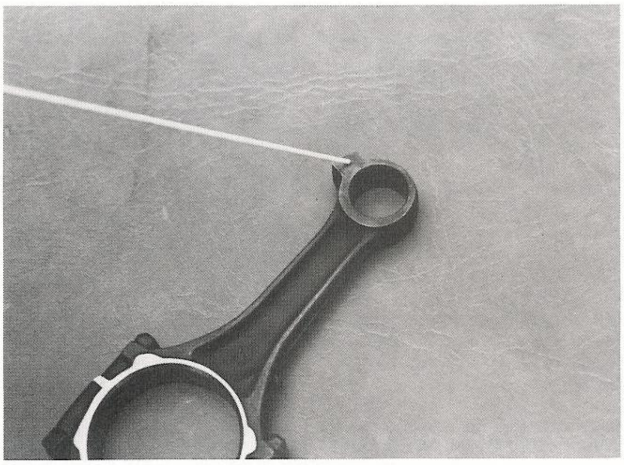
If your rods pass the visual test, take them to a machine shop that has the capability to both X-ray and Magnaflux (Magnaglo fluid) inspect them for cracks. Large crankshaft shops are usually your best bet. If your rods get a clean bill of health after these tests, the preparation process can begin.

Preparing stock connecting rods for performance is delicate, fairly expensive, and time consuming, which brings to light another luxury associated with custom rods in that they do not require practically any of the following preparation procedures. Most custom rods, like Crower rods, are so well finished that you can basically inspect them (for shipping damage), clean them, and run them (assuming the crank has been balanced accordingly).

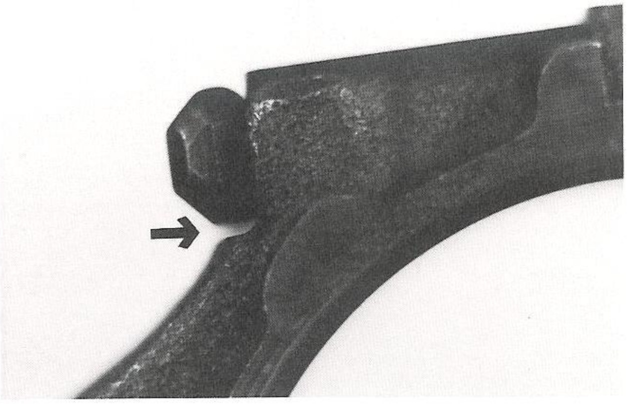
Polishing is the first thing that should be done to any set of stock rods that will be used in a performance engine. This helps prevent crack formation and has the added benefit of reducing



When inspecting a set of rods, look for heat marks around the big end. Heat marks indicate a probable bearing failure and, if this is the case, the rod should be discarded.



While polishing and deburring stock connecting rods, the balance pad located on the small end should be removed as well.

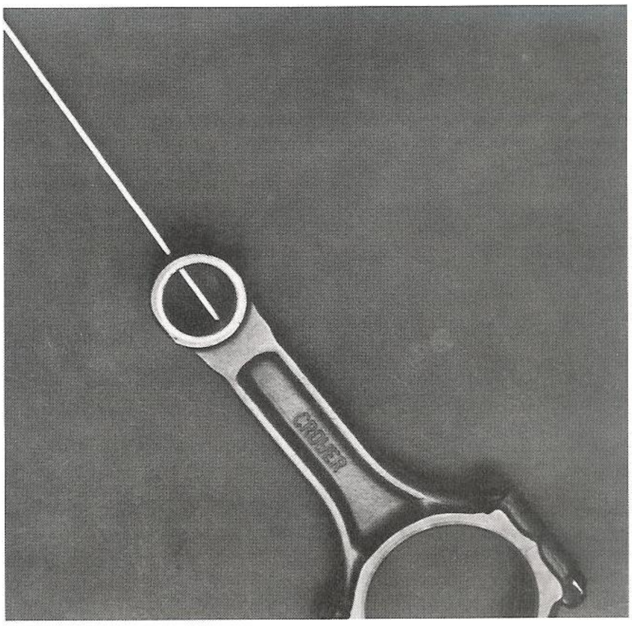


The installation of larger rod bolts in stock rods may require slight modification in the area shown. This is a very delicate procedure and should be left to a professional machine shop.

overall rod weight. The idea is to remove only the forging lines along the beams of the rods. Be extremely careful so that you do not violate the integrity of the beam. Place the rod between two pieces of 1/2in plywood and clamp it in a vise so that one side of the beam is exposed. With a 1/2in carbide cutter, begin grinding the forging line off of the rod by following the "grain" of the beam. In other words, grind the rod parallel to its length. Take special care in the bolt shoulder area. Excessive material removal or damage in this area can cause rod bolt failure. Once the grinding is done, radius the shoulder area with a small, 1/2in, fine round file. Finish polishing the rod using 1/2in medium sanding rolls. Once again, follow the length of the rod during this procedure.

Once you have completed the grinding and polishing procedure, the final finish on the rod is achieved by shot peening. Once again, I prefer to shot peen using #230 steel shot to achieve a finish equal to an Almen "A" arc height of 0.012–0.015in. The shot peening procedures used by most shops will probably be fine for your application. Be sure that the entire rod is peened. Remind the shop to thoroughly protect the crank pin and wrist pin bores from the shot. Additionally, be sure that old rod bolts are installed during the peening process as shot peening will damage new bolts.

On the subject of rod bolts, SPS alloy steel is your best choice. If you are the proud owner of a set of Crower rods, then you have nothing to worry about as they come right out of the box with 3/8in SPS alloy steel bolts already installed. If you are using stock rods, replace the bolts with SPS bolts (available from Crower). This is a very critical investment so don't



Any rod using a floating wrist pin should have a 1/8in oil hole drilled in the top of the pin bore. Again, this is a procedure best left to an expert.

skimp.

Now that the rods look like they are ready to do business and the bolts are up to snuff, the rods are ready to be "sized." Rod sizing is absolutely necessary to maintain the reliability of a performance V-6 equipped with stock rods. The extreme forces imposed on the connecting rod cause the big end to become egg-shaped, ruining the oil wedge and causing bearing failure. Resizing restores the rod bearing bore to its original (correct) size and ensures that it is perfectly round, thus eliminating bearing problems. Essentially, rod sizing is the same procedure as align honing the block. The rod caps are machined to reduce the bore size and produce square surfaces, then the rod is bolted together and honed to the proper size according to the bearing manufacturers specifications. Obviously this procedure should be done by a reputable machine shop using a Sunnen rod honing machine. Keep in mind that this procedure can affect the rod length slightly. Therefore, have the machine shop make sure that all of the rods are finished to the same length.

The wrist pin bore should also be taken very seriously. It must be sized according to the type of wrist pin that will be used (floating or interference fit). I find that there is no particular advantage to the type of pin used, other than that interference-fit pins may be slightly lighter. For ease of assembly, floating pins are the best option because they require no special tools during assembly/disassembly. If floating pins are used, the small end of the rod should be bushed and the bore finished to accept a pin diameter of 0.912in (the stock pin diameter is 0.945in). Before the bushing is honed to its final size, the rod must be drilled to allow for proper oiling of the wrist pin. In my opinion, there is only one right way to do this. Each rod should have a 1/8in hole drilled in the very top of the wrist pin bore, a procedure best left to the machine shop. Finish the oil holes by lightly chamfering them with an 82-degree chamfering bit. If custom rods are used, do not alter the oiling provisions that are designed into the rod. Once the oiling holes have been finished, the wrist pin bore can be finish honed to provide 0.001–0.0015in wrist pin clearance.

Cleaning

Regardless of the type of rods you choose, each one should be thoroughly washed to remove any debris left over by the various grinding, machining, and polishing operations. I have found the best way to start this process is to thoroughly degrease each rod using a quality degreasing solvent (like brake cleaner). This step will save you lots of time by removing the majority of oil left over from machining. Next, draw a sinkful of warm soapy water. I prefer to use a good liquid laundry detergent for this operation. Using an old toothbrush, thoroughly scrub each rod. Rinse the rods in large quantities of clear running water. Repeat this procedure at least twice. Once you have thoroughly rinsed the rods for the final time, pat each rod dry with a soft towel and completely coat it with WD-40. Store each rod in its own sealable sandwich bag until it is needed.

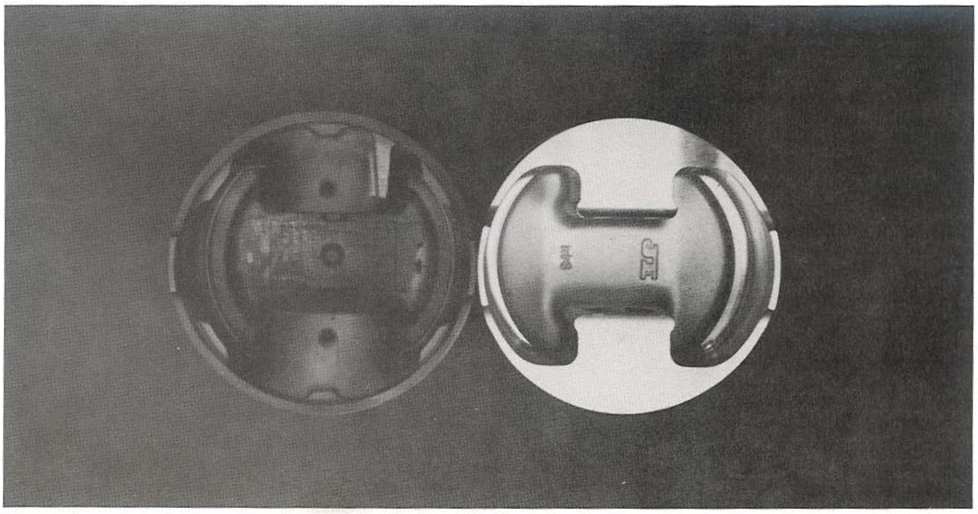
Pistons

3

The piston selection for the Ford V-6 has been sort of hit-and-miss for many years. Over the years several companies have offered replacement pistons for these engines. A common problem with many of these pistons is that the advertised compression ratios are inaccurate. I have found that many of these "catalog" pistons actually miss their advertised compression ratio by at least one point. Secondly, the quality of many of these pistons is somewhat variable. Sure, they are better than the wimpy stock cast pistons, but not by much. Finally, none of them are designed to help correct the engine's internal geometry errors. I believe the only sensible option is to have a set of custom forged pistons made.

If you break down every aspect of modifying an engine to produce more power, most every modification is intended (either directly or indirectly) to ultimately increase maximum engine speed and/or the cylinder pressure. The direct result of increased cylinder pressure is the creation of enormous amounts of heat. The piston is in constant thermal fluctuation. In other words, it is being heated and cooled thousands of times per minute by both the extremely hot (1200+ degrees) exhaust gasses and the relatively cold intake charge. Throw into this equation the increased load associated with the higher average piston speeds and higher rates of acceleration and deceleration common in most performance engines and you have an environment that absolutely eliminates the prospect of using stock cast aluminum pistons. In all truth, there are only two "advantages" to cast pistons from a manufacturing standpoint: they are cheap to manufacture and they operate more quietly due to their extremely tight skirt clearances.

The problems that exist with cast pistons are pretty simple. Cast aluminum has a very "loose" grain structure, which causes uneven expansion rates across the entire piston. This type of grain structure is not at



The difference between a quality forged piston and a stock casting is extreme. A good forging is an absolute necessity in any performance Ford V-6 engine.

all conducive to the strength of the piston. Additionally, heat transfer out of the piston is very poor as cast pistons run considerably hotter than forged pistons, creating an environment that is more likely to create engine killing detonation.

Forged pistons are probably one of the best things that has ever happened to the internal combustion engine. The dense grain structure characteristic of this piston type is considerably stronger than a casting, so forged pistons are usually lighter than cast pistons and generally create less friction.

Hypereutectic versus Forged

Recently, the term "hypereutectic" got thrown into the piston equation and successfully confused the hell out of many people. In many cases, the advertisements for hypereutectic pistons left you wondering if you should throw away your nice new forgings for the "latest in piston technology." If this question should ever cross your mind, the answer is a firm NO! In simple form, the term "hypereutectic" refers to the silicon content incorporated into the particular alloy used. The fact remains that these pistons are still "cast" into shape. Granted, they are a good bit better than stock pistons but they are absolutely not as good as a forged piston. The advice here is to stick with a forging.

Choosing the Pistons

Pistons should be one of the first performance parts that you should buy as part of your project. You must have a finished set of pistons on hand before the cylinder bores can be finished to the proper size. Obviously, you will have to have determined the amount of overbore required on the particular block that you will be using (see Chapter 1). The problem is not all piston manufacturers make pistons for the V-6, so where do you go? Custom piston manufacturers are springing up daily. This is good from the standpoint that increased competition in the market will inevitably force prices down. However, this also means that many of these companies will compromise quality just to sell pistons. A company with a reputation for producing a high quality product and a lot of experience with the Ford engines is JE Pistons in Huntington Beach, California. JE has been making custom pistons for decades and their quality is second to none. JE's pistons are machined so precisely that it is not uncommon for the entire set of pistons to weigh within tenths of a gram of one another, making piston balancing much easier and virtually eliminating the possibility of weakening the piston due to excessive machining.

Compression Ratio and Dome Shape

Finding the right compression ratio is a delicate game. Insufficient compression results in less than optimum power, sluggish low/midrange response, and poor combustion efficiency. On the other hand, too much compression results in severe detonation and difficulty running available fuel. A significant drawback to running too much compression is that it reduces the "detonation threshold." Think of it as a safety margin with regards to detonation. It's kind of like watching the stock car drivers run next to the wall. To a point, it's the fastest way around the racetrack, but if you start to brush against it, or worse yet, slam the heck out of it, your day is over in a hurry. The detonation threshold is the amount of real estate between you and the wall, too much and you are going to be dog-slow; too little and you're a spectator.

For good street/mild race performance, a compression ratio no higher than 10.7:1 is recommended. Actually, 10.5:1 is just about right. Anything above that is going to require racing type (100+ octane) gas. Good performance can be expected from a compression ratio that lies between 9.5:1 and 10.5:1 in the Ford V-6.

Many people believe that decent compression ratios require a domed or "pop-up" style piston. In reality, domes disturb the flame front as it travels across the piston top resulting in less efficient combustion and less power. A dome of any sort usually results in a heavier piston as well. You will find that domed pistons are mostly seen on engines with exceptionally large combustion chambers where the dome is actually used to reduce the volume of the chamber at TDC. Luckily, the Ford 60-degree V-6s have small chambers that allow the use of flat-top pistons to achieve compression ratios of slightly over 11.0:1. Even at ratios of 12.0:1 and higher, the dome that is required is very small. This is a luxury that is often only enjoyed by racing engines that use specially manufactured racing heads.

Piston Rings

Piston rings have become the focus of increasing attention for several reasons. Not only do the rings seal the cylinder pressure, they also provide the medium through which most of the heat from the piston is transferred into the cylinder wall. Choosing a ring configuration that is suited for the application is more complex than many people realize.

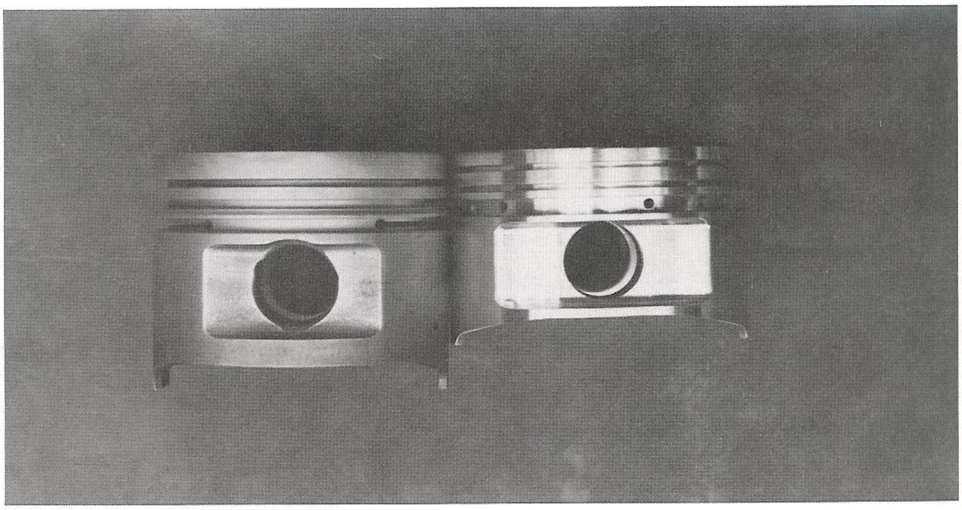
These days piston rings are available in many different widths, materials, and profiles. They can also be made with various "coatings," such as ceramic. Everyone claims to have a better mousetrap. Essentially, three different kinds of rings are available for the Ford V-6. First, there is the tried-and-true ductile iron ring. Most performance ring sets are made from some sort of ductile iron material, because iron provides good sealing characteristics, is very thermally stable, and is very durable. Iron rings have been around forever and this is not likely to change.

In a performance environment, however, the plain iron ring needs a little help. This is where moly rings come in. Many people do not understand what the term "moly" actually means with regards to piston rings. A moly ring is actually an iron ring that has a molybdenum material imbedded into the face of the ring. This material has a lower coefficient of friction than regular iron, and it is very porous, allowing the ring to retain oil better. Moly rings also tend to be more scuff resistant than plain iron rings, and they seat very quickly in a properly prepared cylinder.

The third type of ring that is commonly available is a chrome ring. Chrome rings have, as the name describes, chromed ring faces. This type of ring was originally intended to be used in engines that operate in extremely dusty conditions as they are much more resistant to the abrasive wear characteristic of this type of environment. Since most performance engines do not experience these conditions, I believe chrome rings have no place in a performance engine.

For any Ford V-6 application, I highly recommend a quality set of moly rings. Pay particular attention to the cylinder wall finish recommended in the block honing section outlined in Chapter One. The rings that have shown exceptional performance in the Ford V-6 are those manufactured by Sealed Power Corporation. Their ductile iron moly rings are exceptionally durable and provide better cylinder sealing than any other ring available. Most piston manufacturers have access to these rings and should be able to advise you on the proper ring for your application.

Piston ring width is yet another area that has received a lot of attention. Ring width is critical to good heat transfer from the piston to the cylinder wall. If the rings are too narrow, excessive heat will build up in the piston causing ring seizure and possible piston failure. The current buzzwords among several engine builders are "ring drag" and "ring flutter." The apparent solution to these "problems" is to run 0.043in or thinner top rings. The term "ring drag" is pretty self-explanatory but many people get wild at the concept of "ring flutter," a condition where the ring is thrown off the ring land as the piston changes direction across either bottom or top dead center. I'll resolve this once and for all by saying that this is a problem that is normally associated with *extreme* rpm engines (9000+) and in no way affects the lives of even the most serious Ford V-6s. Besides, it's questionable that reducing ring drag and ring flutter is worth the tradeoff in heat transfer and reliability. If the



The piston on the right is a JE/Vanir unit for use with long rods, hence the higher pin height. Notice the improved ring land placement as compared to the stock piston (left).

ring grooves are properly fitted to the rings, ring flutter can be reduced to nothing.

I find that the best ring widths for the Ford V-6 are 1/16in top and second rings and 3/16in oil control rings. These widths have been the standard of the industry for many years and with good reason. This combination has proved to be the most reliable, stable, and thermally efficient ring package available. So the philosophy here is, "If it ain't broke, don't fix it." Ring placement on the other hand, is something that needs a lot of fixing on the Ford V-6. The stock piston configuration places the rings very low in the piston and spaces them very wide apart. This forces the piston to be exceptionally heavy and difficult to control. The idea is to squeeze the rings up on the piston to allow a higher wrist pin placement, to reduce the "dead space" above the top ring, and to allow the rings to transfer more heat into the thick deck surface rather than into the rather thin cylinder walls. The optimum ring land combination for the Ford 60-degree V-6 is as follows:

Top land thickness = 0.180in
Second land thickness = 0.180in
Third land thickness = 0.150in

I recommend a deck clearance of 0.005–0.010in, if possible. Never run a positive deck clearance (e.g., the piston protrudes above the deck surface). It's a good idea to get familiar with the piston manufacturer so that you know exactly what critical dimensions will be required for your piston order. Finally, all piston ring grooves should allow 0.0015–0.002in side clearance for each ring.

Gapless Rings

Gapless piston rings of some form or fashion have been around for several years. The term "gapless" only refers to the construction and function of the second ring. All of the other rings in the package retain a conventional design and construction. The idea of gapless rings is to try to eliminate "blow-by," a condition where a certain amount of cylinder pressure escapes past the piston rings into the crankcase. This problem was common during the days of 0.006–0.007in piston clearances. However, with today's advanced piston designs and tighter skirt clearances, the piston rings are much more stable, and blow-by is not nearly as much a problem as it used to be. I am sure that gapless piston rings had their place at one time, however I do not believe that they have any place in a Ford V-6. I am reasonably sure that you will not find many reputable piston manufacturers that will recommend a gapless piston ring as a first choice in a gasoline-burning performance engine.

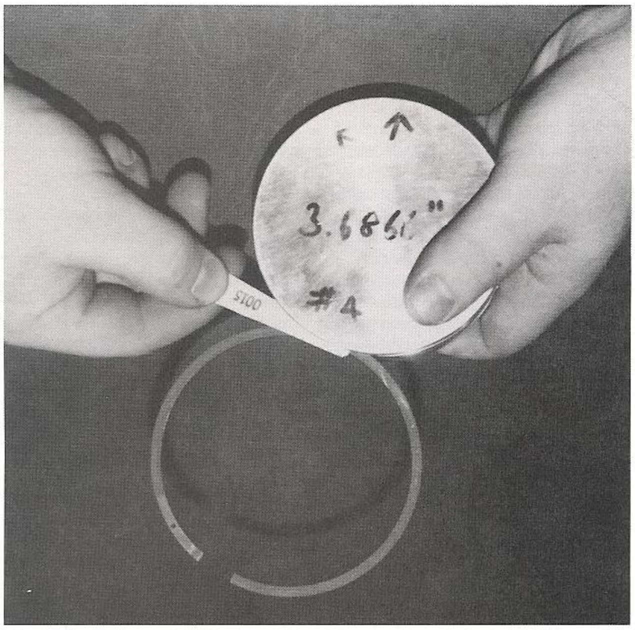
Another problem with some gapless rings is that they utilize two different ring materials, most commonly a combination of a chromed tool steel and some sort of ductile iron. Though some may disagree, I believe this practice is a fundamental no-no in ring construction. Cylinder walls must be finished according to the type of ring material that will be used, thereby allowing the ring to break in quickly and provide ultimate cylinder sealing. When two different ring materials are used, especially a chrome and iron combination, the rings will not break in at the same rate and they most certainly will not wear at the same rate. On the flip side of this argument, there are some gapless rings that are made of a ductile iron material only. If you feel hell-bent to have these things in an engine, I suggest you go with a one-piece, ductile iron, moly-faced gapless ring.

Fitting the Piston Rings

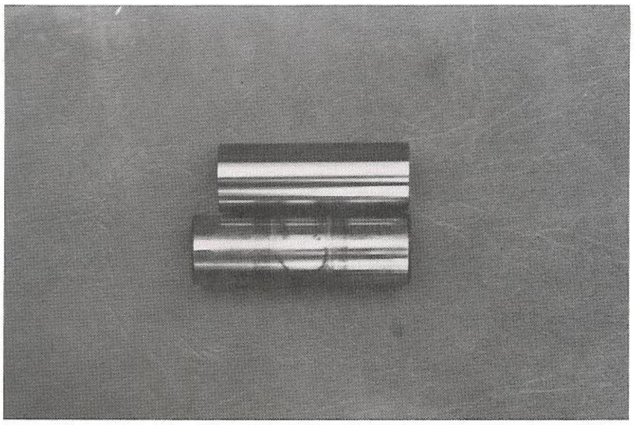
Once you have made your piston ring selection, you should match each ring set to the pistons and carefully fit each ring to its respective cylinder bore. This operation is critical to proper engine performance and reliability, so you should take extreme care during the gapping procedures and acquire the proper tools before you begin the job.

The job of gapping piston rings (top and second rings only) can be properly completed with the use of a few simple, yet very important tools. The most important of these tools is a special piston ring filer, like those manufactured by KD Tools. These filers are designed to file the piston ring gaps both parallel and square, without the risk of ring breakage. The second required tool is a sharp ignition file, which is used to finish the edges of each freshly filed ring gap.

To begin, carefully place each ring in its respective cylinder and square the ring in the bore using the appropriate piston (turned upside-down) or a piston ring squaring tool. Measure the existing ring gap using a feeler gage and record this gap on a notepad. Typically, the Ford V-6 will require between 0.004in and 0.0045in of ring gap for every inch of cylinder bore. For example, if your bores measure 3.690in, the ring gap that you will need will be 0.015–0.017in. Based on the existing ring gap, carefully file each ring to achieve the desired gap. I recommend that the top rings get a slightly larger gap than the second rings. Referring to the example above, it would be best to gap the top rings at 0.017in and the second rings to 0.015in. Note that the oil control rings are not included in this discussion. The reason for this is that the gaps on the oil rings are not critical to the performance of the ring. In most cases, the ring gaps on the rails of the oil ring are at least twice that of the first or second rings. Don't let this alarm you, though. They are supposed to be that way. Essentially, the oil rings



Ring side clearance is important to good ring stability. Side clearance for a good forged piston should be 0.001–0.002in.



A benefit of custom forged pistons is that they are often much lighter than stock. One reason for this is that shorter and lighter wrist pins can be used.

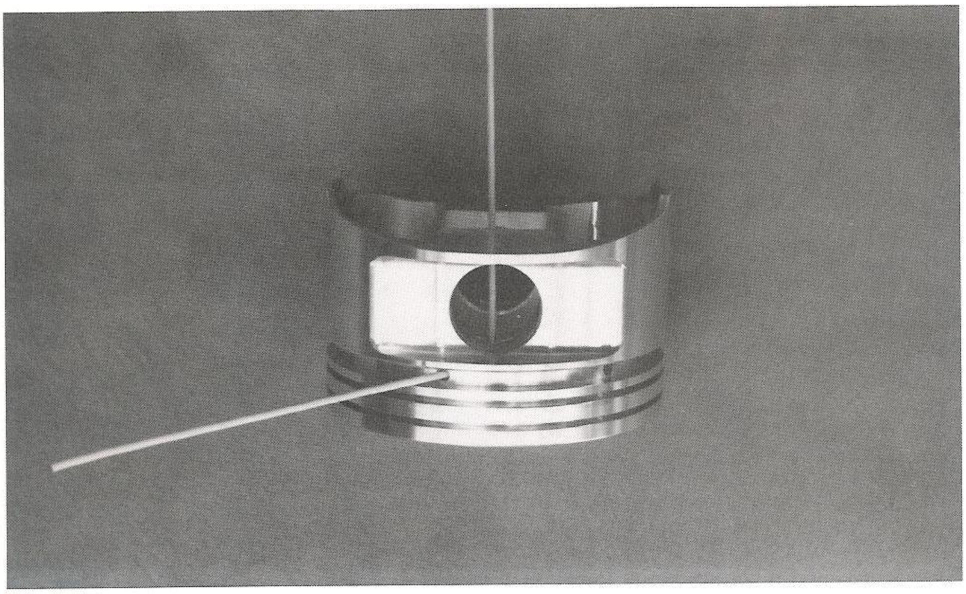
will only require inspection for burrs and defects, and if correct, installation.

Once you have filed each ring to the proper gap, lightly file each edge of the ring gap (except for the ring face) with the ignition file. Finish the job by placing each ring set in a separate sandwich bag that has been marked as to the piston/bore assembly to which it has been matched. Repeat the above procedures until all of the rings have been gapped.

Wrist Pins and Locks

Two types of wrist pins are available with custom pistons: pressed fit and floating. I think that either style is perfectly acceptable in a performance engine, but I favor the full floating pins for several reasons. First, floating pins are very easy to assemble and disassemble. This is important if you do your own engine rebuilds and don't have the rod furnace and tools necessary for proper pressed pin installation/removal. Second, there is practically no chance of damaging the piston when removing the pins, which is not always the case with pressed pins. Third, a full floating pin allows the rod to align itself with the journal better due to its freer movement. Finally, most piston manufacturers offer their pistons in a full floating design. Pressed pins are usually a special order item. Regardless of the pin configuration, I highly recommend the use of either a taper wall or (thick) straight wall wrist pin.

As far as pin locks are concerned, the only configuration to consider is dual Tru-Arc locks. This should also be specified on the piston order. Tru-Arcs are very high quality versions of inside snap ring retainers with one smooth and one sharp side. It is critical to install them with the smooth sides facing each other and with their open ends opposite each other. This allows the sharp sides to dig into the retain-



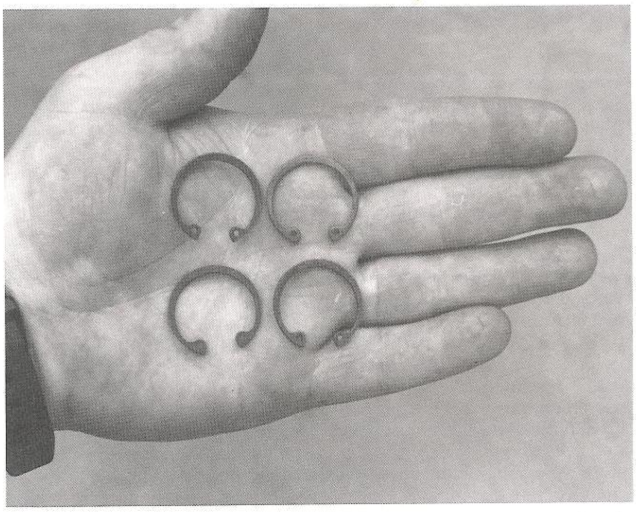
JE forged pistons offer a very unique pressure oiling passage to each wrist pin bore.

er grooves so that the pin is solidly retained. The one rule that you must absolutely, 100 percent, no questions asked adhere to is that any time a lock is removed, *throw it away!* Also, do not replace Tru-Arcs with regular snap rings. Always buy new ones from the original piston manufacturer. Once the locks are installed, the pin end clearance should be between 0.000-0.005in maximum. I like to keep the pins on the tight side of these figures.

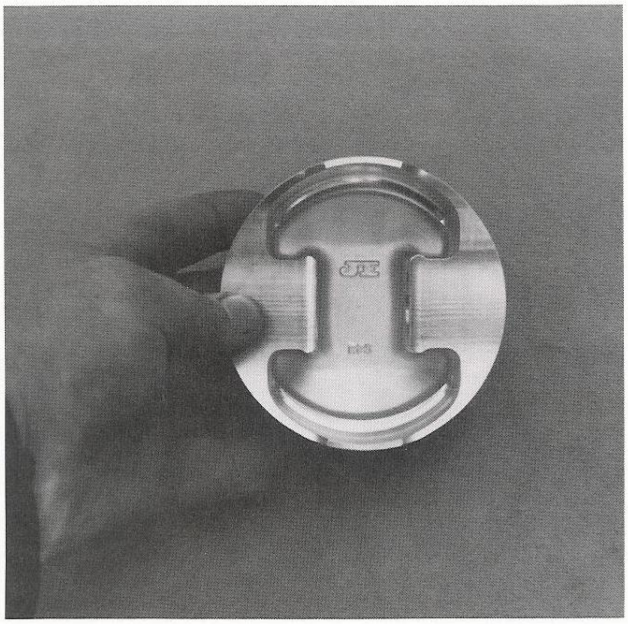
Clearances

There are a number of critical clearances that must be achieved in order for the pistons to operate properly. If any one of these clearances is not within tolerance, it is only a matter of time before either one or all of the pistons try to secede from the union.

Piston skirt clearance is probably the most important



Dual Tru-Arc locks are the most foolproof locks available to the average builder. They are very easy to install with simple tools and secure the pin extremely well.



Piston lightening is never a consideration with JE pistons. Notice the sanitary piston interior. No extra material means no need to remove weight.

clearance involved in piston fitting. This is actually the clearance that exists between the cylinder bore and the piston skirt when the piston is cold. As the piston warms to operating temperature, the piston expands at a rate that will create the proper "hot" clearance. This growth rate has been engineered into the piston and therefore the manufacturer's recommended cold clearance must be followed. This brings to light an interesting point. Even though a piston skirt looks round, in reality, it is actually elliptical or egg-shaped. The proper term used to describe this skirt design is "cam ground." Most forged pistons are cam ground so that when the pistons are at the proper operating temperature the piston will actually become round.

JE Pistons' advanced skirt technology allows skirt clearances of 0.0025–0.0035in. This "tight" clearance allows the piston to be more stable in the bore resulting in much improved ring sealing and wear characteristics. Typically, the skirt clearance required by other forged piston manufacturers is about 0.0065–0.007in, therefore it is extremely important that you use the manufacturer's recommended skirt clearance. Also, make careful note as to where the manufacturer requires that the piston be measured in order to establish the proper piston diameter so that the cylinder bore can be properly finished.

Deck clearance is another very important dimension. If the piston dome protrudes too far out of the block, the piston stands a good chance of smacking the cylinder head, and you know what that means! I do not recommend a "positive" deck clearance or, in other words, a piston that protrudes above the deck. While an engine is running, the connecting rods actually stretch, effectively reducing the deck clearance by, sometimes, several thousandths of an inch, especially with stock rods. Rod stretch is not quite as severe when using a custom, high-quality forged connecting rod, so the deck clearance can be tightened up to at or near zero. I recommend a cold deck clearance of 0.005–0.010in when using stock connecting rods. If custom rods are used, I recommend a cold deck clearance of 0.000–0.005in. These recommended clearances should allow plenty of "cushion" between the cylinder head and the piston while maximizing the quench.

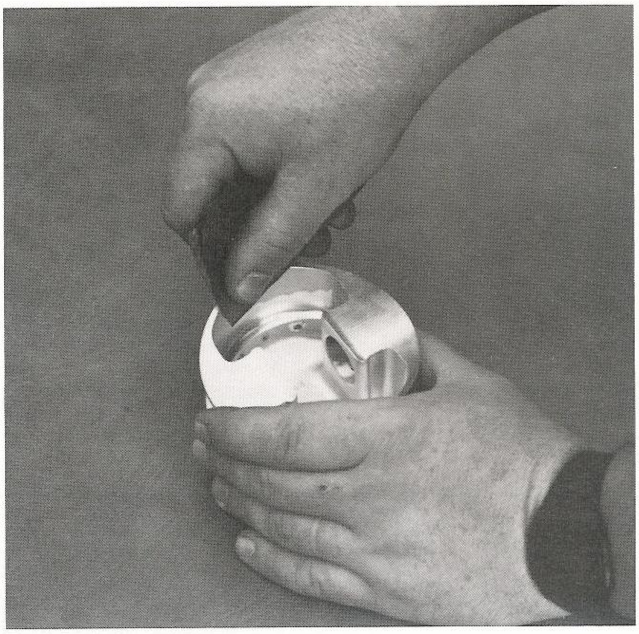
Piston Lightening

Let's get right to the point on this subject by saying under no circumstances should you, or anyone else for that matter, begin removing material from a piston in an effort to lighten it. The underside of every forged piston is carefully engineered to control the piston's expansion rate at operating temperature. Any material removal in this area for any other purpose than balancing will most certainly violate the integrity of the piston. Therefore, let the balance shop do its job and then leave the pistons alone!

Finishing

Finishing a piston is a rather uncomplicated process, especially if you have followed previous advice and purchased a set of JE pistons. Begin by deburring the inside areas around the skirts and pin bosses with a sharp deburring knife (this will already be done on JE pistons). Finish each edge that has been deburred with 400-grit wet-or-dry sandpaper soaked in kerosene. Next, lightly deburr all sharp edges of the piston dome. This includes any markings that may be stamped into the top of the piston, such as overbore size. This should also be done with 400-grit wet-or-dry sandpaper and solvent. Finally, lightly deburr every oil return hole from the inside with a fine grit sanding roll at low speed (once again, JE pistons are already finished in this area).

Once all of this is done, thoroughly wash each piston in a rich soap and water solution. I find that liquid laundry detergent and a soft toothbrush works very well. Rinse each piston in large quantities of clear running water. Repeat this procedure at least twice. Once you have rinsed the pistons for the final time, blow them dry with a hair drier and place each piston in individual, large, sealable sandwich bags. Wrap each wrist pin in generous amounts of newspaper and place each pin in its own individual sealable sandwich bag. Do not put the Tru-Arc locks in with the pistons unless they are wrapped in masking tape. This will prevent them from scoring the pistons.



Lightly deburr the piston with 400-grit wet-or-dry sandpaper. Make sure to use a light lubricant like kerosene to help flush the paper while in use.

Cylinder Heads

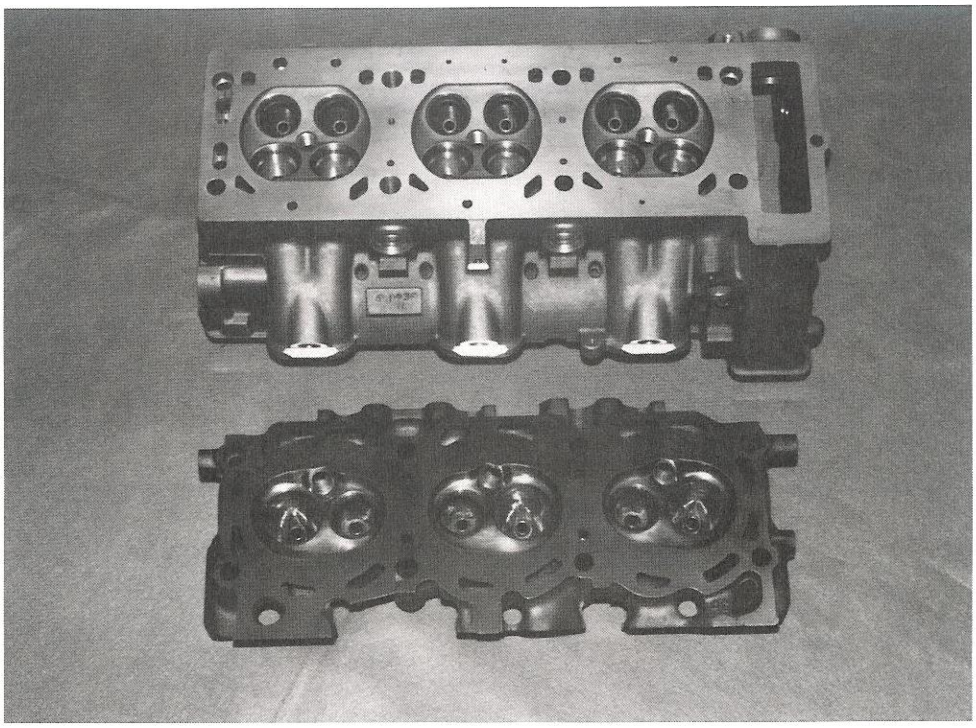
4

Cylinder Head Choices

Choosing the appropriate cylinder heads for the Ford 60-degree V-6 is actually a fairly simple process. In fact, if you are building a 2.6- or a 4.0-liter engine, the only choice you have is to stay with the heads that came on the engine. When building either the 2.8-or 2.9-liter, you have a few options to consider.

The 2.8-liter engine has the "luxury" of two types of cylinder heads, a "non-emissions" head and a "smog" head. The non-emissions head that was available from late 1973 to mid-1975 is the more desirable of the two. The smog heads were available from mid-1975 to 1979 and from 1983 to 1986. The primary advantage of the early heads is that they lack the exhaust crossover passages used in the later (smog) heads. The result is that the exhaust ports in the early heads tend to flow slightly better than the later versions.

The reason for these additional exhaust passages was to increase the rate at which the intake manifold was heated, thereby reducing emissions and im-



Some interesting things have evolved during the development of the Ford V-6 in the last few years. One of the most significant developments is the Cosworth four-valve head fitted to the 2.9-liter in Europe.

proving warmup in cold climates. The early engines used engine coolant to heat the intake manifold instead of hot exhaust gases. At any rate, the heads to have for a performance 2.8-liter engine are the early versions.

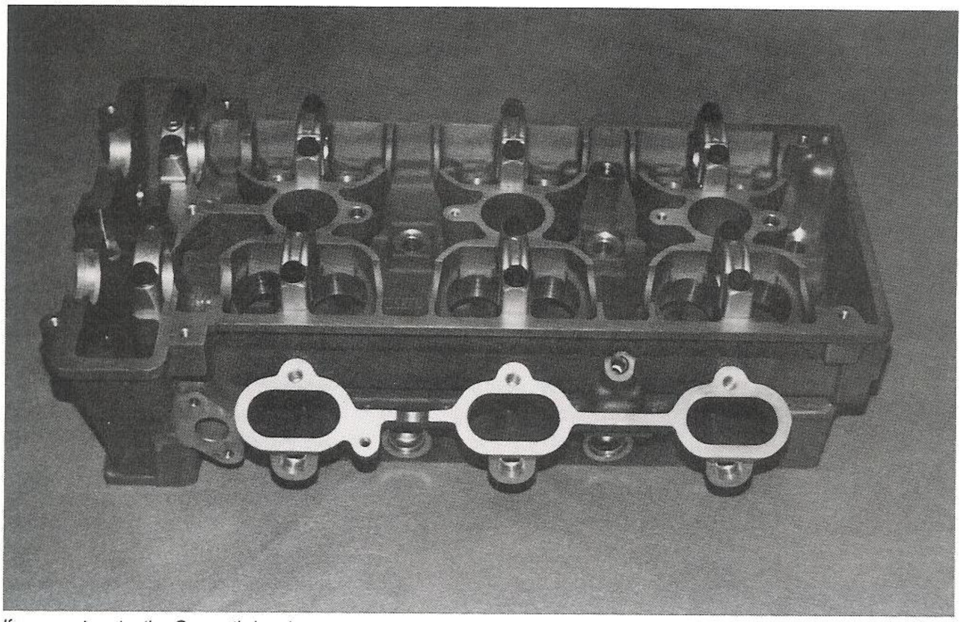
It is quite a bit easier to choose heads for the 2.9-liter engine. The first cylinder head type is the one that was fitted to the Ford Ranger and Bronco II from 1986 to mid-1992. The second type of 2.9 cylinder head was fitted to the Merkur Scorpio. Essentially, the only difference is that the Scorpio heads received valve seat inserts, thus somewhat limiting the potential to install oversized valves. The most desirable of the aforementioned 2.9 liter cylinder heads are those fitted to the mid-1988 and up Ranger trucks. These heads are identified by an 89TM casting number and by their rectangular rocker pedestal bosses.

The earlier 2.9 heads incorporated oval-shaped tower pedestals and had an 86TM casting number. The later 2.9 cylinder heads are improved over the earlier versions in that they have been strengthened in the valve spring pocket area in an effort to deter head cracking in some applications. These casting numbers can be found on the center of the head in the spark plug area. Suffice it to say that the later model Ranger heads are more desirable for performance applications.

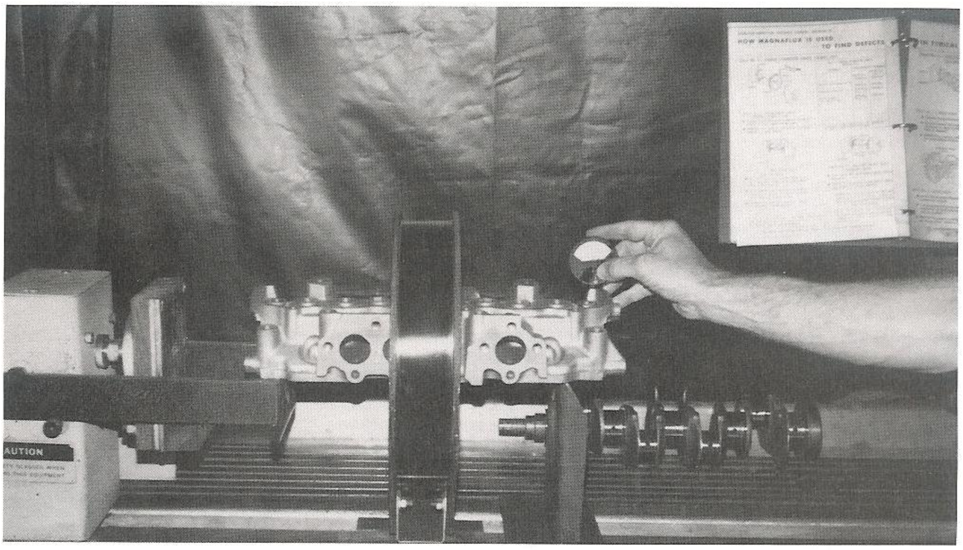
Cleaning and Inspection

Once you have made your head selection, you must determine if the heads are worthy of further attention. Begin your evaluation by disassembling them entirely. Take the bare heads to the machine shop and have them thoroughly cleaned in a hot tank. Immediately following the cleaning process have the shop Magnaflux the heads to check for cracks. Most shops will opt to use the standard Magnaflux powder method, however I recommend the Magnaglo fluid method. This fluid medium is much more "crack seeking" than the standard powder, but most shops will charge significantly more for this service. Be sure to have the shop check not only the valve seats but the water passages and valve spring/rocker shaft area as well.

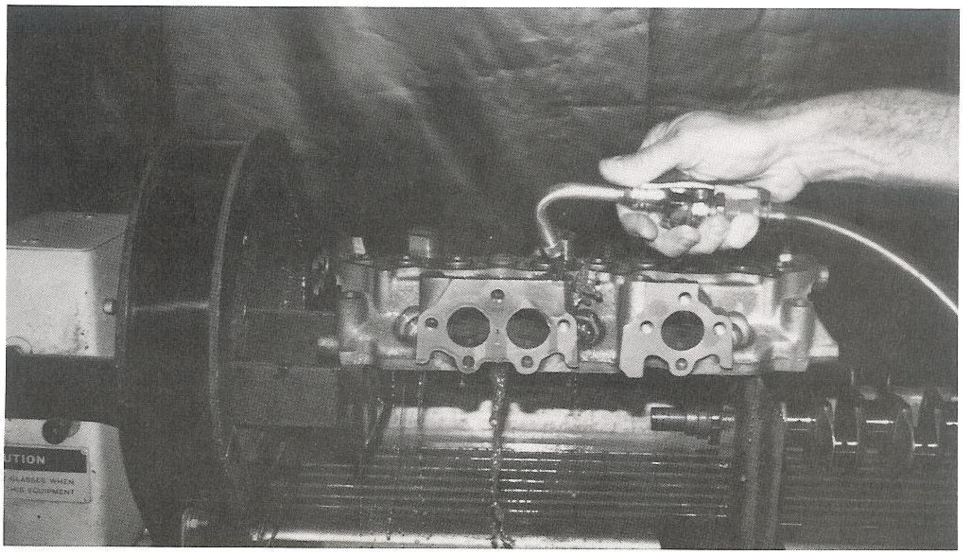
If any signs of cracking are indicated, find yourself another set of heads. Unless you intend to



If you want ports, the Cosworth head has them in spades. These stock four-valve heads are capable of producing in excess of 300hp.



The same crack inspection process that was used for the crankshaft is also used for the heads. Here, the head is being magnetized using Magnaflux equipment.



The head is bathed in the Magnaglo indicator fluid in preparation for crack inspection. Particular attention is paid to the valve seat area when wetting the head with indicator.

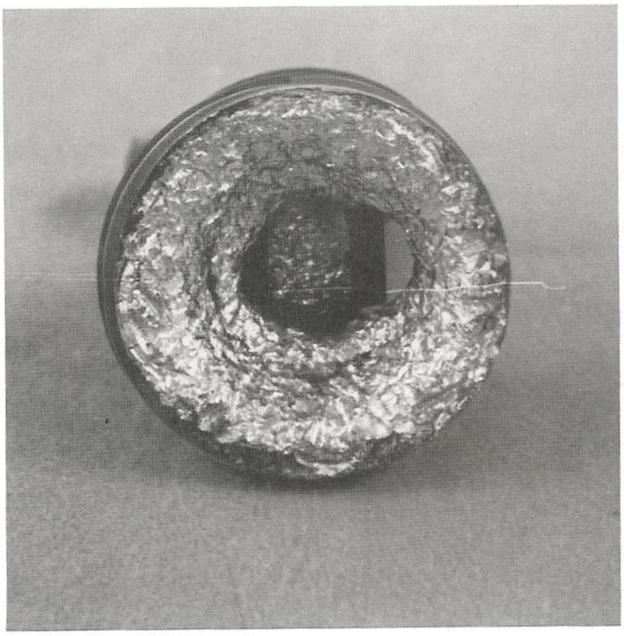
stay with stock valve sizes, it will be absolutely impossible to install oversized valves if the heads will require valve seat inserts to repair cracks. If the Magnaflux testing procedure reveals no cracks, then you can feel confident that the heads will be worthy of the extensive forthcoming work.

Valves

The number of people that actually consider the use of stock valves in a performance engine never ceases to amaze me. Stock valves have a hard time just dealing with everyday loads! Today's engines are required to operate under extreme conditions. The fact that a stock valve can survive for ten minutes is a testament in itself, but when an engine is modified for performance, these extreme conditions become simply unbearable to a stock valve. The exhaust valve is unquestionably the most abused of the two valves. Therefore, exhaust valve failures are by far the most common.

Another drawback to stock valves is that most factory exhaust valves are actually a two-piece construction. The head of a two-piece exhaust valve is made of a material that is extremely heat resistant. The stem, on the other hand, is made of a hardened steel that is not as resistant to high temperatures. The reason that the stem material differs from the head material is that the material used for the valve head cannot be hardened enough to take the pounding from the rocker arm. Therefore, the more hardenable stem material is welded to the valve head, creating a valve with the required characteristics. This type of construction has proven amazingly reliable and cost effective in production engines and positively worthless in performance engines. It is imperative that stock valves be replaced with a high-quality set of performance

Potential cracks are revealed using a special light that makes the fluid glow when it collects along a fault.



The results of using stock valves in a performance engine are often catastrophic as shown by this slightly "relieved" piston.

valves.

At one time, a set of custom performance valves required a pretty healthy investment and was usually reserved for all-out racing engines. That was in the days when we had lead in our gas, big-inch, low-revving engines, and Town and Country radios. Lead was one of the best friends a valve ever had. Now that it is gone, engines must be built to accommodate the lack of this very effective lubricant. These days, a set of custom valves is still a fairly significant investment, but there is no longer any question as to whether or not to invest in them . . . they're mandatory.

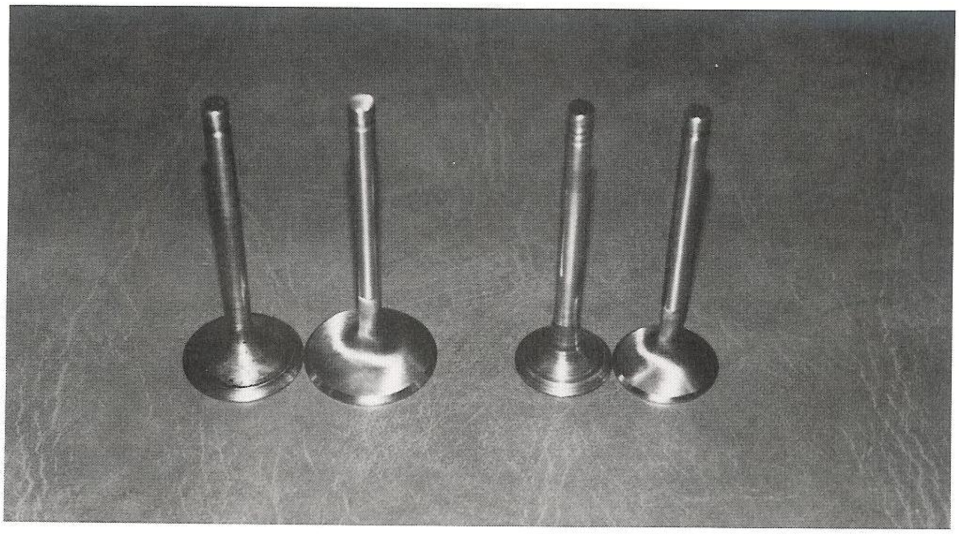
Once you have decided to purchase a set of custom valves, the next step is making sure that you get exactly what you need. The first thing that you must always remember when shopping for valves is that they should be a one-piece forged construction, and they should be manufactured from a high-quality (high nickel) stainless steel. Stainless steel is the only practical valve material that can meet the demands of modern performance engines running on unleaded fuel.

The sophisticated stainless steel alloys that are used in modern performance valves have also allowed the valve design to be greatly improved. The valve heads can now be made thinner, thus allowing a greater flow capacity without sacrificing durability. I have found that the NK-844 stainless steel intake and the XH-428 stainless steel exhaust valve materials used by Manley Performance Engineering offer the best quality and performance available in the custom valve market. Specially designed stainless steel valves are available for all Ford 60-degree V-6 engines through Vanir Technologies. Manley manufactures these valves to Vanir's exact specifications and includes the proper lash caps to prevent damage to the valve stem tip by the rocker arms. These valves have proven to be extremely durable, even under racing conditions, and you can have complete confidence in them no matter what your performance goals.

Valve Size

Undoubtedly, the easiest and most common method of increasing the intake and exhaust flow in a performance engine is by installing oversized valves. This is a very logical modification since it is obvious that more air can flow (in and out) through a larger opening (valve).

Since the dawn of the poppet valve four-cycle engine, many have argued over the "ideal" valve size that should be used to achieve maximum power. The reality of the situation is that there is absolutely no single way to tell what the ideal valve size should be in an engine. There are simply far too many variables to consid-



An increase in valve size is one of the easiest ways to produce more power.

er. However, it is generally agreed that the intake valve size for a two-valve (nonhemispherical) engine is approximately 50 to 54 percent of the cylinder bore diameter. In a nonhemi engine like the Ford V-6, the valve size is limited by the cylinder bore. The side-by-side valve arrangement used in the Ford V-6s, although very efficient, actually limits potential valve size rather significantly. In fact, if the cylinder heads that you are intending to use require the use of valve seat inserts (like the 2.9-liter heads that were fitted to the Merkur Scorpio), it will be difficult to install a properly sized valve because the valve seat insert takes up too much room in the chamber. Remember this when choosing the heads for your engine.

