Chapter 9

Tuning for Performance and Economy

Contents

1. INTRODUCTION

In the previous chapters, I explained the detailed workings of Ford fuel injection and engine control systems. Now I will take a look at the enthusiast's obvious next step—modifying electronic engine-control systems for high performance.

You know enough about the various ways that Ford systems meter fuel. We'll look at what Special Vehicle Operations (SVO), the factory performance group, and the aftermarket tuners and parts suppliers offer you. We'll consider what features of the stock system you might have to give up. You'll know enough to ask questions and to understand the tradeoffs that usually accompany fuel-system modifications.

I'll describe legal issues (some new as of 1993), emissions, and warranties. I'll describe some of the decisions you'll be making, the payoffs and the give-ups of performance mods. After covering some of the basics as they affect performance, I'll describe specific parts, kits, and add-ons available from Ford Special Vehicle Operations (SVO), and from aftermarket suppliers.

Many Ford owners show an intense interest in performance mods. Some devote their energies and their dollars to knock off another tenth of a second. They support several independent monthly Ford buff magazines and dozens of aftermarket suppliers. And Ford Motor Company supports them with the Special Vehicle Operations. You can do a lot at your friendly Ford dealer, buying performance parts and even ready-to-run street-legal performance vehicles such as Ford's Special Vehicle Team (SVT) Mustang Cobra and F-150 Lightning. Look also for aftermarket-created Mustangs such as Steeda Mustang, and SAAC Mustang, complete with warranties.

I know you'll find carbureted Fords laying down rubber and winning NASCAR events, but that's another subject. Here, I'll concentrate on performance relating to fuel injection/engine control. Also, I know you can do a lot with heads, headers, cams, pistons, not to mention suspensions and brakes, but that is another book. And don't forget that when you're considering engine mods and their effect on performance, remember what I said about the effects of temperature and humidity on engine power. SVO advises that your elapsed times can vary by 0.2 seconds or more depending on the local weather conditions.

You'll find many roads to improving the performance of your car, van or truck. Those of you familiar with Bosch fuel injection have a head start. You can tell there's a touch of Bosch in most Ford vehicles: injectors, fuel pumps, fuel-pressure regulators, fuel rails, even Volume Air Flow sensors. In addition, truck and van owners, Mercury and, yes, even Lincoln owners have several possible performance options.

Fig. 1-1. Ford Mustang Cobra shows Ford's path to modifying 5.0L engines: larger intake and exhaust ports, revised intake manifold, high-flow fuel pump, and recalibrated EEC-IV control module.

Fig. 1-2. SVO Performance Parts Catalog shows many ways to improve the performance (and appearance) of your Ford car or truck.

Fig. 2-1. 5.0L H.O. (High Output) version of long-time favorite small block V-8, also known as the 302, found in Mustang GT and Mark VII LSC.

2. FORD AND PERFORMANCE

Ford owners are fortunate. While there's still a lot of Ford carburetor muscle out there, there's also a lot of advanced electronic fuel injection/engine control. Our aim is to wring more performance out of the system.

Race on Sunday, Sell on Monday

Ford is a performance-oriented company. After a recent Ford President experienced track training at a high-performance driving school, he insisted his top executives do the same. That's changed top-down attitudes. Since then, Ford cars have shown improved performance and handling.

Ford builds some performance engines with knock sensors (5.0L trucks but not 5.0L passenger cars), and some with Octane Selectors. With a knock sensor, you can improve full-throttle performance by burning premium, higher octane fuel.

Under the label Motorsport, Ford SVO operates with 23 people. They provide strong support to aftermarket performance shops and owners for track and for street. Sales of performance mods totalled $30 million in a recent year.

SVO develops special EEC-IV for Formula One cars in Europe, and Indy cars, beginning in 1993. See Fig. 2-2 and 2-3. When I examined these EEC-IV units at Ford, I could see they differed from stock EEC-IV so you can't fit one to your Ford. They have military connectors for reliability; they are packaged to get rid of the extra heat caused by rpm up to 14,000 and longer injector pulse-times, and they are sealed against moisture. "Formula One runs in the rain," SVO reminded me. Yet the basic EEC-IV module corresponds to the millions of engine-control units made by Ford for street use. SVO experience feeds back into the production line electronics. For example, Ford SVO was able to cause improvements in production coolant-temperature sensors to be suitable for both production and racing.