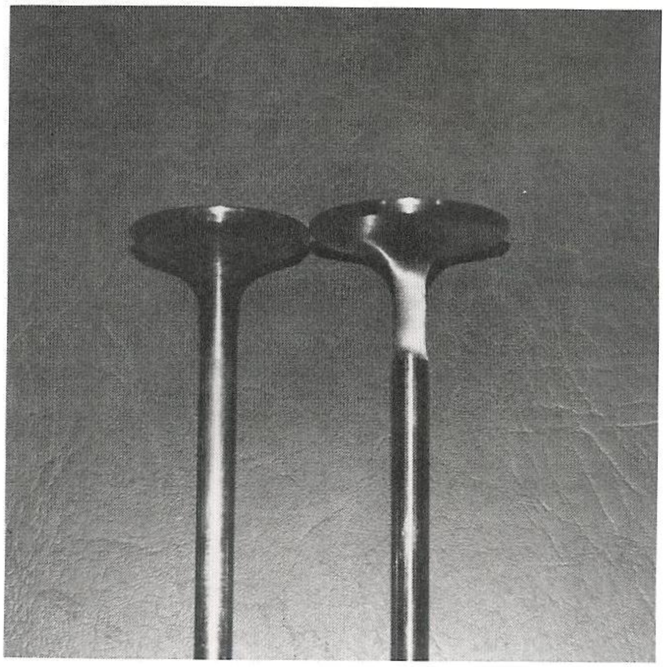
I have found that the 2.6- and 2.8-liter engines work very well with 1.732in intake and 1.400in exhaust valves. The 2.9-liter engine can support a 1.732in intake valve and a 1.400in exhaust valve while the 4.0-liter engines like 1.800in intake and 1.400in exhaust valves. If you stay with these valve sizes, you should not have any problems with valve seat hardness. I will discuss this in more detail later in this chapter.

Valve Guides

Unfortunately, the Ford 60-degree V-6 engines are somewhat notorious for wearing out valve guides. I have found this to be especially true in the 2.8 smog engines. This condition is actually due to several factors, all of which contribute to excessive heat in the cylinder heads. The primary causes are high average cylinder head temperatures due to poor coolant flow around the exhaust valves and rather limited top end lubrication. These conditions, coupled with the fact that cast iron is a marginal valve guide material to begin with, result in a valve guide that is almost destined to fail prematurely. Cast-iron valve guides are typically too porous, making them very difficult to lubricate. Additionally, cast iron galls fairly easily and is rather unstable at high temperatures. Clearly, cast iron does not respond well to any of the conditions inherent in this area of the Ford V-6 valvetrain.

Whether building an engine for racing or street, I recommend a valve guide made of a manganese bronze material. Accept nothing else. I can't think of any reason not to use a quality manganese bronze material. Manganese bronze is the perfect valve guide material for many reasons. As you might expect, the material is very stable under extreme temperatures and is very resistant to galling. In fact, it actually displays a considerable self-lubricating quality allowing tighter valve stem clearances to be used, resulting in less valve seat wear and increased valve stem durability.

When replacing valve guides in stock, unmodified cast-iron cylinder heads, it was once common practice to bore out the entire original guide and replace it with a new one. Luckily, modern automotive technology has created valve guide sleeves, or guide liners as they are sometimes known, that are used instead of entire guides. Guide liners are simply a 0.030in wall tube that is split down one side. The original guide is bored to size and the liner is driven into the head much the same way that an en-



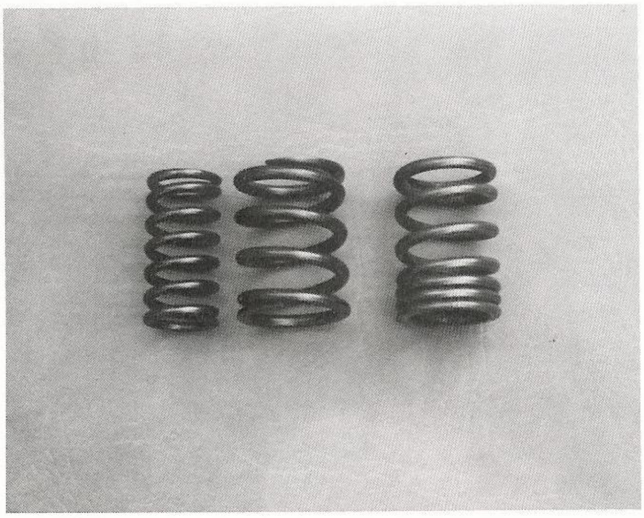
The valve on the right is a custom one-piece valve supplied by Vanir Technologies. Notice the undercut on the stem just below the valve head.

tire guide would be. The advantage to the guide liner is that most of the original core material is maintained, resulting in a durable overall installation. Additionally, guide liners are very inexpensive and easy to install.

Unfortunately, many Ford V-6 engine builders will still find it necessary to use a full replacement guide in their heads due most often to previous valve guide work. This is especially a problem in early 2.6- and 2.8-liter cylinder heads. In these cases, you don't have much of a choice other than to replace the guides with a high-quality, manganese bronze guide. Extreme care must be taken when replacing guides in that a guide that is slightly too large for its bore will tend to crack the valve guide boss in stock heads. This is especially a problem in the 2.8 and 2.9 cylinder heads.

If your heads have been or will be ported, there are a few steps that you should follow with regard to valve guides and liners. If you will be using a set of 2.6 or 2.8 cylinder heads (ported according to the procedures outlined in this book), *always* use valve guides on the intake valve, and, if possible, guide liners on the exhaust valves. If you will be using 2.9- or 4.0-liter cylinder heads, *never* use valve guides if it can be avoided. Instead, use guide liners. If guides are necessary, try to find another set of heads that will accept liners. Finally, once each guide or liner has been installed, each one should be honed or reamed to provide a valve stem clearance of 0.0012-0.0015in.

By now, most of you will have asked yourself, "Where do I get some of these manganese bronze things for *my* engine?" The answer is that most good machine shops have access to guides and guide liners made of this material.



The two springs on the left make up the Crane valve springs recommended for use in the Ford V-6. The stock spring is shown on the right.

Valve Seals

There is probably someone out there who can figure out some monumental reason to use one type of valve seal over another. The truth of the matter is that as long as a seal is used on each valve and it keeps oil out of the chambers, it doesn't matter much what design it is. There is simply no power advantage of one type of valve stem seal over another. I prefer to use Perfect Circle (PC) Teflon valve seals. Although they require modification of the top of the valve guide for installation, they last much longer than the original "umbrella" seals, and they are much smaller, making the use of dual valve springs more practical. That is probably at least part of the reason that Ford is using them on all of the post-1983 V-6 engines. Install a set of good PC Teflon seals and forget 'em.

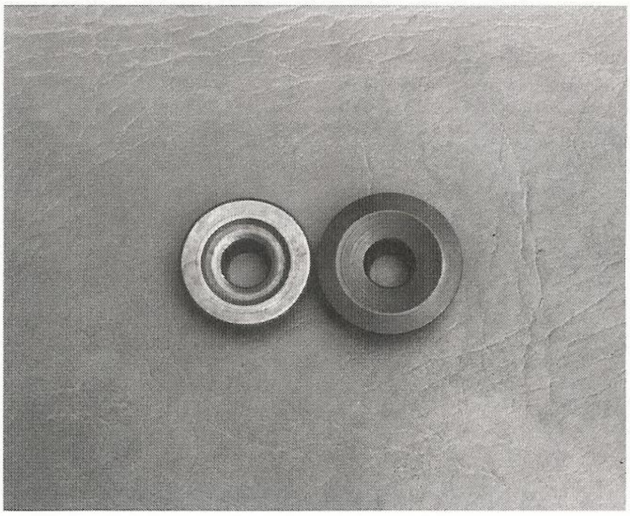
Valve Springs and Retainers

No matter what type of performance Ford V-6 engine you may be building, do not, under any circumstances, use the stock valve springs. Many people underestimate the importance of the job that valve springs are required to accomplish. They must control the valvetrain throughout its entire range of motion. Even in a stock pushrod type valvetrain, the valve springs are usually the first components that will break under the stress. Luckily, most Ford 60-degree V-6 performance engines will work nicely with the springs and retainers available from the cam manufacture.

The one thing to look for is a valve spring that has some sort of damper coil in the middle. This helps control the spring harmonics without creating an excess of spring pressure. One thing is certain, triple valve springs are absolutely unnecessary in most performance engines and will eventually ruin a perfectly good camshaft.

If your engine is equipped with a properly matched camshaft and a set of 1.6 ratio performance rocker arms, the seat pressure should be somewhere around 105lb to 115lb and the pressure "over the nose" at peak lift should be around 285lb to 290lb. Most flat tappet camshafts will not tolerate much more than about 375lb of spring pressure at peak lift.

I prefer the springs and retainers manufactured by Crane Cams in Daytona Beach, Florida. The appropriate parts numbers are: 99858-12 (outer springs), 99834-12 (inner springs), 99947-12 (retainers), and 99091-1 (locks). This spring/retainer combination works very well with just about any performance grind available, however some modification to the valve spring pocket and valve guide will be necessary to accept them. Once you get these pieces in hand and the appropriate machine work has been performed, it's simply a matter of setting them up correctly, a subject we will cover shortly.



The Crane spring retainer (right) is much stronger and larger in diameter than the stock retainer (left). These retainers will be necessary when installing the larger Crane dual-valve springs.

Rocker Arms

For years, high-performance rocker arms have been some of the most difficult things to acquire when building a Ford V-6. In the end, most people end up using the stock cast-iron rockers simply because they have no other alternative. The stock rocker arms are adequate for stock type engines but when it comes to performance, they leave a lot to be desired. First, stock Ford V-6 rockers are notorious for their misalignment with the valve stems. Usually only half of the rockers will actually be centered over the stems. To make this a livable situation, Ford cast the contact "feet" extremely wide to make up for the differences. Second, the rocker arm ratios tend to vary significantly. I have seen stock rocker ratios vary from 1.45 to 1.57. Obviously, this is not at all conducive to getting optimum power from your Ford V-6. In addition, this makes it very difficult to set up a camshaft properly. Despite their dimensional inconsistency, however, the stock Ford rockers are incredibly durable.

For the moment, let's say you have a perfectly matched set of stock rocker arms. You are still faced with the problem of poor rocker arm ratio. The truth of the matter is that the stock rocker arm ratio is simply too low to be effective in a performance engine. The benefit of increased rocker arm ratio is increased lift and greater valve lift rate. These two characteristics combine to create more "area" under the lift curve and thus more power. Ideally, a 1.6 to one ratio rocker would be just the ticket in the Ford V-6. However, the problem is that no such rocker arm exists, unless you have the resources to have a custom set made.

When I began researching the possibility of having rocker arms made for the V-6, I was floored at the cost of such an endeavor. In some cases, a set of roller rockers would have cost well in excess of $1,000. This is obviously way out of the ballpark for even the most dedicated performance engine builder. Another problem associated with these custom rockers was that special hardened rocker shafts would have to be made because the roller fulcrums would tear up the stock rocker shafts. Once again, more money. By the time all was said and done, one would have invested over $1,200 dollars in rocker assemblies alone! Heaven forbid if someone wanted to play with different rocker arm ratios.

Luckily, complete roller-tip rocker assembly kits are now available through Vanir Technologies at a very affordable price. These kits are manufactured by R.J. Max in Fallbrook, California, to Vanir's specifications and include 4130 chromoly rocker shafts (optional), a full set of roller tip rocker arms, and hard anodized aluminum rocker spacers. These assemblies are a complete bolt-on replacement and require no modification or special hardware for installation. The beauty of these rocker sets is their improved ratio.

For those who desire the ultimate in precision, a racing set is available that allows each individual rocker ratio to be adjusted individually using a hex wrench. This method allows the engine builder to adjust each rocker arm with extreme precision, to provide exactly the same valve lift. The most important thing to remember once you have decided on the type of rocker arm that you will use is to make sure your cam grinder knows the exact rocker ratio so a proper cam can be ground.

Stock Rocker Arm Preparation

Rocker preparation is typically required when stock rockers are used. The procedures are very simple yet once completed, the rocker will be able to deal with the increased demand of a high-performance V-6 very well.

Begin the preparation process by soaking all of the rockers in carburetor cleaning solvent. Once you have thoroughly cleaned all of the rockers, check each rocker bore for size, concentricity, and taper. Carefully inspect all of the thrust faces to ensure that they are not galled and do not show signs of excessive wear. Of course, it is not a bad idea to use new rockers if your budget will allow it.

Deburr all of the casting seams and polish all of these areas with a fine grit sanding roll. Lightly chamfer all of the sharp edges, paying particular attention to the shaft bores. Once all of the rockers have been deburred, it is time to have each one honed for proper shaft clearance. Regardless of the type of rocker arm you are using, you should determine the final shaft clearance dimension after measuring the rocker shafts and honing the bores to provide a clearance of 0.0025–0.003in. Proper bore diameter should be around 0.7836–0.7842in.

The Vanir Technologies rockers should require no modification for shaft clearance as they are manufactured with the proper clearances. However, the stock rocker will likely require honing to fit properly. This procedure is somewhat delicate and should be left to a qualified engine machine shop. To create the proper clearance, the rocker is honed on a machine very similar to a connecting rod hone used to size the wrist pin bore in a connecting rod.

Rocker Shafts

Rocker shafts are incredibly simple devices that have extremely demanding conditions imposed upon them. As the primary means of rocker arm support, the rocker shafts must be very rigid and resistant to wear. The rocker shaft must also deliver vital lubricating oil to each individual rocker arm. As the engine output is increased through performance modification, the demands on the rocker shafts increase dramatically. Therefore, it is very important that special care is taken during the preparation of the rocker shafts to ensure reliable service.

Rocker Shaft Preparation

The stock Ford V-6 rocker shafts are actually very impressive pieces right out of the box. Their large diameter provides excellent strength and stability under high valvetrain loads. In fact, most rocker shaft failures can be traced back to a rocker arm rather than a rocker shaft problem. At this point I should mention some of the problems associated with the stock shaft assemblies. The biggest problem with the factory setup is that the rocker arm to shaft clearance is too tight. Typically, the factory rocker to shaft clearance is about 0.0013in. This tight clearance results in severe galling of the bottom of the rocker shafts. Since only one oil gallery feeds oil to the entire upper valvetrain (via the rocker shaft), even a small drop in oil pressure at the bottom end results in a drastic drop in pressure at the top end. It doesn't take long for a seizure to occur under these adverse conditions especially with such a close shaft clearance. Luckily these potential problems can be avoided easily by following the aforementioned rocker preparation procedures and the following rocker shaft preparation procedures.

The first policy to adhere to when preparing the rocker shaft assembly is to always use new rocker shafts when rebuilding the assembly. I've spent far too much time trying to come up with a way to avoid replacing them, and every time I think I have talked myself into it, a "good" used rocker shaft ends up trashing a lot of good parts. Take this advice to heart, and always use new shafts. The following part numbers will help when ordering from your local dealer:

Part Number	Part	Engine Application
E9RZ-6563-A	Rocker Shaft	2.6, all 2.8, 2.9 (86TM casting #)
F0RZ-6563-A	Rocker Shaft	2.9 (89TM casting #)
F0TZ-6563-B	Rocker Shaft	4.0

Once you have your new shafts in hand, lightly chamfer all of the oil holes in the shaft. This procedure will remove all of the burrs that could potentially damage the assembly, and it will significantly help the flow of oil to the rocker. A word of caution; unless you are certain you can deburr these holes without damaging the shaft, let the machine shop do the job. Finally, if your engine is going to see any regular racing activity, consider the purchase of a set of severe-duty moly rocker shafts from a supplier such as Vanir Technologies. The shaft clearance problem is remedied by honing each rocker arm bore to provide 0.0025-0.003in clearance as described earlier in the chapter.

Rocker Spacers and Pedestals

The stock Ford V-6 rocker arms are located in their proper positions by a set of spacer springs that generate constant side loads against the rocker arms. Although inexpensive, this method of rocker location actually causes more damage than good. The Ford V-6 engines pump a fairly small amount of oil to the top of the engine under normal operating conditions. The spacer springs create so much combined load on the thrust faces of the pedestals that the rocker arms begin to erode the thrust faces away. In many cases, the rocker arms will actually friction-weld themselves to the pedestals resulting in catastrophic valvetrain and sometimes complete engine failure. If there are any signs of galling or any measurable wear on the rocker pedestals, replace them. The appropriate part numbers are:

The ultimate method of avoiding this particular failure is to take every last one of those spacer springs, throw them in the trash, and replace them with a set of aluminum rocker spacers. These spacers can be manufactured by a skilled machinist or they can be purchased from some specialty outlets like Vanir Technologies, R.J. Max, Jesel, and others. Installation of solid rocker spacers like these will create a "free floating" rocker assembly that will be much more reliable and will actually free up a little bit of power at the same time. Be sure that each "side" of the rocker shaft has a combined side clearance of 0.020–0.030in (0.010–0.015in for each rocker arm).

Porting for Performance

Until recently, factory engineers have not been too concerned with the flow characteristics of the cylinder heads on any engine. This is obvious during a not-so-careful inspection of the earlier Ford 60-degree cylinder heads. The flow of these low-efficiency heads can be improved considerably through cylinder head porting.

As a general rule of thumb, anything that is done to improve the flow of gasses into and out of the engine will result in an increase in power. That is why porting has become such an exacting and complex art. It is not at all uncommon for fully race-prepared cylinder heads to sell for several thousand dollars. Professional head porters use a very specialized piece of equipment called a flow bench to precisely measure the improvements (if any) that are made in flow. A flow bench is very expensive and is not something that the average enthusiast can afford.

Needless to say, proper cylinder head porting is a very difficult (and expensive) trade to learn. Many engine builders have found that most port modifications that "look right" will actual decrease the flow efficiency of the head. Unless the builder has access to a flow bench, he will never know if he is doing himself (or his customer) any good.

Obviously, a book of this type would not be complete without some sort of guidance with regards to head porting. Luckily, the Ford 60-degree V-6 engines respond extremely well to some relatively simple port modifications. The forthcoming modifications have been proven to work not only on the flow bench but on the dyno and track as well. If you have experience in head porting and you adhere to the following porting recommendations, you will see (and feel) a considerable power increase. If you have any doubt in your abilities, or if you have never done any porting, do not perform these modifications yourself. You will be much better off paying a good shop (that has considerable experience with the Ford V-6) to port your heads properly.

The first thing to remember when porting your cylinder heads for performance is that "less is more." Always keep in mind that once you remove material from the port, there is no reliable way to put it back. This means that you should take extreme care to remove material only in the exact areas that are described in the following text and photos for your heads. It is especially important that you refer to the photos and diagrams included in this

Part Number	Part	Engine Application
E6TZ-6531-A	Rocker Shaft Pedestal	2.6, all 2.8, 2.9 (86TM casting #)
E8RZ-6531-A	Rocker Shaft Pedestal	2.9 (89TM casting #), 4.0

chapter. It is practically impossible to verbally convey the proper port configuration for every individual engine, so the text in this chapter will be of a general nature while the photos and diagrams will offer much more application-specific information.

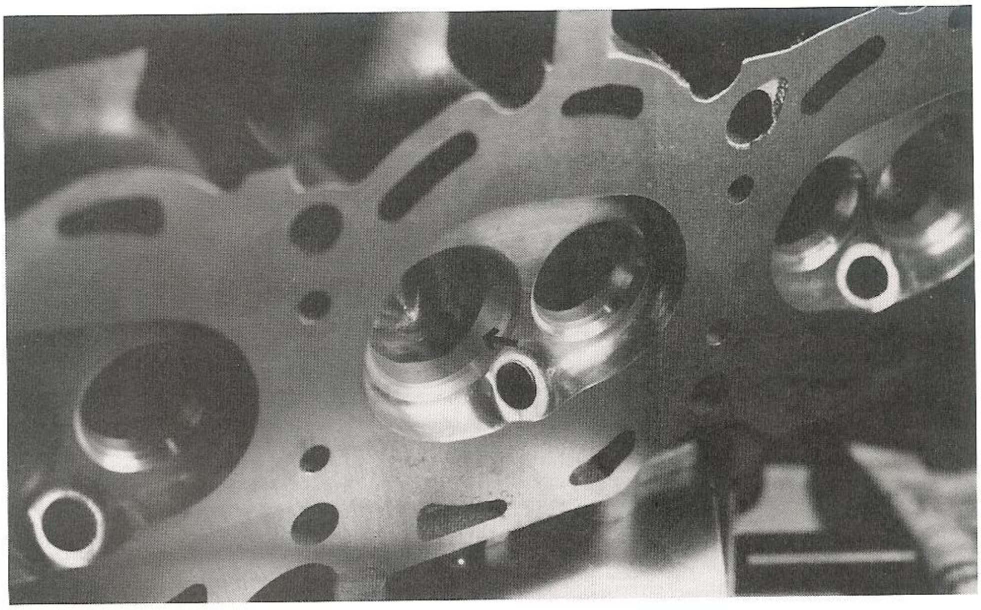
The area that will require the most attention, and as a result will yield the most impressive benefits, is the area of the port known as the valve bowl or pocket. This is the area just below the valve seat where the port runner makes its turn toward the head of the valve. As a curious coincidence, the amount of work required to get things into shape on a Ford V-6 increases with the age of the cylinder heads. For example, the 2.6 and 2.8 cylinder heads require far more work to produce good power than do, late-model 2.9-or 4.0-liter heads. Funny how twenty years of technological development works, huh? At any rate, expect the majority of your port preparation time to be spent in the valve bowl area.

Valve Bowl Preparation

In general, the goal when working in the valve bowl area is to smooth and radius all of the sharp edges that exist as a result of the casting process, to reduce the cross-sectional area of the valve guide boss, and to smooth and re-contour the short turn radius between the port floor and the bowl. The intention is not to increase the cross-sectional area of the entire port, however, as this will take away from the overall efficiency of the port.

Before you begin any bowl work, you must cover a few bases. Obviously, before you begin massaging the valve bowls, you must have a set of valves that you intend to install in the heads, and the heads must be machined for the type of guide or liners that will be used. Do not install the appropriate guides at this time as they will only get in the way. It is imperative, however, that the valve guide machine work be completed before any porting begins.

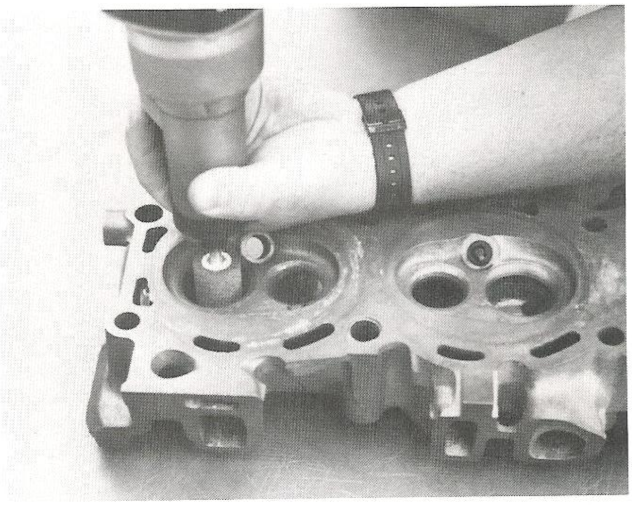
With these valves in hand, have the machine shop enlarge each bowl to 0.85 times the head diameter of the valves. This procedure should be done using a 75-degree bowl hog. This is not a procedure that you should attempt yourself! Once this work has been done, begin enlarging the bowl just below the valve seat. The intention is to bring the bowl walls straight down at the same diameter as the enlarged throat. In other words, if the valve that you intend to install measures 1.732in, the bowl



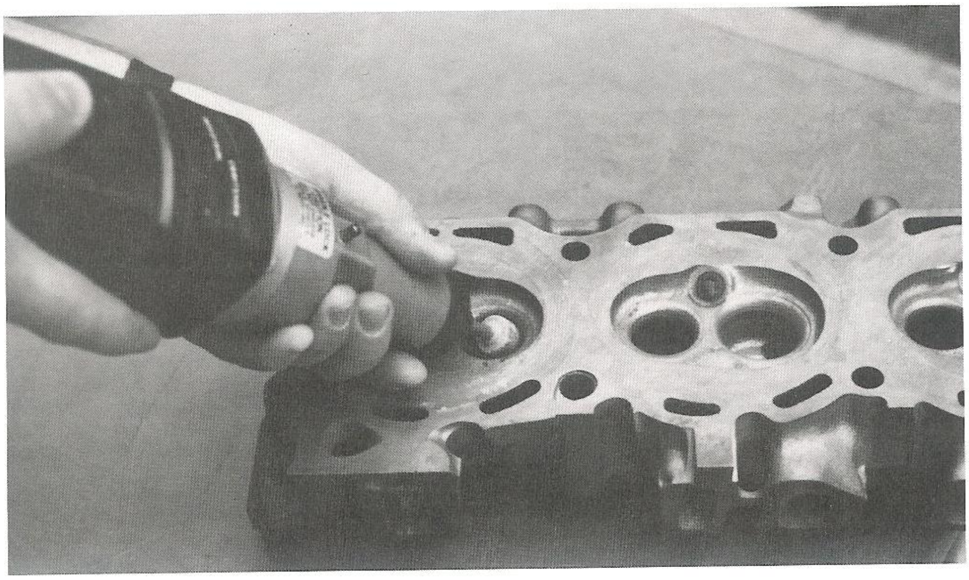
The installation of larger valves requires that the valve seats be enlarged using a 75-degree bowl hog.

should be enlarged to 0.85 times that diameter, or 1.472in.

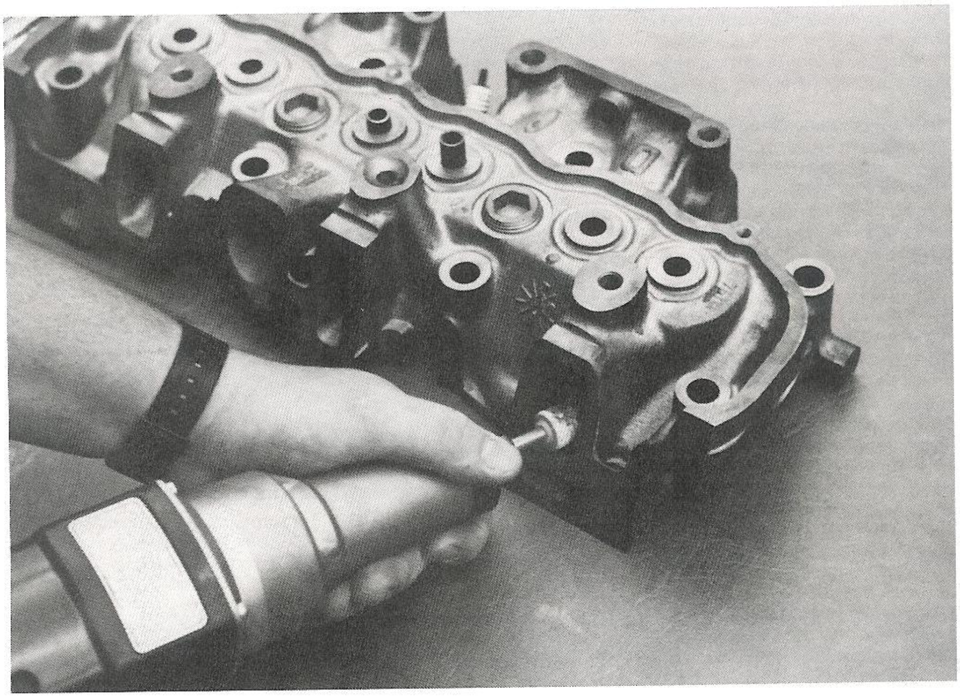
As you begin grinding the throat area of the bowl, you need to maintain this dimension for at least 0.375in to 0.500in below the valve seat. This will allow the flow to straighten out a bit before it encounters the valve head and combustion chamber or vice versa. Be careful not to enlarge the bowl any more than 0.500in below the seat since the bowl tapers down at its base and it is possible to break through into the water jacket. It will help to have a pair of dividers set to this dimension to act as a reference when doing this work. Always grind the bowls beginning from the top and slowly working your way down, gradually smoothing and enlarging to the proper diameter. Once you have enlarged the bowl to the proper depth, gently smooth and radius the



The first operation involved in valve bowl work is the enlargement of the bowl area just below the seat. This area should be enlarged to 0.85 times the valve head diameter.



The sharp edges left by the bowl hog should be gently blended into the bowl walls using a medium-grit mounted stone.



The lower bowl area must blend smoothly into the walls of the port. This is best done using a medium-grit mounted stone. Work slowly letting the stones do the work.

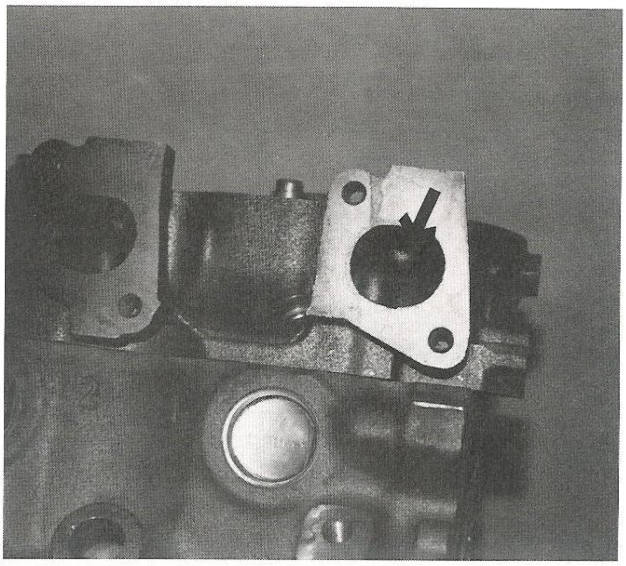
area so that it transfers smoothly into the lower bowl walls. Do not enlarge the lower bowl area. Instead, simply smooth the rough cast surface using light pressure on the stone. The thing to remember during all of these operations is to be patient! Take your time, and let the stones do the work.

As your work moves to the exhaust bowl area, you will quickly notice that the bowl walls just under the valve seat "explode" into the exhaust port. Obviously it will be impossible to maintain a straight port dimension (from the valve seat down) for any more than a quarter inch or so. The exhaust ports are the worst part of the Ford V-6 cylinder heads, and there is not much point worrying about this area. The thing to remember is that enlarging the cross-sectional area of the entire port only magnifies the poor flow characteristics of these ports. Therefore, the best thing you can do is to smooth all of the radii as much as possible and follow up by polishing the rough cast surface of the entire port with fine grit (220 or so) sanding rolls and flap wheels. On the 2.9 and 4.0 liter exhaust ports, it will be necessary to remove the "EGR" bump in each port. This bump resembles a cast iron wart in the exhaust port and serves no function in a performance engine. Try to get the entire port mirror smooth while removing as little material as possible.

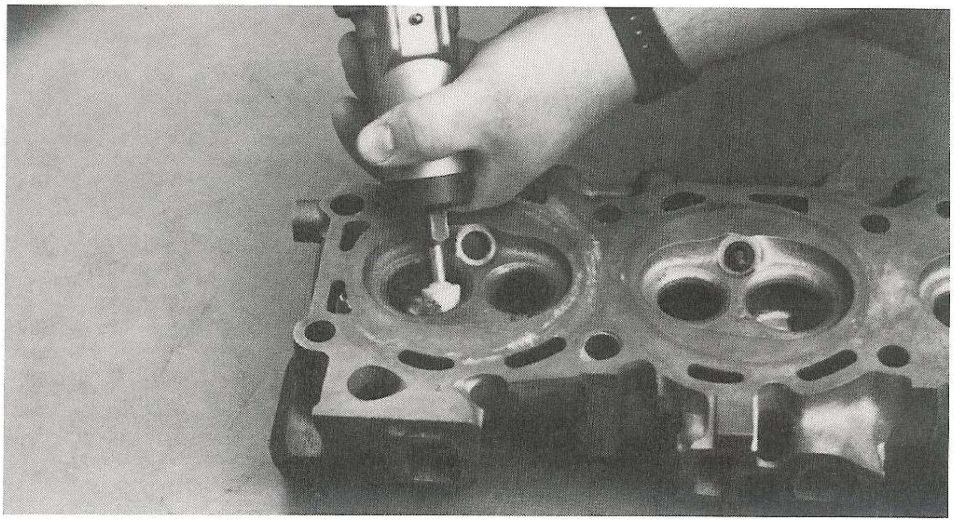
Short Turn Radius

The short turn radius of the port is the area where the floor of the port turns toward the head of the valve. Since the flow is concentrated at this area at low valve lifts, a smooth and gradual radius is critical to good flow. The trick to improving the short turn radius is to carefully remove material so that the radius rolls gently from the valve bowl area into the floor of the port. The more gradual that you are able to make the radius, the more uniform the flow will become as it enters and/or leaves the combustion chamber.

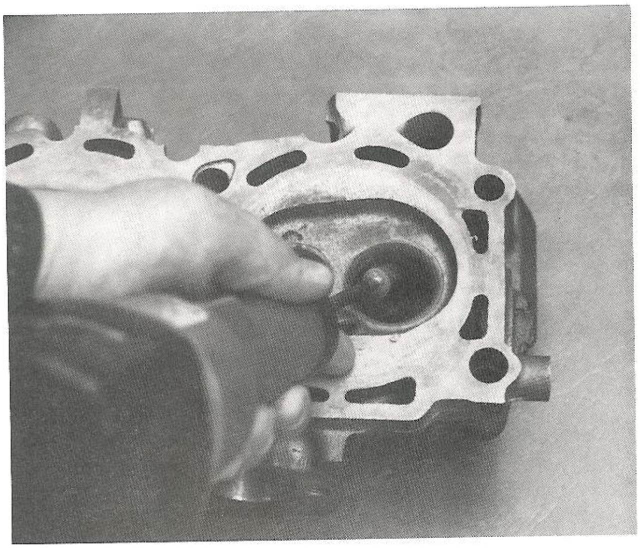
You will probably find that it is much easier to work on the short turn radius from the valve side of the port. It is much easier to shape the radius by first shaping your grinding stone to the desired radius using a carbon stick. This way, you can simply rock the stone across the radius to achieve the proper shape. Do not remove too much material as, once again, it is possible to break through into a water jacket. As you approach the port floor, under no circumstances should you attempt to lower it. Lowering the port floor will make the air try to turn in on itself as it passes through this area of the port. Although turbulence is desirable in the combustion chamber, in the port it is detrimental to power production. Turbulence in the intake port results in what is known as "mixture separation". This is a condition where the homogeneous mixture of air and fuel suddenly becomes disintegrated. As a result, the fuel parti-



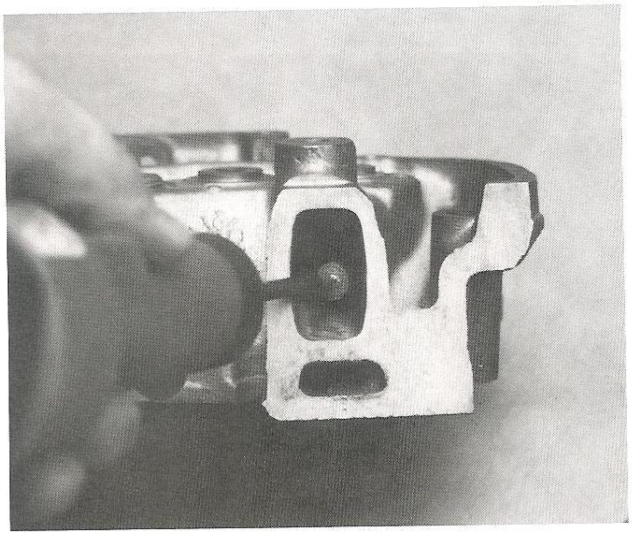
The EGR bump should be removed from the exhaust ports to improve exhaust flow. The photo indicates the bump location in a 4.0-liter exhaust port.



Recontouring of the short turn radius begins with a stone formed to the desired shape.



Smooth the short turn radius using a medium grit sanding roll, working in a back-and-forth, rocking motion.



Once the short turn radius is the desired shape, gently smooth all of the casting lines and rough cast surface using a sanding roll.

cles fall out of suspension and collect on the port walls (not good).

Once you have achieved the desired contour, finish the area by gently smoothing out the rough casting lines as well as the cast surface finish. Don't forget to refer to the accompanying drawings for guidance.

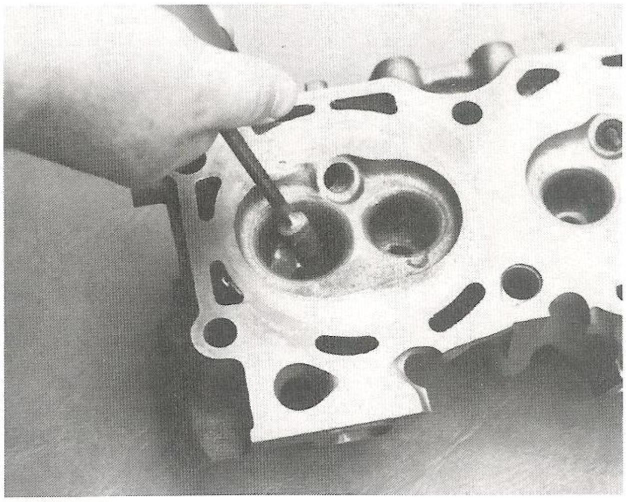
Valve Guide Boss Modifications

Modifications to the valve guide boss in the intake port are very important for achieving adequate port flow for good performance. The valve guide modifications that must be performed are unique to each individual engine. Therefore, it is important to refer to the applicable diagrams to properly accomplish these modifications. The procedures outlined in this section are of a general nature and will apply to all Ford V-6 cylinder heads.

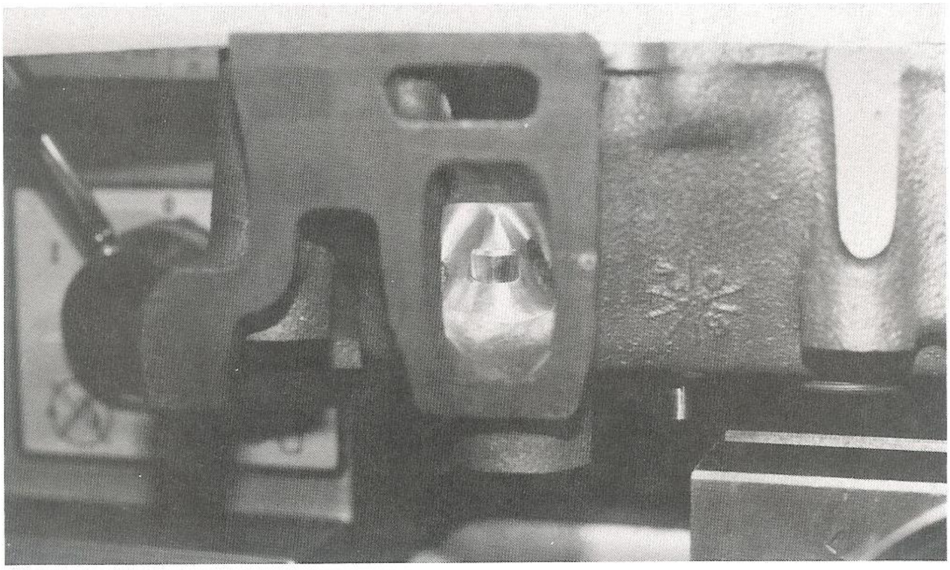
Some of the most dramatic improvements in flow in the Ford V-6 can be achieved with very simple modification of the valve guide boss. This modification consists primarily of reducing the cross-sectional area of the guide boss itself and "streamlining" the remainder of the boss so that air will flow smoothly around it. This procedure requires a lot of patience and a very skilled hand. It is far too easy to remove too much material, so you must take extreme care to remove only the material that is indicated.

Valve guide boss modification is much more involved when preparing the 2.6-and the 2.8-liter heads. Both of these heads require the removal of better than 50 percent of the original boss in order to achieve proper flow. In fact, the 2.6 port shape allows for the entire removal of the guide boss without the worry of reduced integrity. This, however, is not the case with the 2.8. The complete removal of the guide boss in the 2.8 is reserved for race-only applications and will result in a significant loss of long-term valve and guide stability. Therefore, under no circumstances should the guide boss be entirely removed from the 2.8 intake port for street-performance applications.

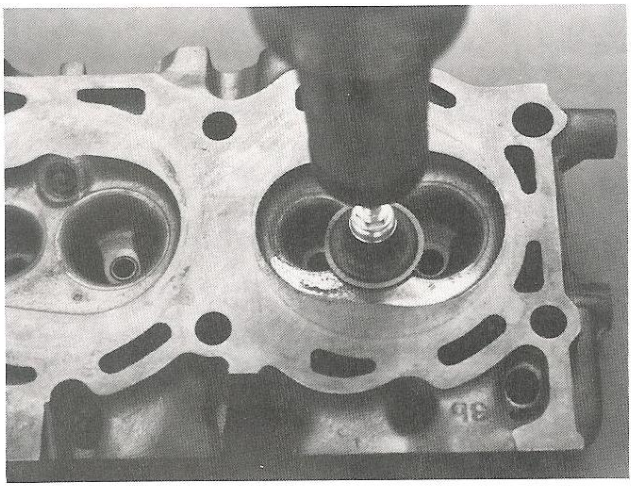
When moving up to the 2.9- and 4.0-liter engines, valve guide boss modifications become comparatively simple. In essence, the 2.9 only requires a slight reduction in the boss height and the 4.0 liter requires no modification at all. In most cases, valve guide boss modification on the 2.9-and 4.0-liter heads result in a less dramatic effect on peak flow than do the same modifications when performed on 2.6 or 2.8 heads. Furthermore, the peak flow capacity of the newer heads rather easily exceeds that of the earlier heads. This makes dramatic improvements in flow much harder to come by.



In most performance Ford V-6 engines, about 50 percent of the stock valve guide boss is removed and the remainder is contoured to enhance the flow quality.



In the 2.8-liter heads, the valve guide boss is formed into a teardrop shape. This shape provides good flow around the valve guide. In racing applications, this guide boss is completely removed, leaving only the valve guide in the flow path.

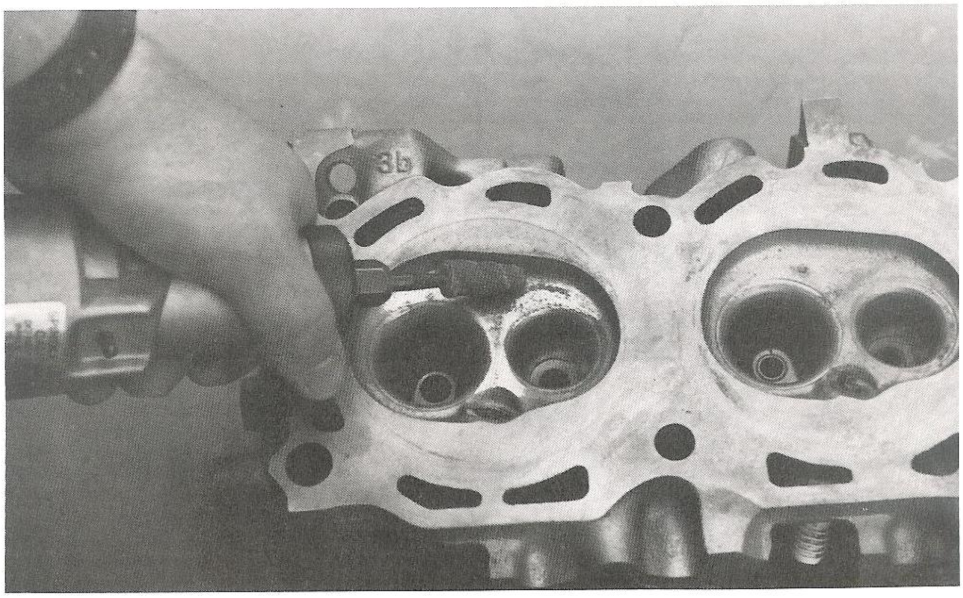


Combustion chamber preparation begins by smoothing the flat surfaces of the chamber with a 100-grit sanding disc.

Where the exhaust valve guide boss is concerned, it is ill advised to begin shortening the guide boss for a couple of reasons. First, any reduction in the valve guide support in the exhaust valve area of a Ford V-6 is just begging for trouble. The exhaust ports tend to run very hot and consequently have a difficult time dissipating the enormous heat that stacks up in the port. This forces the valve stem to act as a heat exchanger, transferring its stored heat directly into the valve guide. Second, there simply isn't that much valve guide boss that requires removal in the V-6. Therefore, the advice for the street is: clean things up, polish things out, and leave things alone.

Combustion Chambers

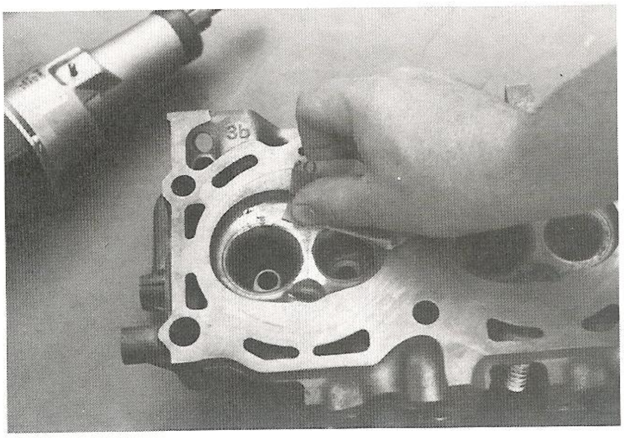
Perhaps the simplest of all porting modifications, combus-



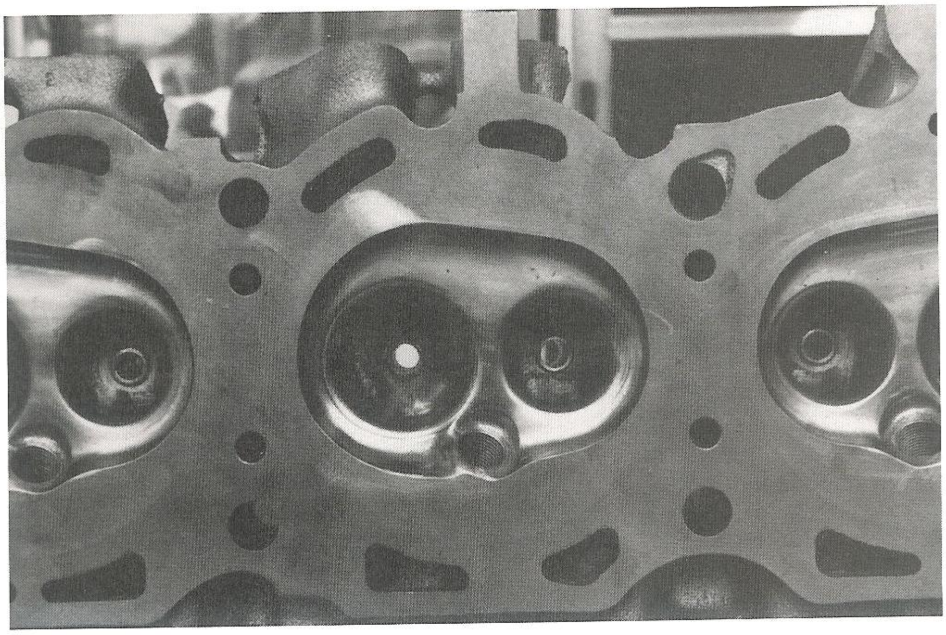
After smoothing the roof of the chamber, move your efforts to the chamber walls. Your goal is to remove only enough material to create a smooth, nonporous surface.

tion chamber preparation is very straightforward and simple. Basically, the intent is to polish the chambers to a relatively high luster without removing a large amount of material. Under no circumstances should you attempt to change the shape of the chamber. The intent is to remove any sharp edges that may cause "hot-spots" in the chamber and, as a result, detonation and/or pre-ignition problems.

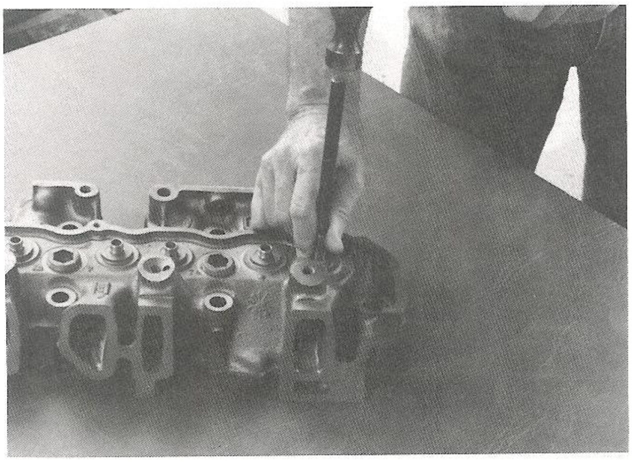
Using a small, 100-grit quick-change sanding disc, smooth the flat, cast surface at the roof of the chamber. Once this has been accomplished, switch to a 100-grit tapered sanding roll and gently smooth all of the radii between the chamber walls and the roof. Only remove enough material to



The real work to finish combustion chambers is done by hand. Here, the chambers are being massaged using 220-grit sandpaper. The final finish is achieved using 0000 steel wool and lots of elbow grease.



The finished combustion chambers are quite attractive. Notice that the chambers are almost mirror smooth with no sharp edges evident.



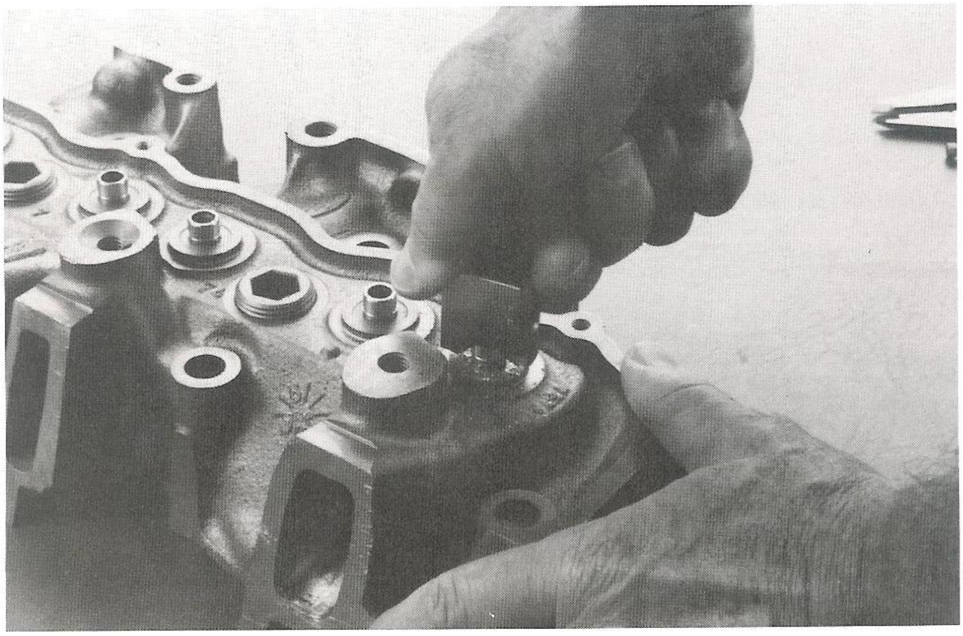
Whether complete guides or guide sleeves are used, each must be driven into place using a special driver.

create a smooth nonporous surface. Next, move your efforts to the walls of the chambers, taking care not to create any new angles. Finish the grinding process by lightly grinding a slight 45 degree chamfer around the edge of the chamber. This chamfer should not exceed 0.020in.

Now that the chambers are relatively smooth, it's time for the hard work. Using 220-grit wet-or-dry sandpaper, work all of the chamber surfaces until no grinding marks are visible. Repeat this polishing procedure using 400-grit wet-or-dry sandpaper soaked in kerosene.

Valve Guide Installation

Now that all of the porting procedures are complete, the heads can be fitted with new



After the guides are in place, the top of each guide must be machined so that the Perfect Circle (PC) seals can be properly installed. Notice that the tool is turned by hand, not a drill.

valve guides or liners. The proper valve guide configuration was discussed earlier in this chapter with regard to the type of cylinder heads that will be used and whether they have been ported. Based on that information, you should have already made your decision as to what type of guide to use and have had the heads machined to accept the guide. Obviously, the only thing left with respect to valve guides is installation.

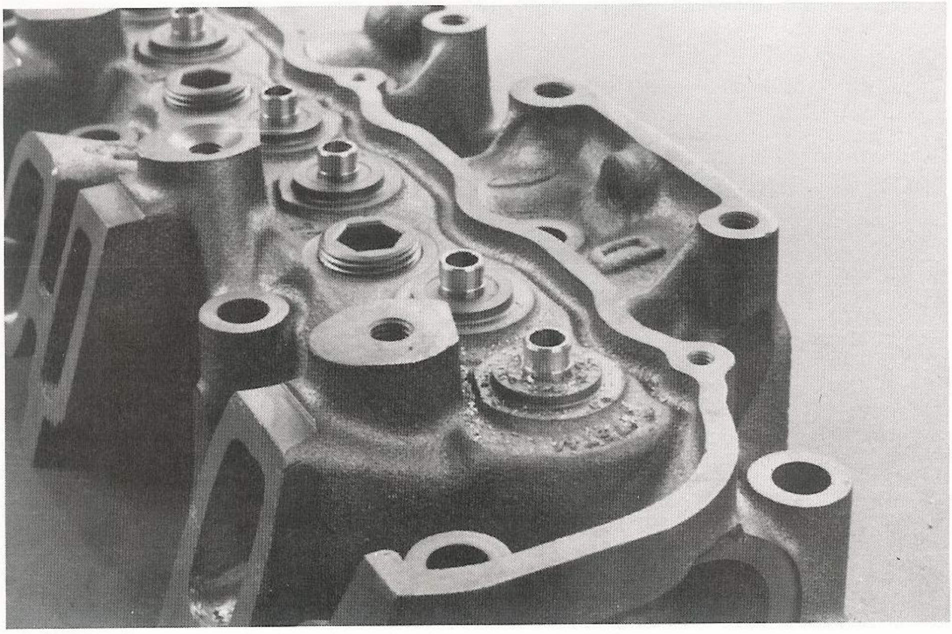
Many information sources have encouraged do-it-yourself replacement and installation of valve guides. This is fine if you happen to be rebuilding a Briggs & Stratton lawn mower engine, but when it comes to building a Ford V-6, the only course is to have a qualified machine shop do the work.