Ford competes in CART, Formula One, IMSA, off-road truck racing, and SCCA Trans-Am. SVO philosophy: "We race what we sell, and we sell what we race."

Ford Mustangs are strong runners on the track. The 5.0L fuel-injected engine is well suited to hop-up for the strip. Its large production volumes attract many aftermarket suppliers of performance gear.

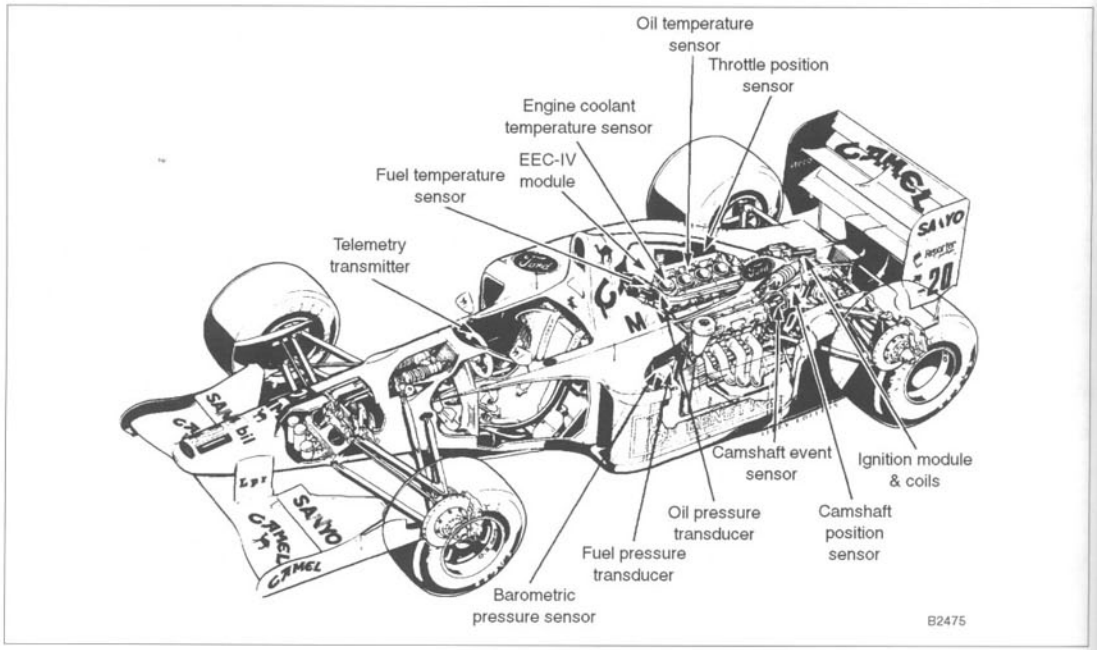

Fig. 2-2. Ford F1 engine uses EEC-IV engine control. Control module is similar to one used on production cars.

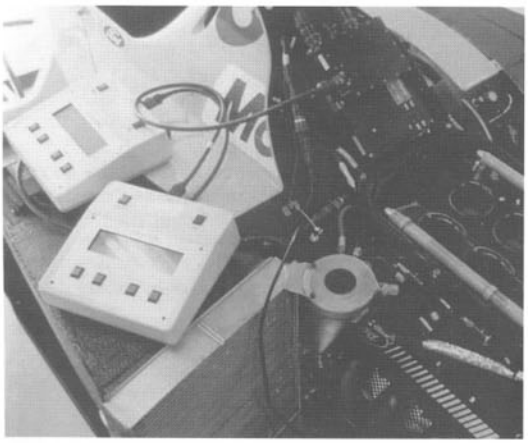

Fig. 2-3. F1 EEC-IV module can be tapped into right at track. Note MAP/BP sensor to right of module, and fuel rail and pressure regulator.

SHO (Super High Output Taurus)

Finally, there's SHO (Super High Output) production Taurus sedans, streetable of course, with performance versions of the 3.0L V-6 (M/T) and 3.2L (AXODE), jointly developed by Ford and Yamaha. You can appreciate EEC-IV when you realize how little the engine-control system had to be changed while bumping the output of the V-6 engines more than 50%. What you have here is a "Q-ship," a four-door sedan that can excite the driver without exciting the police. Word on the track is, Ford and Yamaha have done such a great job with it that you don't need to tamper with it.