The procedures involved in installing valve guides and sleeves are very similar and relatively basic. First, the original guide must be either core drilled (for guides) or reamed (for sleeves) to the proper size. Second, the guide and/or sleeve is driven into the bore with a considerable interference fit. I believe the only proper way to do this is to use a ball broach. Next, the new guide or sleeve is either honed or reamed to its final size. Final valve guide bore finish should provide 0.0012in–0.0015 in clearance between the valve stem and the guide bore. Finally, the top of the guide is machined to accept the PC-type valve stem seals that should be used. Once these procedures are complete, the guides should require no further attention prior to assembly.

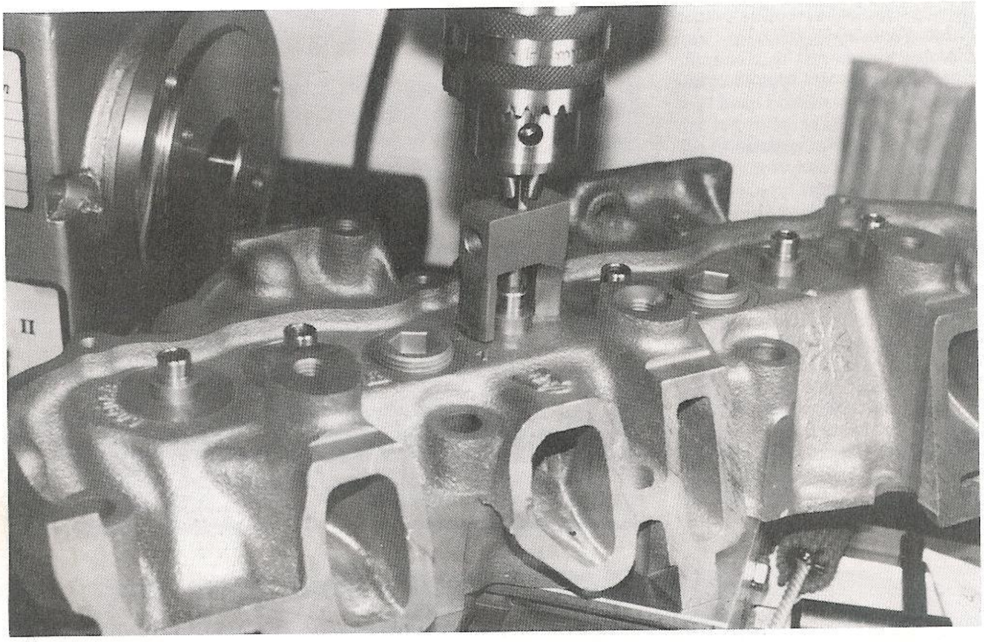
Valve Spring Seats

If you have followed the previous recommendations for valve springs, you will have to modify the spring seats in the heads to allow the new (larger) valve springs to be properly installed. Conveniently, the valve spring seat modifications required for all of the Ford V-6 engines are identical.

No matter what heads you intend to use, the tool that is required to modify the spring seats is the same. This tool is a special carbide "fly-cutter" that is designed to enlarge the spring seat to the proper 1.500in diameter while at the same time turning the diameter of the original valve guide down to the proper 0.625in size to allow the inner valve spring to fit properly. This special tool is available through



The outside of the valve guide is slightly smaller in diameter and is chamfered on the top edge following the machining procedure. This will allow the PC seal to properly seat on the guide, offering a perfect seal.



In order to install the larger Crane valve springs, the spring seats must be enlarged and lowered in the heads. A special fly-cutter, like the one shown, performs this job quickly and easily.

Goodson Auto Machine Shop Tools and Supplies, Winona, Minnesota, under part number VSS-1500. This tool will require the use of a drill press or mill to do its job properly. Once again, I think it is a good idea to let the machine shop perform this operation if you don't have the tools and skills at home. Regardless of who performs this machining operation, there are some guidelines that must be followed.

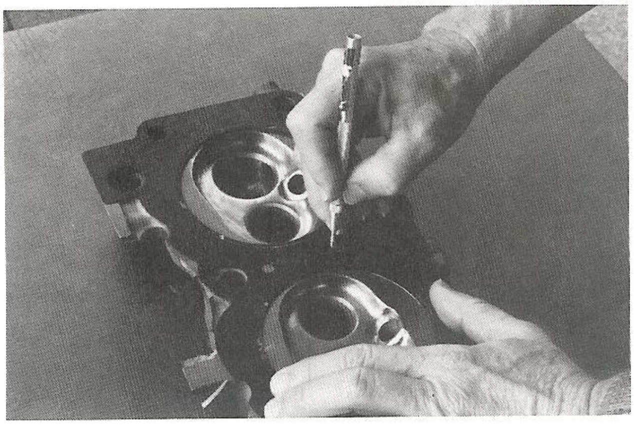
As indicated in the accompanying photos, proper modification of the spring seat consists of simply cutting down the original seat by roughly 0.110–0.120in. This depth will often be where the cutter just begins to remove metal at the base of the spring seat shelf. It is very important that the valve guides be properly sized prior to performing this modification. If this machine work is performed using a worn valve guide to pilot the cutter, it will be impossible to cut the valve spring seats exactly perpendicular to the valve stem axis. Finally, it is not advisable to sink the spring seats any more than 0.130–0.135in below the original seat level as it becomes increasingly possible to break into a water jacket, rendering the head absolutely worthless. It is best to set-up each valve and measure the installed height then calculate the amount of material that must be removed to provide the correct installed height.

Drilling Cooling Passages (2.6-and 2.8-liter only)

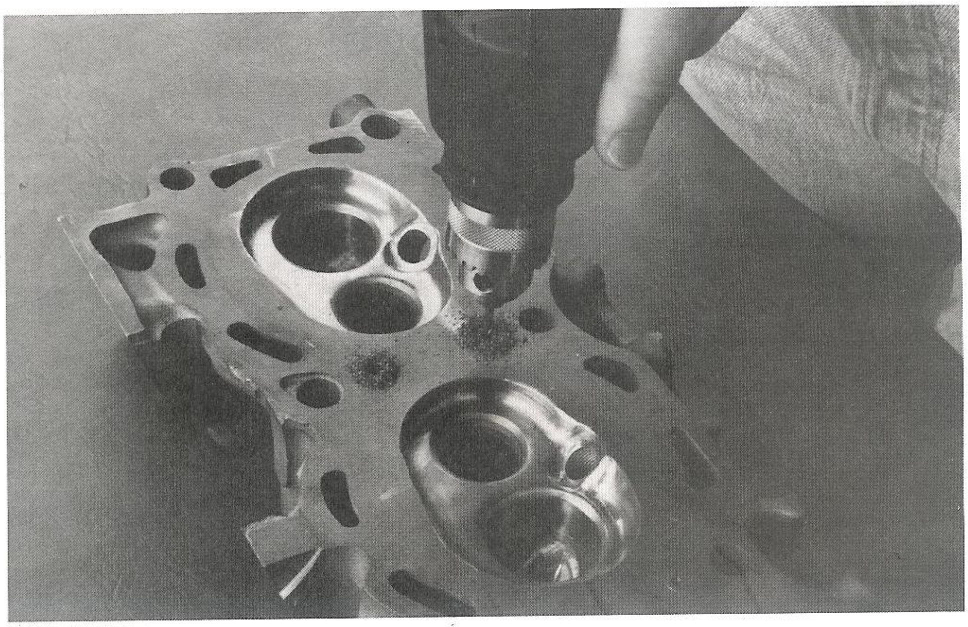
As I mentioned earlier, the 2.6- and 2.8-liter engines trap an enormous amount of heat in the cylinder heads due to a particularly inefficient exhaust port configuration and uneven port spacing (each head has two exhaust valves next to each other). This creates severe cooling problems that often result in cracked cylinder heads, galled valve guides, and broken valves. Since this condition does nothing but get worse when building high-performance versions of these engines, failure to address this particular issue will most likely result in catastrophic engine failure at some point. Luckily, the solution to this problem is very simple and can be accomplished very easily at home using a hand drill and a little patience.

The problem is that very little coolant is allowed to flow around the hottest part of the cylinder head. As you might expect, the hottest part of the head is the area right between the two exhaust ports, between the two combustion chambers. If you examine, for instance, the 2.9- or 4.0-liter heads, you will notice that these engines incorporate four cooling passages between the combustion chambers to allow additional coolant to flow to this area. The intent, therefore, is to create four new cooling passages in the 2.6/2.8 heads in this same area.

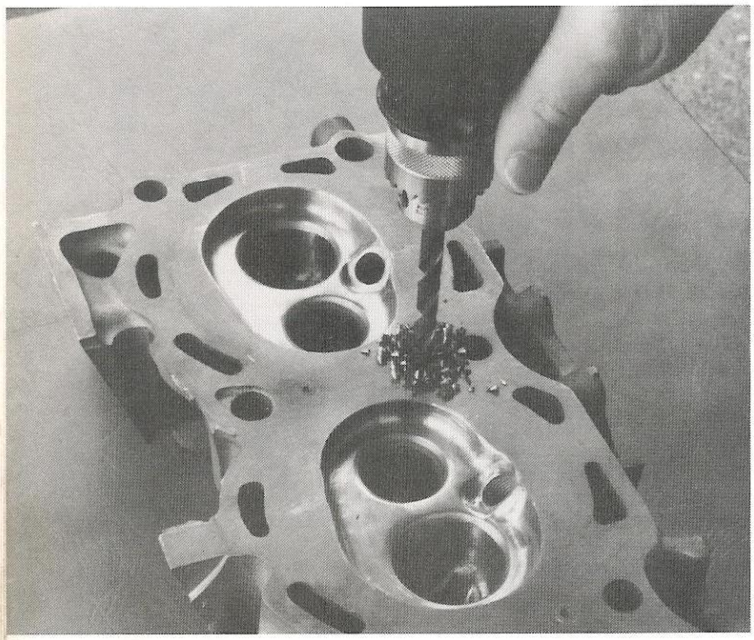
The first thing you must do is go to your local auto parts store and get yourself a Victor® cylinder head gasket part number 3778 or 3779. This gasket will act as your drilling pattern as it already has the proper holes located in it. Do not plan on using this gasket for anything other than a pattern, as it is possible that the gasket will become



Both the 2.6- and 2.8-liter engines have the misfortune of having two exhaust valves right next to one another. This creates a severe localized boiling point that often results in overheating and seat failure. To remedy this, cooling passages are drilled to allow extra coolant to circulate in these areas. Here, the cooling passages are being scribed onto the head using a head gasket as a pattern.



Pilot holes are drilled in the deck surface to act as a guide for the larger drill bit.



The four new cooling passages are drilled to a depth of 1in using a sharp 5/16in drill bit.

damaged during this operation.

Using a pair of cylinder block dowels (the kind used to properly locate the head on the block), locate the gasket on the cylinder head. With a sharp scribe, trace the outline of each of the four cooling passages onto the cylinder head. Once this is done, remove the gasket and dowels and center punch each hole in the exact center. Using a 1/8in drill bit, drill a pilot hole about 3/4in deep through each of the passages. Next, using a 5/16in drill bit, drill out each passage. This time drill into the head approximately 1in to achieve the proper passage configuration. Once these passages have been drilled, lightly chamfer the holes using an 82-degree chamfering bit. Finish the job by thoroughly flushing the water jackets with large quantities of water.

The Valve Job

All Ford 60-degree V-6 engines come from the factory with a single 45-degree seat. This single angle creates two very sharp edges above and below the seat that force the incoming air/fuel mixture (or outgoing exhaust gas) to make very sharp turns as it flows past the valves. The result is a large amount of turbulence and, in turn, a significant restriction to flow into and out of the combustion chamber. As I mentioned before, any modification that will improve the flow efficiency of the intake and exhaust system will directly result in an increase in power. Since the valve and seat area represent the largest single restriction in the flow path, it becomes obvious that proper preparation in this area is most critical to good flow. In fact, the valve and seat area is perhaps the most critical portion of the entire flow path.

Look again at the factory valve job and you will understand the need for a more efficient method of valve seat and face contouring in order to improve the flow in this area. The solution to this malady is known as a "multi-angle" valve job. This type of valve job is usually referred to as a three-angle valve job in reference to the three separate angles that are used for the valve seat area, but it is sometimes called a five-angle valve job, referring to the two valve face angles as well as the three seat angles. Regardless of the term you use, a multi-angle valve job is the universally accepted method of valve seat and face preparation in the performance engine industry.

Basically, the seat area of every multi-angle valve job consists of the same three basic elements: the bottom cut, the valve seat, and the top cut. As you explore the following information regarding the valve job, keep in mind that the only way to properly finish a multi-angle valve job is with a carbide valve seat cutter. These specially designed cutters will actually cut all three of these angles in one pass. This offers a level of consistency and accuracy unattainable with any other method. Be absolutely sure that the machine shop that will be doing your work will be using a carbide cutter on your heads!

The Bottom Cut

The bottom cut of a multi-angle valve job actually marks the beginning of the transition from the bowl area to the combustion chamber in the intake port and marks the transition from the combustion chamber to the bowl area in the exhaust port. The angle of this bottom cut for all Ford V-6 engines is 60 degree for both the intake and exhaust. The width of this cut should be approaching 0.100in.

The Valve Seats

The valve seats are the primary sealing surface of the valves. These seats, both intake and exhaust, are cut at a 45 degree angle on all Ford V-6 engines. The most important dimension on the valve seats is width. Valve seat width varies depending on engine usage, valve spring pressures, cam type, operating temperature, and even the type of fuel that will be used. Most machine shops will be accustomed to cutting very narrow valve seats as this is the optimum configuration in most racing engines. The Ford V-6, on the other hand, requires a wider valve seat width than most shops are used to cutting. The reason for this is that, as we mentioned earlier, the V-6 traps enormous amounts of heat in the heads. Since the valve seat is the primary conduit for heat transfer out of the valve head, the seats need to be wider in the Ford V-6 to allow proper heat transfer. Additionally, since higher valve spring pressures are being used (although not excessive), wider seats will help prevent the valves from pounding out the seats.

Extensive research has shown that the intake seats in the Ford V-6 should be 0.060in wide and the exhaust seats should be 0.080in wide. Although these wide seats will slightly affect the flow, they will provide excellent durability and sealing.

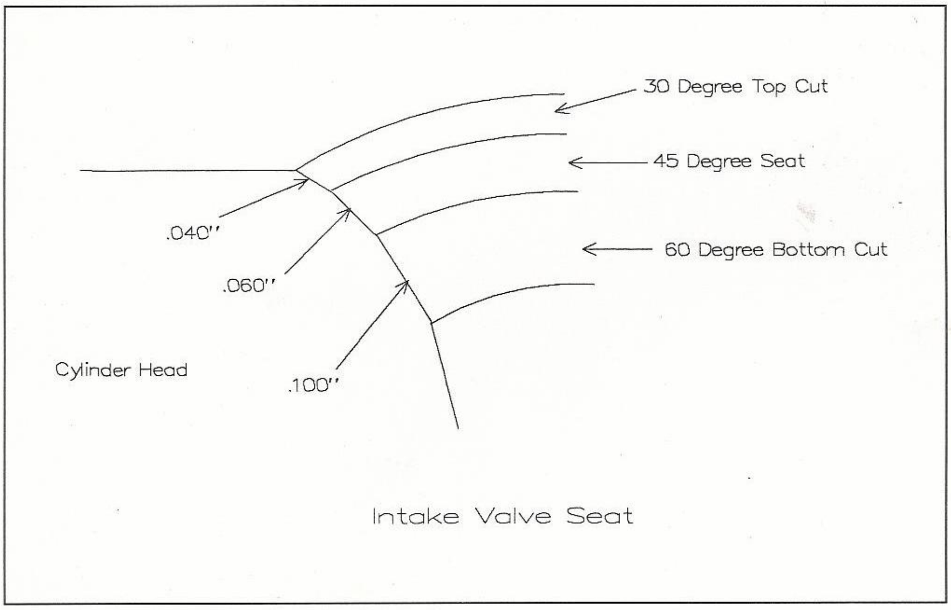
The Top Cut

The purpose of the top cut is to narrow the valve seat to the proper diameter and width and to break the sharp edge where the valve seat meets the combustion chamber. The angle of this top cut should be 30 degrees and the width should be between 0.030in and 0.040in.

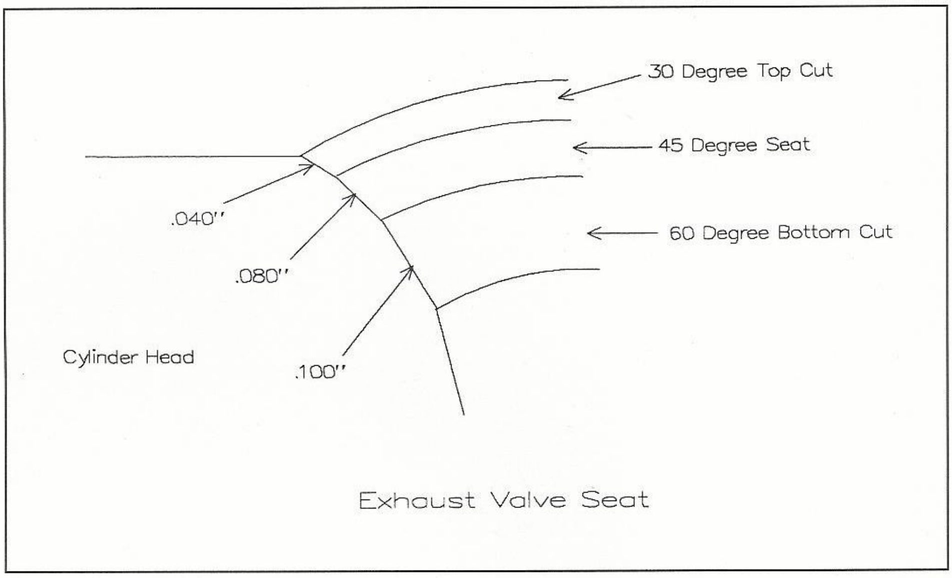
Seat/Face Runout and Valve Depth

Valve seat/face runout is something that is often overlooked during the average valve job. It is extremely important to check the valve seat and face runout throughout the valve job to see that it is less than 0.001in. A special valve seat indicator is used for this procedure and should be a standard tool in any good cylinder head shop. If the runout error exceeds 0.001in, the valves will not seal properly, resulting in a significant loss of power and reliability.

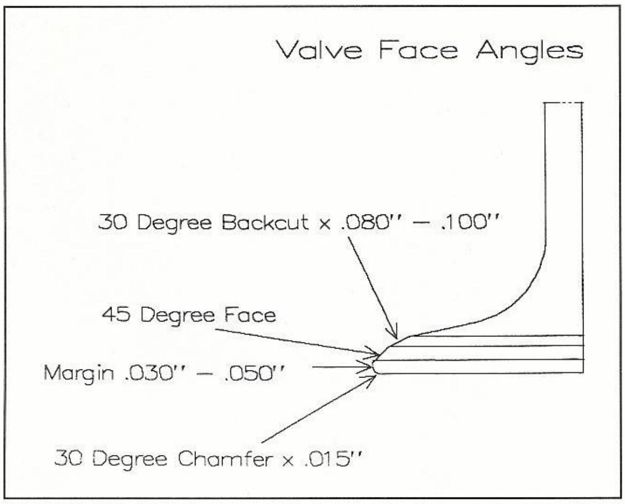
Valve depth is another important consideration in a top-



This diagram shows the proper intake valve seat angles for the Ford V-6.



This diagram shows the proper exhaust valve seat angles for the Ford V-6.



The valve face angles for both the intake and exhaust valves are the same. The diagram indicates the appropriate configuration.

notch valve job. During the valve seat cutting operations, all of the valves should be at the same depth in the cylinder head. Ideally, the valve depths should vary no more than 0.004in across the entire head. Equalizing these depths ensures that the combustion chamber volumes will be consistent and that the flow characteristics will be identical from port to port. Furthermore, when all of the valves are at the same depth, valvetrain geometry is less likely to be askew when the time comes to put everything together.

The Valve Faces

Now that the valve seats have been brought up to speed, you must shift your attention to the valves themselves. Each valve has an area called a "face" that acts as the primary sealing surface of the valve. This face comes into direct contact with the valve seat that has been cut into the head. Since the two must mate perfectly to provide a proper seal, all of the valve faces should be ground to a 45-degree angle. When you grind these faces, pay special attention to the margin or vertical lip at the top edge of each valve. This margin should never be any narrower than 0.040in. Each time the valves are ground, this margin area is reduced. If this margin ever falls below 0.040in, throw the valves away and get new ones.

If your valves have a sufficient margin, the next step is to chamfer the margin where it meets the head of the valve. This chamfer should be 30 degrees relative to the valve head and should be 0.015in to 0.020in wide. This slight chamfer will actually help the mixture to flow around the head of the valve more efficiently.

Back Cutting

Back cutting is done to remove the sharp edge between the valve face and the underside of the valve head. The back cut will effectively radius the transition area from the valve head area to the valve face, resulting in a slight improvement in flow. The back cut that should be used on the Ford V-6 should be 35 degrees relative to the valve head and it should be 0.080in to 0.100in wide.

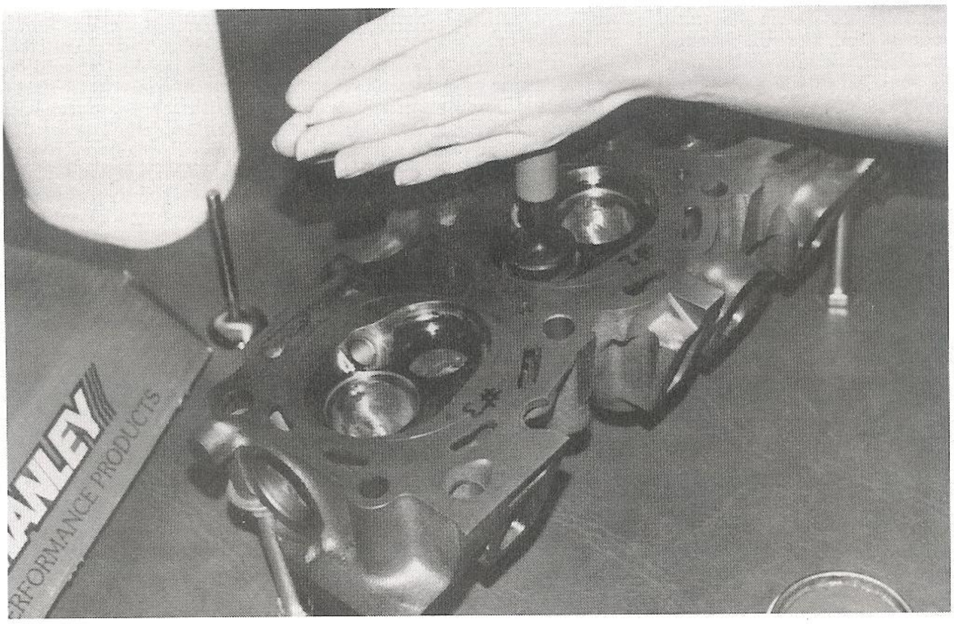
Lapping

Lapping the valves following a valve job is without a doubt the easiest job involved in the preparation of the cylinder heads. I guess you could say that the lapping procedure is a real "no-brainer" since no expensive equipment is used, and no special know-how is required (this is a great job for those family members that want to "help out"). Don't be misled into believing that lapping is not important, however. In fact, valve lapping is the best way to check the quality of the valve job (and the machinist).

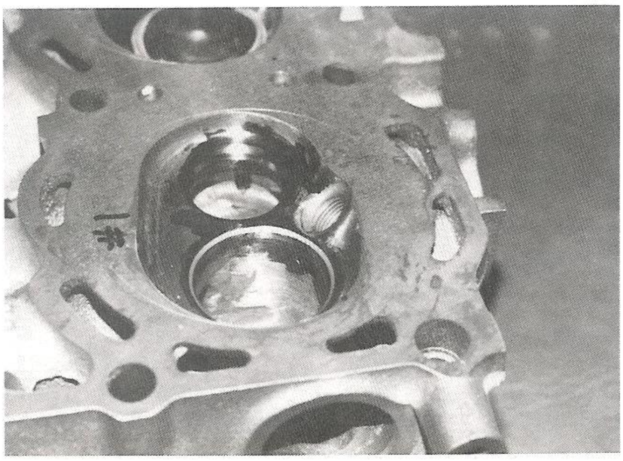
You need only a few things for the lapping procedures. First, purchase a lapping stick from your local auto parts store. This is nothing more than a dowel with a suction cup affixed to one (or both) end. You should get one with a suction cup diameter of 3/4in. Next, you need a jar of extra fine lapping compound. I find that 4A (600 grit) Clover lapping compound works very well. This fine grit lapping compound will not damage the seat finish left by modern carbide cutters. Again, this product should be available at your local parts store. With these two items in hand, you are fully prepared to start lappin'.

To begin, smear the lapping compound around the entire face of the valve. Avoid getting the compound on the valve stem as this will damage both the stem and the guide during the lapping process. Add a few drops of motor oil to the valve stem and install

Other than a little arm work, valve lapping requires only two things: a good lapping stick and Clover lapping compound.



As you lap the valves, you will notice that the abrasive will stop cutting after several turns. At this point, simply lift the valve off of its seat to redistribute the lapping compound then continue lapping.



Valve seat quality is easily checked following lapping by inspecting the gray line around the valve seat. If the line is a consistent width and color, you're in business.

the valve into its respective position. Keep in mind that once you have lapped a valve into a particular seat, it should always be installed in that same seat. It is a good idea to mark each valve and the head so that you will not mix them up.

Begin the lapping procedure by attaching the lapping stick to the head of the valve with the suction cup. Spin the stick between your hands while applying a little pressure to the valve. Once you feel the compound stop cutting, lift the valve off of its seat to evenly distribute the compound, then resume the lapping procedure. After a few minutes, remove the valve and thoroughly wipe the lapping compound from both the valve seat and the valve. You should see a light gray ring around the valve seat and around the valve face toward the outer edge of the valve. If both of these rings have a consistent width and color all the way around, the valve will seal properly, and you're in good shape. If the ring is narrower in spots and/or the ring is lighter in color in some areas, repeat the lapping procedures and check it again. If after the second time the ring is still incorrect, it's time to talk to the machine shop because the valve job wasn't done well.

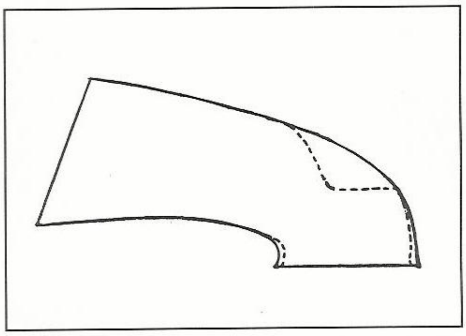
Finishing the Valve Job

Actually, finishing the valve job is more like finishing the porting since you aren't really cutting any more angles. After the valve job is complete, you will notice a sharp edge left in the bowl area by the 75-degree bottom cut. Using a 60-grit rotary stone, carefully radius this edge into the bowl walls and short turn radius. Tape up the freshly cut valve seat with duct tape to help prevent damage to the seats. Gradually work this edge out until the transition from the bowl area to the throat cut is gentle and smooth. Finish up by polishing this area with an 80-grit sanding roll.

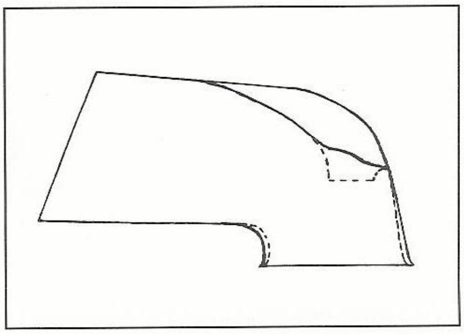
Measuring Chamber Volume

The reason for measuring the volume of the combustion chamber is primarily to determine the mechanical compression ratio. Additionally, however, measuring the combustion chamber volume can give you an indication whether you will need to mill one cylinder head more than its mate in order to equalize the chamber volumes between both heads. Note that this procedure is done after the valve job is complete, not before.

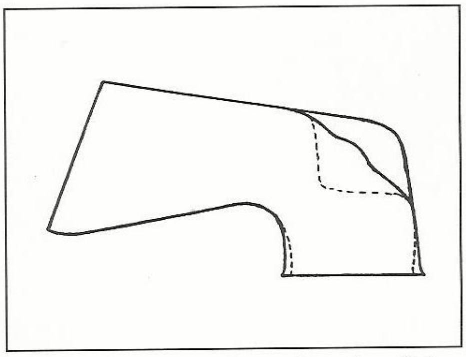
Measuring the combustion chamber volume is a fairly un-



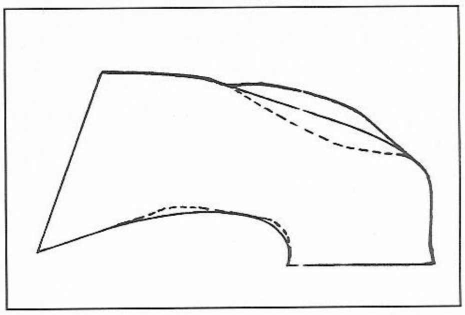
The 2.6-liter intake port requires the entire valve guide to be removed for good performance. The dotted lines indicate the stock port configuration.



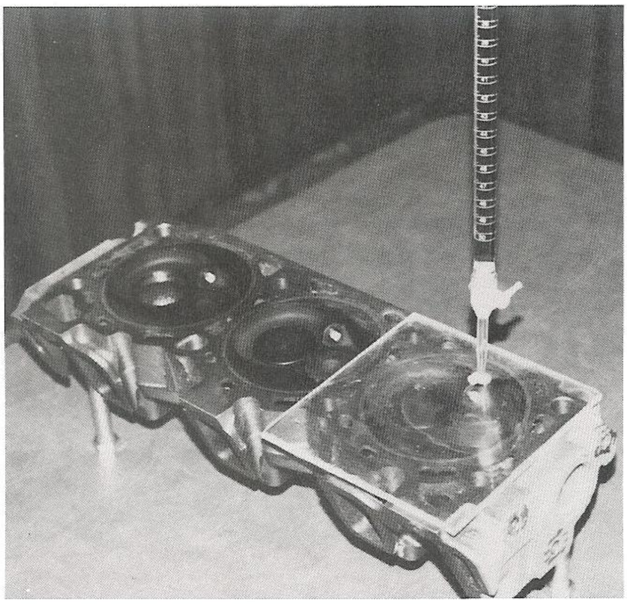
The 2.9-liter intake port performs well with little modification. Again, the dotted lines show the stock configuration before porting.



The 2.8-liter intake port benefits most from valve guide boss reduction. Dotted lines indicate the stock port profile.



The 4.0-liter has a very strange intake port configuration. It is a good idea to make a mold of the port prior to porting so that the diagram becomes more clear. Notice there is very little material removal involved.



The combustion chamber volume is easily measured using a Plexiglas plate and a burette filled with some sort of indicator fluid. The fluid that is dispensed into the chamber via the burette will indicate the actual volume in cc's.

complicated process when you have the proper equipment. The first and most important thing you will need is an instrument called a *burette*. A burette is a long cylinder with a stopcock on one end. This cylinder is graduated in tenths of one cubic centimeter (cc). When the burette is filled with a fluid, it can be precisely metered into a cavity to determine its exact volume in cubic centimeters. Rest assured that any cylinder head shop worth its salt will have one of these devices. The second item that you will need is some sort of thick (preferably plexiglass) plate that will cover the entire combustion chamber. This plate should have a hole drilled into it in the area where the chamber edge is likely to be, to allow the nozzle of the burette to be inserted to fill the chamber with fluid. Finally, you need some indicating fluid that has a very low surface tension so that it does not trap air bubbles easily. This could be colored rubbing alcohol, colored water with a drop of dish soap added, or even a 70/30 mixture of mineral spirits and ATF.

Once you have the above items, the procedure is simple. Fill the burette to the top with the indicator (fluid), then open the valve and drain out fluid until the fluid level is on the zero mark in the burette. Next, install a spark plug of the exact heat range that will be used into the head in the chamber that is being measured, followed by the valves that will be fitted to the chamber. Now, coat the squish area around the chamber with a light coat of thick grease, to act as a seal for the plate. Now carefully position the plate over the chamber making sure that none of the grease has been squeezed into the chamber. Finally, fill the chamber to capacity using the fluid in the burette. Once the chamber is completely filled (no air), read the exact volume of the chamber directly from the scale on the burette (in cc's).

Repeat this process for each chamber on each head. Once you have determined all of the chamber volumes, it will be easy to determine the amount (if any) that must be milled from the head with the larger chambers.

Calculating Compression Ratio

The term compression ratio describes the relationship between the total volume of the cylinder with the piston at bottom dead center and the clearance volume above the top piston ring with the piston at top dead center. Increasing the compression ratio is a very common way to increase the power output of performance engines. An increase in compression ratio creates an increase in the rate at which the air/fuel mixture reacts. The faster the air/fuel mixture reacts, the faster cylinder pressure builds and, as a result, more power is created.

This may lead you to wonder, "If a higher compression ratio is an indicator of more power, why not run the highest compression ratio possible?" Well, to an extent, that's exactly what the overall intent is. Unfortunately, you must also keep in mind that many things limit the amount of compression ratio that the engine will safely support. Some of these things are: fuel quality, ignition timing, combustion chamber shape, piston configuration, and valve timing. In most cases, fuel quality plays a major role in the amount of compression that street-performance engines can accommodate. This is due to the fact that most of the "pump" fuels that are easily available will not tolerate much more than about a 10.5:1 compression ratio before detonation begins. Detonation—the "d" word that every engine builder hates to hear—is what kills the vast majority of performance engines.

Detonation is actually a condition where the air/fuel mixture burns uncontrollably and at the wrong rate. In fact, rather than the desired controlled burn, detonation is actually a very severe uncontrolled explosion. This explosion creates extreme loads on many of the engine components, eventually resulting in failure . . . big failure. To avoid potential detonation problems in street performance engines, the compression ratio must remain below 10.5:1 and furthermore, you must accurately calculate the compression ratio that your engine combination will achieve.

Many novice engine builders blindly assume that since they bought a set of 10.5:1 pistons, that is, in fact, what their compression ratio will be. This assumption is positively wrong! Piston manufacturers' advertised compression ratios are nominal figures at best and are only intended to offer the buyer a general idea of what the piston is designed for. The only sure-fire way to know the actual compression ratio is to calculate it. Never assume anything!

The formula for calculating compression ratio is:

CR=V + VCL/VCL

Where:

CR=Compression ratio

V=Cylinder volume in cc's

VCL=Clearance volume

In the equation above, the cylinder volume (V) is calculated as follows:

$V=0.7854 \times B^2 \times S$

Where:

B = Cylinder bore in cm

S = Stroke in cm

The clearance volume (VCL) is actually made up of several smaller volumes such as :

Volume above top piston ring (VR)

Valve notch volume (VN)

Piston to deck volume (VP)

Compressed head gasket volume (VG)

Combustion chamber volume (VC)

Piston dome volume (VD)

The actual calculation for the clearance volume (VCL) is:

VCL=VR+VN+VP+VG+VC – VD

The first of these smaller elemental volumes is the volume above the top piston ring (VR). This is actually the volume of open space from the top ring to the top of the piston squish surface. To calculate this volume, use the following equation:

$VR=0.7854 \times (B^2 - P^2) \times R$

Where:

B=Cylinder bore in cm

P=Top ring land diameter in cm

R=Top ring to piston squish surface in cm

The valve notch volume (VN) is typically zero in all Ford V-6 engines. This is primarily due to the fact that most performance V-6 engines will utilize either flat-top or slightly dished pistons, neither requiring valve "reliefs" to clear the valves. Therefore, the value for VN should be zero.

The piston to deck volume (VP) is affected by the clearance between the piston and the deck surface. As deck clearance increases, so does the deck clearance volume. Obviously, if the deck clearance is zero, the clearance volume will be zero as well. Calculate the clearance volume as follows: $VP=0.7854 \times B^2 \times D$

Where:

B=Cylinder bore in cm

D=Block deck height –pin height – rod length –1/2 stroke

The compressed head gasket volume (VG) can either be taken from information supplied by the gasket manufacturer or it can be calculated from information obtained from a compressed (used) head gasket. The equation is:

$VG=0.7854 \times G^2 \times T$

Where:

G=Compressed head gasket bore in cm

T=Compressed head gasket thickness in cm

The combustion chamber volume (VC) is the value measured with a burette and indicating fluid. The fluid volume that was dispensed into the chamber was the actual combustion chamber volume in cubic centimeters (cc's). This figure can be used exactly as it was determined.

Finally, you need to determine the piston dome volume (VD). In the case of dished pistons, you can determine this volume with the same cc'ing plate and burette you use to determine the combustion chamber volume. The volume of the "dish" in a dished piston must be recorded as a negative (-) dome volume to correctly perform within the compression ratio calculation. If you use flat-top pistons, this value will be zero. If you use a pop-up (domed) piston, the piston manufacturer will probably be able to supply you with the exact dome volume for this calculation. Enter the dome volume of a pop-up piston into the compression ratio equation as a positive (+) value to yield the proper results. Since it is not likely, nor desirable, that you will use pop-up pistons in a Ford V-6, we will suspend any complicated methods of manually determining the dome volume.

Once you have calculated all of the peripheral elements of the equation, you can plug the results into the original compression ratio formula to determine the actual static compression ratio of your engine.

For example, let's say your "vital statistics" are

Cylinder volume (V) = 473.16cc's.

Volume above top ring (VR) =0.714cc

Valve notch volume (VN) = 0

Piston to deck volume (VP)

=0.700cc
Compressed gasket volume (VG) = 7.8cc
Combustion chamber volume (VC) = 43.4cc's
Piston dome volume (VD) = 0

To calculate the clearance volume (VCL), plug the appropriate values into the clearance volume calculation: VCL=0.714 + 0 + 0.700 + 7.8 + 43.4 – 0

The solution is: VCL=52.614cc

With values for both V and VCL, you can now determine the static compression ratio using the formula: CR=473.16cc + 52.614cc/52.614cc

In this example, the compression ratio works out to be 9.99 to 1, which rounds to a comfortable 10.0 to 1 static compression ratio. As you can see, with a little time and effort and some very simple math, you can accurately calculate the compression ratio.

Milling the Heads

Head milling is a very common procedure in high-performance engine building. The primary reason that cylinder heads are milled is to straighten and true the deck surfaces. Cylinder heads (like blocks) tend to "season" after many hours of use, resulting in a slight warp in the head. Since straight mating surfaces are essential to good head gasket sealing, the heads will often require milling to get them square to the world again. In most cases, a clean up cut of 0.005in will straighten and true most Ford V-6 cylinder heads.

The second reason for milling cylinder heads is to increase the compression ratio. Any time a head is milled, the volume of the combustion chamber is reduced, resulting in an increase in the mechanical compression ratio. As a general rule of thumb, the Ford 2.6-, 2.8-, and 2.9-liter V-6 cylinder heads will drop 1cc for every 0.006in milled from the surface. The Ford 4.0-liter V-6 cylinder heads will drop 1cc for every 0.005in milled from the surface. These dimensions are handy when designing your engine on paper and when calculating the required amount that must be milled from the head to achieve the desired compression ratio.

Note that head milling is *not* used to equalize the chamber volumes of a single head. Some sources have encouraged the practice of "offset" or "angle" milling to equalize the chamber volumes. If this is done to any Ford V-6 cylinder head, it will absolutely ruin the valvetrain geometry, not to mention the head itself. Ford V-6 heads are "0-degree" cylinder heads. In other words, the valve stems are parallel to the cylinder bore. Any attempt to angle mill these heads will result in an incorrect valve to cylinder relationship. If anyone tries to sell you on this idea, take my advice and politely walk away.

If after your heads have been milled you find that the chambers are not within 0.5cc of each other, simply remove a little bit of material from the smaller chambers and re-polish them until they are equal to the larger chamber. Remember, the chamber volumes of both heads should be within 0.5cc.

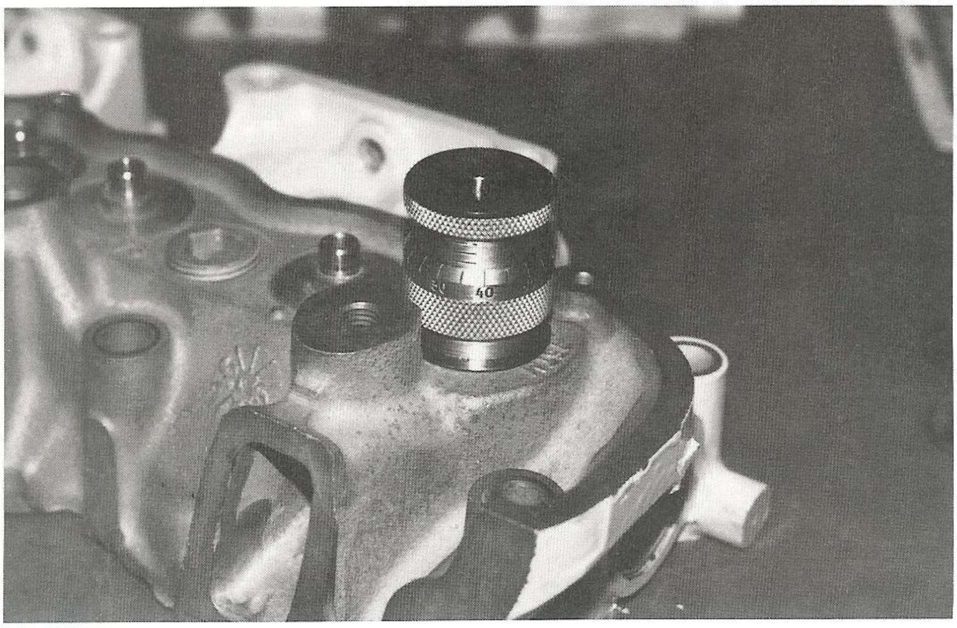
Although head milling is an easy way to increase compression, there are limits to the amount of material that can be removed safely. The deck surfaces on the Ford V-6 cylinder heads are not what one would consider thick. As a general rule of thumb, street-performance V-6 engines should get no more than a 0.025in cut on the heads. For any street-performance engine, I recommend that only enough material be removed from the heads to get them straight, no more. It is easy enough to obtain a desirable compression ratio using the right piston combination instead of hacking the hell out of the heads. If the engine is built for racing and will undergo routine teardowns, 0.045in material removal can be considered the absolute maximum.

Cylinder Head Pre-assembly

Now that all of the cylinder head machine work has been completed, it's time to start thinking about putting everything together. As with any precision piece of machinery, cleanliness is absolutely imperative. Therefore, the first order of business is to thoroughly wash each head in warm, soapy water. Repeat this process a few times to flush all of the residue out of the water jackets and ports. After washing the heads, rinse them in large quantities of clear water, and blow them dry with compressed air.

Next, install brass freeze plugs into each end of the head using Permatex #1 as a sealant. Brass freeze plugs are available at most auto parts stores. They are a little more expensive than steel plugs, but their superior sealing qualities and long-term durability are worth the extra money. Once the sealant has cured for twenty-four hours, mask the cylinder heads and paint them the color of your choice. Be sure to completely degrease each head with large quantities of brake cleaner or lacquer thinner before you begin painting or else the paint will quickly peel the first time the engine is washed. After the degreasing solvent has dried, paint each head with a good quality, high heat engine paint. Be sure that you don't get any paint in the ports, on the deck surfaces, or in the rocker cover area. Allow the paint to dry completely before performing any further work.

The first procedure involved in the actual assembly of the heads is to check the installed valve spring height. I believe the only proper (and easiest) way to



The most accurate way to determine valve spring height is by using a height micrometer. This device takes the place of the valve spring and uses a graduated scale to determine valve spring height with great precision.

determine this dimension is by using a device called a height micrometer. This is a special cylindrical measuring device that actually replaces the valve spring in the valve assembly. The valve is inserted in the head in its respective guide, followed by the height mic and the retainer and valve locks. The mic is expanded to take out all of the slack in the assembly and to provide a certain amount of seat pressure. The installed height can now be read directly from the scale on the side of the mic.

If you are going to install the aforementioned Crane valve springs, the proper installed height should be 1.635in with a 0.030in hardened valve shim under the spring. This will provide 105–110lb of spring pressure "on the seat." If the spring height is too low (say 1.615in without the shim), you will have to lower the spring seats by the appropriate amount (in this case 0.050in). If the installed spring height is too high, you will have to place an extra shim (or shims) under the hardened 0.030in shim to get things in order. For instance, if the measured installed height is 1.675in without the 0.030in hardened shim, it will be necessary to place a 0.010in shim under the 0.030in hardened shim (a total of 0.040in) to bring it to the proper height (1.675in–0.040in= 1.635in). These special shims are available through Goodson Automotive Machine Shop Supply, in Winona, Minnesota. As you calculate each spring height, be sure to record the proper shim combination.

Intake and Exhaust Systems

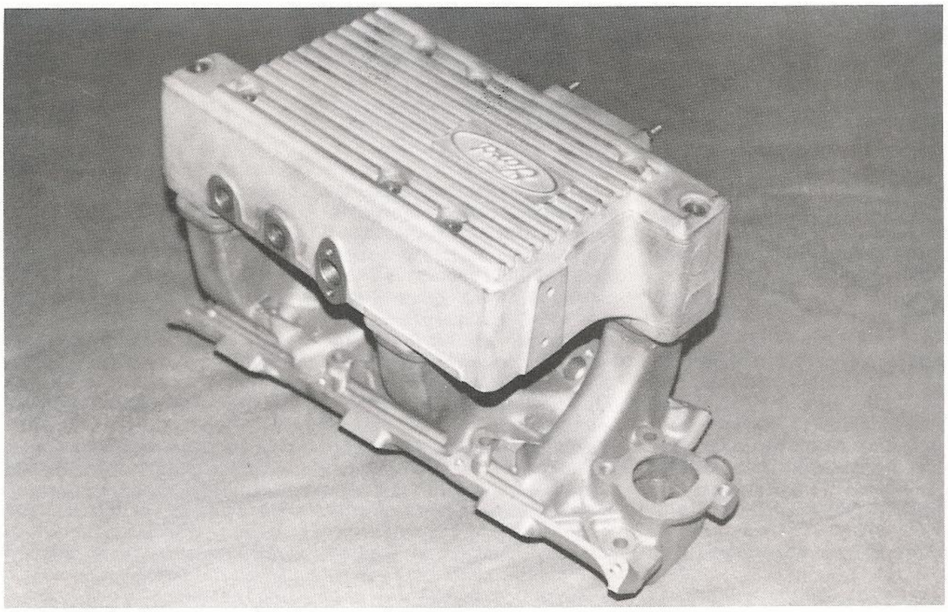
5

Intake System

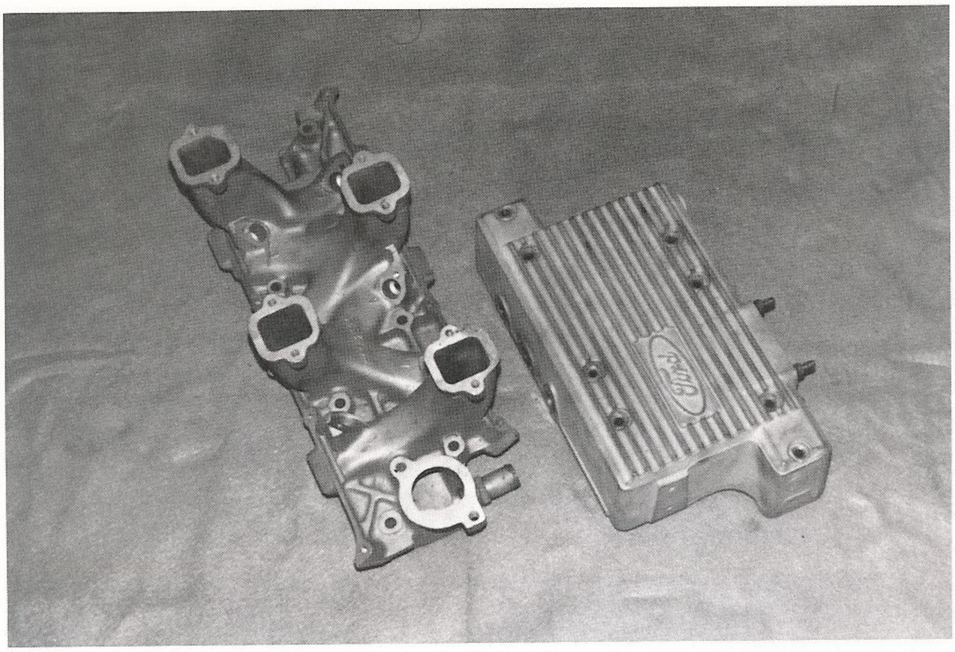
The intake manifold on any engine could perhaps be better described as an air/fuel "distributor" rather than a simple "manifold." Visualize, for a moment, what an intake manifold actually does. Basically, it distributes the air/fuel mixture throughout the engine much like the ignition distributor distributes the ignition spark energy. Obviously, any improvements in the efficiency of the intake manifold will result in increased engine power. This, coupled with the relatively low cost of such an exchange, is why the intake manifold is one of the most frequently changed components as part of one's quest for better performance. Replacing a stock intake manifold with a "performance" unit often results in one of the most noticeable improvements in engine power and economy. Such drastic improvements are the direct result of a dramatic reduction in intake flow restriction due to significantly improved flow channels or runners and the fitting of better (less restrictive) carburetor options. Typically, a well-designed performance intake manifold will offer better fuel distribution, quicker throttle response, and more torque and horsepower output.

Choosing an Intake Manifold

The first thing to keep in mind when choosing an intake manifold is that the manifold itself is nothing more than an extension of the cylinder head intake ports. Therefore, it only



The most abundant of the European manifolds was the 2.8i-liter injection manifold. This manifold only entered the United States in the TVR 280i.



The 2.8i manifold has a unique plenum and runner design. Notice that the middle pair of intake runners are siamesed and actually feed two ports each.

makes sense to complement a well-prepared set of cylinder heads with a well-engineered intake manifold. Realizing the importance of improved intake efficiency, most automobile manufacturers have developed "high-performance" manifolds for most of their engines. The Ford V-6 is certainly no exception, but most of this racing development took place in Europe in the early 1970s. Unfortunately for the U.S. builders, this means that the more desirable factory performance manifolds are not only rare, but expensive as well. In fact, these manifolds are practically unavailable to most U.S. builders. Aftermarket manifolds are not abundant either, and those that are available may not suit all performance needs.

European Manifolds

European versions of the Ford V-6 have enjoyed the use of several very effective manifolds over the years. Arguably the most popular of the "factory" combinations were the RS versions of the Ford Capri. Most of these were some sort of fuel injection manifold. The RS 2600 version of the Ford 2.6-liter engine was the most recognized in the RS fold. This combination was designed in order to homologate several competition components, specifically a unique Kugelfischer fuel injection system, for use in the European Touring Car Series. The end result of this homologation effort was the legendary Weslake/Ford V-6 and several championship wins in both Touring and Rally events.

The latest versions of the Ford 2.8-liter engines used in Europe were equipped with the very effective Bosch CIS (continuous injection system). Bosch CIS is a favorite among European manufacturers due to its simple operation and efficient fuel delivery. It responds well to modification and, coupled with a very attractive cast aluminum plenum box (similar to the RS 2600), offers striking aesthetic appeal as well. This system, like those previously mentioned, was never imported to the United States in appreciable numbers, and does not accommodate the U.S. cylinder head design.

U.S. Manifolds

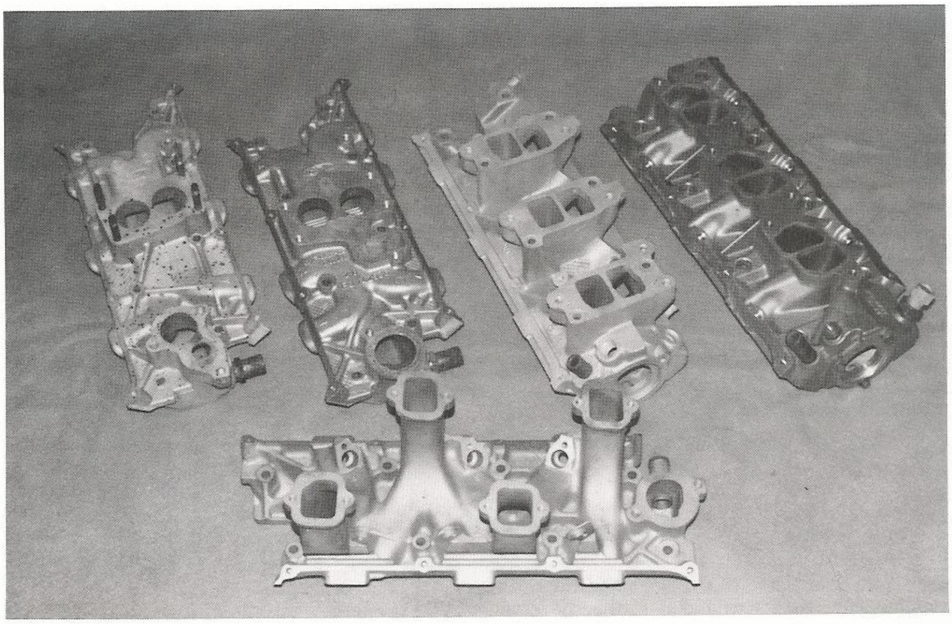
Unfortunately, the U.S. versions of the Ford 60-degree V-6 never enjoyed any performance options, due primarily to the gas crunch of the early 1970s and the subsequent emissions restrictions imposed by the U.S. government. Under these conditions, Ford decided to use the V-6 as an economical alternative to its larger displacement engines in its new line of small and midsized cars. At that time, fuel mileage was in and performance was out, hence the lack of any performance interest in the V-6. Suffice it to say that none of the U.S. (carbureted) manifolds are particularly good for performance use.