"Q-ship" is a term from World War II, when German submarines threatened shipping lanes. The Allied Navies fitted innocent-looking merchant vessels with high-power hidden armament, hoping for a challenge from a U-boat. When the enemy surfaced and approached for the kill, the Q-ship unleashed its power, the big guns came out, and the kill went the other way. In Europe today, autobahn Q-ship cars are usually black and carry no badges indicating the engine size. Consider our U.S. speed limits and the price of tickets—cash, license points, and insurance premiums—you may have more highway fun in an innocent-looking Q-ship such as the Taurus SHO than in a red Fer-

Fig. 2-4. SHO 3.0L engine in 5-speed transaxle (M/T) Taurus delivers 220 horsepower from 3.0L. Beginning '93, SHO 3.2L 220 bhp comes with automatic transaxle, E4OD.

Other fuel-injected engines adaptable to performance include:

- 1.6L turbo four (MECS-I) Capri
- 1.8L DOHC four (MECS-I) Escort/Tracer
- 2.0L DOHC four (EEC/MTX) Probe
- 2.2L four (MECS-I) Probe
- 2.3L Turbo OHC four (EEC) T'Bird/Merkur
- 2.5L DOHC V-6 (MECS-II) Probe
- 3.8L S/C V-6 (EEC) T'Bird/Cougar
- 5.8L V-8 351W (EEC) trucks
- 7.5L V-8 460 (EEC) trucks

Ford has built hundreds of thousands of fuel-injected 5.0L V-8s, with the potential of substantial power gains from modifying the engine under the stock fuel-injection system. In some cases (1987 California, 1988 and earlier 49-state), modification of the engine-control system is necessary to realize the full benefits of other engine work such as radical camshafts, rocker arms, cylinder head porting, or forced induction.

3. THE LEGAL ISSUES

OK, this subject is not the most fun, but it is realistic and must be faced in today's green climate. Before you modify your engine, consider the issues of warranty, and the issues of tampering.

3.1 Warranties

On most cars, the emission-control system (and that includes most of the fuel injection/engine control) carries a warranty of 5 years or 50,000 miles. As of 1993, manufacturers warrant systems for 3 years/36,000 miles. But for 7 years/70,000 miles, manufacturers must replace under warranty any emission-control parts costing more than $300.

Be sure you read the fine print where it says "under normal use." As soon as you bolt on performance equipment, you may give the dealer and the manufacturer a legal claim to void the warranty if they can show that your modifications interfere with the performance or reliability of the original equipment. In one extreme case, a manufacturer (not Ford) voided warranty coverage after installation of an aftermarket car phone. It seems the installer had inadvertently drilled through a circuit in the Anti-lock Brake System (ABS). What can I say? Before you grab for performance, know what you might be giving up.

This catalog lists primarily special, competition parts and is intended only as a supplement to the published service manuals and parts catalogs of Ford Motor Company. Buyers of competition parts are warned that many of these parts are for off-highway use only and that special warranty provisions apply.

OFF-HIGHWAY OR RACING USE

Because U.S., Canadian, state or provincial laws and regulations may prohibit removal or modification of components that were installed on vehicles by Ford Motor Company to meet emission requirements or to comply with motor vehicle safety regulations applicable to vehicles manufactured for use on public roads, Ford Motor Company recommends that vehicles equipped with parts designated "for off-highway use" not be operated on the public roads and offers such parts only for track or off-highway competitive or performance use. Such parts have a special "warning" label which reads:

WARNING:

This part has been designed and is intended for off-highway application only. Installation on a vehicle intended for use on public roads may violate U.S., Canadian, state or provincial laws and regulations including those relating to emission requirements and motor vehicle safety standards. (NOTE: In California this part may legally be used only on a racing vehicle which will never be operated on public roads.) In addition, installation of this part may adversely affect the warranty coverage on your vehicle.

NOTE — CALIFORNIA ONLY

The emission laws and regulations of the State of California apply to all non-racing vehicles. Consequently, those parts marked in this catalog with an asterisk and appropriately marked on their packaging may legally be used in California only on a racing vehicle which will never be operated on public roads.

NO PARTS WARRANTY

*Competition parts are sold "**as is**" without any warranty whatsoever. **Implied warranties, including warranties of merchantability or fitness for a particular purpose, are excluded.** The entire risk as to quality and performance of such parts is with the buyer. Should such parts prove defective following their purchase, the buyer and not the manufacturer, distributor or retailer, assumes the entire cost of all necessary servicing or repair.*

Ford Motor Company vehicle and parts warranties are voided if the vehicle or part is used for competition or if they fail as a result of modification.