The 2.6-liter V-6 was first introduced to the U.S. market in 1972 in the Ford Capri. Throughout its short two-year tenure, the 2.6 was equipped with only one manifold designed to accommodate a Weber progressive linkage, two-barrel carburetor.

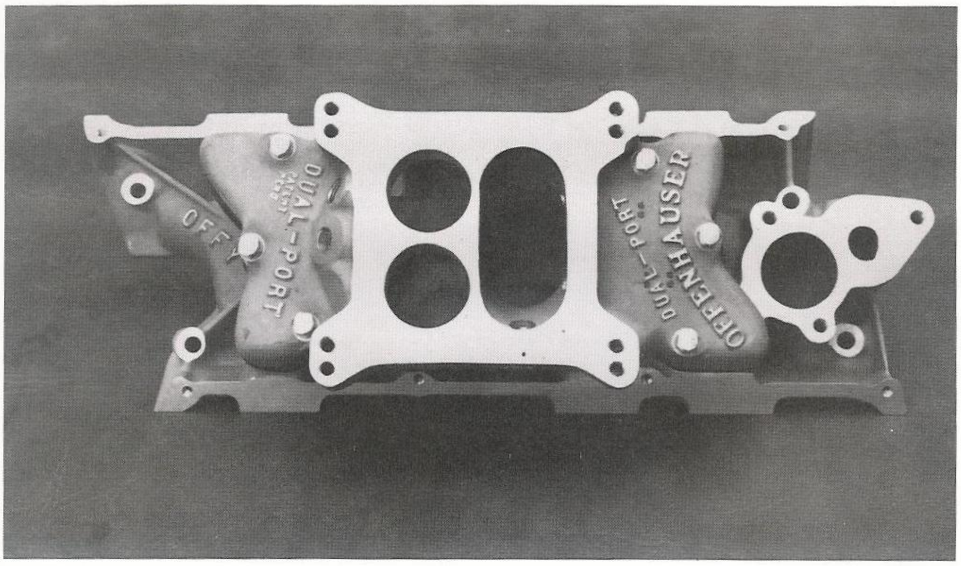
In 1974, the 2.8-liter replaced the 2.6 as the prime mover in the Ford Capri and became a popular option in the Ford Mustang II and several versions of the Ford Pinto. Although the engine had been almost entirely redesigned, the basic manifold combination remained unchanged. In fact, the 2.8-liter V-6 retained the same manifold combination until Ford ceased production of the engine in late 1985.

In early 1986, a new, electronically fuel-injected version of the venerable Ford V-6 was offered in the popular Ford Ranger pickup. This time, however, the engine possessed much more refined characteristics than its predecessors. Displacing a slightly larger 2.9-liters, the new V-6 was equipped with a hydraulic valvetrain and a very sophisticated fuel injection that not only boosted reliability but actually increased performance dramatically compared to the 2.6 and 2.8 versions of previous years. Although not a "performance" manifold combination, the 2.9 does lend itself to performance modifications.

Not too long after its debut, a second version of the 2.9-liter V-6 appeared in a new European-built Ford called the Merkur Scorpio. These luxury/touring sedans were sold through several Lincoln/Mercury dealers throughout the United States. Although essentially identical to the 2.9 Ranger engine, the Scorpio 2.9-liter V-6 incorporated a significantly different fuel injection sys-



From left to right we have the stock 2.6, 2.8, 2.9, 4.0, and in the foreground, the 2.8i intake manifolds. Only the first four examples exist in the U.S. market.



The Offenhauser Dual-Port manifold represents the only aftermarket intake manifold available for the Ford 2.6- and 2.8-liter V-6.

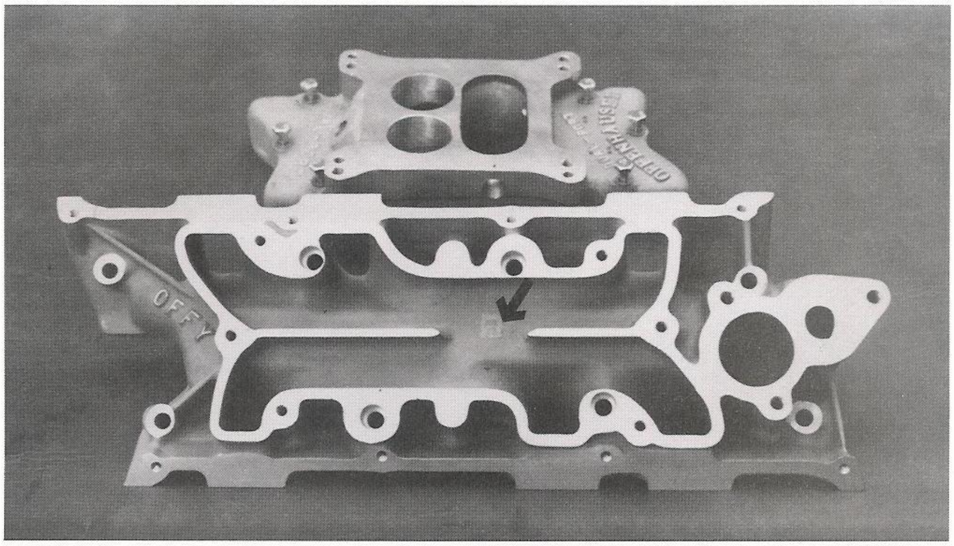
tem, easily identified by its dual throat throttle body. Basically, the Scorpio V-6 retained the same fuel injection system used on the European models of the same car. The Scorpio manifold design lends itself better to high-rpm operation than does the Ranger manifold. Therefore, you should carefully evaluate your intended use of the engine prior to selecting the Scorpio manifold.

In 1989, Ford introduced what would become one of the best-selling sport/utility vehicles in the United States, the Explorer. Once again, Ford turned to the V-6 as its primary source for power. The newest version of the V-6 now displaced a whopping 4.0 liters and had an entirely new design, sharing nothing with any of the earlier models. Once again, Ford incorporated a sophisticated electronic fuel injection system very similar to the 2.9. This time, however, only one version was available to the public.

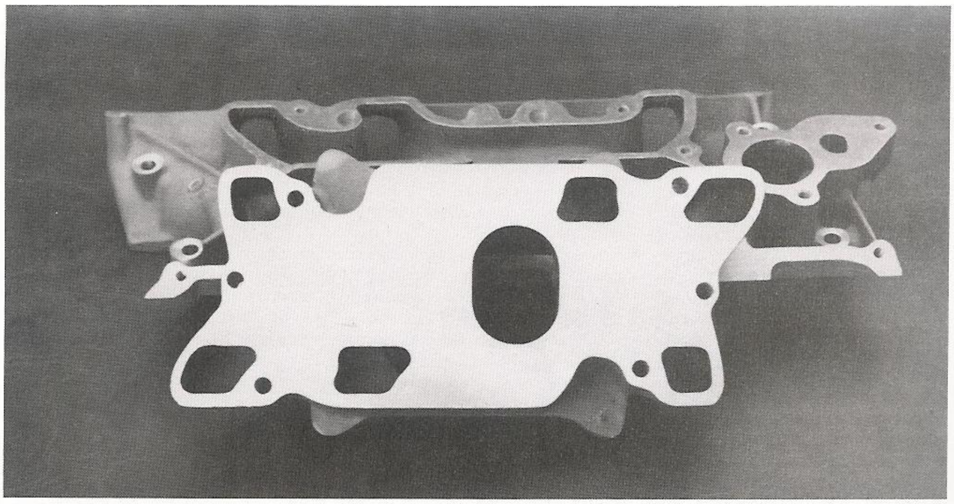
The 4.0 manifold is remarkably well designed and is very responsive to performance modification. In fact, the manifold is so well designed, the first modification to improve the intake system performance is usually the fitting of a larger throttle body. However, if your performance expectations go beyond what the stock manifold will accommodate, the monetary investment required for proper modification will be considerable. It is a good idea to consult with a professional engine builder who is well acquainted with these engines prior to pursuing your goals.

The Offenhauser Dual-Port Manifold

Available in both 2.6- and 2.8-liter configurations, the Offenhauser Dual-Port intake manifold, available directly from Offenhauser Sales Corporation in Los Angeles, is the only aftermarket manifold currently manufactured (at this writing) for the Ford 60-degree V-6. In street-performance applications, the "Offy" offers very good low and midrange power and torque characteristics. The patented Dual-Port design actually separates the primary and secondary carburetor circuits into two individual (relatively small) passages. As a result of this unique arrangement, a high mixture velocity is maintained in both the primary and secondary passages of the manifold thus creating a wider torque curve than would normally result if a conventional manifold were used. An added benefit of the Dual-Port concept is that carburetors can actually be a bit too large and still per-



The lower half of the Offy manifold is almost a carbon copy of a stock intake manifold except that the plenum divider has been relieved in the middle.



The upper portion of the Offy intake shows an entirely separate secondary manifold channel. This, in essence, creates a manifold inside a manifold.

form well. In fact, Holley 465cfm carburetors are frequently used in racing V-6s with little to no loss in low and midrange power.

Both the 2.6- and 2.8-liter Offy manifolds are available in either two- or four-barrel configurations. It has been my experience that the four-barrel Offy manifold is the only option worth considering if serious performance is your goal. I have found that the two-barrel option is only marginally better than the stock two-barrel manifold and becomes a significant restriction at higher rpm.

Manifold Angle Correction

Ideally, installing your new intake manifold would involve nothing more than installing a new gasket and bolting things together. Unfortunately, this is usually not possible because of unique dimensional conditions created when the cylinder block and heads are machined. Anytime the block or heads are milled, the original head, block, and manifold relationship is no longer proper. When you mill either the heads or block (or both), the heads actually move closer together and as they do so, the intake manifold is pushed farther away from the sealing surfaces on the heads and block.

In order to restore the proper relationship, the intake manifold sides and bottom must be machined. By using a fairly complex calculation, you can determine the exact amount of material removal required based on the total combined amount of material that has been removed from both the block and cylinder heads. I am sure, however, that you did not purchase this book in order to exercise your mathematical abilities. Therefore, the chart below will help you with this task. Remember to have all machining done by a qualified machine shop.

Intake Manifold Correction Chart

If head/block have been milled by:	Mill manifold sides:	Mill manifold bottom:
0.005in	0.004in	0.007in
0.010in	0.008in	0.015in
0.015in	0.012in	0.022in
0.020in	0.016in	0.029in
0.025in	0.019in	0.037in
0.030in	0.023in	0.044in
0.035in	0.027in	0.051in
0.040in	0.031in	0.058in
0.045in	0.035in	0.066in

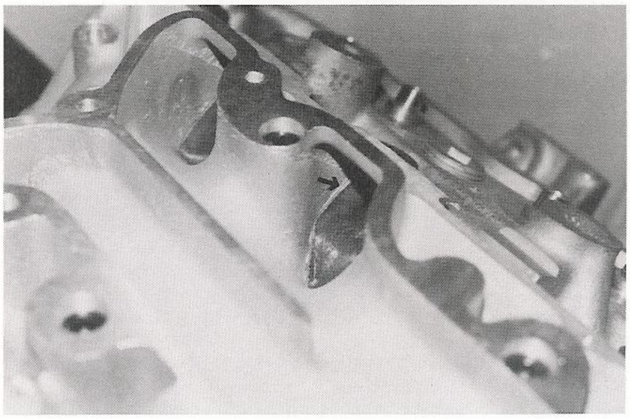
The above figures are based on material removal off the nominal factory deck height.

Manifold Fitting (Offenhauser)

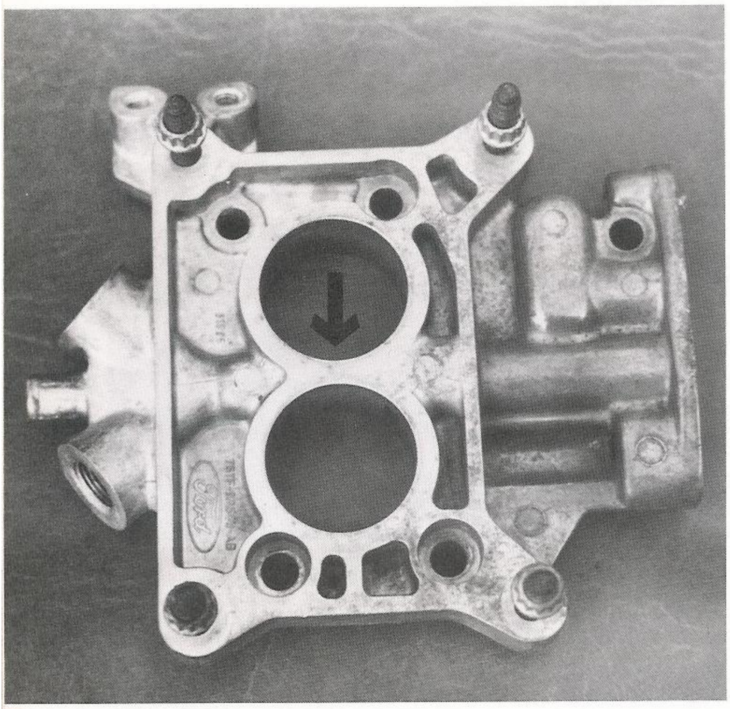
Fitting the intake manifold to the engine is no less critical than fitting the pistons to their respective bores. Even small errors in manifold port alignment can result in drastic intake flow disturbances. Therefore, the time you take to do the job right is unquestionably well spent.

Before you can begin manifold fitting you must have at your disposal the set of finished heads that you will use on the engine and the finished cylinder block. Bolt the heads to the block using the proper head gaskets and torque them to specifications. It is not necessary, nor advisable, to have valves installed in the heads as they may become damaged during the following procedures.

Place the manifold gasket on the block and bolt the manifold base to the block. With a sharp X-Acto knife, trim any excess gasket material that is protruding into the intake port. Once the gasket has been trimmed, inspect the juncture between the manifold and the intake port. If a



In most cases, the intake gaskets will protrude into the intake ports slightly. This blocks a considerable amount of flow if left unattended. Trim the excess gasket material using a sharp X-Acto knife.



Many 2.8-liter U.S. specification engines used a carburetor adapter similar to the one shown. By milling away the center web, this adapter will accept the popular Holley 0-7448 performance two-barrel carburetor.

ridge is present in this area, remove it using a medium grit sanding roll. Be careful not to remove any more material than is necessary to smooth this juncture. You will usually find that the intake manifold runner is slightly smaller than the port. This is purposely done to allow for port matching. Refer to the associated photographs for more information.

Carburetion

The first thing to keep in mind is that this section is not intended as a carburetor tuning guide. Instead, it should help you get started with engine break-in and provide guidance that should help you avoid many of the potential pitfalls associated with the setup of the carburetor. Additionally, this section will offer several time and money saving tips as well as a few low-buck performance enhancements.

Before you begin the procedures described in this section, you should purchase a good tuning manual written specifically for the Holley Model 2300 and 4150/4160 modular carburetors. I can recommend the following: *Holley Carburetors and Manifolds*, by Urich & Fisher; *Holley Rebuilding & Modifying*, by Jeff Williams; and *Super Tuning and Modifying Holley Carburetors,* by David Emanuel. All of these manuals are available through Motorbooks International in Osceola, Wisconsin (1-800-826-6600).

Choosing a Carburetor

Choosing a carburetor for your particular engine combination can be terribly frustrating. After all, numerous carburetors are available for the Ford V-6, and each one will have some advantages and some disadvantages. The one thing that most influences carburetor selection for a performance Ford V-6 engine is the intake manifold. As we discussed earlier, there are basically two choices of intake manifolds for the carbureted versions of the Ford V-6. First, there is the stock two-barrel manifold. I will include the two-barrel version of the Offenhauser manifold in this description as well. Second, there is the more desirable Offenhauser four-barrel manifold. Obviously, the carburetor requirements for these manifolds are vastly different. That being the case, I will discuss them separately.

Two-Barrel Performance Carburetors

For years, the Weber carburetor was touted as the only one to have for the Ford V-6. But after years of performance tuning this is no longer true. The parts are increasingly scarce and, at the hands of the average enthusiast, the Weber carburetor tends to be somewhat difficult to tune. Furthermore, the performance of the applicable Weber is less than spectacular.

Ideally, a good two-barrel carburetor would be easily available, inexpensive, very tuneable, easy to service, and would provide exceptional performance. The Holley Model 2300 (list #0-7448), 350cfm two-barrel performance carburetor meets all of these criteria with ease. This carburetor is essentially the front half of a standard Holley

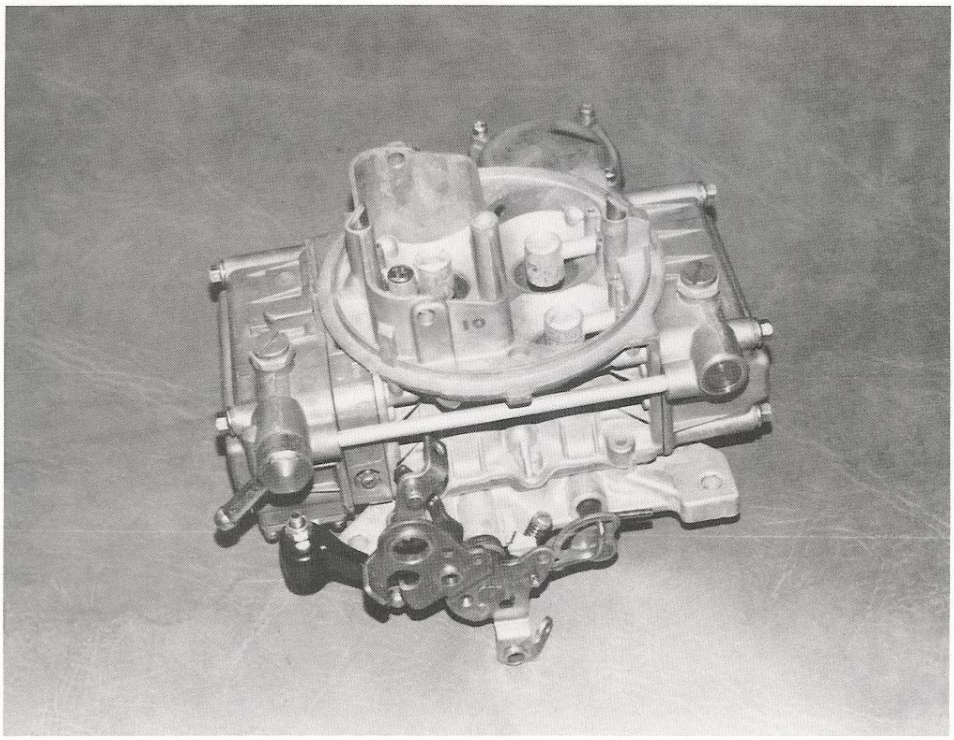
(4150/4160) four-barrel carburetor. Therefore, most of the tuning tips applicable to Holley four-barrels also apply to this one. This carburetor should be used in all performance applications that require a two-barrel manifold combination. Interestingly, this carburetor is so user-friendly, it makes a very desirable replacement to the stock Weber or Motorcraft factory carbs.

When restricted to the use of a two-barrel carb, you should remember a few rules of thumb to get the most from your investment. First, resist the temptation to "over-cam" the engine. Two-barrel carbs will respond better to relatively short duration cams with fast lift rates. Look for something in the 210-225 degree duration (@ 0.050in) range. Second, install an open plenum spacer under the carburetor. This spacer should be a minimum of 3/4in thick. An inexpensive alternative to making a spacer of this type is to use a spacer from a 1976 Mustang II or Capri that was fitted with the Motorcraft carburetor.

Simply mill out the divider between the two throttle bores on the plate and seal off any remaining holes once dedicated to emissions devices. Install the spacer using new gaskets on each side. These gaskets should also have the material between the throttle holes removed. Once you have completed these steps, simply follow the setup and tuning sections in this book that apply to the primary side of the Holley four-barrel carburetor.

The Holley 390cfm Four-Barrel

When Offenhauser introduced its Dual-Port four-barrel manifold for the Ford V-6, it exposed Ford V-6 enthusiasts to an entirely new performance carburetor option. That option was the 390cfm Holley four-barrel carburetor. Holley four-barrels have been used on championship-win-



The Holley 0-8007 four-barrel carburetor is an excellent choice for the Ford V-6.

ning racing vehicles from the drag strips and speedways of the United States to the endurance road racing circuits of Europe. The Holley four-barrel is without question one of the most versatile, successful, and tunable carburetors in the world.

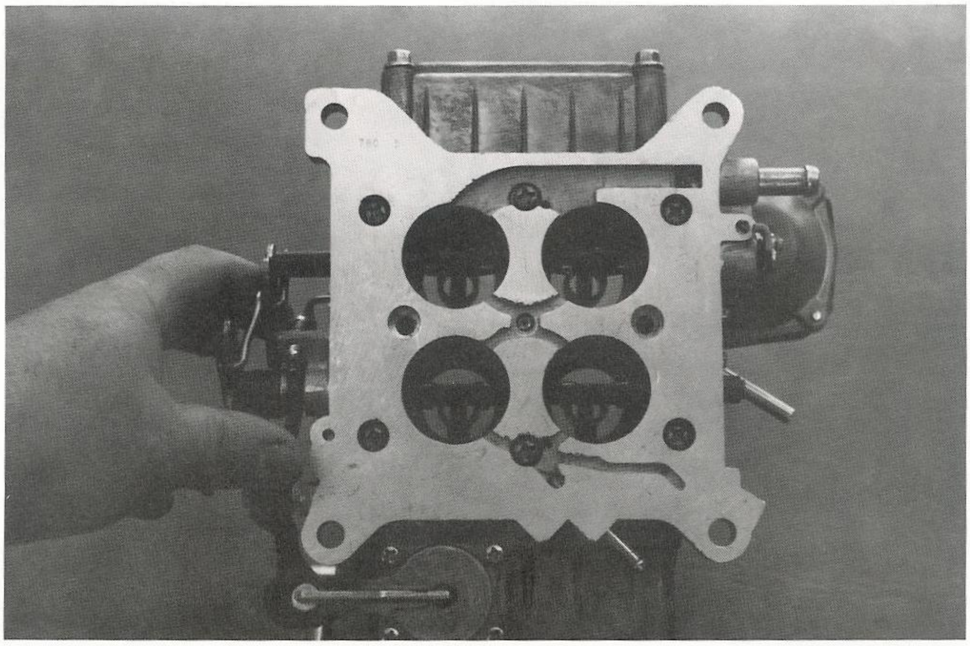
For performance Ford V-6 applications, the best Holley four-barrel carburetor available is the list #0-8007, 390cfm, model 4160. Although other 390cfm carbs are available, the 0-8007 requires the least amount of modification to provide optimum performance. The 0-8007 will accept most of the Holley "trick" parts such as center hung floats, secondary metering blocks, 50cc accelerator pumps, and so on. It works very well with increased compression ratios and "big" camshafts. In fact, the 390 four-barrel easily accommodates engines capable of producing in excess of 220 horsepower. The Holley 390cfm carburetor/Offenhauser Dual-Port intake manifold combination is, without question, the most effective, readily available intake system for a high-performance Ford V-6.

Four-Barrel Carburetor Preparation

Although this section is written primarily for the Holley four-barrel, most of the preparation steps specific to the primary side of the carburetor will also apply to the two barrel. Before you begin preparing your carburetor, you must do away with the "bolt-it-on-and-run-it" attitude. Under no circumstances should you install any carburetor without first ensuring its proper assembly and integrity. Like any other component in a performance engine, the carburetor must be properly prepared before it can provide optimum performance. Additionally, several components of the carburetor will require either alteration or replacement, such as gaskets, seals, and floats. Most of these modification/substitutions make tuning and servicing the carburetor more user-friendly.

External Inspection

Begin the inspection process by unpacking your carburetor and giving it a very careful visual inspection, noting any obvious physical damage to external components. Check to see that all of the throttle linkages operate

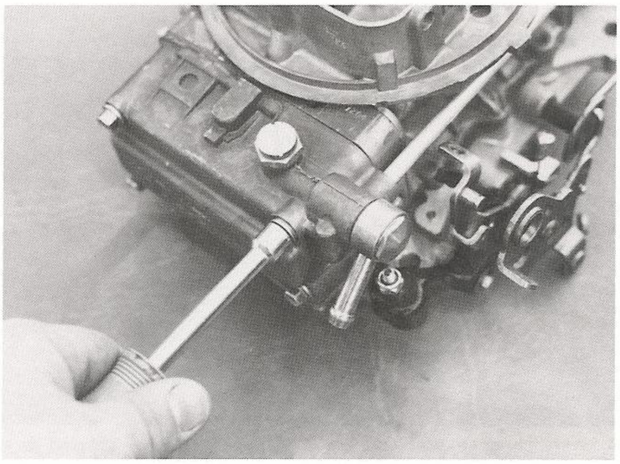


Make sure both the primary and secondary throttles open freely by manually operating the primary and secondary throttle shafts.

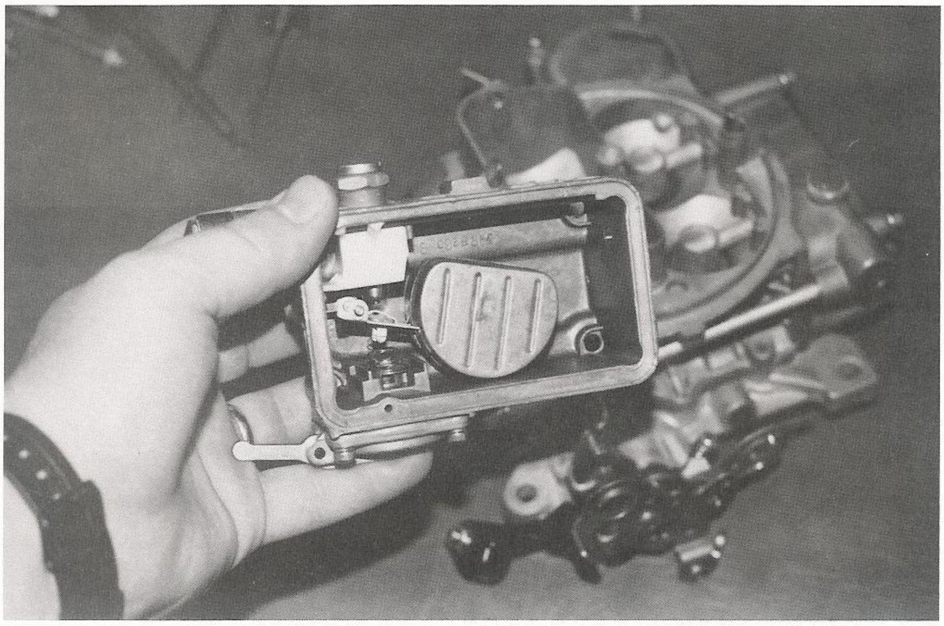
properly with no evidence of binding. Make sure that the accelerator pump linkage operates smoothly and returns to its "neutral" position when the throttles are closed. Manually operate the secondaries to ensure proper movement. If there are no signs of any physical defects, you can begin the internal inspection. If damage is evident during your visual inspection, return the carb to the seller and get a new one.

Internal Inspection

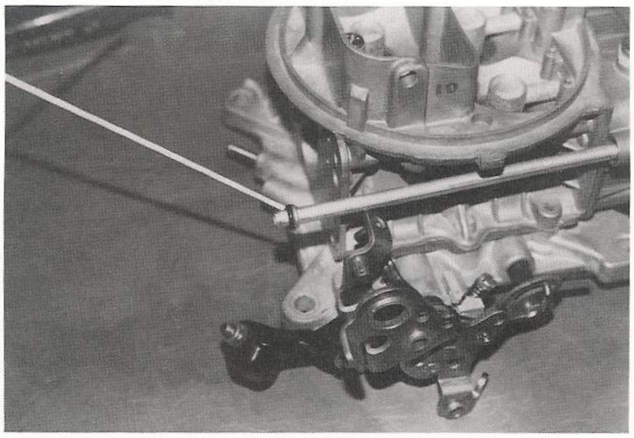
When your visual inspection is complete, it is time to get inside the carb and continue the inspection. First, remove the four float bowl screws from both the primary and secondary float bowls. As you remove each screw, carefully remove the sealing washers from each one. Be care-



A properly sized nut driver will make removing the float bowls very easy.



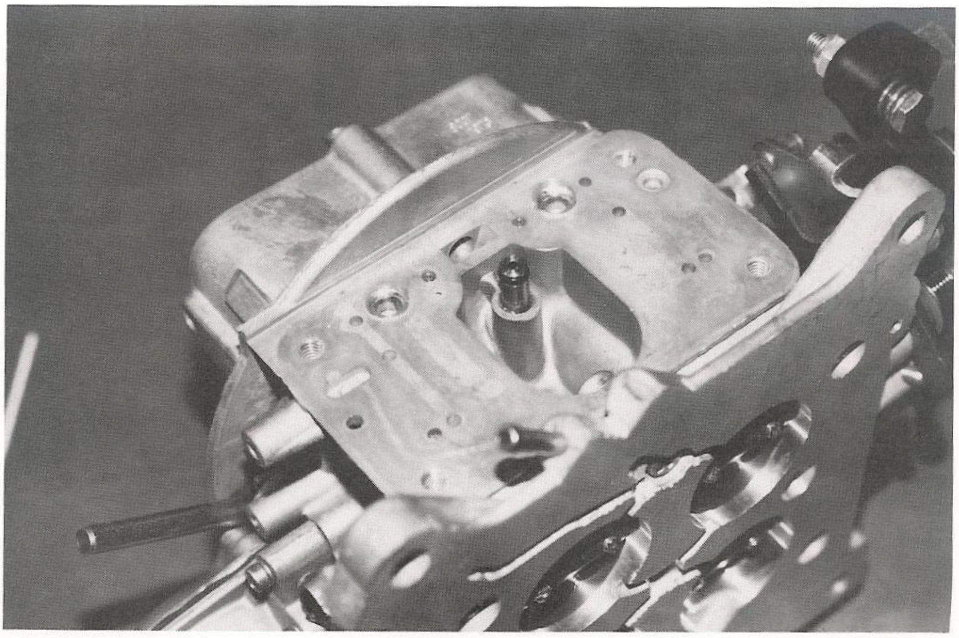
Make sure that each float travels freely and that the needle and seat does not bind.



When removing the float bowls, be very careful to avoid damaging the balance tube O-rings.

ful not to mix up the primary and secondary components as they are removed.

With a small screwdriver, carefully pry the bowls away from the carburetor body. Be careful not to damage the fuel balance tube and its O-rings. With the bowl removed, check to see that the float travels freely and that the needle and seat assembly does not bind. Now work the metering plate gradually from side to side with the small screwdriver until it is free, taking extreme care not to damage the small brass transfer tube. Using a clutch type screwdriver (NAPA #M-135) remove the six retaining screws holding the secondary metering plate to the carb body. Remove the plate taking care not to bend the thin steel

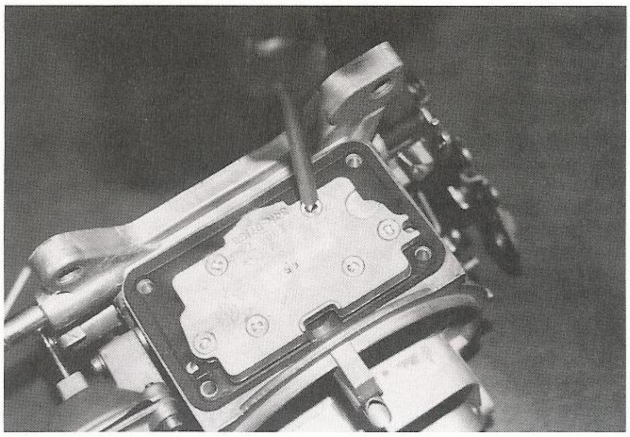


The accelerator pump transfer tube is very delicate. Extreme care should be taken when removing the primary metering block to avoid damage.

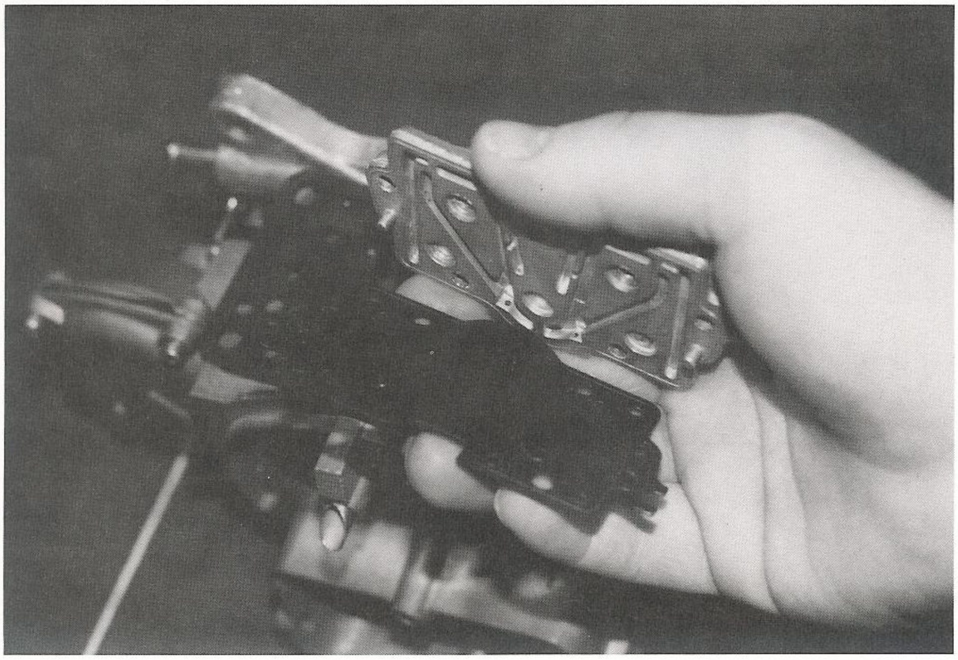
backing plate located between the metering plate and the carb body.

Now that the carb body is exposed, remove any gasket material that remains stuck to the bowls, plates, and carb body using gasket remover. It may help to use a small steel "toothbrush" to loosen this material. Once the gasket material is gone, clean the components thoroughly using large quantities of spray carburetor cleaner. "Canned air," used to blow dust from computer equipment, is wonderfully useful for dislodging small particles of foreign matter and for drying components quickly during these operations.

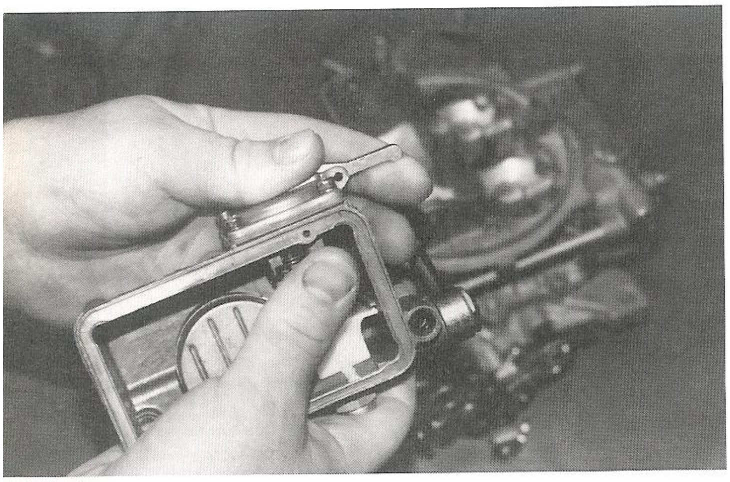
With all of the components cleaned, you can now begin making sure that the carburetor has



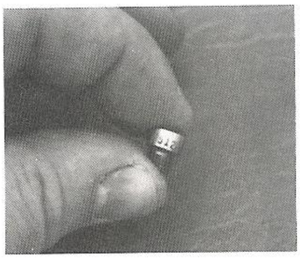
A special clutch-type screwdriver will be required for removal of the secondary metering plate.



When removing the secondary metering plate, do not bend the thin steel backing plate mounted behind it.

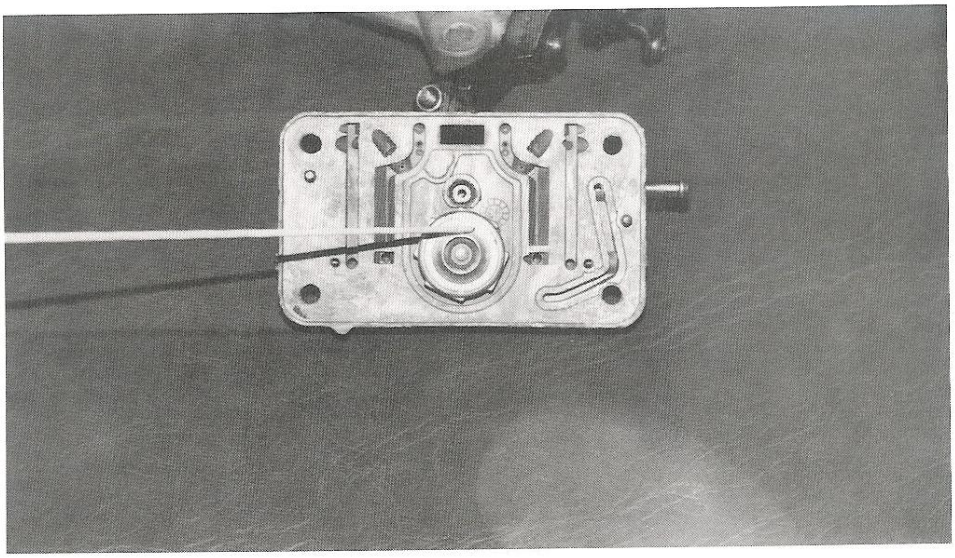


To check the accelerator pump operation, place your thumb over the pump outlet port and operate the pump lever. You should feel pressure build as the pump lever is cycled. If no pressure builds, suspect the pump is at fault and repair it.



All model 8007 Holleys should come equipped with #51 close-limit main jets. This is a good place to start for almost all performance V-6 applications.

been properly assembled, and you can begin the "upgrades" described earlier. Start by checking the operation of the accelerator pump. Place your finger over the pump discharge port in the primary float bowl. As you activate the pump lever, you should feel



The Holley 8007 should be equipped with a #65 power valve. This will likely require no change in street performance applications.

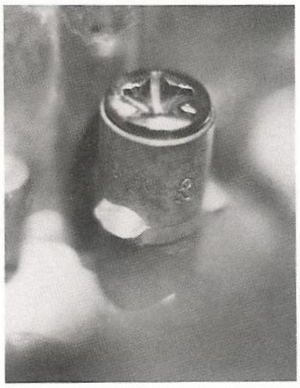
pressure. If you cannot, remove the pump cover to determine the problem.

Next, replace both the primary and secondary float assemblies with brass floats (Holley part #116-4). You should use brass floats in all performance applications except when using a blow-through style turbo or supercharger. In these cases, the plastic or Nitrophyl floats are necessary as the boost pressure will crush the brass units.

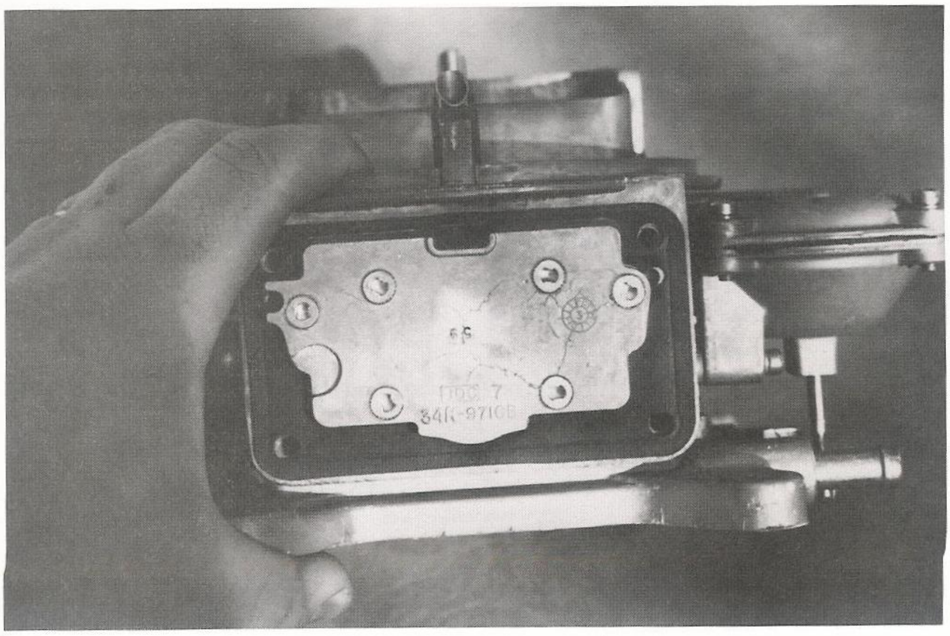
Next, remove the fuel inlet fitting from the primary bowl and discard the brass screen filter. Check to see that the primary metering plate is equipped with #51 main jets and a #65 power valve. Likewise, check to see that the secondary metering plate is a either a #34 (earlier carbs) or a #59 (later carbs). In most cases, the #59 secondary metering plate works best in the Ford V-6 applications since it runs a little richer on the top end than the #34 plates. Finally, check to see that the carb body is fitted with a #25 standard style accelerator pump shooter. When the above procedures are complete and the noted items are correct, you can begin the carburetor setup procedures.

Setting Float Levels

Unquestionably, the most common error in carb setup is misadjusted float levels. A float level that is too low will result in a lean air/fuel mixture and, as a result, a flat spot and/or stumble under acceleration. Conversely, a float level that is too high will re-



Pump squirters for the 8007 Holley should be a standard configuration type with 0.025in orifices. This squirter can be identified by the #25 stamped on its body.



Older Holley 8007 carburetors were equipped with a #34 secondary metering plate. Newer versions of the same carburetor are now equipped with a #59 plate. In many applications, the #59 plate is preferred due to its slightly richer mixture at high rpm.

sult in an excessively rich air/fuel mixture. This condition could result in flooding, fuel percolation, and engine racing just after startup. Most Holley manuals recommend that the floats be set on a running engine, so that fuel just begins to drip from the sight plugs in each float bowl. In reality, it is pointless to set float levels on a running engine. The vibration associated with a running engine is simply too great, making external float adjustment too inaccurate, even for street applications. Therefore, take careful note of the following float level setting procedures so you can avoid future headaches in this area.

Starting with the primary float bowl, loosen the inlet needle set screw. Turn the bowl upside down and insert a #10 (0.1935in) drill bit between the end of the float and the bowl. Turn the adjusting nut on the inlet needle until the float just clears the drill bit when the bowl is level. Tighten the set screw. For the 0-7448 two-barrel with a center hung brass float, follow the same procedure using a 3/8in (0.3750in) drill bit. Repeat the above procedures for secondary float bowl adjustment on the 0-8007 four-barrel using a #2 (0.2210in) drill bit.

Once the floats are adjusted according to the above procedures, they should require little or no future adjustment.

Power Valves

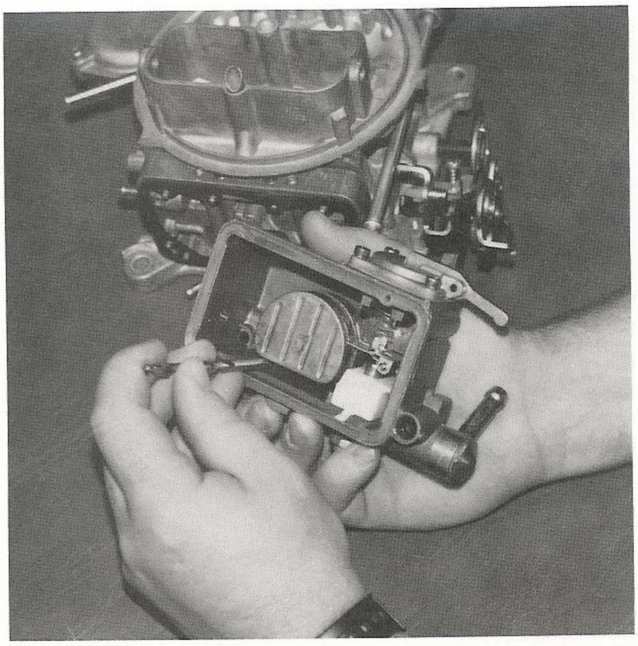
Generally, the 0-8007 four-barrel will require very little attention with respect to power valves. You should have already verified that the carburetor was fitted with a #65 power valve. The power valve number indicates the vacuum level (in inches of Hg) at which the valve opens. In this case, the power valve opens at 6.5in Hg. The #65 power valve should be perfect in all performance applications using the 0-8007 four-barrel with the exception of engines operating at extremely high altitude. In these applications, a #50 or a #45 will usually suffice.

Many prospective builders have been misled into believing that removal of the power valve and plugging the resulting hole is directly associated with true performance carburetion. The truth of the matter is that this is miserably false. Power valve removal is done only on the *secondary side* of racing "double-pumper" carburetors, never the primary side. Since the Ford V-6 does not require the use of a "double-pumper" carburetor, power valve removal is never a consideration.

Power valves are required to augment the fuel supply under hard acceleration by precisely metering an appropriate amount of extra fuel. When the power valve is removed, you run the risk of encountering an extremely lean condition that may result in catastrophic engine failure. To help avoid this problem, a drastic increase in main jet size is required. The resulting over-rich condition caused by the use of excessively large main jets effectively destroys part-throttle performance and economy. To avoid all of these headaches, simply leave the power valve in the carburetor.

Main Jets

As you are now aware, the 0-8007 Holley four-barrel comes equipped with close limit (1.5 percent possible flow variation) #51 main jets. These jets should work well at altitudes below 2,500ft. If your average local altitude exceeds 2,500ft, reduce the

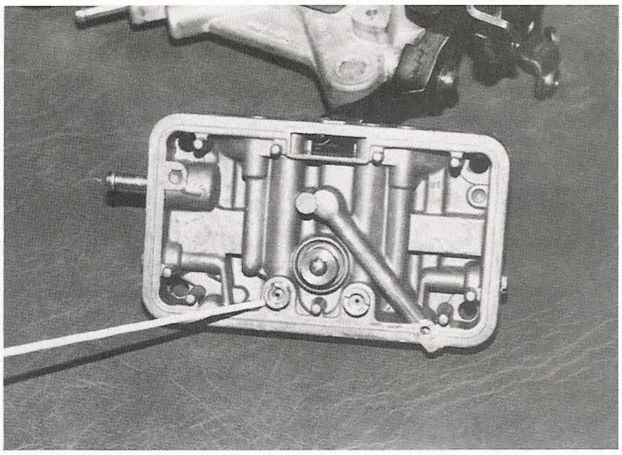


Float levels can be very accurately set using a properly sized drill bit as a gauge. Here, a model 8007 Holley primary float is set using a #10 drill. When setting the secondary float a #2 drill should be perfect.

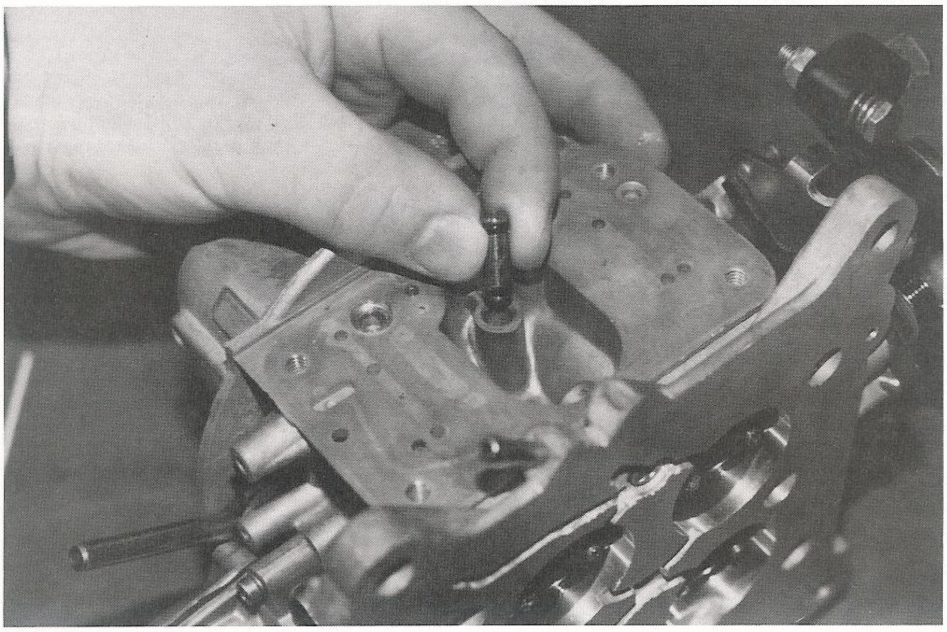
main jet size about one size for every 2,200-2,500ft above sea level. For example, let's say you live in a city with an average altitude of 2,600ft above sea level. In this case, you would want to reduce the main jet size in your 0-8007 carburetor by one jet size, from a #51 to a #50. If you live in the mile-high city of Denver, you would want to use a #48 main jet because the average altitude is close to 6,000ft. As with any engine, it may be necessary to fine-tune the main jet size according to engine demand, but it should not require more than about a one or two jet size adjustment.

Reassembly

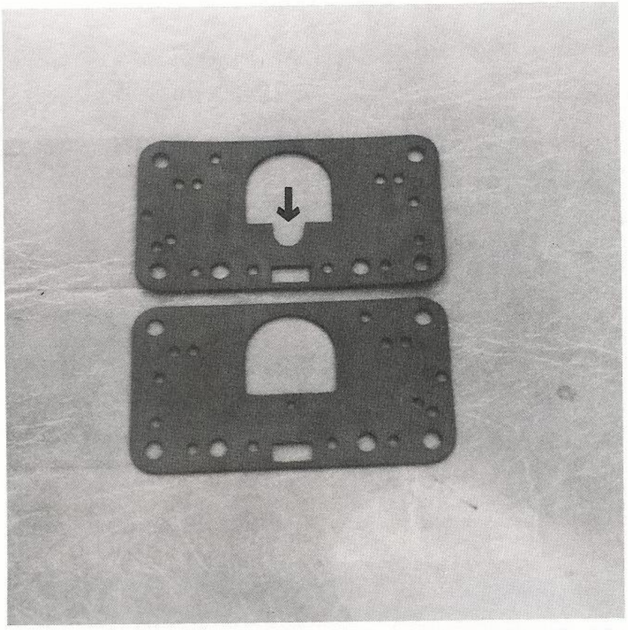
Now that the preliminary setup procedures are complete, the carburetor can be carefully reassembled. Begin by cleaning



Holley main jets are located in the lower front portion of the primary metering block.



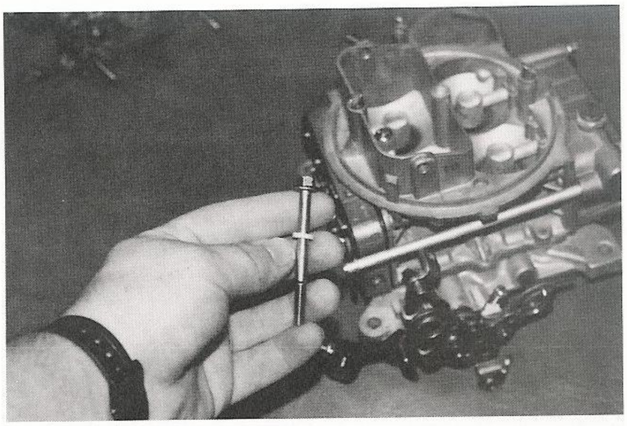
Prior to installing the accelerator pump transfer tube, lubricate each O-ring with petroleum jelly. This will help ease the installation of the tube and prevent damage to the O-rings during assembly.



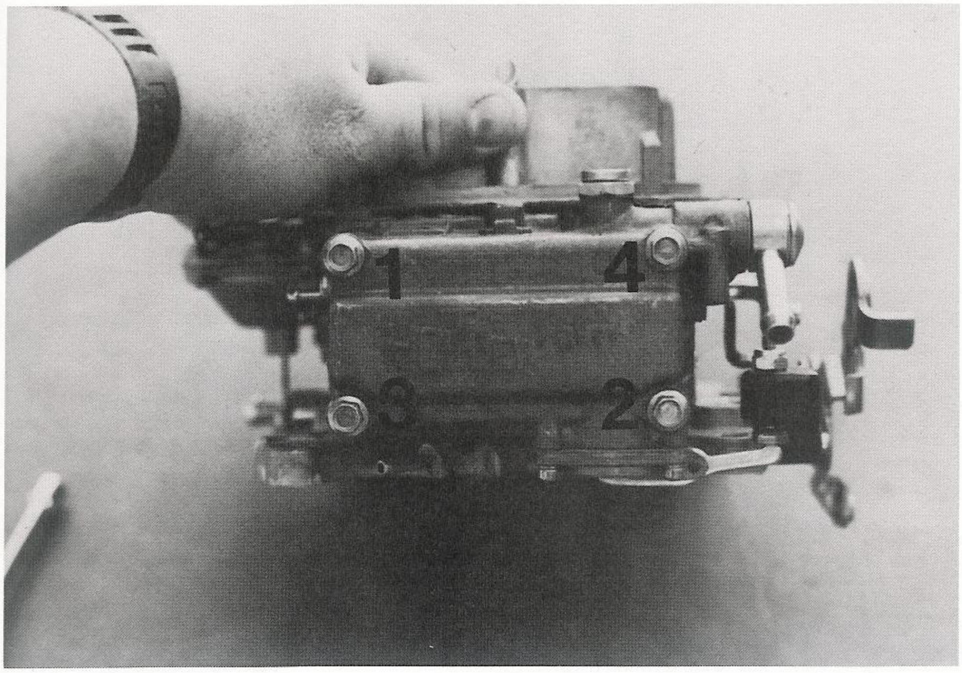
The Moroso #65222 Primary metering block gasket is a very handy, reusable gasket. To fit the 8007, the gasket will require a slight modification to clear the accelerator pump transfer tube (top). The gasket at the bottom is unmodified.

the metering block, throttle body, float bowls, and metering plate with spray carburetor cleaner. Allow these parts to dry thoroughly. When dry, use canned air to blow all dirt out of each orifice. Install the accelerator pump transfer tube into the carburetor body. Be sure to lubricate the transfer tube O-rings with petroleum jelly before installation. Install the primary metering block using a modified Moroso #65222 metering block gasket (see photos). Next, fit the primary float bowl to the carburetor using a Moroso #65224 float bowl gasket. Replace the washers on each float bowl screw using the nylon washers supplied in Moroso kit #65225. Like the Moroso carburetor gaskets, the nylon washers are also reusable and therefore should not be discarded during future carburetor service. Finally, install the four primary float bowl screws and tighten them snugly in a crisscross pattern.

Begin assembly of the secondary side of the carburetor with the installation of a Moroso #65223 metering plate/float bowl gasket. Next, install the metering body backing plate, backing plate gasket, and metering plate using the six clutch head screws. Tighten these screws snugly using the appropriate clutch-type screw driver. Replace the washers on each float bowl screw using the remainder of the nylon washers in the Moroso #65225 kit (you will likely have a few left over). Lubricate the O-rings located at each end of the aluminum fuel balance tube with petroleum jelly. Install one end of the balance tube into the primary float bowl until it is seated firmly. Install the secondary float bowl taking care not to damage the balance tube or its O-rings in the process. Make sure the balance tube is seated firmly. Finally, install the secondary float bowl screws, tightening them



Nylon float bowl washers are an absolute necessity when tuning a Holley carburetor. These are supplied in the Moroso #65225 kit.



Float bowls should be tightened in a crisscross pattern in gradual steps as shown.

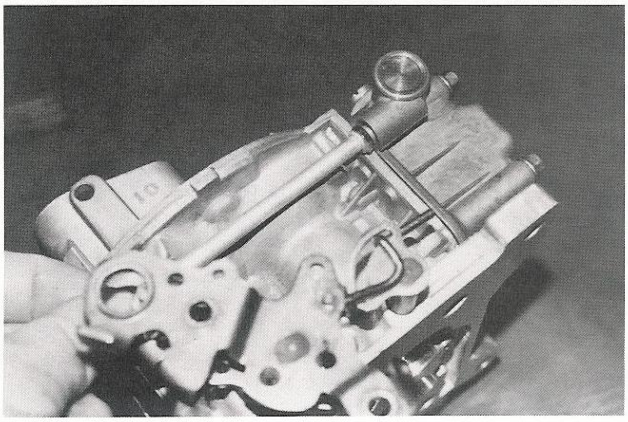
snugly in a crisscross pattern.

Bench-Tuning

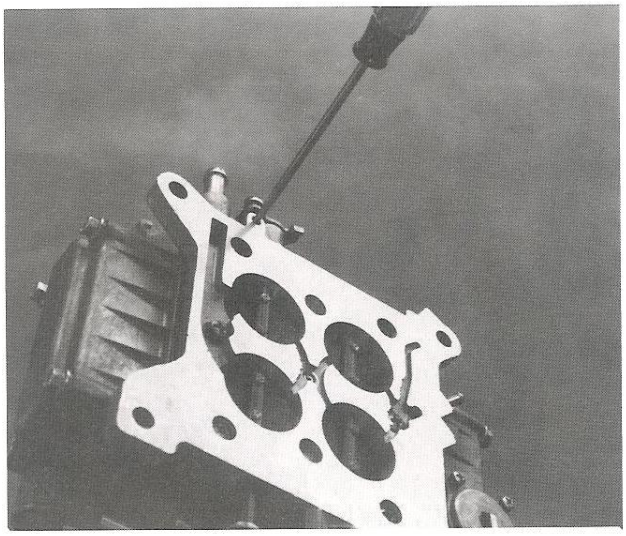
Bench-tuning the carburetor is done so that the carburetor will allow the engine to start and run throughout the break-in procedure with minimal effort. Furthermore, many of the forthcoming tuning steps will save enormous amounts of time when the actual fine-tuning of the engine is at hand.

Secondary Throttle Opening

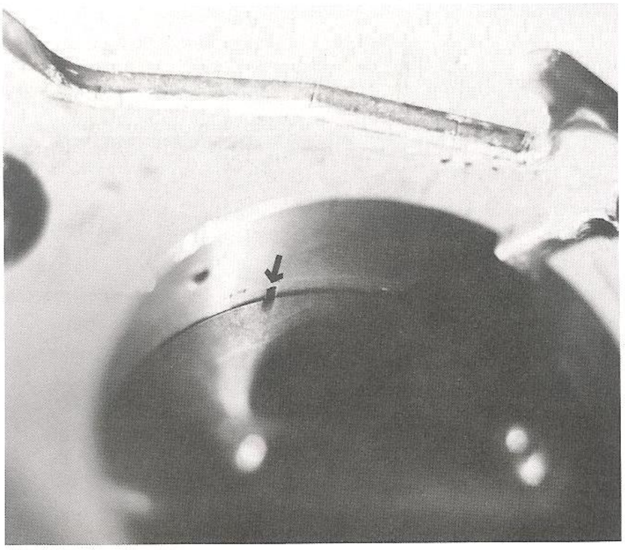
Proper adjustment of the secondary throttle opening is critical to achieving optimum idle mixture sensitivity. Proper adjustment is accomplished by turning the carburetor upside-down on a clean work table. Turn the secondary adjusting screw clockwise



The balance tube O-rings should be lubricated with petroleum jelly to avoid damage during installation.



The secondary throttle adjusting screw can only be accessed from the bottom of the carburetor.



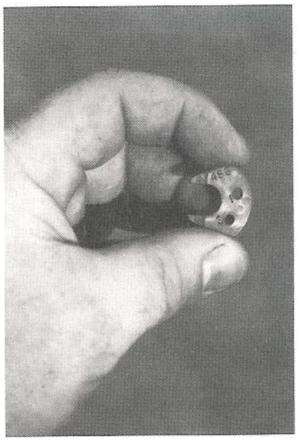
A properly adjusted secondary throttle opening will allow you to see just the top of the secondary idle transfer slots.

until the secondary idle transfer slots are just barely exposed. This will now allow adjustments to the primary idle mixture screws to be more effective.

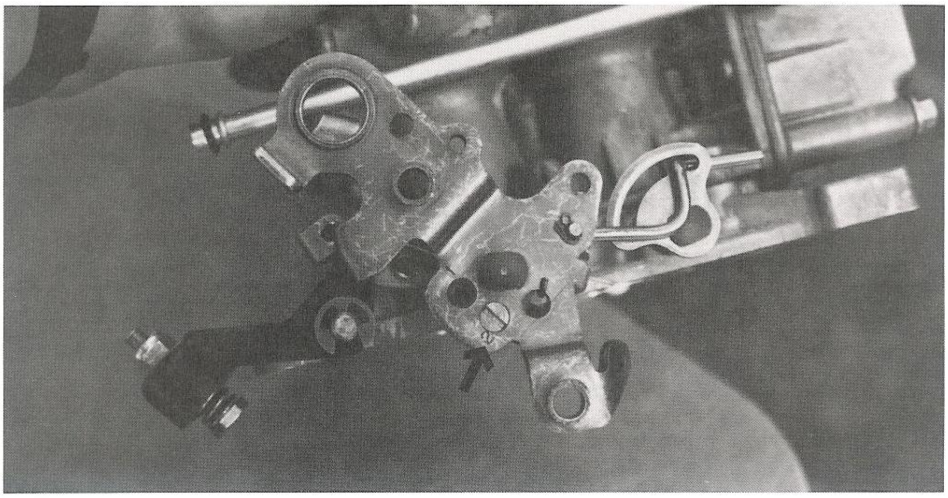
Accelerator Pump System

Most 0-8007 Holley carburetors will require little attention to the accelerator pump system. You should have already verified that the proper (#25) pump shooter is installed and that the pump is functioning properly. This leaves the pump cam and linkage adjustment to be verified.

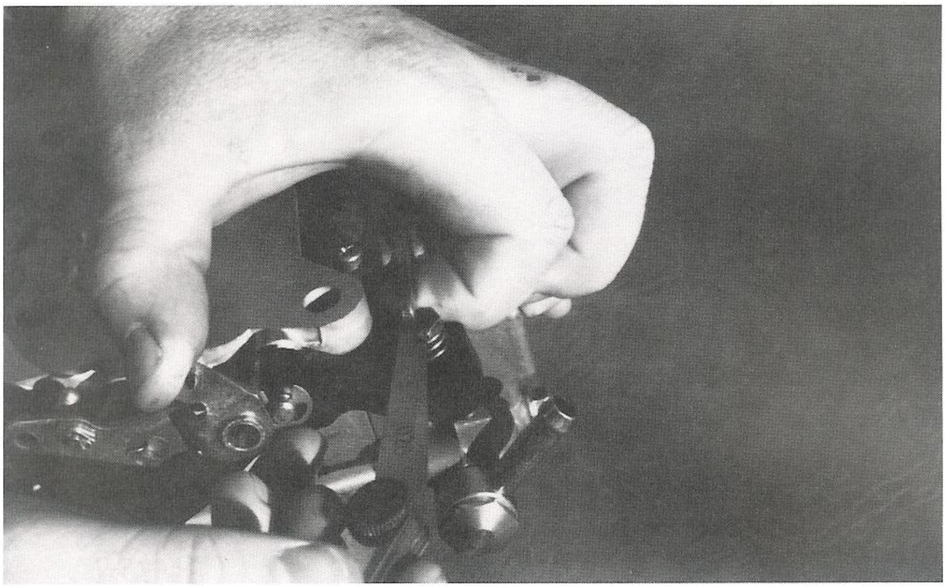
The accelerator pump cam installed in the 0-8007 should be a #466, and it should be installed in the number two (2) position. Adjust accelerator pump lever so that it provides 0.020in clearance when the pump arm is fully compressed at wide-open-throttle (WOT). Refer to the photos included in this chapter for further information. Once these few items have been attended to, the accelerator pump system should require nothing more than a little fine tuning.



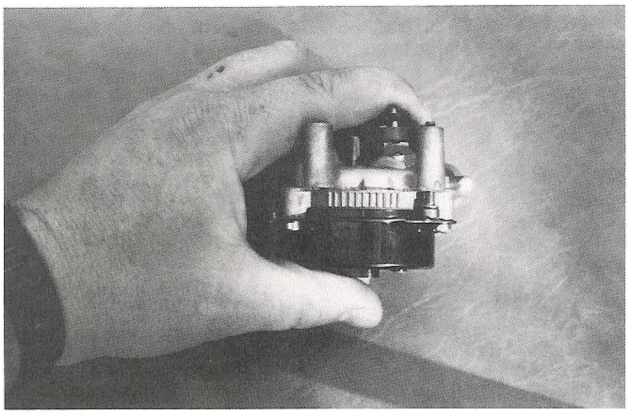
The #466 accelerator pump cam should work very well with most Ford V-6 engines. All Holley 8007 carburetors should be fitted with this cam from the factory.



Make sure that the #466 cam is installed in the #2 position in the carburetor.



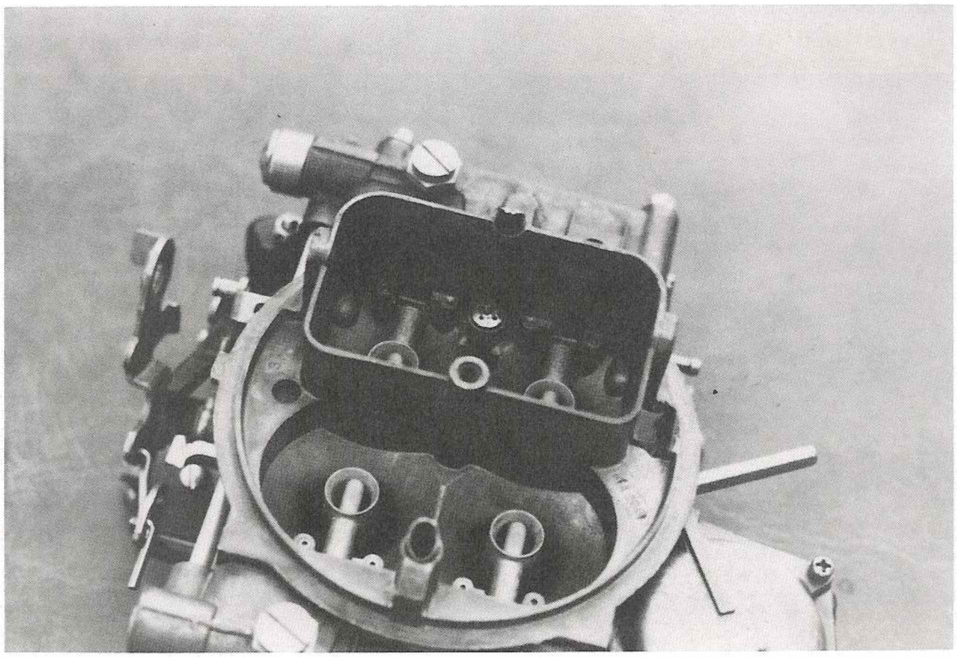
With the accelerator pump lever fully depressed, there should be 0.020in clearance between the lever and the pump arm with the carburetor at wide-open-throttle.



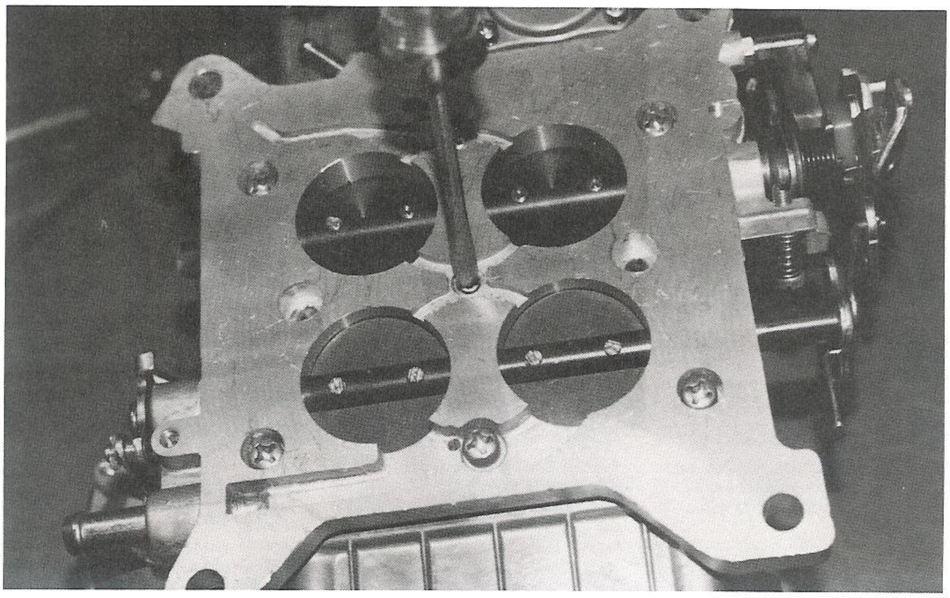
A good place to start with choke indexing is in the middle position. In most cases, no further adjustment will be needed.

Choke Mechanism

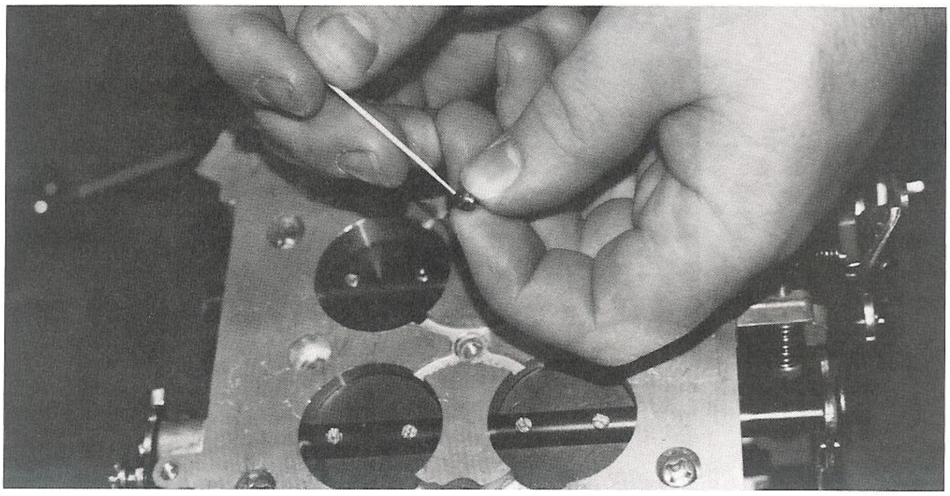
All Holley 0-8007 carburetors are equipped with electric choke mechanisms. Much like the accelerator pump system, the choke mechanism will usually require little attention. In fact, about the only thing to check is the choke cover indexing. The choke cover should be indexed in the center position (as shown in the accompanying photos). Finish by checking to see that the choke unloader adjustment is correct. This is accomplished by fully opening the throttle and checking to see that the choke blade is open between 1/8 and 1/4in. If you want a manual choke, you can easily convert the carburetor using Holley kit #45-225. If you are looking for that last little bit of intake flow, you can remove



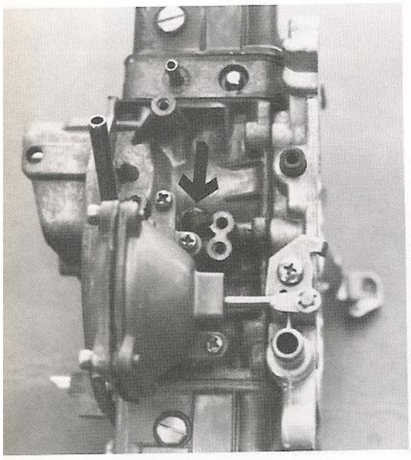
For a small gain in flow, some builders completely remove the choke mechanism.



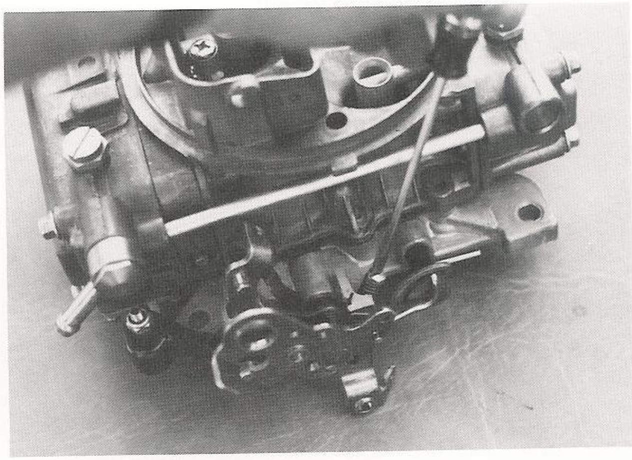
When the choke assembly is removed you must remove the vacuum orifice at the bottom of the carburetor and plug it with epoxy. This orifice resembles a small main jet and can be easily removed with a screwdriver.



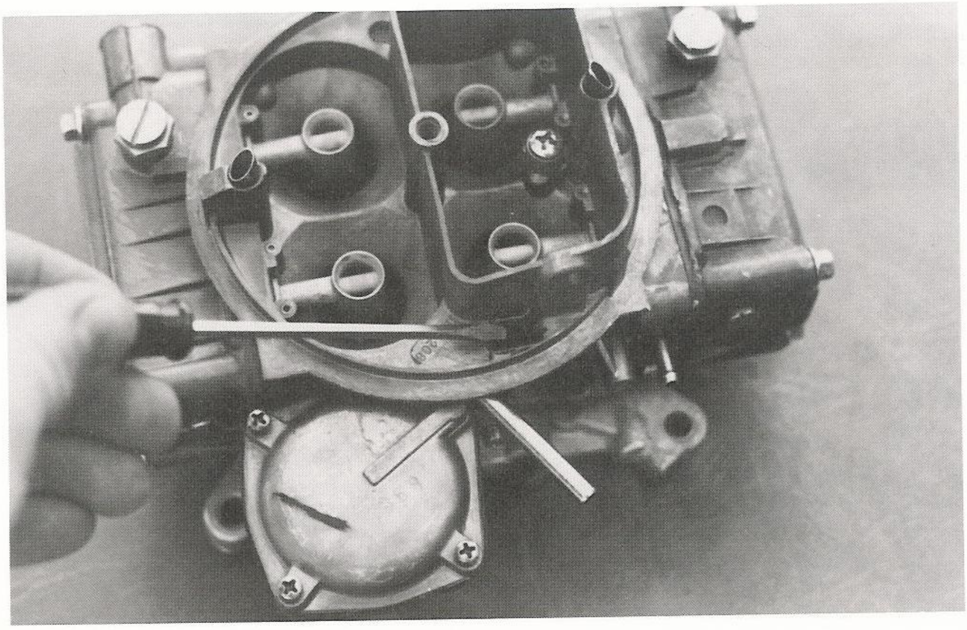
Using an epoxy such as JB Weld, plug the vacuum orifice so that no leakage will occur.



The final modification required when removing the choke assembly is to plug the choke vacuum port with a dab of silicone.



Idle speed is adjusted using the idle speed screw on the side of the carburetor. Static adjustment is two turns off the fully seated position.



If the choke assembly is removed entirely, the choke linkage port will need to be plugged with epoxy as shown.

the entire choke mechanism. If you do this, you must remove the vacuum orifice at the bottom of the carburetor and plug it with epoxy. You should also plug the choke vacuum port with a small amount of silicone. Finally, seal the choke linkage "port" in the top of the carburetor body using epoxy and a small piece of thin aluminum to cover the hole. Refer to the photos for guidance in these procedures.

Idle Mixture and Idle Speed

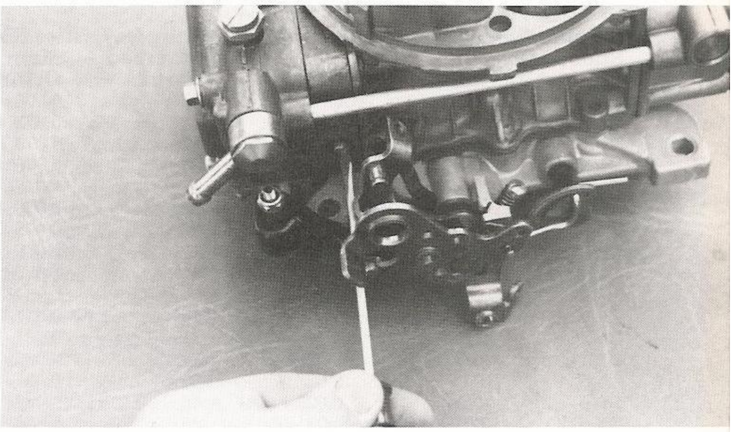
Adjust the idle mixture by turning the idle mixture screws (located on the side of primary metering plate) clockwise until they are lightly seated. Back each screw off 1-1/2 turns.

Adjust idle speed by turning the idle speed adjusting screw counterclockwise until the primary throttle plates are fully closed. Now turn the screw clockwise two full turns. Once you have completed these procedures, the engine should fire quickly on first startup.

Exhaust System

In Ford V-6 performance applications, much latent horsepower is waiting to be liberated with a good set of tube headers. Under no circumstances should the stock exhaust manifolds be used if significant performance modifications have been made. Stock manifolds flow very poorly and trap enormous amounts of heat. This excessive heat quickly transfers directly into the head, creating several detrimental conditions such as excessive cylinder head temperatures, accelerated cylinder and piston wear, and exhaust valve, seat, and guide failure.

From a performance perspective, headers offer more "feelable" power increases than most other modifications. This is a result of the dramatic influence that headers have on the torque output of the engine. Furthermore, the addition of a good set



Idle mixture is adjusted with mixture screws on each side of the primary metering block. Static adjustment is 1-1/2 turns off the seated position.

Holley Main Jet Size Chart

Jet #	Orifice Size	Jet #	Orifice Size
45	0.045	73	0.079
N/A	N/A	74	0.081
47	0.047	75	0.082
48	0.048	76	0.084
49	0.048	77	0.086
50	0.049	78	0.089
51	0.050	79	0.091
52	0.052	80	0.093
53	0.052	81	0.093
54	0.053	82	0.093
55	0.054	83	0.094
56	0.055	84	0.099
57	0.056	85	0.100
58	0.057	86	0.101
59	0.058	87	0.103
60	0.060	88	0.104
61	0.060	89	0.104
62	0.061	90	0.104
63	0.062	91	0.105
64	0.064	92	0.105
65	0.065	93	0.105
66	0.066	94	0.108
67	0.068	95	0.118
68	0.069	96	0.118
69	0.070	97	0.125
70	0.073	98	0.125
71	0.076	99	0.125
72	0.079	100	0.128

Secondary Metering Plates (Listed By Main Jet Orifice Size)

Stamped Part #	Main Orifice	Idle Orifice	Stamped Part #	Main Orifice	Idle Orifice
7	0.052	0.026	22	0.076	0.028
34	0.052	0.029	43	0.076	0.029
3	0.055	0.026	12	0.076	0.031
59	0.055	0.029	53	0.076	0.035
4	0.059	0.026	28	0.076	0.040
32	0.059	0.029	38	0.078	0.029
40	0.059	0.035	52	0.078	0.040
5	0.063	0.026	11	0.079	0.031
18	0.064	0.028	24	0.079	0.035
30	0.064	0.029	44	0.081	0.029
13	0.064	0.031	49	0.081	0.033
33	0.064	0.043	21	0.081	0.040
8	0.067	0.026	31	0.081	0.052
23	0.067	0.028	29	0.081	0.063
16	0.067	0.029	46	0.082	0.031
9	0.067	0.031	25	0.086	0.043
36	0.067	0.035	47	0.089	0.031
6	0.070	0.026	5	0.089	0.037
19	0.070	0.028	27	0.089	0.040
20	0.070	0.031	26	0.089	0.043
41	0.070	0.033	4	0.093	0.040
35	0.071	0.029	15	0.094	0.070
39	0.073	0.029	50	0.096	0.031
37	0.073	0.031	45	0.096	0.040
17	0.073	0.040	14	0.098	0.070
10	0.076	0.026	42	0.133	0.026

Holley Power Valves

Opening Point (inches of Hg)	Part #
2.5	125–25
3.5	125–35
4.5	125–45
5.0	125–50
6.5	125–65
7.5	125–75
8.5	125–85
9.5	125–95
10.5	125–105

Holley Accelerator Pump Shooter Chart

Shooter Hole Size	Tube Style Part #	Standard Style Part #
0.025	121–25	121–125
0.028	121–28	121–128
0.031	121–31	121–131
0.035	121–35	121–135
0.037	121–37	121–137
0.040	121–40	121–140
0.042	121–42	121–142
0.045	121–45	121–145
0.047	N/A	121–147
0.050	N/A	121–150
0.052	N/A	121–152

Holley Secondary Spring Chart (Kit #20-13)

Spring Color	Strength
White	Lightest
Yellow	Lighter
Yellow	Light
Purple	Med. Light
Plain	Medium
Brown	Med. Heavy
Black	Heavy

of properly tuned headers is a fairly inexpensive modification compared to those previously outlined in this book. If you have any plans to increase the performance of your Ford V-6, don't shoot yourself in the foot by neglecting the exhaust system. Finish the job by adding a good set of headers.

I want to emphasize that I do not think it is practical or desirable for the average performance enthusiast to try building his or her own headers. Proper header design and fabrication is a complex science whose subject matter could fill an entire book. Even so, header design is still shrouded in a certain amount of mystery that can only be clarified by hours of dyno and track testing. Further, every engine responds a little differently to various header tuning techniques. However, we are granted somewhat of a reprieve in that the effects of things like primary tube diameter, primary length, collector diameter, and collector length create the same effects regardless of the type of (four cycle) automobile engine that you happen to be building. Therefore, a good understanding of the information that follows should allow you to evaluate the commercially available headers and choose a set that closely matches the requirements of your particular engine.

As you move through this section you will notice that I haven't provided calculations for determining the header dimensions. This is simply because there are so many "formula bashers" in the header business that would sooner argue the superiority of their pet formulas over anyone else's that I decided to save all of you this headache by simply telling you what works and leaving the decision making up to you. Header calculations are certainly useful when designing various full-blown racing and/or experimental engines, but the subject of this book is performance applications, not racing. Therefore, I will try my best to keep everything in layman's terms.

What to Look for and Why

The Ford 2.6- and 2.8-liter V-6 engines benefit more than other engines from good header tuning because of their relatively poor exhaust to intake flow characteristics. These engines require a header that scavenges the cylinder very efficiently. The 2.9- and 4.0-liter engines also respond very well to the installation of headers, but the results are slightly less dramatic than in the 2.6 and 2.8 engines. This is primarily due to the very efficient design of the exhaust and intake ports in both the 2.9- and 4.0-liter engines. This is not to say that the effect of a good pair of headers is not very significant, just that the smaller displacement V-6s get more help where they are weakest.

I will begin by discussing the cylinder head interface and will work my way to the collectors. This is the flow path followed by the spent exhaust gases and is thus a logical progression for this discussion.

Header Flanges

Although not particularly a horsepower concern, header flanges are a very important part of the header system. Think of the flange as the "root" of the header tree. Obviously, a tree with bad roots is not going to be a very healthy tree. Likewise, a broken header can cause a significant loss of power.

The primary function of the header flange is to act as a stable attachment point for the primary tubes and to seal the primaries to the exhaust ports. Remember that thicker flanges are far better than thin ones. The thicker the flange, the less likely it is to warp as a result of the extreme temperatures it will encounter. Therefore, the minimum thickness that you should consider for any header flange is 3/8in, 1/2in being the most desirable.

If you choose to fabricate your own headers, you should consider purchasing 1/2in header flanges from TCK Enterprises in Santee, California. TCK manufactures flame-cut, 1/2in header flanges for all of the Ford 60-degree V-6 engines. These flanges are very good quality and work very well in both street and racing applications. If you choose to purchase a set of catalog headers, it is often possible to talk the manufacturer into using 1/2in material.

Primary Pipe Diameter (OD)

Choosing the proper primary size is much like choosing the proper camshaft for your engine. The most common mistake people make is choosing a header that is too "big" for the application. Curiously, the same goes for camshaft selection, resulting in a serious reduction in power. In short, just as an engine can be "over-cammed," it can also be "over-headered" as well.

Actually, with a little guidance, the selection of an appropriate primary size can be fairly easy. The thing to remember is that as the primary pipe diameter is increased, the rpm at which peak torque is produced increases as well. Conversely, as the primary pipe diameter is decreased, the rpm at which peak torque is produced is decreased. Thus, the primary pipe diameter establishes the peak torque rpm.

Primary diameter affects the exhaust gas velocity as it travels down the primary tube. The higher the gas velocity, the greater the "scavenging" effect. Scavenging is a condition where the exhaust "burst" from one cylinder creates a low pressure condition as it passes through the collector. This low pressure (below atmospheric) helps to draw out the exhaust gasses from the other exhaust tubes that share the same collector. Additionally, since both the intake and exhaust valves are open during the overlap period of the camshaft, this same low-pressure condition helps to draw more fuel/air mixture into the cylinder. Since some of this (cool) air/fuel mixture will inevitably be drawn into the header tube, it also cools the exhaust valve a bit.

The safest way to choose the proper primary size is to first measure the diameter of the exhaust port and choose a tubing size slightly larger than the exhaust port. This tubing size is normally within 1/8in or less of the port diameter. Obviously the minimum inside diameter (ID) would be that of the port, but since all header tubing dimensions are outside diameter (OD), you will have to account for the wall thickness of the tubing to calculate the inside diameter. To save you a little time, refer to the following recommended tubing sizes (OD) that correspond to your particular engine:

Ford V-6 Primary Tube Diameters (based on 0.049in wall tubes)

Engine	OD
2.6 liter	1.500in
2.8 liter	1.500in
2.9 liter	1.500in
4.0 liter	1.625in

It is likely that the primary tube will be slightly larger than the exhaust port when using these recommended sizes. Do not attempt to equalize the port size as this slight mismatch is actually desirable. In actuality, this mismatch works to control reverse-flow of the exhaust gases back into the chamber. This reverse-flow condition contaminates the incoming air/fuel mixture with noncombustible residual exhaust gas, resulting in a loss of power.

Primary Pipe Length

Once you have established the primary pipe diameter, you can focus your attention on the primary pipe length. As you might expect, primary length also affects the torque characteristics of the engine, but the effect of primary length hinges upon the peak torque rpm established by the primary pipe size. In this case, an increase in primary length results in an increase in low rpm power, whereas a decrease in primary length results in an increase in high rpm power. Although pipe length does not appreciably affect exhaust gas velocity, it does affect the resonant tuning of the entire system. Hence the term "tuned" headers. As was established earlier, primary pipe diameter fixes the rpm point at which peak torque is produced. Primary pipe length, on the other hand, determines the torque influence above or below peak torque rpm. In other words, longer primary pipes will increase the power below the peak torque rpm, and shorter primary lengths will increase the power above the peak torque rpm.

Once again, I have included appropriate primary pipe length recommendations to ease your choice. These recommendations are based on the recommended primary pipe diameters outlined earlier.

Ford V-6 Primary Lengths

Engine	Length
2.6 liter	36–42in
2.8 liter	36–42in
2.9 liter	36–42in
4.0 liter	44–50in

These length are likely to be in excess of what many manufacturers are currently offering. The main reason for this is that most vehicles will not allow the fitment of a header with the proper primary lengths. The only choice you have at that point is to purchase (or fabricate) a header with dimensions as close to these recommended lengths as possible.

Collector (Secondary) Pipe Diameter (OD)

A secondary pipe, or *collector* as it is commonly known, is a section of tubing at the end of each primary tube "cluster." The purpose of a collector is to gradually reduce the pressure of the exhaust pulse before it reaches the atmosphere. Therefore, smaller collectors tend to offer the most gradual reduction in exhaust gas pulse pressure. A collector that is too large will create a drastic reduction in the pressure pulse, hurting the scavenging effect in the process. The exhaust gas pulse will begin seeing the collector as atmosphere, causing an undesirable increase in reversion. The lesson here is to keep the collectors relatively small.

Collector pipe outside diameter is usually set by the primary tube diameter. In most cases, the collector diameter should be slightly less than twice the diameter of the primary tubes. As with the primary tube diameter, it is important that you stay conservative when choosing collector diameter. It is advisable to use a collector diameter no larger than twice the primary pipe diameter. The following collector diameters have proven very effective:

Ford V-6 Collector Outside Diameters

Engine	OD
2.6 liter	2.5in
2.8 liter	2.5in
2.9 liter	2.5in
4.0 liter	2.75in

You will notice that the above tubing dimensions are very common. Most manufacturers will offer collectors in these sizes, so selection should be very easy.

Collector (Secondary) Length

Ultimate control of the exhaust pulse is achieved by correctly selecting the collector length to complement the collector diameter. It is critical to use a collector length that is long enough to produce an "insulation barrier" between the high pressure pulse and the atmosphere. This "insulation" quality is extremely volume sensitive, making collector length and therefore collector volume very important to proper tuning.

Minimum collector volume should be at least twice the volume of one cylinder. Although exact length varies with application, collectors that are longer than this minimum dimension create a broad tuning band, resulting in a pronounced increase in low and midrange power. This being the case, it is advisable to use as long a collector as possible. If you are an using automatic transmission, you will find that your engine will absolutely love long collectors. If you are following all of the above header dimensions, you should also use the following minimum collector length guidelines.

Ford V-6 Collector Lengths

Engine	Length
2.6 liter	10.5in
2.8 liter	11.5in
2.9 liter	12.0in
4.0 liter	14.0in

Once again, if packaging problems exist in your application, try to find a set of headers with the longest collectors that will fit your vehicle. Longer collectors will make the engine less "peaky" and therefore much more fun to drive. Although collectors have a minimal effect on horsepower, they greatly affect the low end grunt of the V-6. This is a definite plus on any performance application.

Putting It Together

Now let's build a header using the above information. First, I assume that you have constructed a very capable 2.8 V-6 engine and are at the point where you can choose a header. First, you know that you would like a 1/2in header flange for good stability and sealing. You follow the recommended primary size and decide that a 1.5in OD primary is just the ticket. Next, you find that you would need to choose a primary length between 36in and 42in. You decide that you would like as much low end as possible. You know that using longer primaries lowers the peak torque rpm, therefore you choose to go with a primary length of 42in. Now that your primaries are in shape, you move to the collectors. Referring to the charts again, you find that a collector diameter of 2.5in should be just right. Finally, you crawl under the car and decide, after careful measurement, that your little rod will accommodate a collector that is 13in long. Again you refer to the charts and find that you need a collector that is at least 11.5in long. Since you know that longer is better where collectors are concerned and you are well above the minimum length in the chart, you stay with your 13 inch collector. After a few seconds of figuring, you decide that the length of your "ideal" header is about 4.5 feet, and it will fit the car.

Now you hit the catalogs and try to find a header that matches these dimensions as closely as possible. Just for good measure, you call the better manufacturers and evaluate your options. After careful consideration, you find a header that offers the least amount of compromise *and* fits your car. Out comes the checkbook and you are in business.

Camshaft, Lifters, Pushrods, and Cam Drives

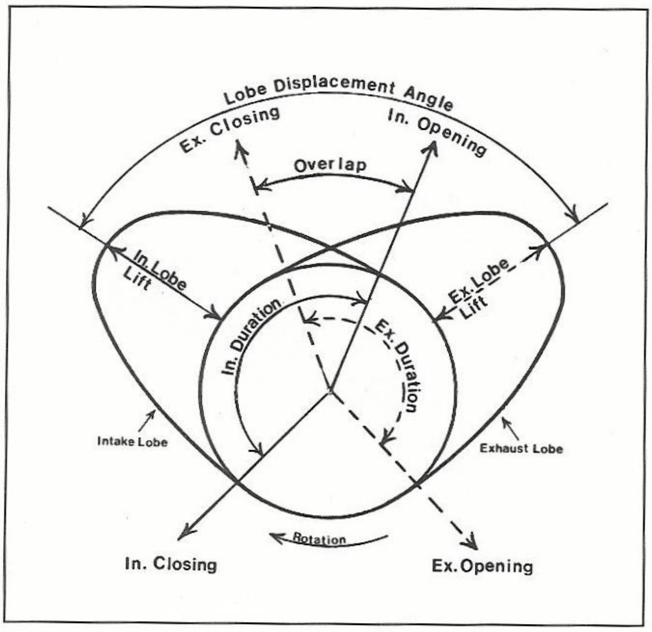
6

In the grand scheme of things, the camshaft and associated valvetrain components are ultimately responsible for liberating the maximum amount of power that any engine is capable of producing. It simply doesn't matter how much high-dollar porting has been done to the heads, or how trick your new set of pistons are, or even how much time and money you spent getting the bottom end set just right. If you don't have a camshaft and valvetrain that are carefully matched to the engine, it is simply not going to do what you expect it to. If I had a nickel for every time that this area of performance engine preparation was neglected, I could retire now.

The Camshaft

If I took the time to explain all of the ins-and-outs of camshafts (practically impossible), it would likely take up this entire book. I think the mystery and complexity of camshafts scares many people into making a bad selection. Over the years, I have come to realize that, unless you build engines for a living, there is no reason to burden yourself with trying to learn and *understand* all aspects of camshaft design. The simple fact of the matter is that camshaft manufacturers have such good technical assistance departments available that all you have to know are a few details about the components used in the engine, the level of preparation, the type of vehicle, and where you want it to perform (rpm), and the cam manufacturers can pick out the proper camshaft.

Over the years, Competition Cams in Memphis, Tennessee, has proven to be one of the best sources for everything from advice to camshafts and parts for all Ford V-6s from mild to wild. Its Ford V-6 camshafts have consistently produced more power and torque in my engines than anything else I have tried. I strongly recommend them for off-the-shelf camshafts and related equipment.



This diagram shows the various timing points for both the intake and exhaust lobes of one cylinder.

Camshaft Basics

Before I go any further, I don't want to lead anyone to believe that a good understanding of camshaft basics is not important. In fact, unless you understand the basics, it's a waste of time to talk with a cam manufacturer in the first place. Therefore, I will attempt to cover the essentials of camshaft design in an effort to help you understand many of the terms used in "cam talk" and what they mean to the performance of the engine . . . in general of course.

The following are some of the more common terms that you will encounter when discussing camshafts:

- Intake opening point
- Exhaust closing point
- Intake closing point
- Exhaust opening point
- Duration
- Lobe displacement angle
- Overlap
- Lift
- Cam advance and retard

If this list appears somewhat daunting, fear not. Once again, I will only cover the basics.

Valve Event Timing

The first four events in the previous list are actually the order in which the valves open and close during one complete four-stroke cycle of one cylinder in your engine. I will discuss these events in their respective order. Since each event occurs over at least 180 degrees of crankshaft rotation, you will notice that it will require two rotations of the crankshaft to complete the entire process. Most valve timing events are expressed in degrees of crankshaft rotation. You will be glad to know that valve timing events are not a common point of discussion when talking with a cam manufacturer, but it is important to know what effect changes in event timing have on engine power. The main thing to remember is that changes in the intake valve timing have a greater effect on the torque and power curves of the engine than do changes in the exhaust valve timing.

Intake Opening

Obviously, the intake valve is opened so that the air/fuel mixture can be introduced into the engine for combustion. The problem is that the intake charge is a particularly difficult beast to get moving quickly, so the intake valve opens at some point before top dead center (TDC) to allow sufficient time to get the column of intake mixture moving. An added benefit of opening the intake valve before TDC is that it allows the valve to open into a higher flow area (i.e., farther off of the seat) before peak cylinder demand occurs. However, if the intake valve opens too early, the result is a rough idle and poor low-end response. Generally speaking, the earlier the intake valve opens, the higher the engine operating rpm will be.

Exhaust Closing

One might think that the proper time to close the exhaust would be exactly at TDC of the exhaust stroke. After all, the piston is no longer moving upward to expel the gasses, right? Wrong! The exhaust valve actually closes quite a bit after TDC. There are many reasons for this. First, closing the exhaust valve after TDC allows the dynamics of the fast moving exhaust gases to actually help begin the intake event. This is possible because the intake and exhaust valves are, for a period of time, both off their respective seats at the same time. This condition is called "overlap" (more on this later). A second benefit of a "later" exhaust closing point is that incoming (relatively cold) intake charge actually cools the exhaust valve, greatly increasing valve life. Many manufacturers also use a later exhaust valve closing point to actually "help out" an engine with a poor-flowing exhaust port. This helps bring the intake-to-exhaust flow ratio to a level more conducive to good power output. This is a delicate game, however, as closing the valve too late will allow too much fresh air/fuel mixture to be expelled into the exhaust, creating extremely high exhaust gas temperatures (not good).

Intake Closing

The intake closing point is the single most important timing event. Once again, due to the "column inertia" effect, the intake valve is closed long after bottom dead center (BDC). The fast moving intake charge will continue "stuffing" the cylinder even while the piston begins moving upward on the compression stroke. Many refer to this phenomenon as "inertia ram." There is no question that more air in equals more power out. That is why the intake closing point is so important. However, the later the intake closing point, the higher the engine rpm will be at peak torque. Extremely late closing points hurt low end torque and response due to a severe loss of cylinder pressure. Conversely, if the intake valve is closed too early, the engine will tend to "lay down" on the top end. The optimum intake valve closing point is dependent upon many things. As I said before, the higher the intended engine operating rpm, the later the closing point should be. A poor-flowing (restricted) intake port will require an earlier closing point in order to develop a sufficient amount of cylinder pressure. Finally, a long-stroke engine responds well to a later closing point. Obviously a very delicate game, this camshaft thing.

Exhaust Opening

At the risk of over-simplification, the exhaust opening point actually controls the length of the power stroke. Generally, the longer the exhaust valve stays shut, the longer the power stroke. Interestingly, however, the exhaust opening point has the least effect on the torque (power) curve. Changes in the exhaust opening event produce subtler changes in engine power than, say, the exhaust closing point. Typically, the exhaust valve opens before BDC. Delaying this particular event results in improved low-end torque and economy. The primary reason that this event is so "flexible" is that approximately 60 percent of the exhaust gases escape the cylinder before the piston begins moving away from bottom dead center, due primarily to the extremely high pressures involved.

Duration

The term "duration" simply describes the time that the valves stay off their seats (open). Duration is always expressed in crankshaft degrees. Because duration figures are often used to describe how "big" a cam is, this figure can get people into trouble when choosing a camshaft. Far too many well-intentioned novice engine builders subscribe to the "bigger-is-better" method of camshaft selection and, in turn, choose a cam that destroys the performance potential of what could have been a very enjoyable machine.

Advertised Duration Versus Duration at 0.050in

For every camshaft, there are two different (and very confusing) duration specifications: "advertised duration" and "duration at 0.050 inch." Advertised duration is, at best, a feeble attempt to describe the time "off the seat" for the valves. The best thing to do when choosing and/or comparing camshafts is to pay only passing attention to the advertised duration figures. The fact is, a cam with an advertised duration of 280 degrees can actually have less effective duration than a cam with an advertised duration of, say, 270 degrees. This is because every manufacturer has its own idea of how to rate a cam's "off seat" duration. Take this figure with a grain of salt and move on.

Duration at 0.050in is a more accurate method to describe camshaft duration and is now the standard of the industry. Duration at 0.050in is measured (in crankshaft degrees) from the point where the lifter rises 0.050in from the base circle of the cam on the opening flank to the point where it returns to 0.050in above the base circle on the closing flank. This method of measuring duration provides a standard point of reference by essentially eliminating differences in the lift characteristics of the clearance ramps (the gradual transition from the base circle to the "working" part of each cam lobe that reduces noise and improves component life by gently taking up all the slack in the valvetrain). Therefore, this is the only duration figure to which you should give thought during the preliminary stages of analyzing available camshafts.

Dual-Pattern Versus. Single-Pattern

Breaking the duration subject down further, we can also look at the intake duration and exhaust duration separately. When perusing cam catalogs, you will likely find that the duration figures (at 0.050in tappet lift) listed for the intake valve will actually be different than the figures listed for the exhaust valve. In this case, the exhaust duration is usually longer that the intake. Cams with this configuration are known as "dual-pattern" cams. This type of cam configuration is most often found in street/performance applications. The advantage of dual-pattern cams on the street is that they widen the torque band by increasing the exhaust efficiency. Most street-performance engines using stock-type cylinder heads are not capable of flowing enough exhaust to produce maximum power. The longer exhaust duration typical of a dual-pattern cam helps increase the exhaust efficiency, thereby creating more power.

As the level of engine preparation increases, the ratio of intake to exhaust flow also increases to a level that is more nearly ideal for power production. Consequently, most cam manufacturers design the cam with identical duration on both the intake and exhaust lobes. This configuration is known as a "single-pattern" cam. As the intake and exhaust tracts become more balanced, as a result of extensive porting, bigger valves, or possibly an entirely new (specially designed) cylinder head, it becomes unnecessary to use a cam with different intake and exhaust durations. You will find that the majority of racing camshafts are single-pattern designs.

I think it is safe to say that duration is one of the elements that has the most pronounced effect on engine power. Shorter duration cams allow the engine to create more low-end torque by creating a longer compression stroke (creating more cylinder pressure) and creating a longer power stroke. But short duration cams tend to hurt top-end performance. Long duration cams, on the other hand, move the engine operating rpm higher at the expense of low-end torque and response. Since all cam manufacturers determine the correct duration based on the intended use of the engine (e.g., towing, racing, etc.), it is essential that you know such things as the expected operating rpm, the transmission type, and the weight of the vehicle before you start on your quest for a camshaft. The rule of thumb to remember is that a cam that has slightly too short a duration will actually be very close to the optimum power output attainable with a perfectly matched cam, whereas a cam with slightly too much duration will be dramatically off on power and driveability. For most performance applications, when it comes to duration, less is more.

Lobe Displacement Angle

Lobe displacement angle (or "lobe spread," as it is sometimes known) is simply the angle between the intake and exhaust (geometric) lobe centers for one cylinder. This angle is expressed in degrees of camshaft rotation.

In days of old, overlap (the time that both valves are off their seats) was often used to describe the positional relationship of the intake and exhaust lobes. This proved to be a very unreliable method of describing this relationship. The problem is that overlap is greatly affected by duration. Typically, the more duration, the more overlap, assuming the lobe displacement angle remains constant. The lobe displacement angle, on the other hand, is not affected by duration at all. These days, for that reason, the lobe displacement angle is often considered the most important camshaft specification. The ultimate benefit of using the lobe displacement angle instead of overlap is that it is much easier to compare one camshaft to another and derive a better idea of the expected performance of each one.

The reason that lobe displacement angle is so important to camshaft selection is its tremendous effect on engine power. The trend in most performance cams is to narrow the lobe displacement angle. This improves midrange torque and response by allowing both valves to stay closed longer, thereby creating more cylinder pressure. Additionally, cams with tighter lobe displacement angles work well with increased compression ratios. The one drawback when tighter lobe displacement angles are used is that longer durations can cause excessive overlap and a proportional reduction in low-end power and idle quality. Therefore, as a general rule of thumb, the longer the duration, the wider the lobe displacement angle should be.

As engine operating speed increases, cam manufacturers tend to widen the lobe displacement angle to move the torque peak up in the rpm range, in turn forsaking some low-end performance. Wider lobe displacement angles create smoother idle quality and the higher manifold vacuum necessary for accessories such as power brakes and air conditioning. A nice benefit of cams with wide lobe displacement angles is that they tend to be more forgiving if the cam is not properly matched to the engine. Additionally, wide displacement angles allow the use of longer durations without excessive overlap, work well in lower compression "smog" engines, and generally offer better gas mileage.

In general, most Ford V-6 performance camshafts will have between 110 and 112 degrees of lobe displacement.

Overlap

As mentioned earlier, overlap describes the period of time that the intake and exhaust valves of one cylinder are simultaneously off their respective seats. This period is expressed in degrees of crankshaft rotation. Overlap is, for the most part, a non-negotiable factor when choosing a camshaft. The overlap period of the camshaft is merely a product of the more important (and influential) duration and lobe displacement angle. Do not, however, assume that overlap should go unobserved when choosing a camshaft. Remember, as overlap increases, low-end driveability suffers.

Recommending a desirable overlap figure is very difficult since almost every engine combination will require a different camshaft with different lobe displacement angles. However, some basic rules of thumb are as follows. Most Ford V-6 performance engines will respond well when 0.050in overlap figures are between 0 and 25 degrees. These same figures are roughly equivalent to advertised overlap figures of 45 to 70 degrees. So when choosing a cam for your Ford V-6, be aware of the overlap figures but don't base your cam choice solely on them. The best thing to do is to get the advice of the cam manufacturer.

Lift

Lift is a term used to describe a number of related valvetrain functions. The two most common types of lift are lobe lift and gross valve lift.

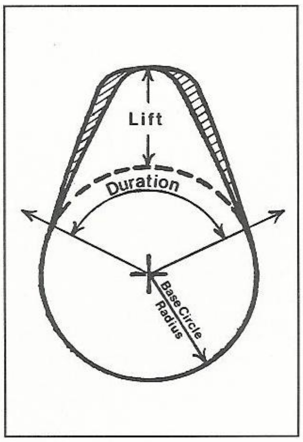
Lobe lift (or cam lift as it is also known) represents the height of the lobe above the base circle of the cam. Obviously, this dimension also describes the actual distance that the tappet moves away from its "neutral" point on the camshaft.

Gross valve lift describes the distance in inches that the valve is lifted off its seat plus valve lash. This is the lift dimension that you are concerned with when choosing a cam. Valve lift is extremely important to engine breathing and horsepower. Basically, higher lift equals higher horsepower. Therefore, you want as much lift as practical for your application. There are several limiting factors to consider when evaluating valve lift, including piston to valve clearance, valve spring capability, cam journal size, rocker arm ratio, tappet design, and cylinder head flow. As a general rule of thumb, increases in lift *without* increases in duration improve low-, mid-, and even some high-end performance. The camshaft manufacturer will be able to recommend the highest practical lift for your engine based on the level of preparation and the quality of the components used in your engine.

Lift Rate

Unfortunately, the camshaft lift rate is something that you will not likely find described in any of the information that is supplied by the cam manufacturer. Very often, the lift rate is what makes two otherwise identical camshafts have a significant difference in performance.

The lift rate describes the amount of lift per degree of camshaft rotation, or in other words, how fast the lifter is moved away from the base circle



This diagram illustrates how lift rate can dramatically affect one cam's characteristics even though the two cams may share the same specifications. The shaded area indicates the amount of active area above that of the compared lobe. Also note that there is absolutely no difference in the duration between each lobe.

on its way to peak lift. This rate is not constant throughout the valve opening event. Basically, the higher the lift rate, the more area under the "lift curve." In general, this means the cylinder head is allowed more time to flow air, which equates to more power. The same theory that we applied to lift can also be applied to lift rate: the more lift rate that you can practically use in your engine the better. More extreme rates of acceleration, however, increase the stresses in all parts of the valvetrain, so the diameter of the lifter and the quality of the rest of the valvetrain components makes the biggest difference when deciding what is practical.

Camshaft Advance and Retard

Although cam advance and retard has little to no bearing on camshaft selection, it is important to know what these terms mean and how they affect the performance of the engine.

Advancing or retarding a camshaft simply adjusts the valve event timing, which results in an adjustment of the rpm at which peak torque is produced. Camshaft advance/retard is expressed in degrees of crankshaft rotation and is relative to the placement of the intake lobe centerline with respect to TDC.