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Fig. 3-1. Ford Motorsport spells it out. Some performance parts are for "off-highway or racing." The parts are not warranted, and may adversely affect warranty coverage on your vehicle.

Ford SVO sells competition parts "as is," without any warranty whatsoever. If you really get a defective SVO part, don't go back to your friendly Ford dealer under the vehicle warranty. SVO will listen to you on a case-by-case basis, but they're covered in writing: "Entire risk...is with the buyer."

3.2 Tampering

For emission-controlled cars—and that includes all Ford vehicles I'm talking about in this book—fuel injection systems are considered to be part of emission-control equipment. Modifying the fuel injection system is, therefore, modifying the emission controls, and that raises some questions relating to federal laws of the U.S. and Canada, as well as state and provincial laws.

You may have heard that only the professional technician is subject to a fine if he alters emission-control equipment but the owner was exempt from such restrictions. That was before the 1990 Amendments to the Clean Air Act. Now the $2500 fine extends to owners and individuals. Regardless of who does it, tampering is a Federal offense. In effect, future performance mods fall in two classes:

- Strictly for the track, never to be driven on public roads
- Exempted by the state or federal government as not affecting emissions

"What is street-legal?" It's a rapidly changing picture. One of the important movers and shakers in performance mods is Specialty Equipment Market Association (SEMA). Frank Bohanon, SEMA Director of Technical Affairs, told me of the new emphasis on performance products: "There's room for performance mods to go beyond the Original Equipment Manufacturer (OEM), who had to design and build to meet the needs of his total market. It is possible to modify these vehicles, and when you use these products as directed, you can get higher performance, still meeting the applicable guidelines and laws"

SEMA has created a voluntary parts-labelling system:

- Green #1 = 50-state legal
- *Blue #2 = 49-state legal, not California*
- Amber #3 = Race only, not legal for use on highway (this also applies to "non pollution-controlled vehicles", but all EEC engines are now pollution controlled.

SEMA prepares a monthly update of CARB E.O.s (Exemption Orders). Frank Bohanon said that you can obtain this list by writing, SEMA, address on p. 437. Or check with manufacturer regarding the status of their product. My only caution: some manufacturers seem more anxious to sell you their mods than in helping to keep our vehicles on the street "street-legal".

To help toward Clean Air, 1991 and later California cars and trucks have first generation On-Board Diagnostics (OBD-1) in the engine control unit. By 1994, 10% of each manufacturer's nationwide must have second-generation diagnostics (OBD-II), and by 1996, 100% of vehicles must have OBD-II. OBD-I and II keep a closer look at sensors and inputs to the control unit that could affect emissions. "They reduce our options," says Bob Stelmaszczak of Ford SVO (see later in this chapter). "On the other hand, we'll be looking at ways to improve performance of vehicles with alternate fuels, even Natural Gas (NG)!"

Practically speaking, if the car is to be registered and driven on public roads, the laws in your state and the legality of your modifications are more important than ultimate performance.

3.3 Modifications and Future Legislation

Tom Wilson, Editor of Super Ford magazine, told me where we're headed:

- Cars will be one or the other—really street-legal, or track, nothing in between. No more "street legal" (wink, wink). The fine print ("for use only off-road" or "not legal for sale or use in pollution-controlled vehicles") will get larger and be enforced. Note: All Ford fuel-injected vehicles are considered pollution-controlled
- Less exchanging of chips. Ford now solders chips to the board. But you'll see more electronic changing, under control, and street legal. (See Chapter 5 for information on FLASH and EEPROM)
- Less changing of cams, rockers, pistons, heads on newer engines
- Less need to change cams, rockers, pistons as manufacturers reach for better performance while remaining clean and economical. The new Ford "modular" engines, beginning with the 4.6L V-8, have greatly increased power outputs, but do not modify easily. As we go to press, parts are not available
- Increased certification of turbos, superchargers, and Nitrous bottles. NOS mods do not affect the engine control and they may run only about 10 miles in *50,000, and mainly at full throttle*
- Continued Ford support of performance enthusiasts, both street-legal and track

The early '90s are a time of change concerning exemption certificates. I'll indicate which mods are exempt as of time of writing, but that does not mean they are not "green." After all, no smog test is run at Wide Open Throttle.

Several aftermarket suppliers and tuners tell me their mods will pass emission tests but the paperwork and cost of exemption is discouraging. They are saying, "We think we're clean but it costs too much to prove it." California Air Resources Board (CARB) is saying, "We'll make it easier to exempt, but some of the mods have been completely careless about emissions. From now on, let's agree that your mods test clean. With an Exemption Order, we don't have a problem with tampering."

See the Appendix for a listing of the modifications as we went to press.

4. STREET OR TRACK?

I talked street or track at Ford SVO in Allen Park, Michigan, just down the road from Ford World Headquarters in Dearborn. Bob Stelmaszczak, SVT engineer, is one of the reasons Ford owners have such a rich supply of performance parts. Bob breathes Ford performance and has been responsible for more than a little of the street-legal performance and handling built into the production lines.

Even more so, he and other Ford engineers have designed and tested performance parts on the tracks. They have arranged for manufacture and distribution of the bolt-ons and major mods that support racing. John Vermeersch runs the Motorsport Tech Hot line, and publishes answers to common questions. SVO sheds new light on performance in the '90s in the time of serious movement toward clean air.

Word From the Top at SVO

Probst: At Ford SVO, you look at all the elements of improving performance, but let me ask you specifically about the engine-control systems.

Stelmaszczak: Before I explain control systems, let me give you an overview of Ford SVO and its place in Ford Motor Company structure. Ford SVO is organized in two departments: 1) Motorsport Department administers its motor racing business; 2) Performance Equipment Parts Department provides the Ford enthusiast with a source of high-performance and racing goods.

Through this Performance Equipment Parts Department, we can provide customers with a catalog of unique aftermarket items that are especially engineered for Ford vehicles. This includes engine "hard-core" parts, such as cylinder heads, manifolds, cams, and engine electronics, all designed to improve vehicle performance. The key word here is "designed." Our product offerings are engineered, built by quality suppliers (many of whom manufacture our standard production parts), and then undergo rigorous laboratory and vehicle testing.

These design elements are included in our production engine-control systems. The electronics must meet a number of specifications, the most notable of which are emission regulations. The Clean Air Act of 1970 and the 1990 Amendments legislate very stringent tailpipe standards. To us at SVO, that means absolutely no tampering with street vehicles. That's why some of our products are for off-road use only. The decision our customers must make is whether the modifications are easily reversible, or of the more permanent nature.

So don't let what you do for racing or off-road contribute to air pollution on the highways. We label our competition parts and do not encourage evading the laws, whether California, 49-state or Canadian.

P: OK, we can improve performance on the highway and still stay legal, or we can run off-highway. Where do we start?

S: There are ways of improving performance, and then again, there's "just being foolish." Don't just jump in and start increasing fuel pressure and installing larger injectors. And don't look for the magic chip. Unlock the performance of your engine one step at a time.

P: It's not like changing carburetor jets. What's the first step?

S: I think the first step is getting more air into the engine, particularly the 5.0L. Sometimes simple modifications can make quite a difference. Larger throttle bodies, low-restriction MAF (Mass Air Flow) sensors, increased-flow manifolds. Many times, these modifications work well within the reserve of the stock EEC-IV control system. That means you still have properly matched fuel flow and spark timing.

P: What would you change in the EEC system?

S: Convert the speed density to MAF. Ford SVO offers a Mass Air conversion kit for the early EEC-IV Mustang 5.0L, and it's no challenge to install in about an hour. You'll see a real improvement in the idle quality and low-speed driveability. As a result, you can do more for the high end with camshafts, aluminum cylinder heads, ported heads, headers and so forth while still maintaining driveability. This kit includes a new EEC-IV processor with better fuel flows and spark timing for stock and modified engines. We are offering a new MAF that handles increased air flows with less pressure drop.

Fig. 4-1. Mass Air Flow (MAF) kit converts Manifold-Absolute Pressure (MAP) system from indirect sensing of air-flow to direct sensing for performance mods. Includes new EEC-IV control unit.

Fig. 4-2. Ford Motorsport Explorer.

P: With more air flow, sometimes you really do need a lot more fuel flow, right?

S: Right, you may get some enrichment with stock injectors and elevated fuel pressures. Or use larger injectors with a high-capacity fuel pump from our catalog.

P: What about replacing the chip? What does that buy you?

S: Generally speaking, replacing the chip will buy you a lot of trouble unless you have the resources to perform an entire engine calibration. Up to 1992, Ford EEC-IV systems are not designed to be reprogrammed. Therefore, changing the chip is not an option. If you purchase an aftermarket stand alone engine-control system, you may need an engine dynamometer, a qualified electronic technician, and most of all, a lot of patience. After all, you will be trying to duplicate the resources of the Ford Motor Company to re-map the engine. This includes all fuel flow and spark-timing values, during cold start, hot start, and all normal off-road engine operating conditions.