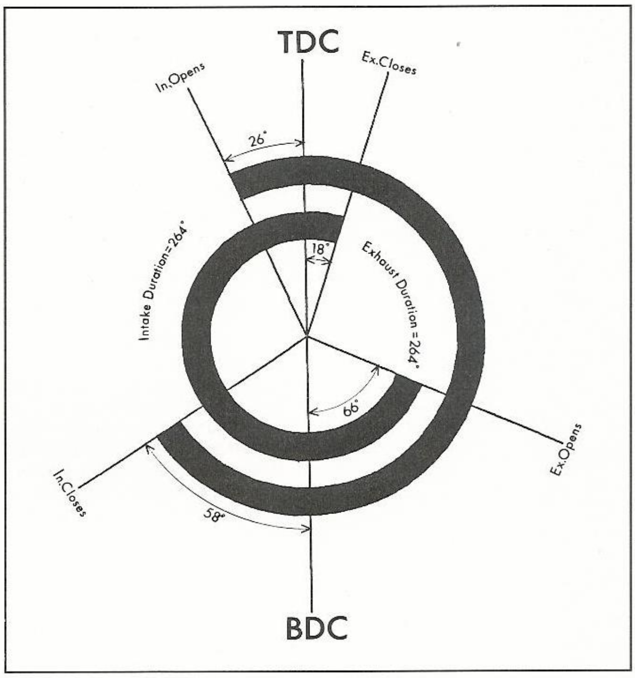
When the camshaft timing is advanced, the low-end performance is increased at the expense of top-end power. When the cam is retarded, the mid- and high-end performance is increased at the expense of low-end power. As you can see, what you gain on one end is lost on the other.

Changing the cam timing, or "degreeing," as it is commonly known, can be done in a couple different ways. First, it is possible for the camshaft manufacturer to grind the camshaft in an advanced or retarded configuration during production. If this is done, the amount of advance/retard will usually be indicated on the cam specification sheet. The second and most common method for advancing/retarding a cam is to install offset keys in either the crankshaft or camshaft drive gears.

Cam timing is covered in more depth in Chapter 10.

Pushrods

Pushrods are the most simple, reliable, and generally fool-



This diagram shows the relationship of the valve opening and closing events relative to the top and bottom dead center locations. Notice the cam events are advanced 4 degrees.

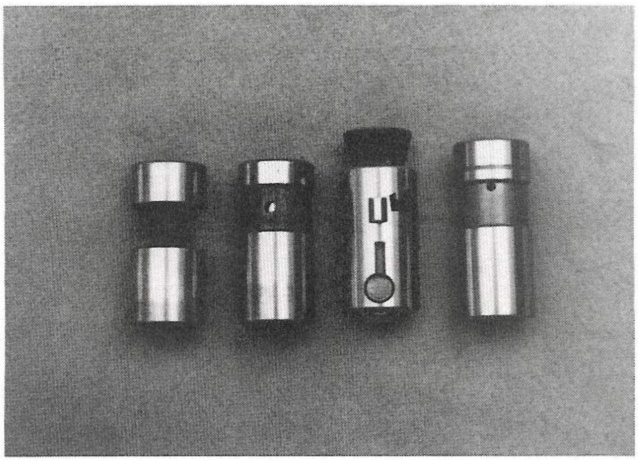
proof components in a performance engine. Basically, if the pushrod is straight and of the correct length, you will likely never have any trouble with it. Most of the valvetrain modifications that are outlined in this book will require the use of custom pushrods. Fortunately, custom pushrods are relatively inexpensive and are available from several manufacturers. When making your selection, you should look for pushrods that are as light and stiff as possible. I recommend tubular pushrods, which offer the greatest strength to weight ratio and have the added benefit of delaying valve float because of their light weight.

Some of the best pushrod kits are manufactured by Smith Brothers Pushrods. Due to the numerous valvetrain combinations available for the Ford V-6, I recommend that you call a specialist like Vanir Technologies for advice on pushrod selection. Be sure you indicate the type of lifter, rocker arm, and camshaft you intend to use.

Lifters

A solid lifter is used in all engines except the 2.9- and 4.0-liter. The 2.9-liter engine uses a conventional hydraulic lifter, and the 4.0-liter uses a unique hydraulic roller lifter.

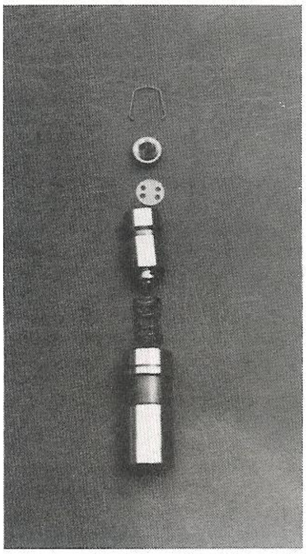
For all applications, I recommend that you stay with the basic type of lifter fitted at the factory. This will save you enormous amounts of money, and you will also avoid a fair number of headaches, especially where the 2.9- and 4.0-liter engines are concerned. In fact, in the case of the 4.0-liter, I would stay with the stock lifter as a matter of affordability. The 4.0-liter uses a unique locating groove in the lifter bore to keep the roller lifter in alignment with the cam lobe. At this time there are no "drop in" replacements for these lifters, nor are there any affordable camshafts available. I expect that as 4.0-liter development continues, the availability of these components will increase.



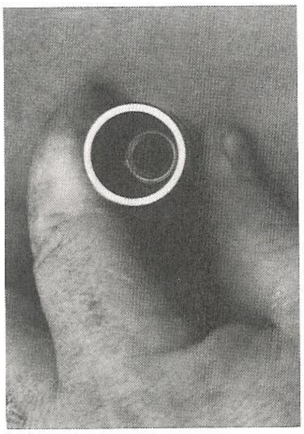
Three different lifter types have been used in the Ford V-6. From left to right, we have the stock 2.6- and 2.8-solid lifter, the 2.9 hydraulic lifter, and the 4.0-liter hydraulic roller lifter. Notice the unique locating pin in the side of the 4.0-liter roller lifter. The lifter at the far right is a small-block Ford V-8 hydraulic lifter like we used in our project engine.

In all of my engines except the 2.9- and 4.0-liter, I use a high-performance version of the Ford small-block V-8 hydraulic lifter. I advise ordering a set of Ford V-8 lifters at the same time you order your camshaft. They are usually cheaper that way, and you can be sure that the materials used in the cam and lifters will be compatible.

When using the V-8 hydraulic lifters in either a 2.6- or 2.8-liter engine, you must remove the spring, plunger, and retaining clip that make up the hydraulic portion of the lifter. Once this is done, you simply place the pushrod cup at the bottom of the lifter. This little trick has many advantages. First, it creates the lightest possible solid lifter. Second, the pushrod tip is placed closer to the cam lobe, resulting in a much more stable lifter and better valvetrain geometry.



A small-block V-8 hydraulic lifter is a fairly complex device. Of the six parts shown, only two will be used when fitted to the Ford V-6: the lifter body and the pushrod cup.



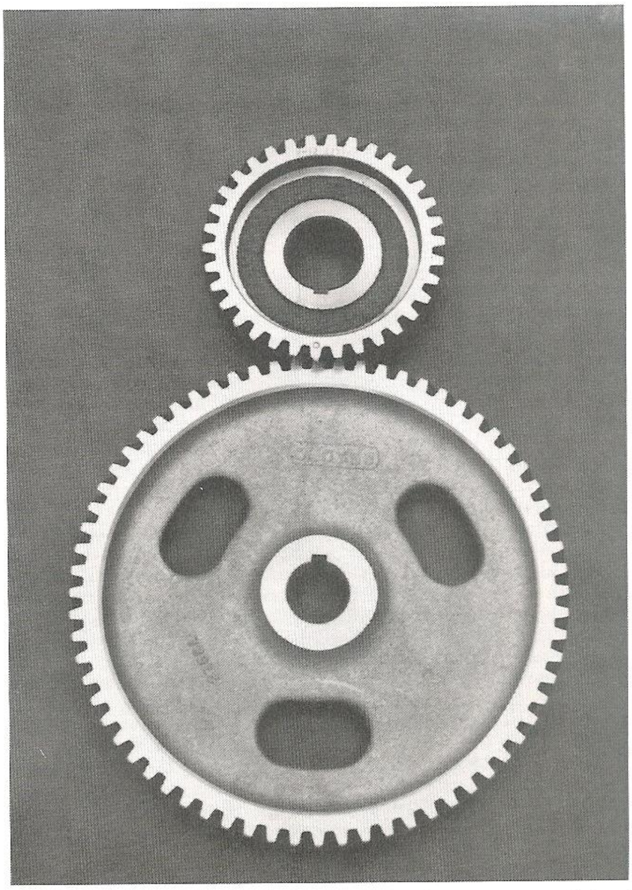
To convert the small block lifter to solid configuration, it is simply gutted of its internals and the pushrod cup is placed at the very bottom of the lifter body.

Third, as the engine runs, the lifter is able to fill with oil. As the lifter spins in its bore, oil is thrown out through the bleed hole, which in turn lubricates the lifter bore. This completely eliminates the lifter seizure problems that are somewhat common in the Ford 2.6- and 2.8-liter engines. I will warn you ahead of time that this practice tends to freak-out most cam grinders, but once you explain the aforementioned advantages, everything should be all right.

In the 2.9-liter, you actually have two lifter choices available to you. First, you can install a high-performance (V-6) hydraulic lifter available with the appropriate hydraulic cam, or you can install a solid 302 Ford V-8 lifter as offered by Competition Cams. If you choose to go solid, you will need to be aware of a few things. First, you will have to make sure that the cam grinder knows that you will be using a solid lifter instead of a hydraulic unit since cams ground for use with hydraulic lifters have no clearance ramps ground into the lobes. Second, the oil passages that feed the lifter bores will require restrictors. Since converting a 2.9 to solid lifters can be a somewhat complex endeavor, I recommend that you call a Ford V-6 specialist like Vanir Technologies and have them help you through the tough spots and supply you with the proper components to make the job easier.

Cam Drives

Cam drives are not only responsible for transferring crankshaft rotation to the camshaft, but they also maintain the "phasing" between the camshaft, valvetrain, and the crankshaft. Many good parts have been wasted over the years simply because someone did not take the time to properly install and set up a solid cam drive system. All



The 2.6-and 2.8-liter engines use a very precise gear drive to operate the camshaft. The gear set in this photo is a high performance set manufactured by Cloyes Gear and Product.

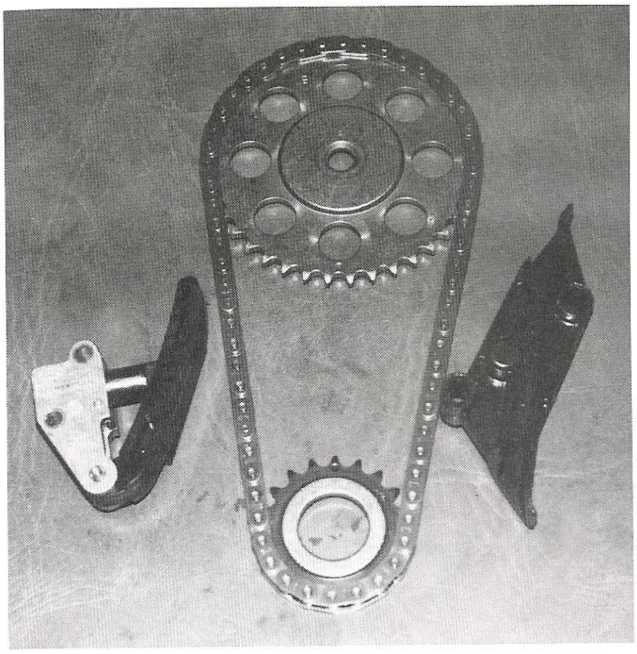
of the camshaft tuning in the world is worthless unless you have a solid cam drive to keep things swinging in the right direction. Remember that every time an engine is rebuilt, a new cam drive should be installed.

Ford V-6 Drive Types

The Ford 60-degree V-6 has undergone some significant cam drive changes in later years. Early on, the 2.6- and 2.8-liter engines utilized a gear drive mechanism. When the 2.9-liter engine was introduced in 1986, a more conventional chain drive was incorporated. This same chain drive was also used in the 4.0-liter versions.

For performance applications, the gear drive is the most desirable. Gears are much more accurate timing devices than chains, and tend to be much more durable.

Interestingly, the chain drives used in the 2.9- and 4.0-liter engines are very similar to each other. This similarity is more than simple coincidence as they actually share the same upper and lower sprockets and automatic tensioner. The only components that differ are the chains and the "anti-slap" chain guide. The best feature of these chain drives is the automatic tensioner and the chain guide incorporated into their design. The tensioner automatically eliminates excessive slack in the chain via a unique ratcheting mechanism and, in cooperation with the "anti-slap" chain guide, it virtually eliminates the violent "whipping" action that plagues conventional chain drives. This system works very well and has proven to be very reliable in performance applications. As with the gear drives, all drive components should be replaced during an engine rebuild. Don't forget to replace the tensioner and the guide at the same time.



The 2.9- and 4.0-liter engines use a conventional chain drive mechanism to drive the camshaft. Both use the same tensioner (left), antislap guide (right), and gears, but the chain is a different length (longer) on the 4.0-liter.

Component Selection

One of the first things that many people find when shopping for timing components is that the availability of performance timing sets is minimal at best. In fact, most of the timing sets that are sold as "performance" sets are nothing more than stock replacement timing components.

My choice for timing components for the Ford V-6 are those manufactured by Cloyes Gear and Product in Willoughby, Ohio. Cloyes is well known in the performance and racing industries for its excellent quality and service. Even though the Cloyes timing sets for the V-6 are not sold as "performance" timing sets, the fit and finish of Cloyes' products is better than the performance sets offered by many other manufacturers. The following is a list of part numbers that correspond to the proper Cloyes timing sets for the Ford V-6:

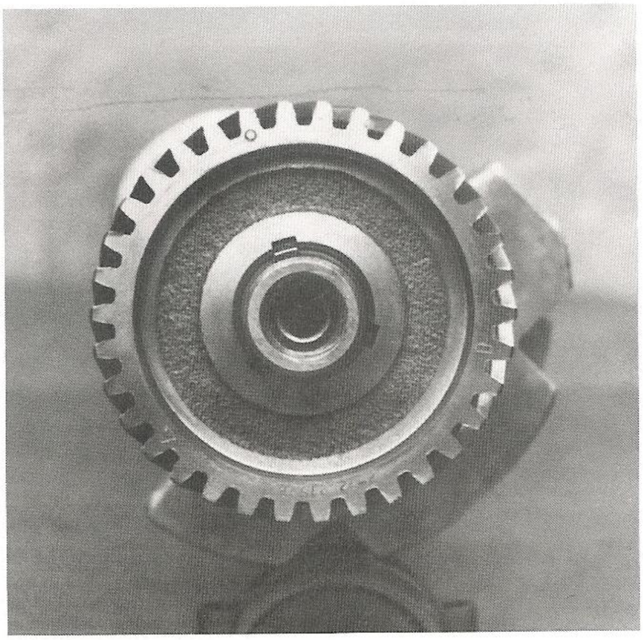
Engine	Part Number
2.6 (gears)	2762-SA (matched set)
2.8 (gears)	2760-SA (matched set)
2.9 (chain)	C-3075
4.0 (chain)	C-3078

You can expect excellent service and reliability from the Cloyes products in any engine that will operate at sustained rpm's below 6500.

Indexing

Normally, the replacement Ford V-6 timing sets offered by Cloyes do not come with an "indexed" crankshaft gear. An indexed crank gear has three different keyways cut into it. Each keyway represents a different cam timing setting for use when tuning a camshaft. For example, a keyway marked "O" would indicate a factory or "straight up" timing position. A keyway marked "Δ" would indicate a setting of 4 degrees cam advance (crank degrees), and one marked "❑" would indicate a setting of 4 degrees cam retard (crank degrees). The use of an indexed crankshaft gear is much more desirable than using offset keys. The reason for this is that keys tend to shear under high loads whereas with an indexed gear, a standard key and keyway is used, eliminating such problems. Additionally, offset keys are somewhat inaccurate as compared to a properly indexed gear. If you would like to have a fully indexed Cloyes gear set, contact Vanir Technologies with your requirements.

Note that if the camshaft you intend to use has any advance/retard ground into it, you must remember to account for this when installing the gear in either the 4 degrees advanced or 4 degrees retarded position.



To increase camshaft tuning capability, Vanir Technologies offers fully indexed crank gears for use on all Ford V-6 engines.

7

Ignition

I have seen the ignition system ignored during performance buildups many times over the years. After considerable pondering, I have decided that this is one of those areas that causes a lot of confusion simply because most people don't understand it. Ignitions have long been shrouded in some sort of black magic mystery and, therefore, many builders have avoided a deep relationship with the subject. The job gets even more complicated when you realize just how many different options you have with regard to stock ignitions. No less than six different ignition configurations were available on the V-6 through 1986.

Although the ignition system will not create horsepower, it is, however, absolutely essential to releasing the horsepower that the engine is capable of producing. This job, in itself, is actually very simple. Basically, the ignition must provide a spark of sufficient energy, at the proper time, and of the proper duration during the compression of the combustible gases inside the combustion chamber. If this is not accomplished precisely and efficiently, there is no possible way that peak power can be realized.

From a performance standpoint, there are a few very important issues. First, there's spark timing, or the point at which the ignition system delivers the appropriate amount of energy to the spark plug in order to ignite the air/fuel mixture. This timing "point" is adjusted according to the demands of engine speed and load. This adjustment is called ignition advance. Advance is controlled either mechanically or electronically depending on the type of ignition used. Optimum spark timing depends on many things including compression ratio, combustion chamber design and efficiency, fuel quality, camshaft characteristics, and,most importantly, air/fuel mixture quality within the cylinder, which is affected by fuel distribution. Fuel distribution is especially a problem with the Ford V-6, particularly in the 2.8-liter engine. Uneven port runner lengths and cross-sectional areas create an environment in which some cylinders run rich and others run lean. This condition magnifies the importance of a properly timed spark and ample spark duration so that there is a better chance of producing a more complete reaction and less chance of power-robbing misfires.

Selection

The rather large number of ignition options available to the builder of a Ford V-6 is probably the reason that this system is so frequently ignored. Decision making is tough when faced with so many viable options. On that note, I will tell you that I have been 100 percent satisfied with the Ford Motorsport Extra Performance Ignition. This system is essentially a high-performance version of Ford's impressive DuraSpark II electronic ignition system that was fitted on most Ford products beginning in 1977. However, the only component that is used in a performance application is the DuraSpark II distributor, easily identified by its large diameter cap and male spark plug-type terminals. Since all Ford 60-degree V-6 engines share the same firing order (1-4-2-5-3-6), this distributor works well in almost all applications.

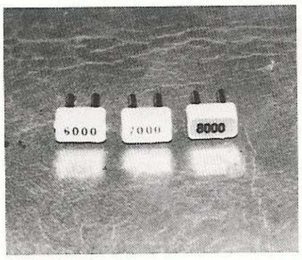
The Extra Performance system will provide the best ignition control and quality of any conventional ignition available for the V-6. The benefits include a spark duration that is five to ten times longer than conventional points type ignitions and has much higher spark energy, much more accurate spark timing, and very low maintenance. Another thing that I have found very useful is that this system either works or it doesn't, thereby virtually eliminating the annoying process of identifying ignitions problems.

Two things require special attention when using a high energy ignition system. First, conventional spark plug wires are not capable of controlling the increased spark energy produced by this type of system. Therefore, a good quality set of ignition wires are an absolute necessity. Second, the ignition cap and rotor assemblies must be upgraded to the type used on the DuraSpark II distributors (more on these items later).

The Hardware

The Ford Motorsport Extra Performance Ignition system has a couple nice features that make using it a real pleasure. First, the unit is adaptable to either 4-, 6-, or 8-cylinder engines. Second, it incorporates a rev limiter that is adjustable by simply changing a small programming chip. Finally, the unit uses an entirely self-contained harness that practically eliminates wiring errors and leaves no question as to the proper wire gage that should be used. If your car was originally equipped with DuraSpark II, then you can use the factory harness (with appropriate modifications) and you won't need the Motorsport harness. If you intend to use this ignition, you will want to order the following parts from your local Ford Motorsport dealer:

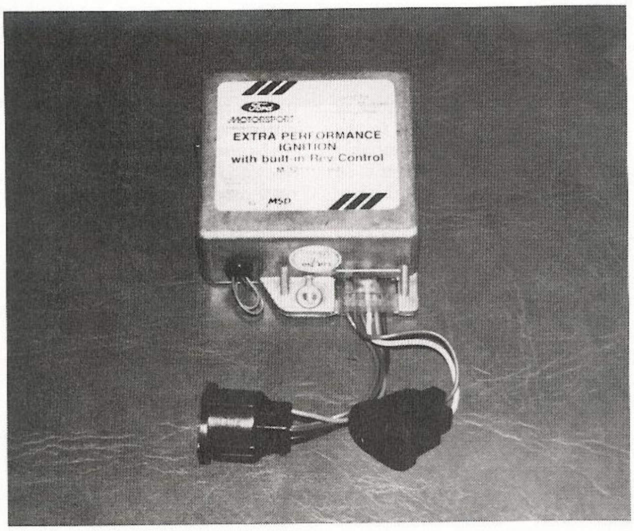
Part Number	Part Description
M-12199-C301	Ignition Control Module
M-12029-A302	High Energy Coil
M-12071-A301	Wiring Harness
M-12120-A301	Distributor Spring Kit
M-12449-A600	RPM Programming Chips (6000-6800)



The rev limiter in the Extra Performance ignition is adjusted by replacing programming chips that are calibrated to a specific rpm.

Additionally, you will want to order the appropriate distributor, distributor cap, and rotor. I have been very pleased with the remanufactured distributors offered by Rayloc. The part number shown below is for the single vacuum unit from a 1979 Mustang II. I have also been impressed with the ignition cap and rotors manufactured by Echlin. I have tried just about every performance cap and rotor currently available and can safely say that those made by Echlin are excellent. These components are available through any NAPA auto parts dealer under the following part numbers:

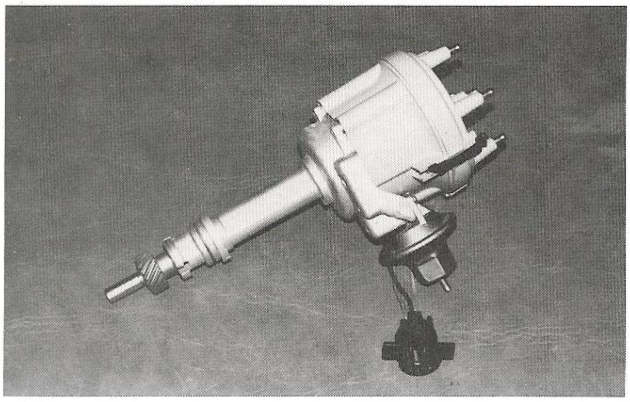
Part Number	Part Description
48-2691	Distributor Assembly ('79 single vacuum)
FA-136	Ignition Cap
FA-139	Ignition Cap Adapter Collar
FA-159	Ignition Rotor



The heart of the Ford Motorsport Extra Performance Ignition is the M-12199-C301 ignition module. This module offers extremely good ignition quality and a built-in, adjustable rev limiter.

If you are building a 2.9, you must use the proper distributor drive gear. Since the camshaft in the 2.9 engine rotates clockwise (as contrasted with the counterclockwise rotation in the 2.6 and 2.8s) the gear teeth are cut differently. These gears should be available through your local Ford dealer. Note that although a 4.0-liter engine can be modified to accept the DuraSpark ignition, it will likely be more economical to remain with the factory crank-fired ignition.

Finally, there's the subject of spark plug wires. These little critters have been the cause of more ignition problems than I care to count. The main problem associated with plug wires is that most of them, including most "high-performance" wire sets, cannot properly control the spark energy produced by high-performance electronic ignitions. This results in everything from misfiring, cross-



The DuraSpark II distributor assembly is easily identified by the large diameter cap that incorporates male terminal ends that resemble spark plugs.

firing, and in some cases total ignition module failure. Spiro Mag wires, manufactured by Taylor Cable Products in Grandview, Missouri, are an excellent wire set for the Ford V-6. These wires are made with a gray 8mm silicone material and feature a spiral wound stainless steel conductor core. After years of fighting with so-called "high-performance" wire sets, I have found Taylor wires to be quite capable of producing the level of spark energy control that is.so vital to proper ignition performance. These wires are available directly from Taylor in a fully tailored set under part number 108632.

This should take care of all of the components that you will need to bring the ignition system up to speed on your Ford V-6. Now you can begin assembling the system.

Distributor Setup

The first order of business when setting up the ignition is to have the distributor recurved. This means that the ignition advance curve must be tailored to provide the engine with optimum spark control. Obviously this is not something that you can do at home, so I advise finding a reputable ignition shop that can do the job and uses a Sun distributor machine. Take your distributor, distributor cap, adaptor, rotor, and spring kit with you to the shop. The goal is to have 38 degrees total advance by 2800–3000rpm. The distributor should provide 20 degrees advance by no later than about 2200rpm. Have the shop make note of the number of degrees that the distributor advance mechanism is able move in *distributor degrees*. To find out what the static timing should be, multiply the distributor advance by 2 and subtract from 38. The result is the static timing that you should set the ignition at for startup (for example, 13 degrees x 2 = 26 degrees. 38 degrees—26 degrees = 12 degrees static timing). Of course, a little tuning will be necessary depending on your geographic location.

The Module and Coil

Every once in a great while, something simple comes along. Setting up the Extra Performance ignition is probably one of the simplest operations that you could possibly hope for during your entire engine buildup. When you receive your ignition module, it will include an instruction sheet. This piece of literature is very easy to understand and very well illustrated. Therefore, I will not reinvent the wheel by explaining these rather simple procedures. If you follow the instructions to the letter, you will have no problems.

Taylor Cable Products offers what I consider to be the best ignition wire sets available for the Ford V-6. These are the Taylor Spiro-Mag wires as used on our project engine.

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Lubrication and Cooling

The lubrication and cooling systems require the least amount of attention of any of the systems involved in the construction of a performance Ford V-6. In fact, significant modifications in these areas only become necessary in racing environments when the engine speeds exceed 6500rpm on a regular basis. Therefore, most performance engines will require very little lubrication and cooling work to get them in shape.

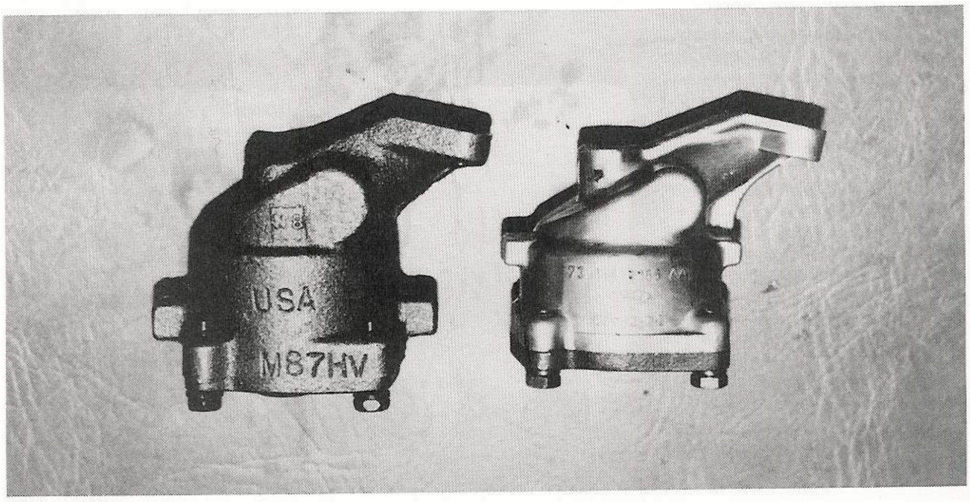
Lubrication

I suppose it would be safe to say that the oil pump is the "heart" of any performance engine. After all, if this little hummer stops doing its job, everything else quits in pretty short order. Therefore, you should pay specific attention to the oil pump. Finding an aftermarket performance oil pump is not very easy. In fact, if you happen to be building a 2.9- or 4.0-liter engine, the only option you have is the part #M128 cast iron replacement oil pump offered by Melling Tool Company in Jackson, Michigan. However, if you are building a 2.6- or 2.8-liter engine, Ford Motorsport (SVO) offers a very nice high volume oil pump under part #M-6600-C2.

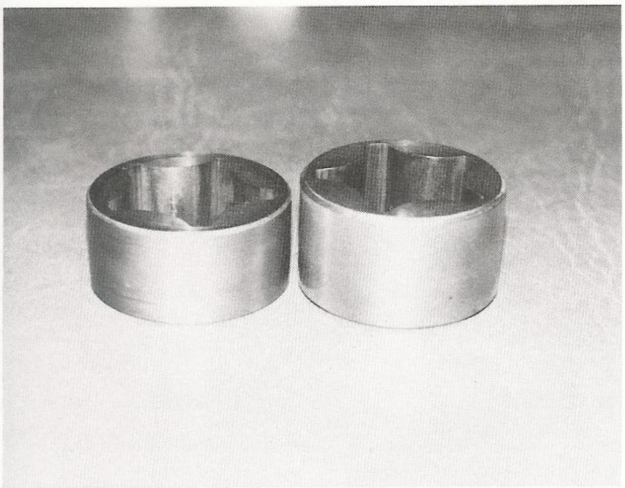
The Ford Motorsport pump features a cast iron pump housing that eliminates the fracturing problem associated with the stock pumps that are regularly operated at higher rpm. Additionally, the pump cover also doubles as a pump shaft girdle, thereby providing much more support for the pump shaft. This pump should deliver 65–70psi of hot oil pressure at about 2500 rpm. If the pressure drops below 55psi, you probably have a problem that must be remedied. This is a really nice pump, however, and you can have complete confidence in its performance.

Oil Pump Preparation

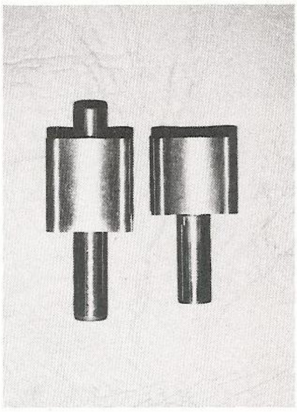
Just like everything else, you must put a certain amount of work into a pump before you subject it to the rigors of a performance Ford V-6. First, you must entirely disassemble and deburr



The Ford Motorsport high volume pump (left) is significantly more stout than the stock pump (right). Furthermore, the pump housing material is iron on the Motorsport pump as opposed to aluminum for the stock pumps.



Here is where the differences between the high-volume and stock pumps become evident. Notice the considerably thicker external rotor used in the high volume pump (right).

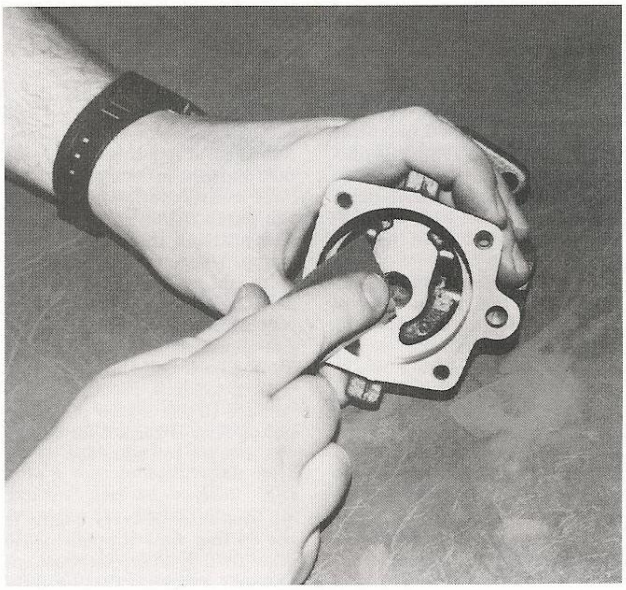


Once again, the high-volume pump inner rotor (right) is significantly thicker than the stock piece. Also, notice that the high-volume pump uses a longer pump shaft that is supported by the pump cover, offering increased strength and durability.

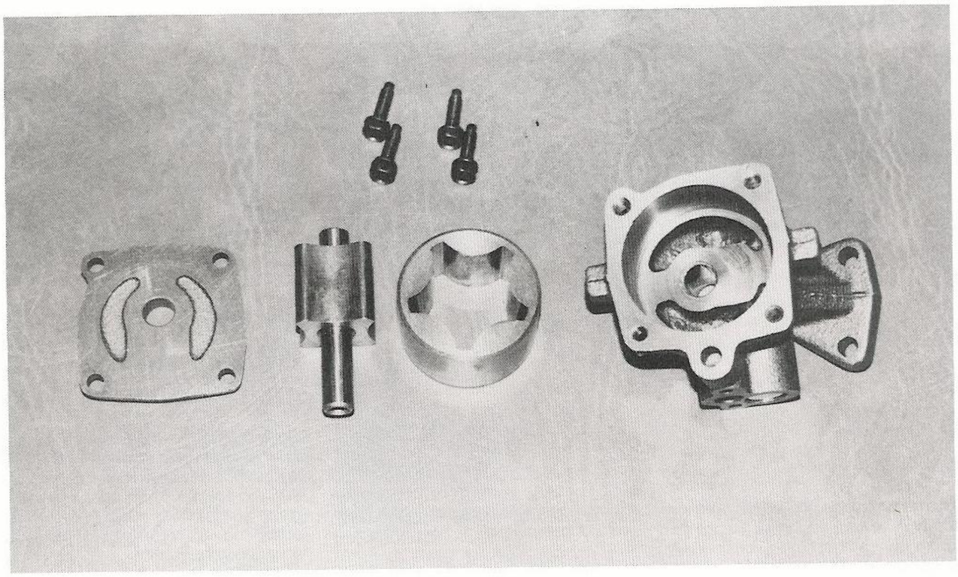
it. Lightly deburr any sharp edges using 400-grit emery cloth soaked in kerosene. Pay particular attention to the pump rotor and housing. Make sure that the pump shaft and shaft bore do not have any burrs or nicks that may cause the pump to fail. Carefully inspect the cover for similar damage as well. Finally, carefully deburr the oil pump inlet and outlet passages. It is very important that no flash be left in these passages. Once this process is complete, wash the pump thoroughly in a rich soap and water solution two or three times. After washing, rinse the pump in large quantities of clear water. As soon as you finish rinsing the pump, coat everything in ample quantities of WD-40.

Oil Pump Assembly

Assembling the oil pump is simply a matter of following a few important steps. There are two products that you should acquire prior to the assembly of the pump: a tube of Loctite #242 for



Deburring the pump should be done by hand using 400-grit wet-or-dry sandpaper soaked in kerosene. Be sure to wash each component thoroughly before reassembly.



Here is a high-volume pump ready to be assembled. It's amazing that such a simple device is so vital to engine life.

securing the pump cover bolts, and a few tubes of Lubriplate #105 Engine Assembly Lube. You will use the Lubriplate extensively throughout the engine assembly process, so it wouldn't hurt to have a few extra tubes on hand.

The first step in the assembly process is to clean the bolt holes in the pump body with some kind of degreasing agent. I find that brake cleaner works very nicely. The idea is to remove any grease or oil that may prevent the Loctite from bonding properly. Use the degreaser sparingly as you don't want to remove the protective coating of WD-40 from the entire pump. Next, completely coat the inside of the pump housing and shaft bore with the Lubriplate assembly lube. Coat the pump gear and rotor with a liberal coat of assembly lube (inside and out) and install them into the housing. Once the gear and rotor are seated, rotate them a few times to evenly distribute the lubricant.

Finally, coat the shaft bore in the pump cover with lubricant and position the cover on the pump. Degrease all the cover bolts and let them dry. Apply a drop of #242 Loctite to each cover bolt and screw them into the pump as far as they will go. Torque each bolt in a crisscross pattern to 8lb-ft. Finally, always be sure to use a new oil pump pickup that is correct for the oil pan that you intend to use.

Oil

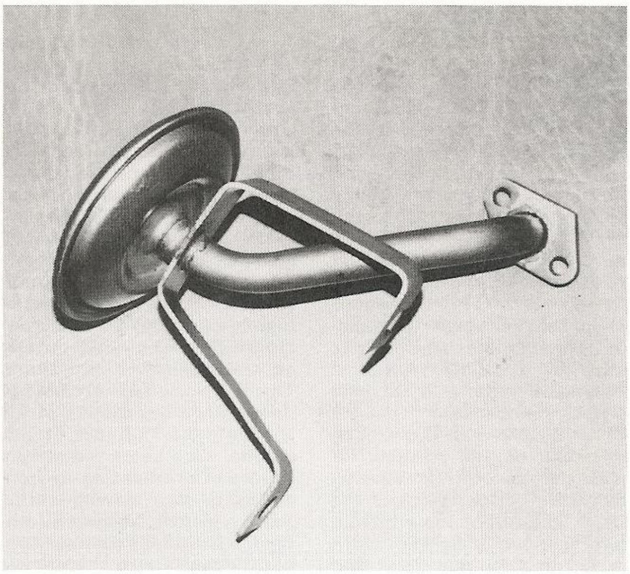
The blood of every engine is the oil that runs through it. No other fluid in an engine must endure the extremes that are present during operation. Ever since the first piston engine sputtered to life, engineers have been trying to improve the oil that is so vital to an engine's longevity. About twenty years ago, synthetic engine oil technology began edging its way into the minds of engine builders and manufacturers all over the world, but a few minor problems kept synthetics from being a viable alternative. Today, synthetic lubricants are so advanced, I can't think of any reason that a person would even consider the use of a petroleum-based oil for anything other than breaking in a brand new engine. It is no secret that synthetic lubricants are the way to go. Just about every major manufacturer now has a synthetic oil on the shelves.

Of course there are a few companies that have been wise to this synthetic business for years. My own "favorite" synthetic oil is Amsoil. Amsoil has been in the synthetic oil business as long, if not longer, than anyone. Amsoil products are sold through independent dealers, so look in the yellow pages for your nearest source. Of all of the engines that have passed through my shop, I have never lost one due to an oil-related failure. I recommend that before you convert any engine to a synthetic oil, it must first be broken in on a high-quality petroleum oil. A new engine actually requires a certain amount of friction so that its internal components can "seat." Synthetics are just too slippery and will not allow the engine to properly break in. I think that running an engine on petroleum oil for about 2,500 road miles should be enough to properly break in any Ford V-6. If you have the pleasure of using a dyno, I think a few hours on the dyno are plenty. Whatever you do, plan on using a high-quality synthetic oil for your Ford V-6.

Oil Temperature

Oil temperature is often overlooked by many engine builders. Engine oils are designed to produce maximum lubrication at a certain minimum operating temperature. This is usually somewhere in excess of 190 degrees. In the Ford V-6, oil temperature should be kept at 215–230 degrees. Anything over this is doing no particular good in a nonracing application; in fact, you should consider such high temperatures (235+ degrees) a warning that something may be wrong inside the engine and perform an immediate investigation.

Once your engine is running, find out what the running oil temperature is. If it is toward the high end of the recommendations (and no problems exist), install an oil cooler to bring the temperature under control. Nice oil coolers and cooler kits are available from Earl's Performance Products. Before you install any oil cooler, thoroughly flush it with large quantities of clean solvent. Then run about 4 quarts of clean oil through it to finish the job. This procedure should remove any particulate matter that might cause damage to the engine in the future.



No matter what type of Ford V-6 you are building, always use a new oil pickup when building your engine. These items cannot be cleaned well enough to warrant their reuse, and over time, small cracks develop in the tube connections that will eventually cause failure.

Filters

Oil filters are really not very complicated, and I don't have any earth-shaking information that will brighten your day. I personally use the oil filters manufactured by Amsoil. These filters are specially designed to filter synthetic lubricants. They incorporate a very dense filtering medium that does an excellent job of trapping the particulate matter that lurks in the oil.

Some of you may find it necessary to use a remote mounted oil filter in order to ease the installation or service of your engine. If this becomes necessary, I recommend the use of the remote filter kits supplied by Earl's Performance Products. It is not necessary or desirable to use a dual filter setup on any street-performance engine. Wet-sump-type oil pumps, even the high-volume types, have a tough time trying to shove oil through a filter. This problem only gets worse when you throw in another filter. It is very possible that with a dual filter the oil delivery will be affected enough to cause an oil starvation problem somewhere in the engine. It is best to stay with one high-quality standard-sized filter and change it regularly, even with synthetics.

Cooling

High-performance engines produce enormous amounts of heat during their operation. This heat energy is the result of many phenomena inside a running engine including friction and the combustion reaction. In fact, heat is the basic element that makes an engine run. About 30 to 40 percent of the total amount of heat energy produced by the engine is transferred into the cooling system. It is, therefore, the responsibility of the cooling system to transfer that heat energy into the atmosphere. In most automotive engines, the primary medium used to transfer this heat energy is a water-to-air heat exchanger, or radiator. Through this radiator flows some sort of coolant, typically a mixture of water and ethylene glycol, or antifreeze.

Antifreeze is an essential element of engine coolant. Its main purpose is to significantly raise the boiling point of the water and to provide a certain level of protection for some of the rather delicate materials that are used in modern cooling systems. An added benefit is that antifreeze does, in fact, lower the freezing point of water as well, allowing an engine to be operated at temperatures far below freezing.

The final essential element to a cooling system is pressure. Although antifreeze does a fairly good job of raising the boiling point of the water, it doesn't quite get the job done. To remedy this problem, cooling systems are designed to operate under a certain amount of pressure so that the boiling point will be raised to a level that will allow the engine to operate properly. In most performance engines, this pressure is 15–18psi.

Fans

No street-driven car should be without an electric cooling fan. Electric (thermostatically operated) cooling fans are far better than engine-driven cooling fans for several reasons. First, electric fans are usually more efficient because they can be more easily positioned closer to the radiator than a typical engine-driven fan. Second, engine-driven fans can require significant horsepower to turn them at higher engine speeds whereas electric fans do not rely directly on the engine to run them. Third, electric fans are able to move large quantities of air through the radiator at low speeds. This helps reduce the chance of overheating in stop-and-go or slow moving traffic. Finally, electric fans can be configured to actually continue supplying cool air to the engine after the engine has been shut down. This helps moderate the heat "spike" that develops after an engine has been shut down. Very nice electric fan kits are available through several performance equipment and RV outlets.

Coolant Recovery Bottles

Coolant recovery bottles will not free up one bit of power from your engine, but you can rest assured that the day will come when one of these bottles will save your ass-ets. Although it is virtually impossible to eliminate all the air from the system when filling it with fluid, it is important to eliminate as much as possible so that air pockets are not created in the engine while it is running. As the system heats up, it tries to expel a good bit of the air that is trapped in the system through the pressure cap and out of the radiator overflow. It is unavoidable that a certain amount of coolant is also expelled as well. If a recovery bottle is used, this coolant can be captured and reintroduced back into the system. Since the bottle is kept about half full of coolant at all times, the system has no choice but to ingest coolant instead of air. This is probably the easiest method of maintaining the optimum coolant level in your engine, and it is certainly cheap insurance.

Thermostats

For years, people have been removing the thermostats from their street engines on the assumption that this will allow the engine to run cooler. Pretty soon, they find that the engine protests in a rather undignified manner by puking its coolant. A thermostat acts as a variable flow orifice that allows the coolant to remain in the radiator long enough so that it can dissipate a sufficient amount of heat into the atmosphere. Removal of the thermostat allows the coolant to flow too quickly through the radiator, resulting in a less than adequate level of heat exchange to the atmosphere. In other words, if you take out the thermostat, your engine's going to puke. A 180-degree thermostat should work quite nicely in all Ford V-6 applications.

Balancing

9

When an engine is running, the internal components are being accelerated and decelerated at incredible rates. As rpm increases, the forces imposed on these components become practically unimaginable. A piston that weighs mere ounces on the table can weigh thousands of pounds when subject to the extremes of an engine operating at maximum rpm. In this environment, very small differences in weight between like components (for example, rods and pistons) can result in a huge imbalance within the engine. An imbalance of this magnitude usually results in the failure of either the crankshaft, bearings, connecting rods, or any combination of these components. To avoid such a catastrophe, reciprocating engines are balanced.

Balancing is absolutely essential to the proper operation and reliability of the engine. The balancing process is a very delicate operation that requires very specialized equipment and a high level of skill on the part of the technician. No part of the balancing process can be done at home, therefore you should find a shop that specializes in engine balancing. Usually, the crankshaft shop that prepared your crank is as good a place to start as any.

What Do You Balance?

The Ford 60-degree V-6 is an internally balanced engine. This means that the crankshaft has enough counterweight material to offset the weight of each piston and rod assembly, thus requiring no additional counterweights attached to the end of the crankshaft (such as counterweighted harmonic balancers). Basically, (almost) every component inside the engine must be properly balanced. The list includes:

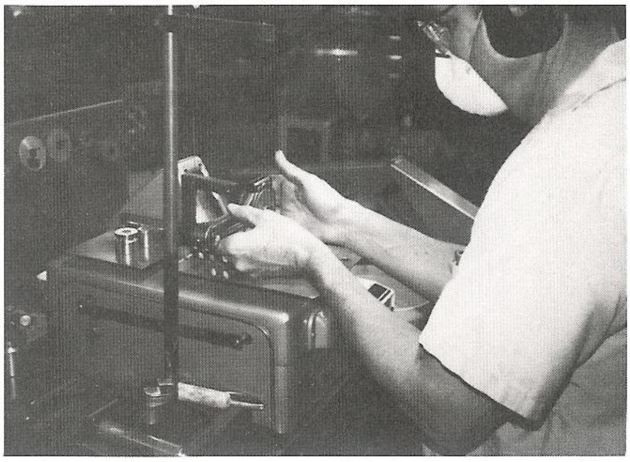
- Complete piston assemblies (including pins, locks, rings)
- Complete connecting rod assemblies (including bushings, bearings, bolts)
- Finished crankshaft (including cam timing gear/sprocket, dowels)

You will notice that a few components are missing such as the flywheel, clutch assembly, damper, and crank pulley. Since the Ford V-6 is an internally balanced engine, these components must be balanced separately. This allows you to change or replace these components without upsetting the balance of the engine.

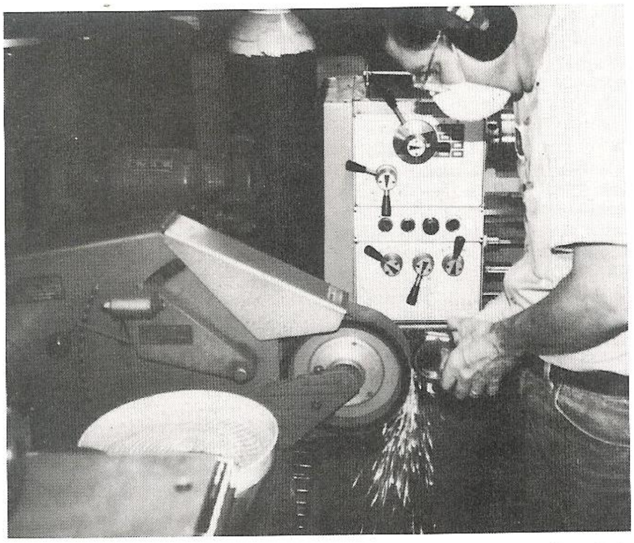
Every component must be completely "finished" before you take anything to the balancer. This means that things such as valve to piston clearance, deck height, bearing clearances, ring gap, wrist pin bore and end clearance, pin oiling holes, and so on must be correct before the engine can be balanced. If you have been following the recommendations in this book, you will have already completed these tasks. Once all of these details are in order, you can be confident in the balancing results.

The Balancing Process

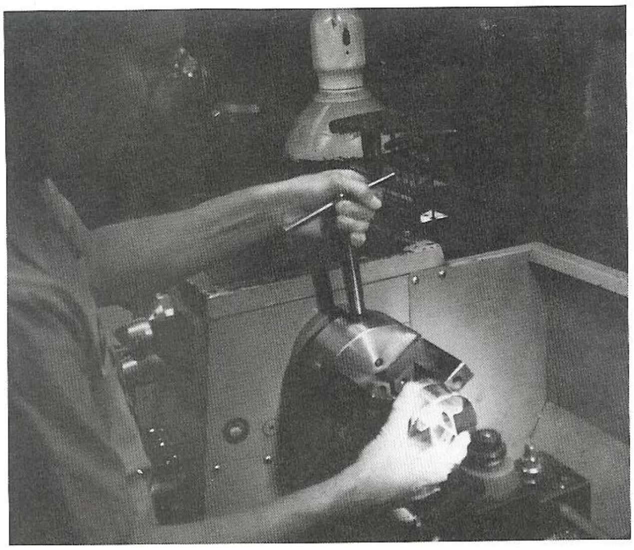
The first thing that the balancing technician will do is separate each component into one of two groups representing either rotating or reciprocating weight.



Proper balancing of the internal engine components is vital to engine longevity. Here, the machinist checks the weight of the rod big end using a special balancing fixture and scale.



Once the lightest of the components has been identified, material is carefully removed from the heavier components in order to equalize their weights.



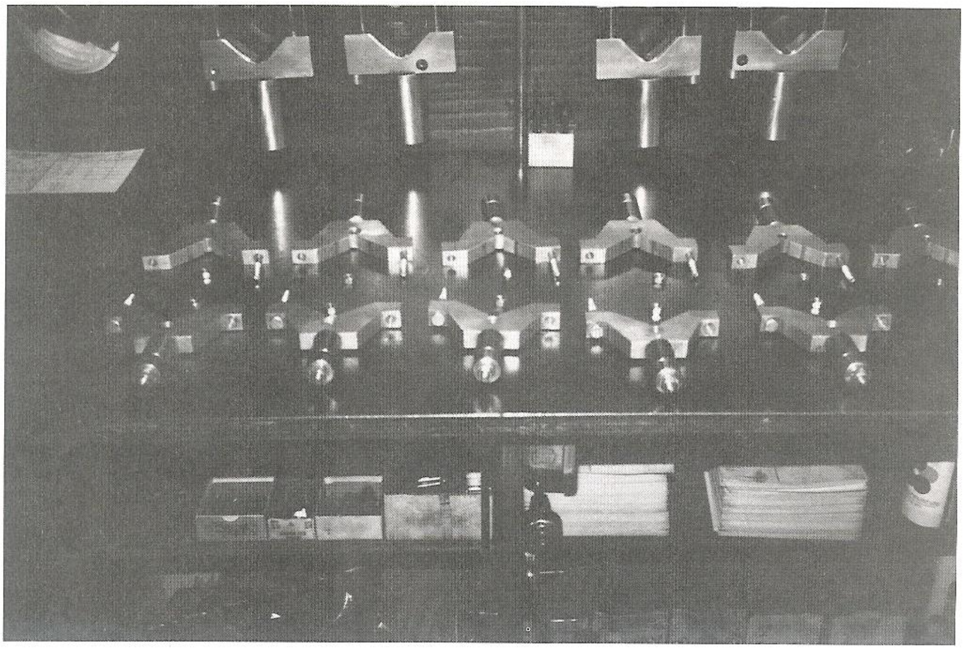
Typically, pistons will only require a very small amount of material removal to bring them into balance. This requires the use of precision equipment like this specially equipped lathe.

The rotating weight consists primarily of the crankshaft and rod bearings, while the reciprocating weight is made up of pistons, rings, pins, and locks. Notice that connecting rods have been excluded from either category. The reason for this is that rods actually fall into both groups. Since the big end of the rod rotates with the crank journal, it is considered part of the rotating weight and is grouped accordingly. The small end, on the other hand, moves in an up-and-down (reciprocating) motion with the piston assembly and therefore is considered part of the reciprocating weight.

The first order of business involved in the balancing process is to very accurately weigh every component. This is primarily done to identify the lightest part (a piston for example) so that the weight of every other like part can be made equal. This procedure is continued until all parts are equalized. This process is usually very easy when custom rods and pistons are used because the manufacturing tolerances are so close that they require very little work to achieve equal weights. Stock pieces, on the other hand, commonly require a good deal of work to be made even.

Once again, connecting rods require a special method of balancing due to their dual role in the balancing equation. First, the technician must balance the big ends of the rods using a special balancing fixture. Once the big end weights have been equalized, the small ends are balanced using the same fixture.

As each component is balanced, the respective weights are recorded so that the bob weight can be calculated. The bob weight is a mass that is bolted to each rod journal. Its purpose is to accurately duplicate the proper percentage of the total reciprocating and rotating weights (including oil). Each bob weight is

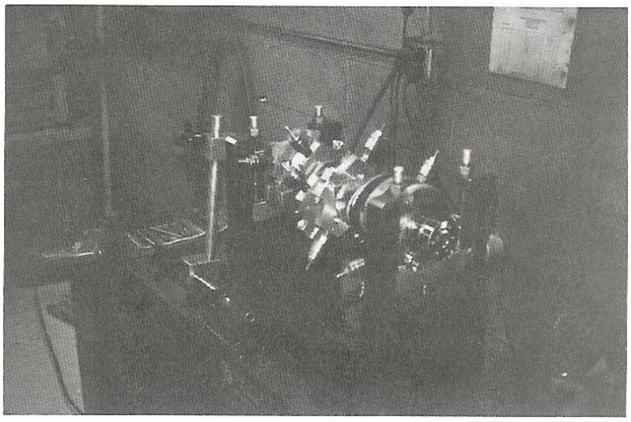


Once all of the component weights have been equalized, special bob weights are assembled. They are bolted to each journal to reproduce the assembled component weights on the crankshaft.

calculated using a special formula that is specific to each engine configuration. With the bob weights secured to the journals, the crankshaft is then spun in the balancing machine. Sensors "read" the crankshaft as it is spinning and indicate the exact point where an imbalance occurs. Depending on the type of imbalance that exists, the technician will have to either add weight to or remove weight from the counterweights on the crankshaft to achieve balance.