P: How can you tell a good aftermarket control system?

S: Look for signs of quality engineering and production. Look for clear instructions and a phone number for service and assistance—you'll probably be calling it for help during your installation.

P: What can you tell about quality from seeing the system, or talking with the supplier, or studying his literature?

S: First, look for quality electrical connectors. They're the source of many problems. Ford Performance Equipment Products electrical connectors are so well-sealed they will work even under water. Second, look for built-in diagnostics. You can't guess about what's happening in these engines. (As described in this book) Ford EEC-IV will alert the driver or the technician to faults with sensors, actuators and systems. Third, ask the supplier if his control system will work alongside other aftermarket equipment, such as CD ignitions, CB radios, and cellular phones. All these create Radio Frequency Interference (RFI), or electronic noise problems. We're dealing with tiny current flows to control these engines and it doesn't take much to bother them.

P: What can you tell from the supplier's literature?

S: Can the supplier demonstrate broad-based improvement, or does he cut your ET's but leave you unable to start cold or in wet weather? Does he try to sell you with a few glowing testimonials and anecdotes, or does he show you some real measured improvements?

P: How does an owner find a good performance shop?

S: Well, to start, no single performance shop is able to answer all questions. But there is a way, the Ford Motorsport Performance Equipment catalog. We list several hundred of our worldwide distributors by name, address, and phone number. (See also the Appendix) I've found they are an invaluable source of information, and they are willing to help. They are

also great for obtaining references to other experts in the field. Also, you can talk to us here at Ford Motorsport. Our technical-assistance hot-line (313) 337-1356 gives customers direct access to some of Ford's SVO technical experts with answers to really tough problems.

P: Your Motorsport Department works with many different kinds of racing from dirt track to Formula One. "Race on Sunday, sell on Monday," right? But does racing really improve the breed?

S: You bet! At Ford Motor Company, we improve the breed several ways. As I explained earlier, we deliver our performance parts with production quality through our engineering staff, our testing labs, and many of our Q1 suppliers (Q1 is Ford's name for Quality is Job One.) We're committed to this level of quality assurance in the aftermarket.

In our racing and motorsport involvements, feedback is bi-directional. I mean, the engineering flows freely from the race track to the production environment literally on a daily basis.

P: Such as?

S: We use aerodynamic test data from Ford NASCAR teams to improve air-flow management on production-vehicle sheet metal. Conversely, Formula One race engines and off-road racing engines in Ford cars and trucks use many of the same EEC-IV sensors designed, engineered and developed for use in production cars. There are many more examples, but I think you see what I mean.

P: Since the first Ford flat-head V-8s, when I was learning to drive, Ford cars have always attracted the performance aftermarket.

S: Right, and you can bet Ford will continue to meet the performance enthusiasts with more new products into the 1990s.

SVO Tips

Bob passed on a couple of other tips, particularly applicable to the 2.3L SVO turbo.

- Many control modules include two separate memory maps for different-octane fuels. Switchover occurs when you change the Octane Switch from Regular Unleaded to Premium.
- Be careful if you consider bypassing the boost-limiter. That's a no-no unless you have an intercooler.

4.1 Parts, Kits, and Factory Performance Cars

If you look closely at Ford performance cars such as Cobra and Sport Truck, and even at independents such as Saleen and SAAC Mustangs, you'll notice they are street-legal even though they use parts listed as not street legal. It seemed strange to me until SVO explained the difference between certified-legal cars or packages and certified-legal parts.

- Changing one part, such as a 65mm throttle body, or a 77mm MAF kit may be street legal depending on the camshaft timing and many other factors, including the transmission, or it may not.
- Changing one part without considering the rest of the engine and its control system could damage the converter, or ruin idle quality.
- You can buy a street-legal complete engine, or a complete car with performance mods that individually are not street legal because SVO or the modifier, and the government (EPA, CARB) has certified the complete system. They have demonstrated that the modifications work properly with each other.

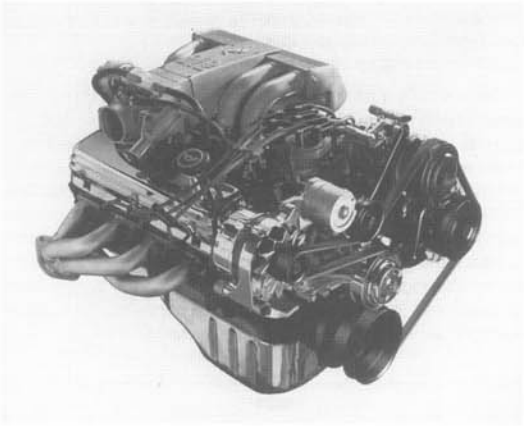

Fig. 4-3. You can buy street-legal GT-40 complete engine or car with same, delivering 285 hp, but some individual parts are not certified as street-legal because separately they might increase emissions beyond limits.

4.2 Modifications and Emissions

As I write, at least 37 states require some sort of inspection program; so do over 100 non-attainment areas. Unless waivered or equipped with exempt parts (CARB/EPA), the car is ineligible for use on public roads if it is found to be modified, or if it fails to pass an exhaust emissions test.

California regulations are especially tough, defining illegal tampering as "missing, modified, or disconnected smog-control systems or parts." No matter how clean your exhaust is, passing a Smog Check in California includes passing a visual inspection. Any missing or modified parts must be restored to their original, functioning condition. The cost incurred by the owner to bring a non-tampered engine into compliance is limited by law. For 1990 and later cars, the limit is $300, $175 for 1989-1980 cars (those years include Ford cars with fuel injection/engine control). California cars may come under the new

Federal limit of $450. But if the inspection reveals evidence of tampering, *there is no limit; the owner must bring the engine* into compliance whatever the cost.

Vehicle Age	Limit
1971 & older	$50
1972–74	$90
1975–79	$125
1980–89	$175
1990 & newer	$300

Fig. 4-4. Just to be sure we get the message: this is a typical list of repair-cost limits to pass a smog test without evidence of tampering. Such a list comes from DMV with each application to renew registration in California.

Several tuners say their mods are clean, based on passing an emission test. In California, it's officially "smog check," but in most states, and in Federal-speak, it's called Inspection & Maintenance (I&M). Passing such a test is not the same as certifying performance mods; in most states and provinces, that's not good enough. I expect more suppliers will comply with certification, so I advise you to check any source you plan to use. If the government says you cannot operate your vehicle on the highway, and won't issue plates for it, you have stepped over the line. You must make it compliant, using government-approved (CARB/EPA) parts or engine swap.

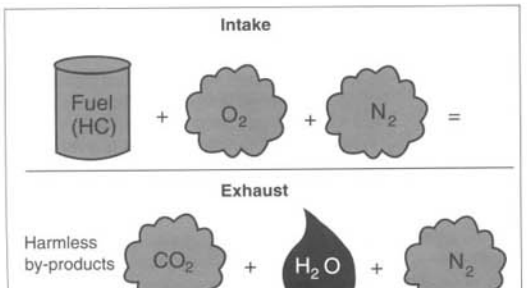

Fig. 4-5. Three exhaust pollutants are controlled by the Federal and California test procedures. NO_x is not measured at decentralized Smog Test stations. Increasingly in the '90s, centralized testing with a dynamometer loads the engine, testing all three.

"Mind your appearance," say tuners in California, where the Bureau of Auto Repair (BAR) operates the Smog Check program. Pay attention to the appearance of your mods. When they are properly and neatly installed, clean, and look like stock, your vehicle is more likely to pass the inspector or the referee. If your modified engine looks like a rat's nest, forget it.

Another tip, beyond street-legal and clean air. Consider what the mod means to your maintenance. If you need to pull the mods to get at the plugs or change the filter, at least realize the built-in extra price of the mod.

The matter of emissions and their effect on health and the environment is becoming increasingly serious, and increasingly legislated by Federal and state governments in response to public demand. It's called "Going Green." New York, Massachusetts and other states are moving toward the standards set by California. If you want to keep up with a fast-changing set of standards, call your local EPA office, listed under government agencies in your phone book. Regardless of state regulations, clean air is everyone's responsibility.

Fig. 4-6. Check state or community laws before making any fuel-system modifications.

4.3 Planning for Performance

At first glance, it may seem that I'm out to discourage fuel-injection system modifications, but that is hardly the case. Time spent under the hood, investigating and experimenting with fuel-injection modifications is fascinating and educational. My intent is simply to help you:

- Avoid wasting time and money
- Avoid some of the more common and costly mistakes

You need basic knowledge to build the best running fuel-injected engine for your needs. For many applications, the stock fuel system is generally the best system, so my recommendation is to keep your changes to a minimum.