After Balancing

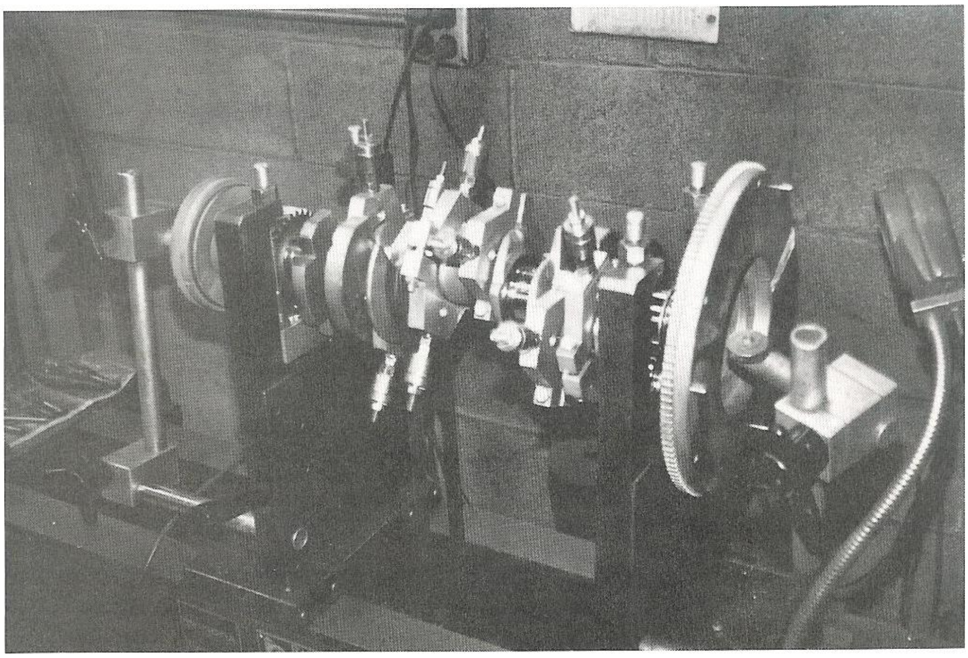
Once the balancing procedures are complete, a good shop will provide you with a balance card. This card will list the weights of each component and the calculated bob weight and



With the bob weights in place, the crankshaft is mounted in the balancing machine and spun in order to determine the amount of imbalance that exists. Once the machine "reads" the crank, the machinist can accurately remove or add weight to the exact area of imbalance.

percentage. Keep this card in a safe place. If you ever need to replace a component (e.g., a piston or rod), you can match it to the specifications on the data card so that the entire assembly does not have to be rebalanced.

Once you bring home all of your newly balanced parts, take the time to thoroughly inspect them before going any further. Begin by inspecting all of the components around the areas that required grinding to achieve balance. Lightly deburr these areas using 400-grit wet-or-dry sandpaper soaked in kerosene. Next carefully inspect each rod around the wrist pin bores to see that none of them have become too thin. Most shops are very careful about this, but it's worth a look anyway. Next, carefully inspect all of the crank journals for any damage that may have surfaced during the balancing procedures. If everything is in order, you can start thinking about putting it all together.



Since the Ford V-6 is an internally balanced engine, the flywheel and damper assembly should be balanced separately, after attending to the crankshaft.

Assembly Tips

10

Before you proceed any further, understand that this chapter is not intended as a complete Ford V-6 assembly manual. Instead, you should use the following information as a supplement to the Ford factory shop manual that applies to your particular engine. The procedures and suggestions below are included so that you can accomplish the assembly of your engine with as little pain and agony as possible. Many of these steps may seem trivial to the average weekend engine builder, but if you want to ensure that your engine is properly constructed and will yield ultimate reliability you should follow each and every step.

Before You Begin

The assembly process includes the most critical procedures involved in the preparation of any Ford 60-degree V-6 performance engine. Due to the delicate nature of engine assembly, a few practices must be meticulously followed at every step of the process.

First, every single part must be totally clean, both inside and out. This means that every component must be thoroughly washed in a warm soap and water solution then rinsed in large quantities of clean, clear water. Next make sure that all parts are thoroughly and completely dry. I advise blowing these components dry with filtered compressed air. The closer each part is to being laboratory clean, the better.

Once the parts are cleaned, lightly coat all parts that are prone to rust with Marvel Mystery Oil. It is best to soak several clean paper towels with Marvel and rub down each part thoroughly. This will provide excellent rust protection and a thin coating of lubrication. Be sure to dribble a little Marvel into any oil passages that may be subject to rust contamination.

The second thing to remember is to keep your work area spotless and organized. Lay out all of the associated components that are part of the assembly that you will be working on. This way the assembly process for these components will flow smoothly. Furthermore, always remember to begin assembling the engine from the bottom up. In other words, don't jump from one area to another during the assembly. Always complete one assembly procedure before beginning another. Make sure that you understand each and every procedure before you begin. If you have any doubts about what should be done or how, ask someone who knows! Do not, under any circumstances, guess or assume anything.

The final tip is to check and recheck every single specification, dimension, or tolerance that applies. Remember that each component (even bolts) has a specific dimension or value that must be achieved. If you have any doubts whatsoever as to whether a component is within specifications, for heaven's sake fix the problem before you go one step further! The appropriate Ford factory shop manual along with the information provided in this book should provide you with all of the critical specifications and dimensions that are required for proper engine assembly.

Always remember that proper engine assembly takes a lot of time and effort. You will probably spend days getting everything just right. Even the most experienced engine builders often spend in excess of twenty-five hours assembling one engine. My advice here is to take the time to do the job right. Now let's begin putting everything together!

The Cylinder Block

Following a thorough cleaning, the first thing you must do is

Lighter colors are best for performance engines because they show leaks and cracks much sooner than darker colors. A high-quality paint such as that manufactured by VHT is a good investment.

thoroughly degrease and paint the block. Brake cleaner and lacquer thinner are excellent products for the degreasing chore. Both clean away the oily deposits very well and evaporate very quickly, leaving a clean, dry surface. Once the block is clean and dry, carefully mask off all surfaces that will not require paint. The intent is to only paint those surfaces that will be visible once the engine is fully assembled.

Although trivial to most engine builders, the color that an engine is painted can actually have a significant effect on diagnosing engine problems. The folks at Vanir Technologies recommend the use of lighter engine colors such as red, yellow, and gray. Fluid leaks are more readily identifiable against a lighter background, and cracks can be spotted far sooner and more easily. Finally, be sure to use a good quality, high-temperature paint such as VHT.

Gallery Plugs

Fortunately, the Ford V-6 is not known for problems in the gallery plug area, however, there are a few things that you must not overlook during their installation. The most important thing to note is that all of the gallery plugs should be installed in the same gallery from which they were originally removed. This is especially true for the main gallery plug at the rear of the block. For some strange reason, many aftermarket replacement gallery plugs weep oil when installed, thus requiring the use of some type of pipe sealant (not advisable). The simplest solution to this problem is to use the original plugs. If a plug was damaged on removal, make every effort to get a new OEM plug from your Ford dealer. Finally, make sure to coat the threads with Loctite #242 (blue). This will help seal any tiny imperfections in the thread-sealing surfaces, and it will prevent the plug from loosening during operation.

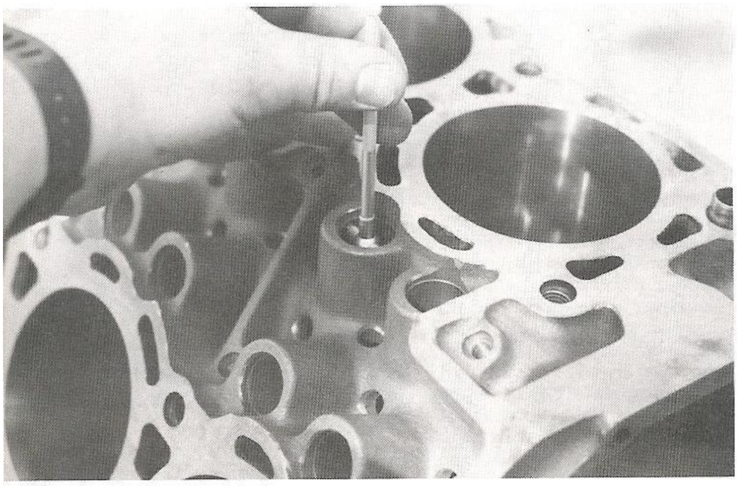
Test-Fitting the Camshaft and Lifters

Test-fitting the camshaft and lifters is a very important step that you should not overlook under any circumstances. Many times, you can find potentially fatal flaws by simply checking the installation of these assemblies. Many Ford V-6s have been lost to simple problems that could have been avoided had the builder taken the time to check the installation of the cam assembly.

The first order of business is to install the cam into the block using no lube. Turn the cam several revolutions by hand to check for any tight spots. If a slight binding occurs, take the block to the machine shop and have a new set of bearings installed as it is likely that the reason for the bind is either a bearing that is cocked in its bore or a nick on one of the bearings.

Once the cam rotates freely, check the oil hole alignment of the center cam bearings. The center cam bearings supply vital oil to the upper valvetrain via passages through each head. If these holes are misaligned, a significant loss of oil pressure will be noted in the valvetrain even though the cam bearings have annular grooves to help prevent this.

Now that the cam is spinning freely and capable of properly delivering oil to the valvetrain, it is time to make sure each lifter will fit into its respective bore properly. Carefully wipe each lifter bore clean using a soft cloth soaked in lacquer thinner. Slide a new lifter into each lifter bore, one at a time, to check that no binding occurs and that each lifter rotates in its bore freely. If a slight drag occurs, lightly hone each lifter bore using an appropriately sized flex-hone lubricated with Marvel Mystery Oil. Clean each bore thoroughly and reinstall the lifter(s) to check that the resistance is no longer present. If you feel a significant bind on any of the lifters following a light honing, first check to make sure the lifter shows no signs of damage



Lifter bores should be measured to ensure they are concentric throughout.

or burrs. It is more common to find a bad lifter than a bad lifter bore. If you find a damaged or flawed lifter, do not attempt to repair it. Instead, throw the errant lifter in the trash and buy a new one. If you find that all of the lifters are in shape and the bind still exists, have the machine shop check the lifter bores for evidence of seizure or eccentricity and discuss repairs accordingly.

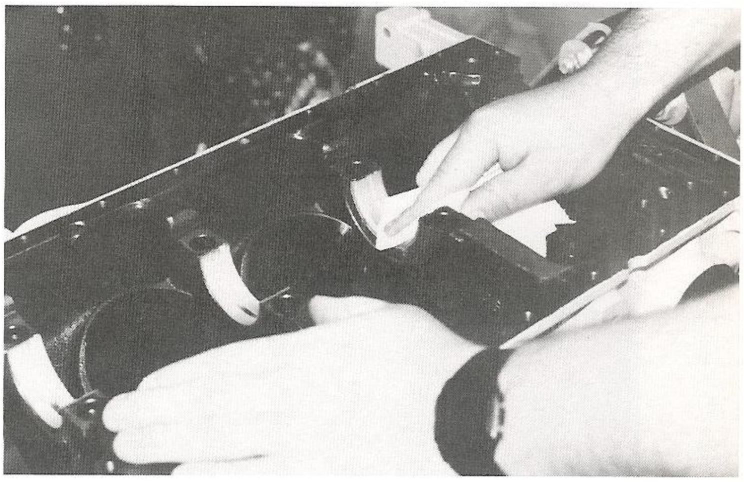
Once all of the required preparatory procedures are complete and the camshaft assembly is in order, you will need to wash the block again, making sure that no contaminant remains from any of the machining operations.

The Crankshaft

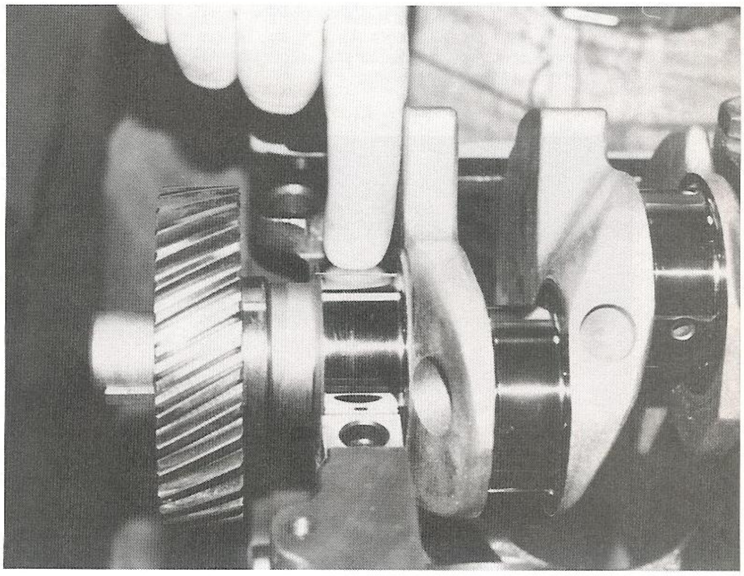
The installation of the crankshaft is the first of the actual assembly procedures. To properly install the crankshaft, you must have at your disposal absolutely spotless components including the block, crank, and bearings. To begin, carefully clean each bearing saddle, main cap, and all bearing shells (front and back) with lacquer thinner. Inspect each bearing saddle and cap for any burrs. Install each bearing half into its respective position in either the block or main cap saddle, making sure that each is seated fully. Next, clean each crankshaft main journal with lacquer thinner and carefully inspect each journal for any burrs. If any burrs are present, polish them out using 600-grit wet-or-dry sandpaper soaked in kerosene and rewash the crankshaft. Lower the crankshaft into the bearings using no lube.

Checking Bearing Clearances

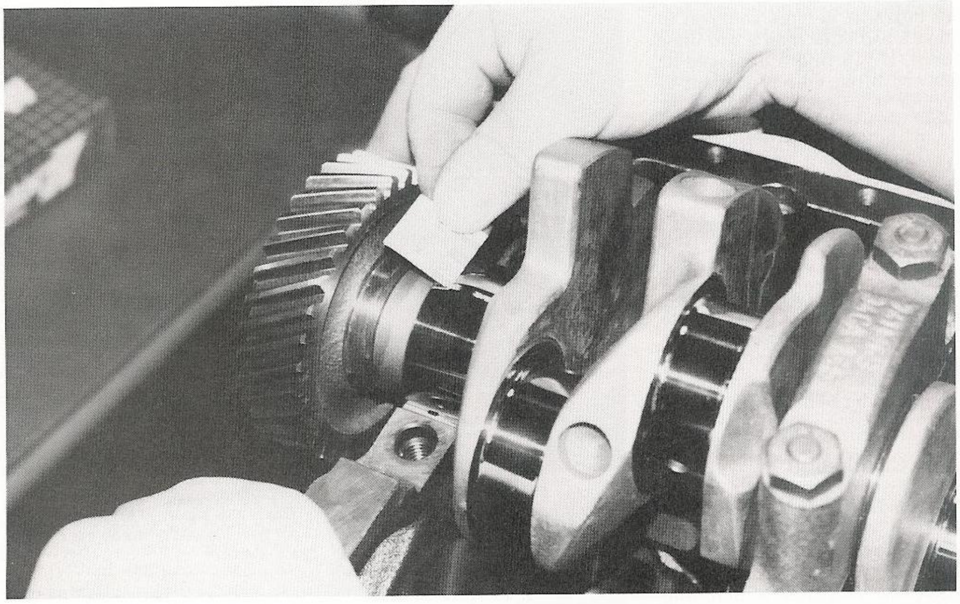
With the crankshaft seated in the block, you can now begin checking the critical bearing clearances. Ideally, you would do this with only the bearings installed in the block and torqued to specs. Then you would use a



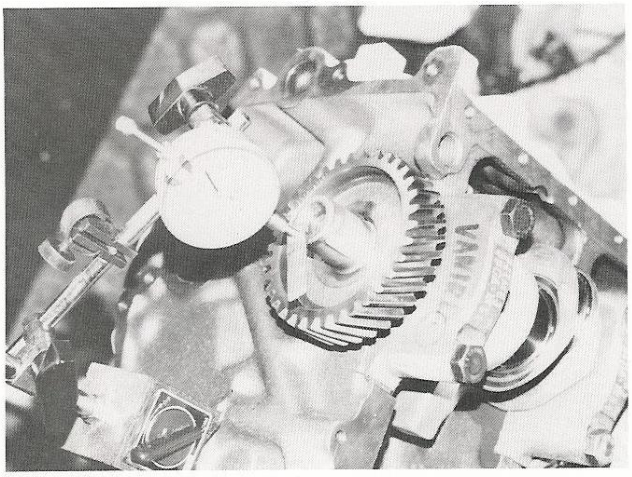
Cleaning the front and back of each bearing half and each bearing bore ensures that maximum bearing contact will be made and heat will be properly dissipated out of the bearings. This is also important to ensure that no dirt gets trapped between the bearing and the bore.



Plastigage is a wonderfully simple yet accurate tool for checking bearing clearances. Here a strip of Plastigage has been placed on a main journal. The main cap will be torqued to specifications, and the Plastigage will be squashed to a given thickness.



To determine the bearing clearance when using Plastigage, compare the width of the compressed material to the chart on the Plastigage package.



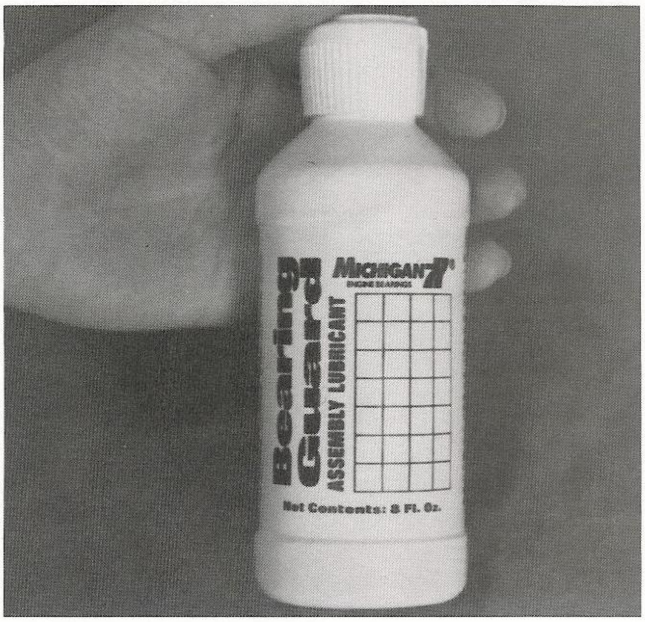
Crankshaft end float is easily checked using a magnetic-based dial indicator.

dial bore gage to determine each bearing internal diameter, which you would then compare to each crankshaft main journal in order to determine the clearance. This procedure requires the use of some very expensive specialty tools and is not within the budget of most builders. However, there is a very ingenious, reliable, and inexpensive way to check bearing clearances at home. That method is called Plastigage. Plastigage is simply a length of soft plastic string material that is placed between the crank and the bearing. As the assembly is torqued to specifications, the string is compressed into a thin flat ribbon. The width of the ribbon is then measured and converted into the appropriate bearing clearance using a special scale provided with the material. Although this procedure is shunned by some engine builders, it is without question the easiest way for the average builder to verify the proper bearing clearances on the crank and rods.

Using Plastigage

First, install all but the #1 main cap and torque them to specifications. Place a piece of the Plastigage material on the #1 crank journal on the centerline of the crank. Install the main cap and torque it to specifications. At this point be very careful not to turn the crankshaft or the reading will be in error. Next, remove the main cap and compare the width of the compressed material to the scale provided on the sleeve supplied with the Plastigage to determine the bearing clearance. Ideally, this clearance should be 0.002–0.0025in on all Ford V-6 engines. It is always better to err on the loose side of these figures than on the tight side.

In most cases, you can swap around the bearing halves to achieve acceptable clearances. However, in some cases, you must use a special set of undersized bearings to achieve the proper clearance. Luckily, most good crank grinders know their stuff and this will not be necessary. Clean the journal where the Plastigage was just used with lacquer thinner, and replace the main cap and torque to specs. Repeat the above procedures for the remaining three main bearings until all of the clearances have been verified.



When installing the crank and rod bearings, always use a good quality assembly lube like Bearing Guard, manufactured by Michigan 77.

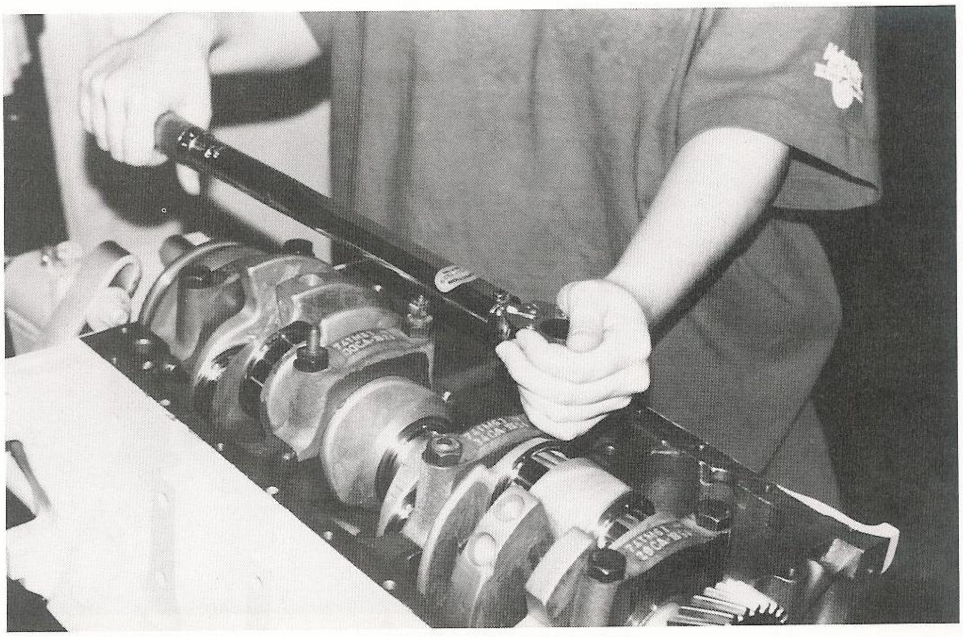
Checking Crankshaft End Float

Once you have completed the bearing clearance checking procedures, install all of the main caps and torque them to specs, leaving the # 3 main loose. Using a soft-faced mallet, align the thrust bearing by tapping the crank snout, first backward, then forward. With the crank forward, tighten the # 3 main cap to specifications. Using a magnetic base, position a dial indicator on the crank snout so that its plunger is parallel to the crankshaft axis. Using a large screwdriver or pry bar, force the crankshaft to the front of the block and zero the indicator. Pry the crankshaft as far to the rear of the block as possible, and read the crankshaft end float on the indicator. This end float should be between 0.005in and 0.008in. Once again, it is better to err on the loose side of these figures.

If you find that the end float is too tight, remove the thrust bearing halves and sand the thrust faces on a surface plate or a sheet of thick glass using 600-grit sandpaper soaked in kerosene. Be sure to check your progress frequently so you do not remove too much material. Additionally, carefully clean each bearing half prior to any test fitting, and make sure to align the thrust bearing as described above before you take any measurement. Once you have established the proper end float, remove all of the main caps and the crank from the block, and reclean everything with lacquer thinner. Be sure to note the location of each bearing shell to avoid getting them swapped around during the final assembly that follows.

Installing the Crankshaft

Now that all of the bearing details are in order, you can begin the actual assembly of the crankshaft. First, place each upper main bearing half in the block. Coat each bearing half and



The main bearing caps should be torqued to specifications in three equal steps. Never use a needle-type torque wrench as it is too inaccurate. A vernier adjustable click-type torque wrench is much more reliable.

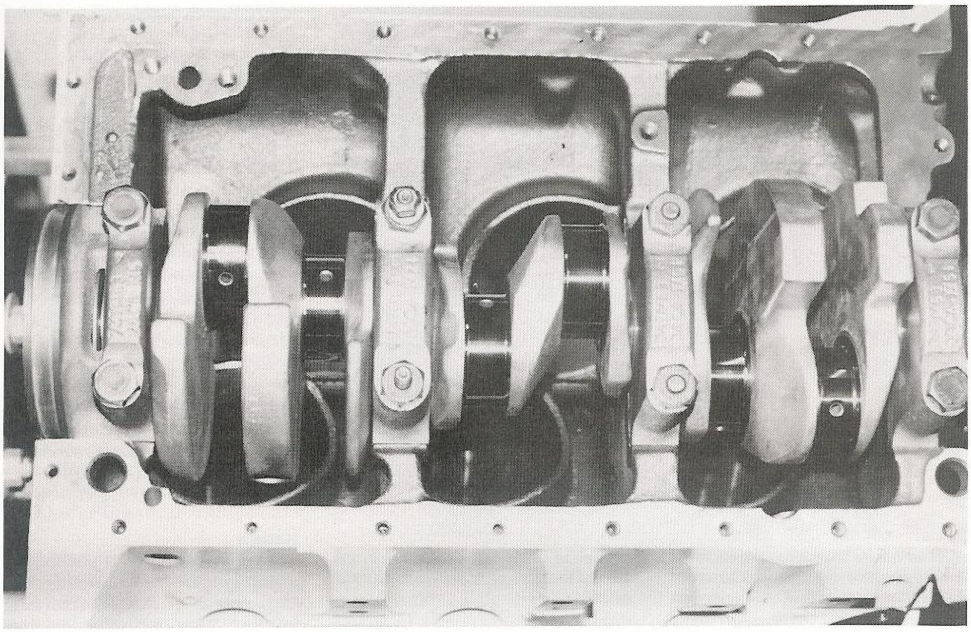
each crankshaft main journal with generous quantities of Michigan 77 Bearing Guard assembly lubricant. Carefully install the crankshaft and rotate a few turns to ensure that no binding occurs. Lubricate each lower main bearing with Michigan 77 Bearing Guard, and install the main caps starting from the rear. Remember to apply a small amount of sealer to the rear main cap, adjacent to the main seal bore (Permatex Form-A-Gasket works very well). Coat the threads on each main cap bolt with antiseize compound and lightly snug up the bolts so that each cap is lightly seated. Tighten all main cap bolts, except the #3 thrust bearing, in 10lb-ft steps to a final torque of 70lb-ft.

Next, align the thrust bearing by tapping the crank snout, first backward, then forward, using a soft-faced mallet. With the crank forward, tighten the #3 main cap to specifications. Finish the procedure by installing the rear main seal. Coat the seal lip with #105 Lubriplate assembly lube. Do not coat the seal bore or the seal OD with lube. Finally, drive the seal into position using an appropriate seal driver.

Connecting Rods and Pistons

Before you can assemble the rods and pistons, you must verify the piston-to-cylinder wall clearance. To do this, insert a feeler gage between the bare piston and its respective bore. You will find that inserting the piston upside-down will make this procedure much easier. Refer to the piston manufacturer's recommended clearance, and choose a feeler gage that is 0.002in smaller than this specification. With such a gage installed between the piston and the cylinder wall, a light drag should be evident. Move up in steps of 0.001in until you have reached the recommended clearance. At this point, a significant amount of drag should be evident. If the piston binds solidly at the recommended clearance, it's time to have a long talk with the machine shop that bored the block. If the clearance checks out OK, you can now proceed with the assembly of the rods and pistons with confidence.

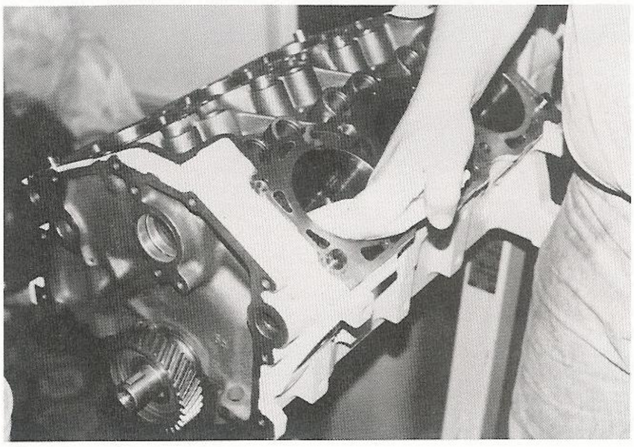
At the balance shop, each rod/piston combination should have been matched and marked accordingly. Furthermore, each rod should be marked as to its proper location in the engine.



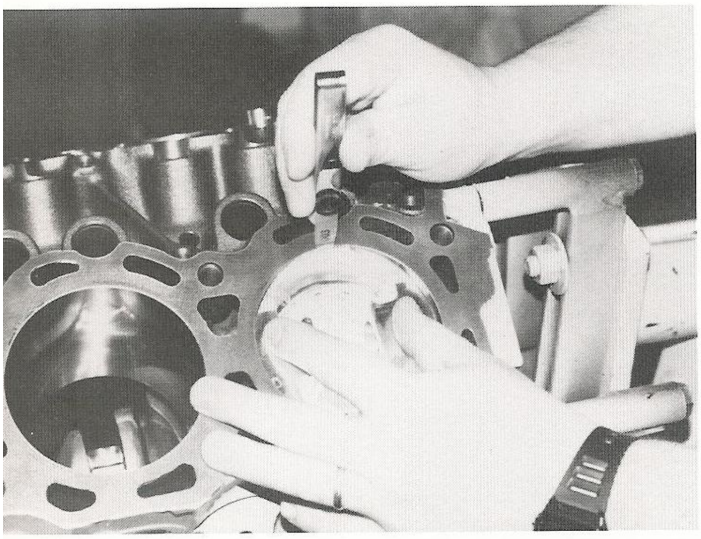
Once the crankshaft is in position, rotate it a few turns to make sure no binding occurs.

These marks should be stamped on both the rod cap and on the side of the rod that has the bearing locating notches in it. Always remember that these notches face the left side of the engine. Also note that some pistons have offset pin bores and must be installed one way. These pistons will have arrows that must point toward the front of the engine. Pistons that do not have these arrows have centered pins and can be installed in either direction. If you have any doubt about the installation of the pistons, call the piston manufacturer and find out the proper installation position.

Beginning with absolutely clean components, install each piston on its respective connecting rod. If your pistons are equipped with pressed pins, you



Before the piston-to-wall clearance can be checked, each cylinder should be wiped clean using paper towels soaked in lacquer thinner.



A feeler gauge is inserted between the piston and the cylinder wall to verify the proper clearance. At the specified clearance, moderate drag should be felt as the piston is pushed into the cylinder.

The top and second piston rings should never be installed by hand. Instead, use a piston ring expander available through most good auto parts outlets.

will need to have the machine shop assemble them using a special rod heater and piston pin fixture. Do not attempt to assemble these yourself as severe piston damage will certainly result. If your pistons are equipped with floating pins, begin the assembly by installing the retainers in one side of the wrist pin bore. If you are using dual Tru-Arc locks, be sure that the smooth sides of the locks face each other, and that the gaps are located at the top and bottom of each bore. Using #105 Lubriplate, lubricate the wrist pin, pin bore, and rod. Slide the wrist pin into the piston and rod and install the remaining clips in the manner described above. Repeat these procedures until all of the assemblies are complete.

Rings

When you open a package of piston rings, you will notice that each ring is packaged according to its position on the piston (top, second, oil) and which side faces up. It is important that each ring be installed exactly according to the ring manufacturer's specifications. Where ring installation is concerned, there are a few things to remember to avoid potential damage to the rings and pistons. First, always begin installing the rings from the bottom up. In other words, begin with the oil ring, then the second ring, and finally the top ring. Second, always use a good ring spreader to expand the rings to allow them to be placed over the ring lands without damage. If you keep these two items in mind, ring installation should provide no headaches and should go very quickly.

Start the ring installation by installing the oil ring spreader into the oil groove. Make sure that the ends of the spreader do not overlap in the groove. Next, install the lower oil ring rail followed by the upper rail. Now, install the second and top rings into their grooves, being careful to position the rings with the correct side facing up. Rotate each ring in its groove to check for any binding that may be present. In most cases, the oil rings will be slightly more difficult to turn, but they should turn freely with a little effort.

Rod Bearings

If you followed the crankshaft grinding procedures outlined in Chapter 2, the crank grinder will have matched the rod bearing clearances to the actual rods and bearings used in your engine. If the grinder was worth his salt, you should have no need for concern, but do yourself a favor and check his work with Plastigage, using the same procedures you used when checking the crankshaft main bearings.

Clean each rod bearing bore and journal with lacquer thinner. The balance shop should have matched each rod bearing to the rod that it was mated to during the balancing process. With each rod and bearing pair identified, carefully clean both the front and the back of each bearing shell with lacquer thinner. Install each bearing shell in its appropriate position in each rod. Once each bearing is in place, the rod and piston assemblies are complete and ready for installation.

Fitting the Rod and Piston Assemblies

In order for the pistons and rings to provide optimum performance and service life, the cylinder bore must be absolutely free of any deposits. Therefore, cleaning the cylinder walls is very important.

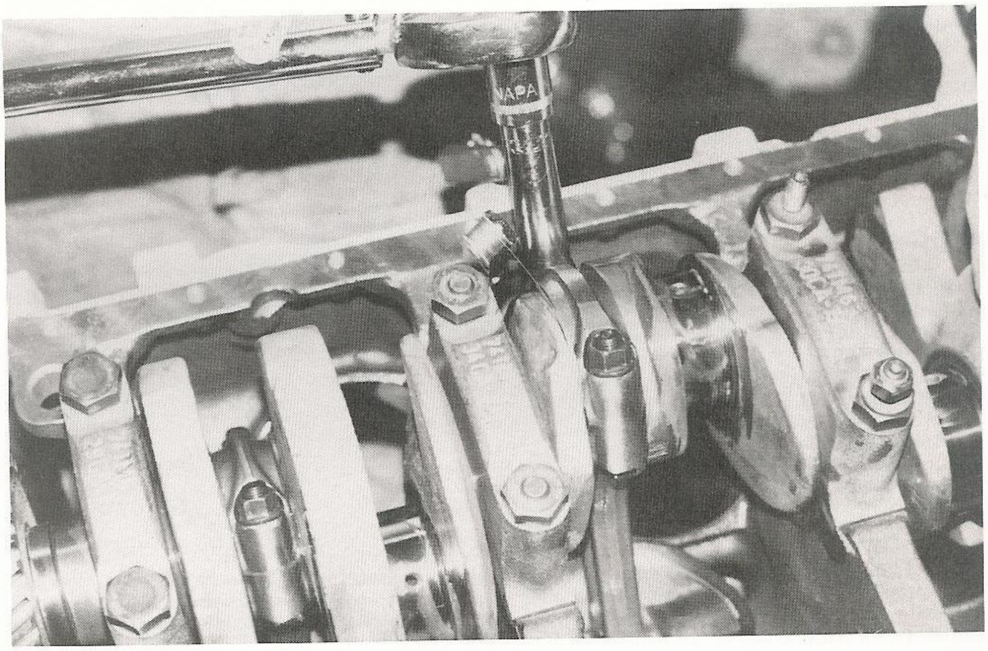
Using clean automatic transmission fluid (ATF) and paper towels, scrub each cylinder wall thoroughly. You will notice that the first few towels will be soiled with deposits from the cylinder wall surfaces. Scrub the walls with ATF-soaked towels until you find no deposits on the towels, and change towels often to avoid embedding dirt into the pores of the walls. Once each bore is clean, wipe it dry with fresh paper towels. Next, clean the cylinder walls with towels soaked in lacquer thinner and let them dry completely.

The best way to install the pistons into your engine is to use a tapered ring compressor like the one shown. These compressors allow the ring to be compressed slowly and evenly without the risk of ring breakage.

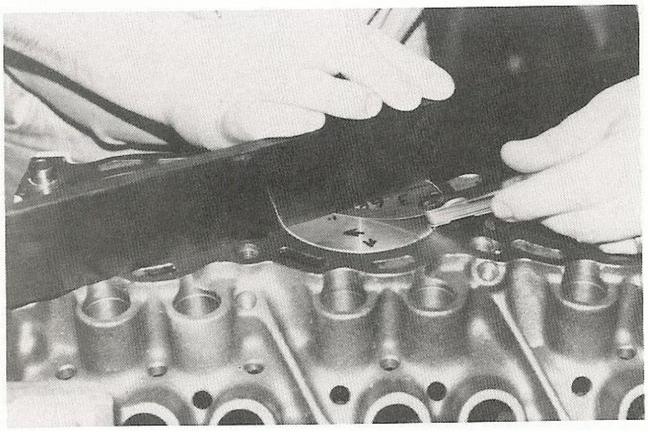
Once each bore is clean and dry, completely coat each cylinder with fresh, clean, petroleum-based (not synthetic) motor oil. Position the piston rings on each piston according to the factory-recommended specifications. Place a length of fuel hose over each rod bolt to help protect the rod journals and cylinder walls from damage. Lubricate each bearing half and each journal with generous amounts of Michigan 77 Bearing Guard assembly lube. Additionally, lubricate each piston with large amounts of fresh engine oil and thoroughly soak each ring pack with oil.

Using a well-oiled tapered ring compressor, carefully press each piston/rod assembly into its bore. Be sure to position each crank journal at its bottom dead center (BDC) position before installing each assembly. Once the piston is about 1/4in below the deck surface, use the sections of hose to carefully guide the rod onto the journal. When the rod is fully seated on the crank journal, remove the guide sleeves and install the rod cap, making sure that the cap is aligned properly (numbers on the same side). Lightly oil the threads on each rod bolt and gradually draw each rod nut down with a speed handle. Before you begin torquing the rod nuts, insert a feeler gage between each rod cheek and the crank journal to keep the rod from cocking while the nuts are being torqued. Torque the rod bolts in three equal steps, alternating between the two, to the final manufacturer-recommended torque value. As each rod/piston assembly is installed and torqued to specs, rotate the crankshaft through several turns to ensure that no binding occurs.

If everything is satisfactory, bring each piston in turn to its top dead center (TDC) position and measure the deck clearance using a precision straightedge and feeler gages. The deck clear-



Inserting a feeler gauge between the rod and its journal face will help ensure that the bearing is not damaged while torquing the rod nuts.



As each piston is installed, the deck clearance can be easily checked using a precision straightedge and feeler gauges.

ance should be between 0.000 and 0.010in—ideally 0.005in or less. Remember, under no circumstances should the piston protrude above the deck surface. Once you have recorded all of the deck clearances, rotate the crankshaft several times to make sure that the entire assembly rotates freely.

Degreeing the Camshaft

In order for any performance engine to produce optimum power, the camshaft must be installed properly and the camshaft "phasing" must be verified. In other words, every cam must be checked, in the engine, to make sure all of the "bumps" are in the right place and to make sure that all of the associated parts are going to follow the bumps as they should. The process that is used to verify these camshaft events is called "degreeing" the cam.

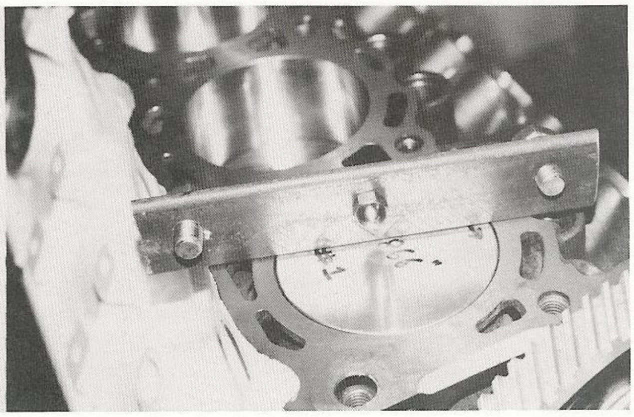
Before you can begin degreeing the camshaft, you must have a few special tools. First, a professional quality degree wheel is a necessity. This is quite possibly the single most important tool used in degreeing; therefore, a high-quality wheel like that manufactured by Jomar in Rochester Hills, Michigan, is critical.

The next required item is a pointer. Many very successful engine builders have had very good luck using a pointer made of heavy gage wire that was simply bolted to a convenient location on the front of the cylinder block. Although easy to fabricate and use, these wire pointers are only accurate to about 1/2 to 1 degree. Jomar offers a pointer that uses a razor blade turned on its edge as the actual indicator. This type of pointer is accurate to 1/4 degree or better and is well worth the investment.

The last two required items are a dial indicator and stand assembly and a piston stop. Look for an indicator that reads 0.100in per revolution and that has a minimum scale graduation of 0.001in. You will find that you will need a magnetic indicator stand to properly locate the indicator on the engine.

Piston stops are available in two basic configurations, one that bolts to the deck surface with the heads off, and one that screws into the spark plug hole with the heads on. It is recommended that every Ford V-6 camshaft be degreed with the heads off the block. With a little patience, a hand drill, and about five bucks in parts, you can make a very effective piston stop that will fit the bill perfectly for many years to come (refer to accompanying photos).

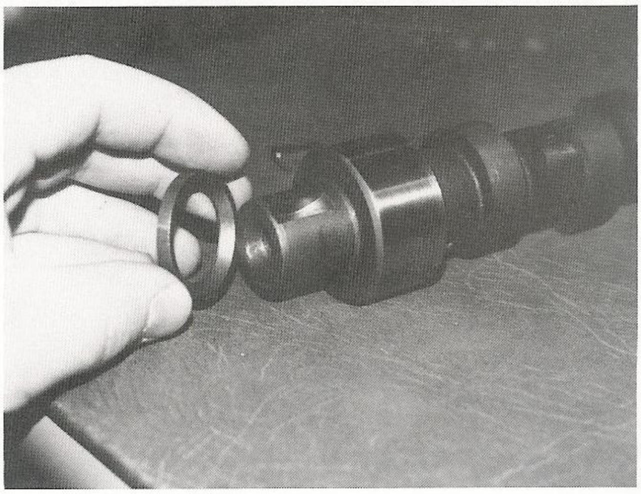
With the few aforementioned items in hand, you will find that degreeing your camshaft is far easier than you might expect. Just take your time and follow the steps below, and in no time you will have your camshaft set up perfectly.



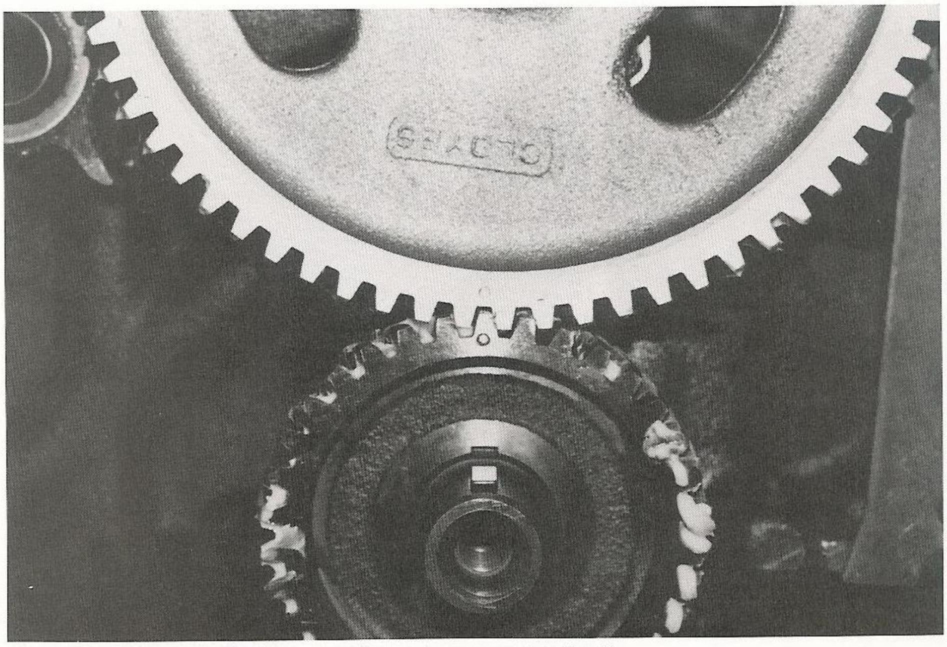
A simple but effective piston stop can be fabricated from a piece of angle iron, an acorn nut, and a few bolts. A piston stop is necessary to ensure the accurate location of top dead center for camshaft degreeing purposes.

Finding Top Dead Center (TDC)

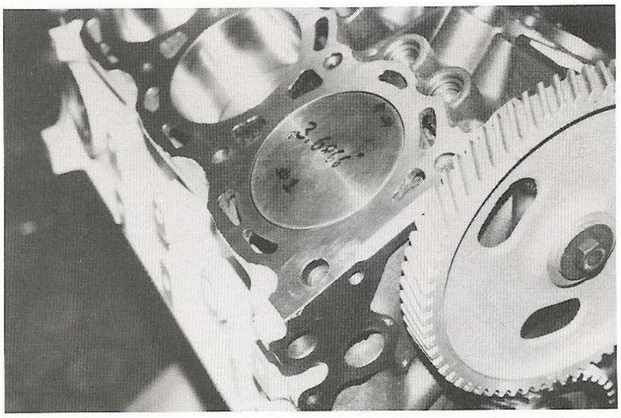
Finding the absolute top dead center position is the first and most important step in the cam degreeing process. Without knowing the exact location of the



The camshaft thrust washer must be installed to properly mount the timing gear. Always install this washer with the chamfer toward the cam.



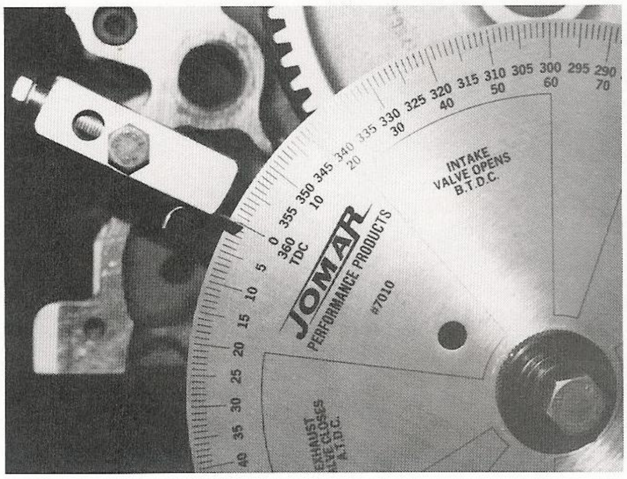
When degreeing the camshaft, always start with the timing marks set in the straight-up (stock) location. Note the 105 Lubriplate assembly lube liberally smeared on the gears.



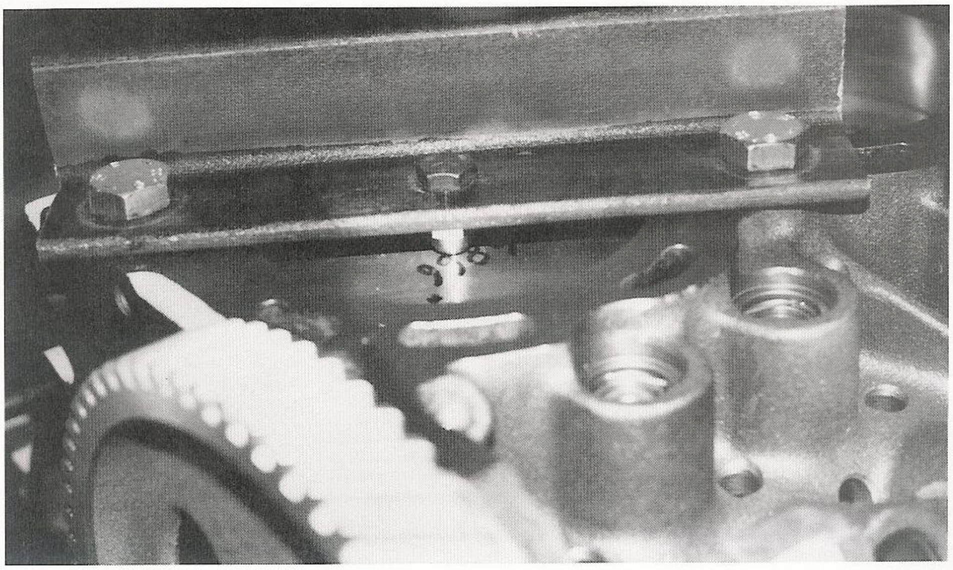
To begin the process of accurately locating TDC, bring the #1 piston to TDC according to your eye. Although the piston may appear to be at top dead center, you will likely find that you have missed it by several degrees once you begin working with the degree wheel.

number one piston's top dead center, it is absolutely impossible to know if the camshaft has been installed correctly.

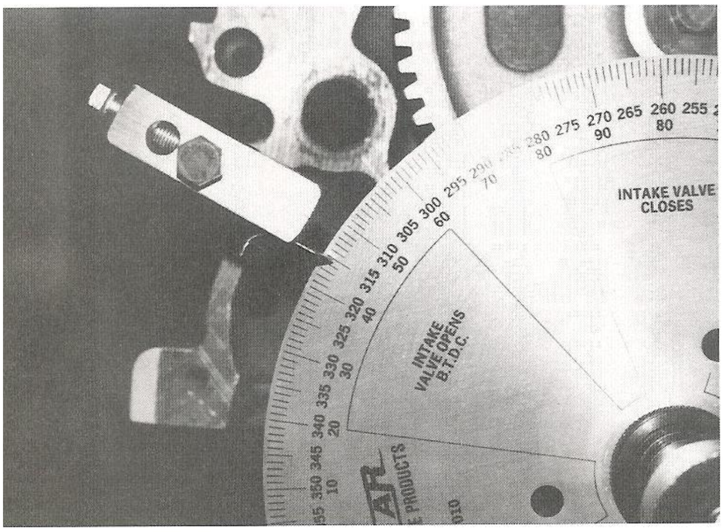
To begin, install the camshaft in the block using no lube on either the bearings or the lobes. Since the camshaft must be installed as it would in a running engine, the cam spacers, keys, and thrust plate must be installed and torqued to specs. With the cam in position, install the timing gears and related hardware and align the timing marks in the "straight up" or stock position. Once this is done, bolt the degree wheel to the crank snout, and locate the pointer in a convenient location relative to the wheel. Turn the crankshaft until the number one piston is at top dead center according to your eye. Loosen the degree wheel attachment bolt and rotate the wheel until the pointer lines up with the TDC mark on the degree wheel, then tighten the bolt. Rotate the crank until the number one piston is about 1in away from TDC. Install the piston stop, making sure that it is fastened securely. Turn the crankshaft clockwise until the piston contacts the piston stop, and record the reading on the degree wheel (for example 45 degrees). Now, rotate the crankshaft counterclockwise until the piston contacts the piston stop. Once again, record the reading indicated on the wheel (for example 49 degrees). To find the absolute top dead center location, add the two readings together and divide by two (45 degrees+49 degrees)÷2 = 47 degrees). Carefully adjust the pointer/wheel so that the pointer lines up with



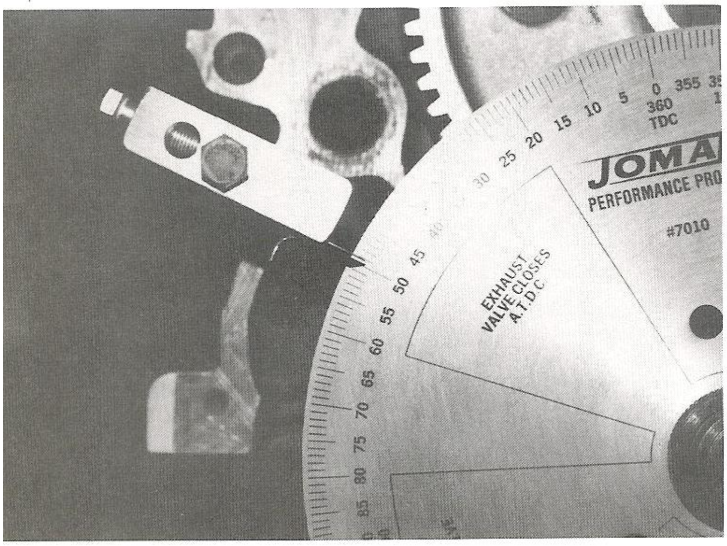
Once the #1 piston is visually at TDC, bolt the degree wheel to the crank snout and set the wheel precisely at TDC.



Rotate the crankshaft clockwise until the piston is about 1in down from the deck and install the piston stop, making sure the bolts are secure.



With the piston stop in place, rotate the crank clockwise until the piston contacts the piston stop. Read the degree wheel and record the number on a sheet of paper. Here you would record 45 degrees.



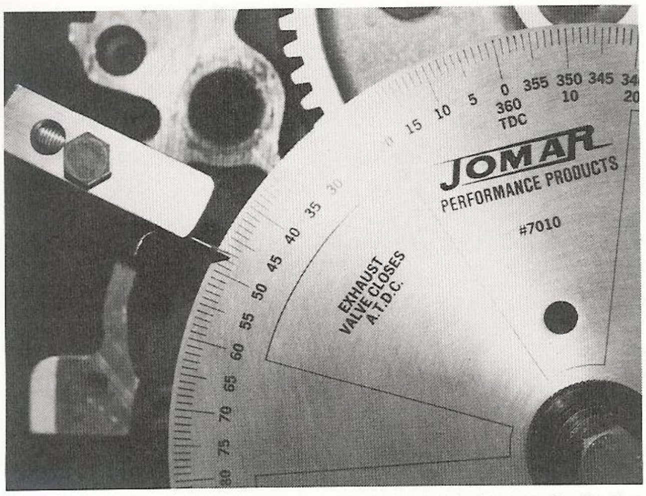
After you have recorded the reading after clockwise rotation, turn the crank counterclockwise until the piston contacts the stop. Once again record the reading. In this photo, that reading is 49 degrees.

this number on the wheel. In this example, you would line up the pointer with the 47 degree mark. Once you have made this adjustment, rotate the crankshaft clockwise until the piston contacts the piston stop. At this point, the degree wheel should read precisely the same number as previously indicated (in this case 47 degrees). If everything checks out, remove the piston stop. From this point on, be very careful to avoid hitting the degree wheel or the pointer, and always turn the crankshaft in a clockwise direction to avoid disturbing the degree wheel position. If either the degree wheel or the pointer is disturbed during the degreeing process, you will have to repeat the entire setup procedure.

The Degreeing Procedure

The degreeing procedure begins by installing new lifters in the lifter bores of the number one cylinder using no lube. With both lifters installed, rotate the crankshaft until the intake lifter is on the base circle of the intake lobe. Install the dial indicator stand on the deck surface and position the indicator point on the edge of the lifter and parallel to the lifter bore axis. Do not install the indicator in the pushrod cup as this will result in erroneous readings. Preload the indicator plunger by approximately 0.100in and zero the indicator.

Locate the specification card that was included with your camshaft. This card will provide all of the critical reference information that you will need to determine if the camshaft was manufactured correctly and if it is installed in the engine correctly. The first piece of information that you must find on the cam card is the manufacturer's "checking lift." All the valve opening and closing specifications on the cam card are based on the checking lift, so make sure you know what this figure is be-

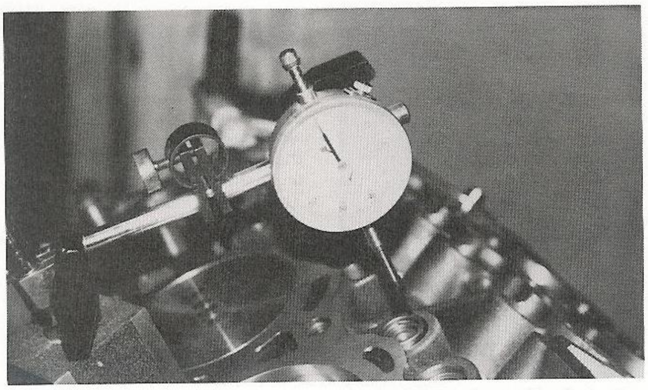


By adding the two readings together and dividing by two, you find that the proper location should be 47 degrees. Knowing this, you now adjust the degree wheel so that it reads precisely 47 degrees. To check your work, turn the crankshaft in the opposite direction until contact is made with the piston stop. At this point, the pointer should align with the 47 degrees mark on the opposite side of the wheel. If this is true, remove the piston stop.

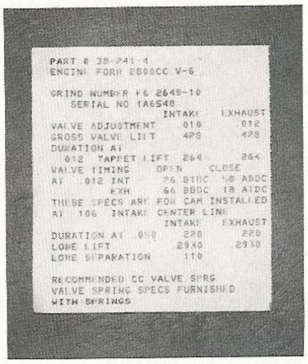
fore you go any further.

Once you know the proper checking lift and the intake lifter is on its base circle, slowly rotate the crankshaft clockwise until the dial indicator registers the exact checking lift. Look at the degree wheel and record the number of degrees before top dead center (BTDC) (26.0 degrees, for example). This is the nominal intake opening point. If you rotate the crankshaft too far, do not back up to the checking lift. Instead, continue rotating it in a clockwise direction until the intake tappet begins to open again. With the intake opening point recorded, continue rotating the crankshaft in a clockwise direction until the maximum lift value is achieved. Record this value as the maximum cam lift for the intake lobe.

Continue rotating the crank until the lifter begins to descend on the closing ramp of the lobe. Stop the crank rotation once the indicator again reads the exact checking lift. Read the degree wheel and record the number of degrees after bottom dead center (ABDC) (e.g., 58.5 degrees). This is the nominal intake closing point. At this point, all of the essential data has been collected relative to the intake lobe. Without disturbing the degree wheel or the pointer, move the dial indicator assembly to the exhaust lobe. Rotate the crankshaft until the exhaust lifter is on the base circle of the number one exhaust lobe. Install the dial indicator assembly as described above, and



To begin the actual degreeing process, you must position a dial indicator on the intake lifter. Rotate the cam until the intake lifter is on its base circle and zero the indicator. Make sure that the indicator is parallel to the axis of the lifter bore before proceeding.

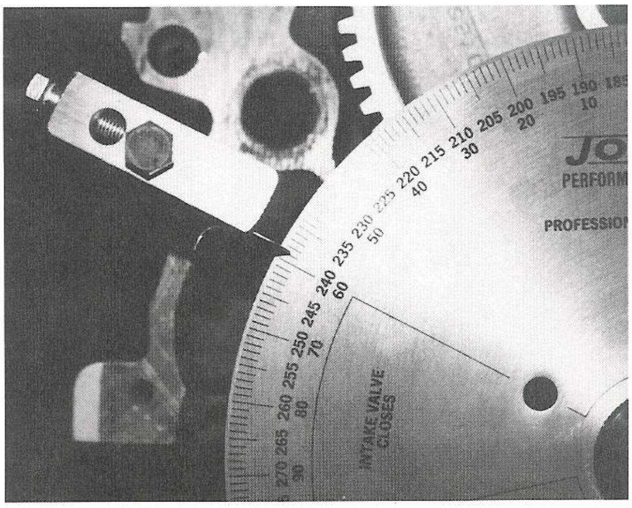


All camshaft manufacturers provide a cam specification card with their cams. This card will provide all of the necessary information that you will need to properly degree-in your cam.

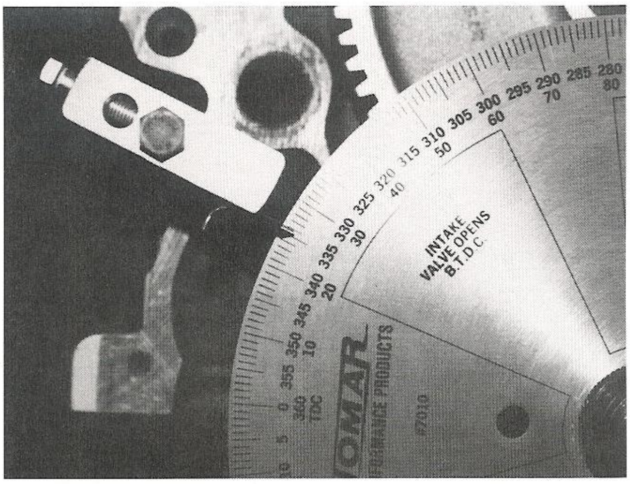
zero the indicator. Following the same techniques that were used to degree the intake lobe, carefully degree the exhaust lobe. Note that the exhaust opening event occurs before bottom dead center (BBDC), and the exhaust closing event occurs after top dead center (ATDC). In our example, we will use 68.5 degrees BBDC as the exhaust opening point and 21.5 degrees as the exhaust closing point.

Calculating the Installed Cam Specifications

At this stage of the game, it should be obvious that the first thing you will want to do is compare the specifications that you have just recorded to those that are on the manufacturers cam card. Ideally, they should match within a half degree or so. If this is the case, then the camshaft is manufactured perfectly and is installed in the "straight up" position. If the valve events that you recorded occur sooner that the cam card specifications, the cam



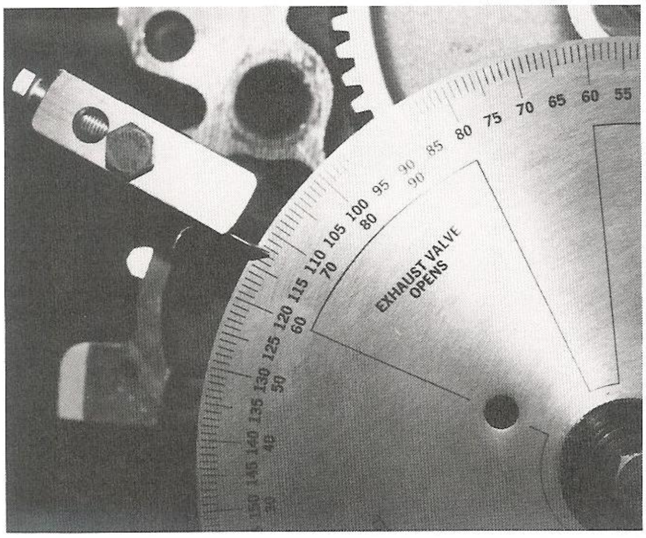
Continue rotating the crank in a clockwise direction until the intake lifter begins to descend on the closing flank of the cam lobe. Stop rotating the crank once the indicator reads the proper checking height. The number indicated on the degree wheel at this point is the installed intake closing point. This photo indicates a closing point of 58.5 degrees after bottom dead center (ABDC). Now you can move the dial indicator to the exhaust lobe and repeat the procedure.



Rotate the crankshaft clockwise until the intake lifter rises to the correct checking lift (in this case 0.012in). The number indicated on the degree wheel is the actual installed intake opening specification. As the photo indicates, this cam opens at 26 degrees before top dead center (BTDC).

is advanced relative to the manufacturer's specs. If the opposite is true, the cam is retarded. The difference between the installed specification and the cam card specification is the amount of advance or retard in degrees of crankshaft rotation. For instance, let's say that your camshaft shows an installed intake opening of 28 degrees BTDC and the cam card shows the same dimension to be 25 degrees BTDC. This would indicate that the installed intake opening event is advanced 3 crankshaft degrees from the factory specifications.

To correct an advanced/retarded camshaft to the proper specifications, you can install offset crankshaft or camshaft keys, an "indexed" crankshaft timing gear, or a combination of these parts in order to bring it up to the proper specs. Remember, however, that a 1 degree change



Once the dial indicator has been moved to the exhaust lobe and zeroed with the lifter on the base circle, rotate the crankshaft clockwise until the indicator reads the proper checking height. Once again, record the number indicated on the degree wheel as the installed exhaust valve opening point. The photo shows this to be 68.5 degrees before bottom dead center (BBDC).

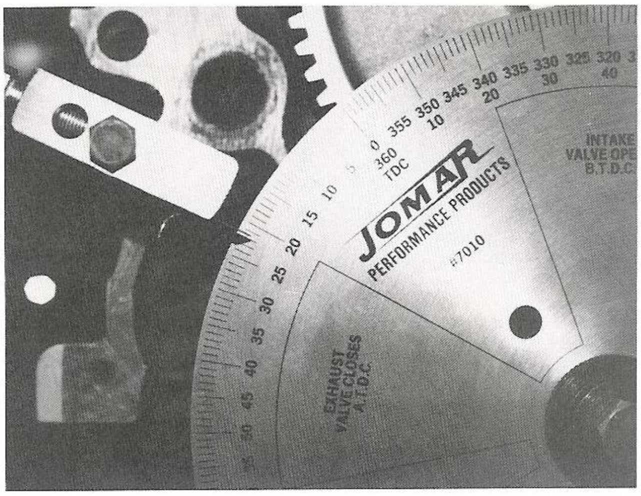
in the camshaft position corresponds to a 2 degree change in the crankshaft position since the crank rotates twice for each turn of the cam. If you find that you must adjust for an error in valve timing, consult the cam manufacturer for suggestions on how to best correct the problem. Of course, any time you make a correction, you should redegree the camshaft to verify the adjustments that you have made.

If you are satisfied with the general installation position of the camshaft, you can now calculate the remaining specifications that you will find on the cam card. These specifications will include valve overlap, intake and exhaust duration, intake and exhaust lobe centerline, and lobe displacement angle. For a more thorough description of each of these cam timing elements, refer to Chapter 6. The calculations for these remaining events are as follows:

- Overlap = Intake opening + Exhaust closing
- Intake duration = Intake opening + Intake closing + 180 degrees
- Exhaust duration = Exhaust opening + Exhaust closing + 180 degrees
- Intake lobe centerline = (Intake duration ÷ 2) - Intake opening
- Exhaust lobe centerline = (Exhaust duration ÷ 2) -
- Exhaust closing lobe displacement angle = (Intake centerline + Exhaust centerline) ÷ 2

If we plug the sample data into the above formulas, the installed camshaft specifications would be

- Overlap = 26.0 degrees + 21.5 degrees = 47.5 degrees
- Intake duration = 26.0 degrees + 58.5 degrees + 180 degrees = 264.5 degrees
- Exhaust duration = 68.5 degrees + 21.5 degrees + 180 degrees = 270 degrees
- Intake lobe centerline = (264.5



Continue rotating the crankshaft clockwise until the lifter reaches the proper checking height on the closing flank. The number indicated on the degree wheel is the installed exhaust valve closing point. This photo indicates an exhaust closing point of 21.5 degrees.

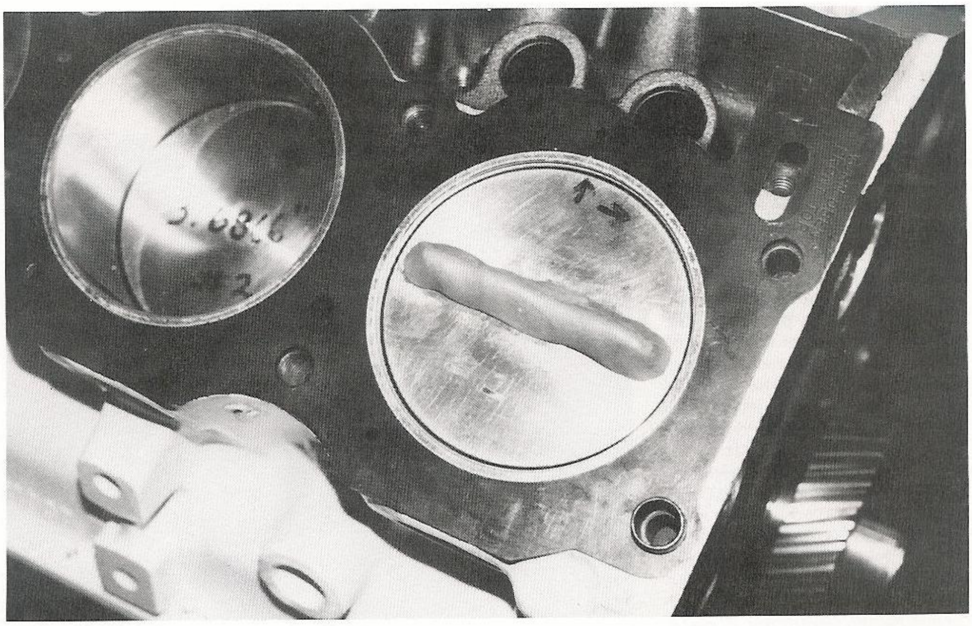
degrees ÷ 2) - 26.0 degrees = 106.25 degrees
• Exhaust lobe centerline = (270 degrees ÷ 2) - 21.5 degrees = 113.5 degrees
• Lobe displacement angle = (106.25 degrees + 113.5 degrees) ÷ 2 = 109.9 degrees

Remember, most cams will vary slightly from the cam card specifications, but usually no more than 1 degree or so. If you find that your observed specifications differ by more than 2 degrees, recheck the cam. If you obtain the same results, contact the cam manufacturer and discuss a solution.

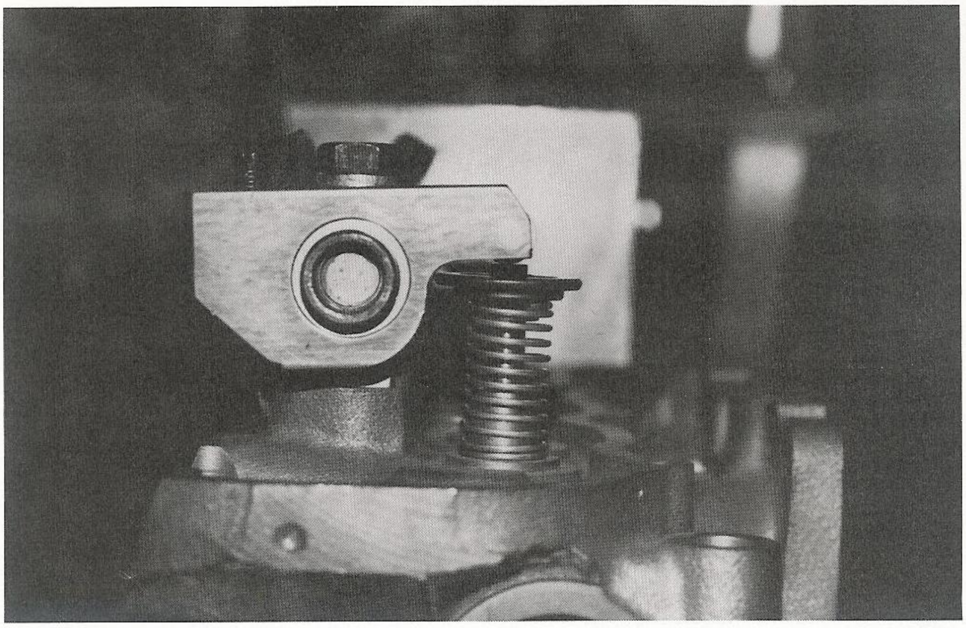
Checking Valve-to-Piston Clearance

Checking the valve-to-piston clearance is best done immediately following the degreeing procedure since the camshaft specifications have been either verified or corrected and the cam is already installed in the engine as if the engine were running. Although it's ignored by many engine builders, checking the valve-to-piston clearance is very important when building a Ford V-6. The procedure takes only a little extra time, but knowing that the valves will not contact the pistons when the engine is fully assembled offers an enormous amount of security.

To properly determine the valve-to-piston clearance, it is best to check one cylinder at a time. First, lay a 1/4in roll of modeling clay in the middle of each piston dome, parallel to the crankshaft centerline. Make sure that the clay adheres to each piston well. Next, install all of the valves in one head using light springs and the actual retainers, locks, and lash caps if applicable. Bolt the head on the block using precompressed (used) head gaskets, and torque to specs. Install the lifters and pushrods in the first cylinder to be checked, followed by the rocker assembly. Torque the rocker assembly to specifications and lash the valves to the recommended hot specs. Rotate the crankshaft two full revolutions. This will allow both valves to cycle completely. If, at any time, you feel resistance, stop turning the crankshaft immediately and find the cause of the bind. If the crankshaft rotation is uneventful, remove the cylinder head and inspect the clay. You will notice two distinct indentations left in the clay by each valve. Using a very sharp



The most reliable way to check the valve-to-piston clearance is to place a roll of modeling clay on the dome of each piston. Once the heads and valvetrain are bolted together, this roll of clay will compress as the valves open and close as the engine is cycled.



Correct valvetrain geometry places the rocker arm contact point slightly inboard of the valve tip center.

razor blade, cut the clay in half at the lowest part of each indentation. Using a machinists rule, carefully measure the thickness of the clay at the thinnest point of each indentation and record your findings. This measurement will be the actual valve-to-piston clearance. As a general rule of thumb, there should be at least 0.080in clearance on the intake valves and 0.100in clearance on the exhaust valves. Repeat this process until all of the cylinders have been checked.

If the measured clearance is less than these figures, the valves will have to be sunk into the head by the appropriate amount to achieve the proper clearance. For example, let's say the clearance on an intake valve is 0.070in and on an exhaust valve it is 0.080in. This would require the intake valve be lowered into the head 0.010in and the exhaust lowered 0.020in. Under no circumstances should the piston be fly-cut to achieve these clearances. Although this is common practice on many American V-8 performance engines, this only results in problems for the Ford V-6. Also, do not forget the importance of equalizing valve depths and chamber volumes. If you find that a pair of valves is significantly lower than the rest, consider having all of the remaining valves lowered to the same depth. Since flat-top pistons are used in most performance applications of the Ford V-6, it is rare that the valves will require a large amount of work to achieve the optimum clearance. Once you have corrected all of the valve-to-piston clearances, remove the heads, lifters, cam, and timing components, and wash everything thoroughly.

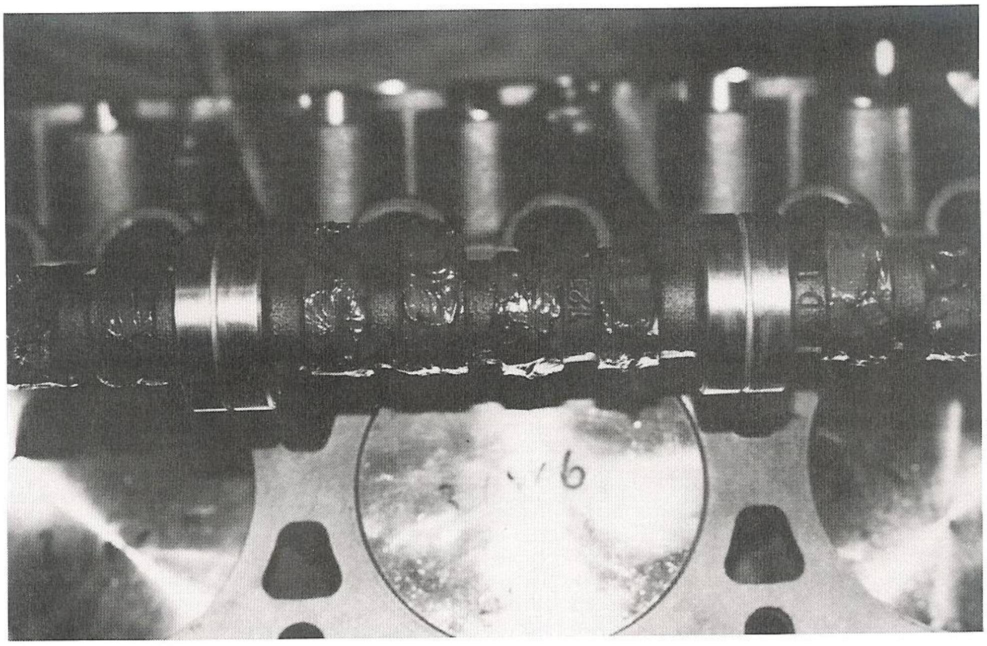
Checking Valvetrain Geometry

Valvetrain geometry describes the relationship between the lifter, pushrod, rocker arm, and valve stem through the full range of movement. This geometry is affected by many things including valve length, rocker arm ratio, rocker shaft pedestal height, and manufacturing tolerances. You should never assume that the geometry will be correct even if you are using new stock parts. Improper valvetrain geometry results in accelerated wear on the valvetrain components and in the worst cases can even result in catastrophic valvetrain failure. The following steps explain how to check the geometry and, if necessary, correct it.

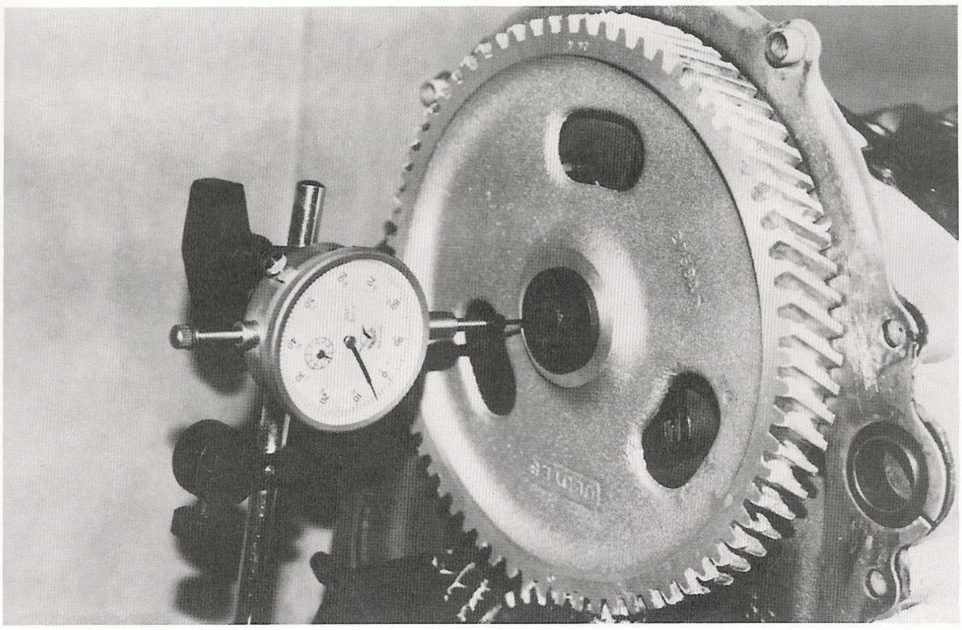
Inspecting the valvetrain geometry begins by assembling the valvetrain for the number one cylinder during the mockup for checking the valve-to-piston clearance. Lash the intake and exhaust valves to the proper hot specifications. Turn the crankshaft by hand paying careful attention to the movement of the rocker arm tip as it sweeps back and forth across the valve tip. Ideally, the point of contact should be slightly inboard (toward the engine centerline) of the valve tip center with the valve on its seat. As the cam lifts the valve, the contact point should move slightly outboard and should then stop at or slightly (no more than 0.020in) beyond the tip axis at about one-half of the total lift. From one-half lift to total lift, the contact point should move back toward the inboard side of the valve tip. The amount that the contact point moves will depend on the actual peak lift of the cam. If you witness this condition, chances are that your valvetrain will require no adjustment in geometry. But if not, you will have to make corrections to bring the geometry within specifications.

Luckily, valvetrain geometry is fairly easy to correct on shaft-mounted rocker assemblies. If the rocker tip rests on the outboard side of the valve tip at the one-half lift point, the pedestal is too high. To correct this condition, you will have to mill the pedestal base. Since this is essentially a cut-and-try operation, remove only a few thousands of an inch from each pedestal and recheck the geometry. Continue removing material until you achieve the proper relationship.

If the contact point rests on the inboard side of the valve tip at the one-half lift point, the rocker pedestal is too low. To correct this condition, the pedestals will require steel shims under their bases. Once again, add shims in small increments until the proper geometry is achieved. Once you know the proper shim thickness, fabricate a single shim of the proper thickness if at all possible. Of course, it is imperative to recheck everything after making any adjustment.



When installing the camshaft, each lobe must be coated with a moly-based camshaft break-in lube. Do not use this lube on the bearing surfaces.



Camshaft end float is measured using a dial indicator with a magnetic base. The cam is forced back and forth and the total end float is read on the indicator.

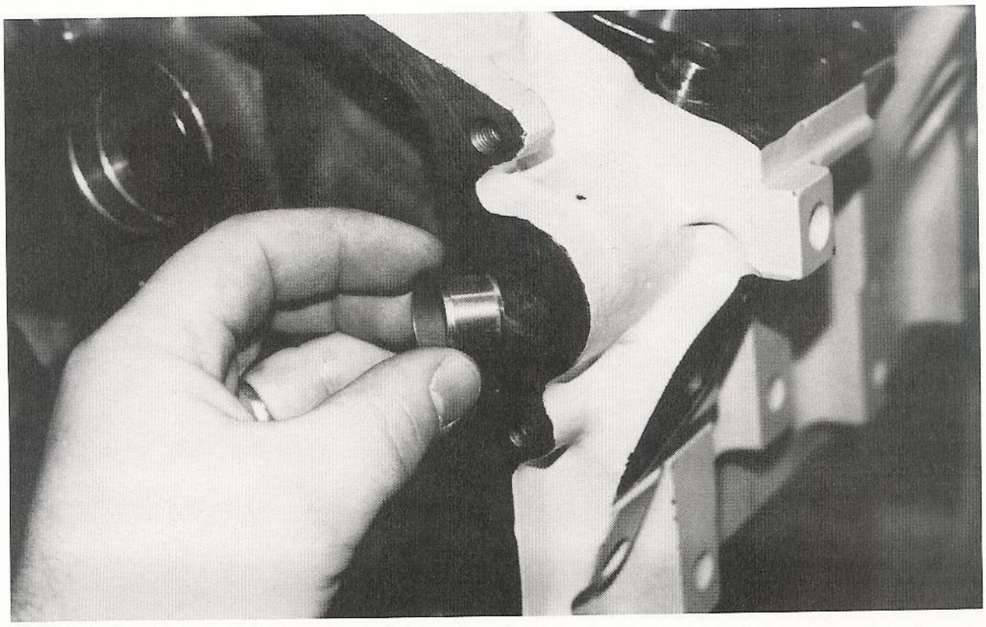
Installing the Camshaft

The camshaft is one of the most abused components in any engine. To avoid damaging the camshaft during the break-in period, coat each lobe with camshaft moly lube. This special moly grease will provide essential protection to each lobe and lifters on first startup. Note that only the lobes receive this type of lubricant, not the journals. To properly protect the journal surfaces, coat each one with generous quantities of Michigan 77 Bearing Guard. Once this is done, slide the cam into the block. Be very careful to avoid nicking the journals or the bearings. You may find it very helpful to use a 6–8in long bolt in the end of the cam to act as a handle during the camshaft installation. With the cam in position, rotate it several turns to ensure that no binding occurs. Install the cam spacer and key and then tighten the cam thrust plate. Next, install the cam core plug located at the rear of the block. Coat the outer edges of the plug with #1 Permatex sealer and drive the plug into the block.

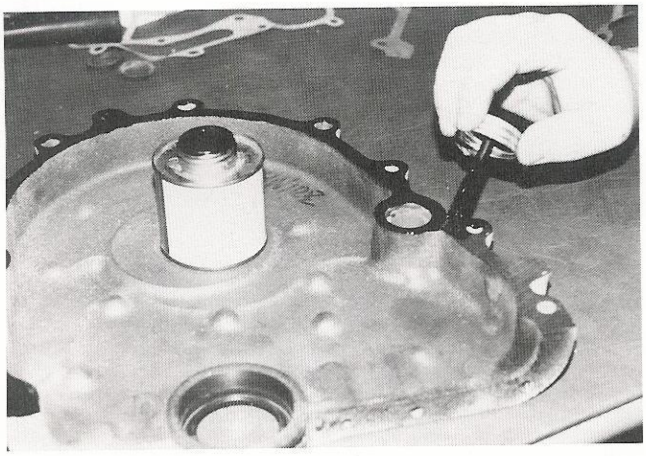
Moving back to the front of the block, install the timing cover backing plate on the engine. You will find it much easier to position the gasket if you first glue it to the block using Permatex High Tack adhesive. Once the gasket has set in place, run a thin bead of blue RTV silicone sealer around the sealing surface and torque the plate to specifications. With the backing plate in position, install the camshaft timing gear with the timing marks aligned in their proper position. Tighten the camshaft retaining bolt to specification and lubricate both timing gears with plenty of #105 Lubriplate.

Checking Camshaft End Float

Position a dial indicator so that the plunger is parallel to the axis of the camshaft. Force the camshaft as far back as it will go using a small soft-faced mallet. Preload the indicator plunger about 0.100in and zero the indicator. Using a screwdriver, move the camshaft to its most forward location and read the end float on the indicator. The specification should be between 0.004in and 0.006in. If the end float requires adjustment, you can purchase camshaft thrust plates and spacers in different thicknesses to bring everything up to snuff. In-



Always use new connector sleeves between the timing cover and block when rebuilding the older Ford V-6 engines.

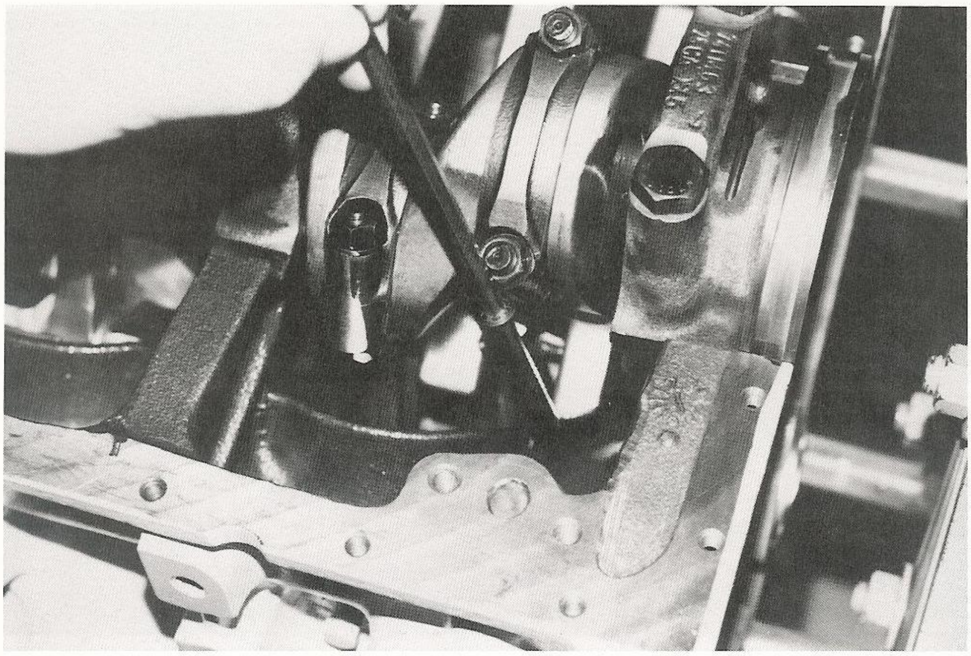


You will find it much easier to manage the thin timing cover gasket if you coat the sealing surface of the timing cover with Permatex High Tack gasket adhesive. This will allow you to position this unwieldy gasket firmly on the cover with no worry of misalignment.

quire at your local Ford dealer for the proper components.

Fitting the Timing Cover

Clean the front seal bore using lacquer thinner and carefully inspect it to make sure no burrs exist. Press the seal into the cover using only the Ford factory tools. Glue the timing cover gasket to the timing cover using Permatex High Tack sealant. As the sealant sets, install the special guide sleeves and O-rings into the water inlet ports on each side of the block. Do not use any type of sealer on these components; they must be installed dry. Coat the timing cover sealing surfaces with a thin bead of blue silicone sealer. Lightly lubricate the crankshaft seal with petroleum jelly and slide the cover into position. Center the timing

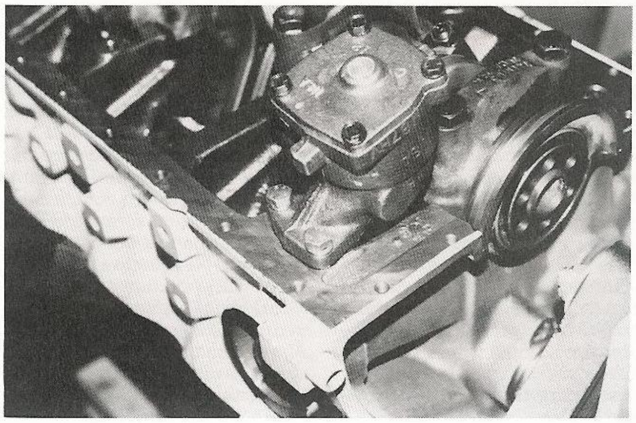


When installing the oil pump drive-shaft, make sure that the flanged end points into the shaft bore.

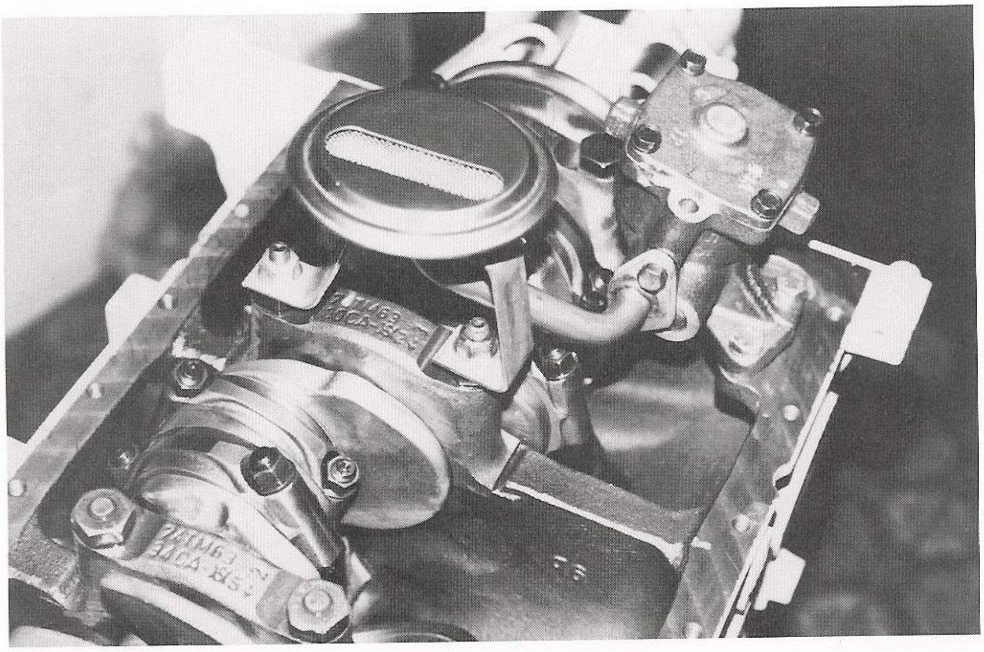
cover using the appropriate factory tool and tighten the cover bolts to specifications.

The Oil Pump

All Ford V-6 oil pumps are driven by a driveshaft, which is in turn driven by the cam. It is important that this shaft be installed in the block with the flanged end toward the block. Once the shaft is in place, you can bolt the oil pump into position using a new gasket. Do not tighten the bolts until the oil pump pickup tube is in place and finger tight. With the pump and tube assembly in place, tighten all of the bolts to specifications, beginning with the pump and then the tube. Remember to fit a new gasket to the pickup before tightening the bolts.



Install the oil pump, making sure the driveshaft fully engages the pump drive. Tighten the bolts only finger tight until the oil pickup screen can be fitted.



Position the pump screen, first on the pump, then the block. Once it is in position, tighten all bolts, including the pump, to specification.

The Damper/Pulley Assembly

Be sure that the damper or pulley that you will be using is compatible with your water pump and accessories. In some applications, you will need a special spacer kit to properly offset the damper so that it will align properly with these components. Install the damper by pulling it into place using a new crankshaft bolt and washer. Always lightly lubricate the crank snout and the damper bore with oil before drawing the two together.

Indexing the Timing Pointer

Indexing the timing pointer is procedurally very similar to finding top dead center (TDC) when degreeing the camshaft. First, bolt the degree wheel to the front of the crank damper/pulley and attach a suitable pointer to the timing cover. Rotate the crankshaft until the number one piston is at TDC according to the eye, and zero the degree wheel. Rotate the crank counterclockwise about 90 degrees, and then screw a piston stop into the number one spark plug hole. Next, rotate the crankshaft clockwise until the piston contacts the piston stop, and record the degree wheel reading. Rotate the crankshaft in the opposite direction until the piston contacts the piston stop. Once again, record the degree wheel reading. Add the two readings together, divide by two, and adjust the degree wheel pointer to the proper specification. Rotate the crankshaft clockwise to confirm the reading on the opposite side of the wheel. Now, remove the piston stop and rotate the crankshaft until the degree wheel pointer indicates the exact top dead center location. Carefully inspect the timing pointer to make sure that it is precisely set at TDC. You may find that the timing pointer mounting holes may require slotting in order to achieve an accurate TDC indication. Once the timing pointer has been indexed, remove the degree wheel and pointer.

Lifters

Installing lifters demands the same care that the camshaft requires during installation. Since the lifters impose the most dramatic loads on the camshaft, the most important thing to remember is lube, lube, lube! Once you have cleaned each lifter with lacquer thinner, coat the sides of each lifter and each lifter bore with #105 Lubriplate assembly lube. Just before you drop each lifter in its respective bore, coat its base with camshaft moly lube. Slide each lifter into its bore and spin it to make sure that it will turn freely. If the lifter is not able to spin in the bore, the camshaft lobe and lifter will become damaged soon after startup.

The Cylinder Heads

Beginning with the intake valves, generously lubricate each valve stem with Lubriplate #105 engine assembly lube. Blow each valve guide clean with compressed air and install each valve into its respective guide. Repeat this procedure with all of the exhaust valves until they are all in place.

Now that each valve is in its proper guide, you can install the PC-type Teflon valve seals. To properly install a PC seal, you will need to use a special protection sleeve over the valve stem tip to protect the seal from damage caused by the lock groove in the valve stem. These sleeves are usually supplied with the seal kits. If you find that you are without one, you can purchase them from most auto parts outlets. With the protection sleeve over the valve stem, slide the seal onto the valve guide, making sure that the seal sits firmly on the guide. Then remove the sleeve and repeat the process until all of the seals are in place.

With the valve seals properly installed, begin placing the appropriate number of shims on each valve. Don't forget that every valve will require at least a 0.030in hardened shim under each spring. Install the valve springs (both inner and outer) on the valve along with the retainers. Using a sturdy valve spring compressor, compress each spring so that you can install the valve locks. With the locks in place, carefully release the compressor, move on to the next valve, and repeat the above procedure until all of the valves have been fitted. **NOTE: Because there is the possibility of eye damage should the keepers pop out, always wear eye protection when performing this procedure!** If your application requires the use of lash caps, install them using no lube. Once all of the caps are in place, put a dab of #105 Lubriplate assembly lube on each cap to prevent excessive wear on startup.

Installing the Cylinder Heads

Clean the gasket surfaces of the block and cylinder heads with lacquer thinner. These surfaces must be totally free of any grease or dirt or the head gaskets will not seal properly. Place a new head gasket on each side of the engine. Note that each gasket is marked "top, front" so that it can be positioned correctly. It is very important that the gaskets be installed according to these directions or the water passages in the gasket will not line up properly, and severe overheating will result.

Keep in mind that all head gaskets are not created equal. The most desirable head gaskets on the market today are coated in a Teflon/graphite material that greatly improves sealing and stability. The premium quality head gaskets manufactured by Victor are good examples. They are available through many top auto parts outlets. Absolutely no sealer should be applied to the head gaskets.

Once the gaskets are in place, position each head on the block. It is important to use new head bolts to secure the heads. Coat the underside and threads of each bolt head with antiseize compound, and hand tighten the bolts into the block. Torque the bolts in 20lb-ft steps to a final torque of 80lb-ft. Be absolutely sure that you follow the factory torque sequence or cylinder head warpage may occur.

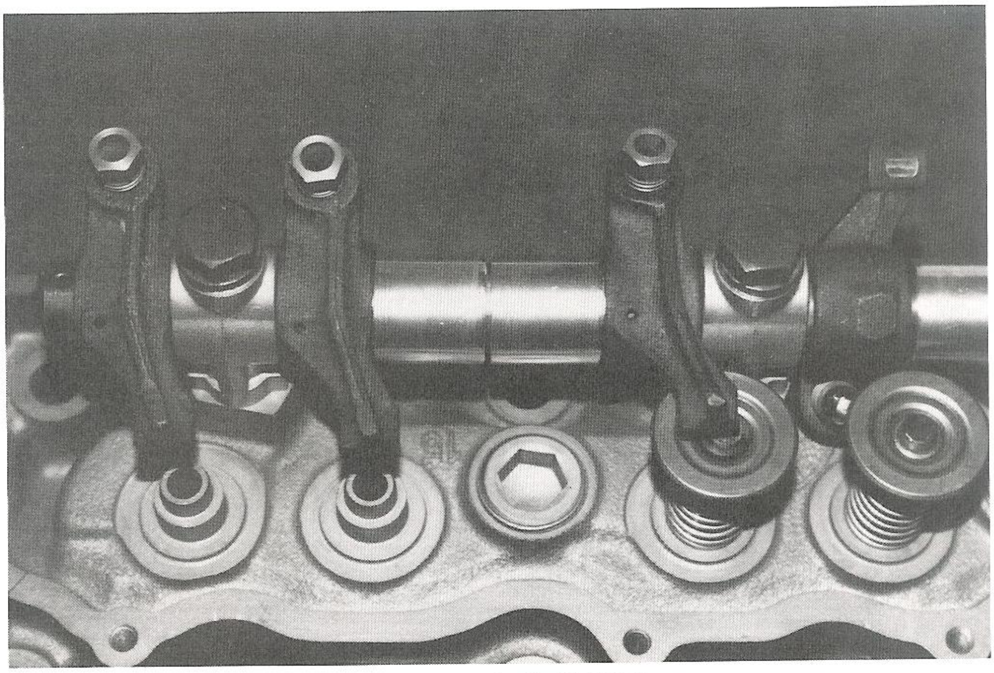
The Upper Valvetrain

The upper valvetrain is another very highly stressed area of the Ford V-6. Follow these simple yet important preparatory procedures to ensure that the assembly will survive in a performance application.

Begin assembling the rocker shaft assemblies using new rocker shafts and roll pins. Do not attempt to incorporate used components as these are very high wear items and are not normally suitable for reuse. In most cases, the rocker pedestals will require replacement as well. Once again, remember that under no circumstances should the rocker spacer springs be used in a performance Ford V-6. Call a Ford V-6 specialty shop and order an aluminum rocker spacer kit. These kits are extremely durable and will last the life of the engine.

Begin the assembly by lubricating all load-bearing surfaces with #105 Lubriplate assembly lube. Starting from one end, install a roll pin and a thrust washer followed by a rocker arm and the first rocker pedestal. Make sure that the machined notch on each end of the rocker shaft faces the cylinder head. Next, install the second rocker arm and the first aluminum rocker spacer. Following the first spacer, install the third rocker, another pedestal, the fourth rocker, and the second aluminum spacer. Continue the assembly by fitting the fifth rocker along with the third pedestal and finally the sixth rocker. Finish the assembly by installing the final thrust washer and a new roll pin.

Install the completed shaft assembly on the head, and torque the three securing bolts to 45lb-ft in three equal steps. Check the side clearance of each



Aluminum rocker spacer kits are an important addition to a Ford V-6 valvetrain. Specially designed kits are available from companies like Vanir Technologies.

rocker using a feeler gage. The optimum side clearance is 0.010–0.015in per rocker. It is better to stay slightly on the loose side of these figures.

To complete the installation of the upper valvetrain, lubricate each end of the pushrods and install them into the lifters, making sure that each is fully seated in the pushrod cups. Loosen the rocker adjusting screws and bolt the rocker assemblies to the heads in three equal steps to a final torque of 45lb-ft. Be sure to include the required number of pedestal shims (if required) to maintain the proper valvetrain geometry. Lash each valve using a steel feeler gage. Always check the lash from the end (parallel with the valves) if you are using stock rockers, and from the side when using roller rockers. This technique will ensure that the lash specifications are accurate.

The Intake Manifold

Clean all of the manifold gasket sealing surfaces with lacquer thinner and, once dry, coat the block surfaces and mating gasket surfaces with Permatex High Tack gasket adhesive. Don't forget to coat the block-side mating surfaces of each manifold end seal as well. Always use end seals made of a cork composite material, not rubber. Rubber end seals leak when subject to the rather extreme compression forces exerted by the V-6 manifold.

Install the two manifold studs located at the far ends of the lifter valley. Put a drop of blue Loctite on the threads of each stud before tightening them into the block. Once the gasket sealer has had sufficient time to dry, carefully place the intake gaskets on the heads, making sure to precisely align each port opening. If any material protrudes into the ports, trim the excess using a sharp razor blade. Position the end seals so that maximum contact is achieved with the block. Most end seals have excess material on each end so that they can be custom fit to the application. It is very helpful to bevel the ends of the seals so that they mate to the angle of each head. Apply a small dab of silicone sealer to the ends of each seal before gluing it into position. Apply a thin bead of silicone sealer around each sealing surface of the intake manifold. Don't forget to seal the water passages as well.

After the silicone has tacked for fifteen minutes or so, install the manifold and torque to specifications following the factory torque sequence. Remove any silicone that has extruded into the ports using a sharp X-Acto knife. If you are using the two-piece Offenhauser manifold, you can now bolt the manifold top to the base. Vanir Technologies builders recommend discarding the Offy plenum gasket. In its place, they use Gore-Tex RT gasket material that is 2.0mm thick. This material is available through W.L. Gore & Associates in Elkton, Maryland. Finish the installation by bolting on the selected carburetor using the appropriate gasket.

Startup Procedures

Now comes the moment of truth: starting and running the engine for the first time. For the first-time engine builder, this experience is just as exiting (and complex) as the launching of the space shuttle. Everything must be perfect or disaster can result. The first startup is, without question, the single most critical point in an engine's life. If things go sour here, they will remain sour forever.

There is a lot more to firing a fresh engine than installing it into the car or dyno, connecting the battery, and turning the key. Think for a moment here. Everything in the engine is fresh, nothing has had a chance to be brought up to operating temperature, and none of the surfaces have had a chance to take a set to one another. Countless brand-new engines have been lost due to excessive cranking and/or improper run-in on first startup. It is essential that all of the engine systems be perfect (or damn close) so the engine will fire and run immediately, on its own.

Typically, most of the damage inflicted upon sensitive engine parts is caused by excessive cranking during first startup. The first components to go in the dumpster are the parts that carry the highest unit loadings and those that receive only splash oiling: the cam, the lifters, and the piston rings.

The camshaft endures the highest unit loadings in the entire engine and relies totally on splash oiling to lubricate the lobes. Though break-in lube is used liberally on a new cam when it is installed, it is wiped away very quickly once the engine is cranked a few revolutions. If immediate lubrication is not available to the cam and lifters soon after the engine is cranked, an irreversible deterioration of the cam lobe and lifter base will result. If the engine starts quickly, however, the cam lobes and lifter bases harden and seat into each other and this deterioration is completely avoided. It is critical that the startup procedures go uninterrupted in order for the cam assembly to provide optimum service life.

Piston rings are also very susceptible to damage on first startup. Like the cam lobes and lifter bases, piston rings rely on splash oiling to provide the necessary lubrication. If excessive cranking is performed and the engine fails to start, the rings will become glazed and will never seat to the bores, resulting in permanent cylinder pressure leakage. If this happens, the engine will feel absolutely miserable on power and will eventually fail.

By this time, many of you are probably sweating blood and wondering if starting your engine is a good idea. Relax! Starting the engine for the first time simply takes a good measure of preparation and a little patience. The trick is to give the engine the essential elements that it needs to run, and at the right time. The most important of these elements is your undivided attention to detail.

Providing the Essential Elements

An engine requires three basic components to sustain combustion: compression (air), spark, and fuel. If any one of these elements is missing or is not available in sufficient quantity, nothing good is going to happen in your engine, period. It is vitally important that you are sure that the engine is supplied with the required amounts of these elements so it will have no problem starting on just a few turns of the starter motor.

Compression

If you followed all of the construction techniques discussed in this book, compression should take care of itself. Obviously, the pistons and rings must be installed correctly and the valves must be properly seated in the heads. Furthermore, the camshaft must be installed correctly and the valves lashed to specifications. If these items are in order, the essential compression requirements should already be met.

Spark

Herein lies the most common cause of engine failure during attempted startup. Engines are typically much more reactive to ignition tuning than anything else. A comparatively small error in ignition tuning will result in a no-start condition, or, in other words, failure of the sensitive components due to excessive cranking effort. With a careful preparation, such ignition evils can be avoided.

Providing an appropriate amount of ignition spark begins with proper installation of the distributor. First, bring the number one cylinder to top dead center (TDC) on the compression stroke. From TDC, turn the crankshaft counterclockwise until the timing pointer lines up with the 12 degrees before top dead center (BTDC) mark on the damper. Lube the distributor gear with #105 Lubriplate, install the distributor until it is seated fully, and check that the ignition rotor is approximately in line with the #1 terminal in the distributor cap. Rotate the distributor until the rotor aligns exactly with the #1 terminal and the #1 stator pole aligns with the core of the magnetic pickup coil. Once everything is aligned, lock the distributor down securely. You have now set the initial spark advance at 12 degrees, just right to start the engine. Finish by installing the distributor cap, plugs, and wires, making doubly sure that each wire is positioned properly on the cap and that each goes to the proper spark plug. To eliminate any further possibility of failure, always install a new (not used) coil, rotor, cap, plug wires, plugs, magnetic pickup coil, and module. It will cost a little money, but it assures that no equipment problems will exist in the ignition system.

Fuel

If you performed the carburetor preparation steps correctly, you can be reasonably sure that the carburetor will perform adequately to allow the engine to start and run. Luckily, engines will run, albeit not well, with rather significant errors in the air/fuel mixture.

Check every fuel system fitting to make sure that no leaks will occur. Next, fill each fuel bowl, through the vent tubes, using a small plastic container like a measuring cup. Check to see that fuel is available to the accelerator pump by opening and closing the throttle while looking into the throttle bores. If you see that fuel squirts into the primary bores, everything should work. If fuel injection is used, you can rely only on the fuel pump to deliver enough fuel to prime the system. When you turn the key to the "on" position, you should hear the pump run for a few seconds until pressure builds in the fuel lines. If you do not hear the pump, investigate the problem before you attempt to start the engine.

Starting the Engine

Now that the engine has sufficient compression, a hot ignition spark, and adequate fuel, it should fire and run with minimal cranking effort.

Prepare to start the engine by installing a new oil filter and priming the oiling system with an engine prelube tank. These pieces of equipment are far superior to the old "spin the oil pump with a drill" routine. In fact, later Ford V-6 engines have a unique oil pump driveshaft that does not accommodate normal drill priming shafts, making a prelube tank a necessity. An excellent prelube tank is available from Goodson. The Goodson tank is filled with five quarts of fresh oil then pressurized to 120psi with an air compressor. A hose is then connected to the oil pressure sender port in the engine and the delivery valve is opened, allowing the engine to be primed and, at the same time, filled with five quarts of oil.

With the engine primed with oil, continue the startup preparation by connecting the starting and ignition systems to a new, fully charged battery. Then prepare the cooling system and check for any leaks. Once this is complete, make a few trips around the engine to check for any loose or forgotten fittings and bolts and such. Once you are sure that everything is perfect, you can prepare yourself for first startup. With no air cleaner installed, start the engine, immediately bring it to 2500–3000rpm, and keep it there for at least thirty to forty-five minutes. Carefully monitor the oil pressure and coolant temperature for any irregularities. Have a friend circle the engine looking for any leaks that may cause a problem. If any fuel leaks exist, fix them immediately. Carefully monitor any oil and/or coolant leaks. If an oil leak is small, complete the break-in procedures and then repair as needed. If a coolant leak is external, continue the break-in procedures and then repair. However, if coolant is leaking into the engine, repair immediately.

Once the engine has run above 2500rpm for the entirety of the break-in, allow it to idle and check the ignition timing and, if necessary, adjust it to proper specifications. Then take the car on the street and perform about five or six moderately hard acceleration runs to help fully seat the rings. If you're lucky, you'll only have to do the usual fine-tuning of the ignition and fuel systems and an oil change, followed by pure enjoyment. Good luck!

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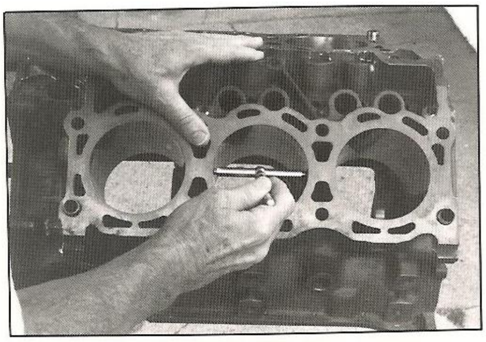

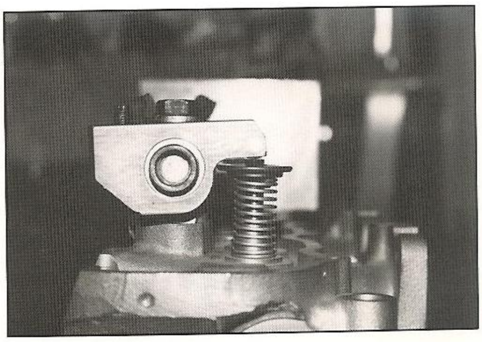

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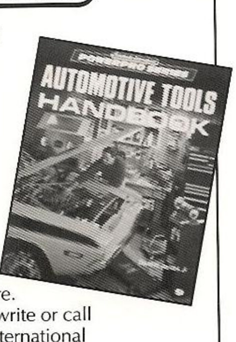

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