Of course, in the presence of the "tree," or a waving green flag, the whole scene changes. Some exciting examples of Ford fuel injection can be found on many tracks.

If you're going to haul your car to the track, legality is only an issue in terms of the applicable rule book. Emissions are not usually a factor at all in racing. Especially in production-based racing classes, the rules governing fuel-injected cars will usually include some distinctions between modifications that are allowed and those which are not. The best advice is to study the rule book carefully before modifying the fuel-injection system. If possible, consult someone who is knowledgeable about race-preparation of cars in your particular class.

If the moral argument isn't convincing, then consider this: Before automotive fuel injection ever found its way into a passenger car, it was used in racing cars by manufacturers seeking a more controllable and more efficient alternative to carburetors. Later, the first passenger car applications began on high-performance models. The point is this: Precise control of fuel delivery results in more complete combustion and a more efficient engine. Efficiency is the one basic building block for optimum horsepower, clean exhaust, and maximum fuel economy.

4.4 Driveability

One of the most significant advances that fuel-injection systems offer over carburetors is improved driveability. Driveability is the delivery of smooth-running performance under a wide variety of operating conditions. A fuel-injection system measures many of the factors that affect driveability—engine temperature for example—and compensates for different conditions to deliver the appropriate air-fuel mixture.

Any stock fuel-injection system is a compromise design that balances power output against concerns of driveability, fuel economy, and exhaust emission control. When you plan to modify fuel injection to deliver more performance, or to match engine modifications, you will be making tradeoffs. Many people overlook just what the tradeoffs are. The important point is this: Not all modifications will retain the driveability or fuel economy of the original, unmodified system.

Fuel-injection driveability concerns are quite different from those with carburetors. For example, if the camming is too aggressive, fuel injection can be a total pain. Extreme fluctuations in manifold air flow and manifold pressure can send false signals to the engine control module.

4.5 You Have To Decide

I'll discuss the details of some of these modifications later in this chapter. For now, just remember that any set-up is a compromise. Part-throttle responsiveness, fuel economy, and low-speed torque are all balanced against power at wide open throttle. Most high-performance enthusiasts are willing to put up with some sort of driveability problem in exchange for increased power. That is something you have to decide for yourself. If the car has to start and run in cold weather, idle, and run smoothly in stop-and-go traffic, carefully consider the driveability tradeoffs.

5. High Performance Basics

In a practical sense, fuel injection/engine control is one system of the engine, and all the systems must work together in a balanced way to achieve peak performance and efficiency. So, before getting into the nuts and bolts of fuel injection modification, I'll run through a quick review of internal-combustion engine basics. I'll begin by discussing the basics of high-performance, and some of the good and not-so-good ideas. For street use, I'll describe the general implications of feedback control found on all fuel-injected Fords, and what happens when you modify these systems that all use an oxygen sensor and catalytic converter.

5.1 Air Flow and Volumetric Efficiency

Keep in mind that an internal-combustion engine is an air pump. A piston, traveling downward on its intake stroke, creates a pressure lower than barometric (sometimes called vacuum) in the cylinder. Pushed in by barometric pressure, the air mixes with fuel and burns to produce power. When you increase the air flow through the engine, the injection system is programmed to add more fuel and produce more power.

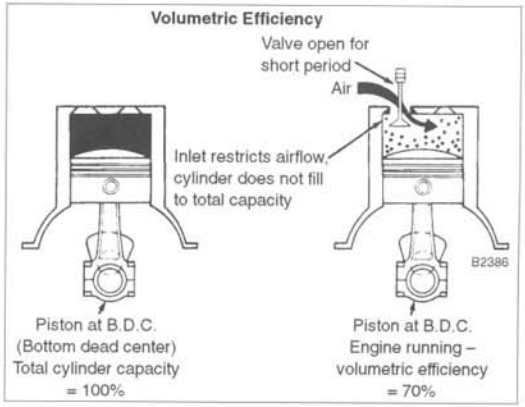

Fig. 5-1. Volumetric efficiency is measured as a percentage of total cylinder volume. If cylinder takes in only 70% of its capacity, V.E. is 70%.

In theory, the amount of air that is taken in by an engine is determined by displacement and rpm. In practice, two factors reduce the theoretical maximum:

- Valve timing and valve lift limit the amount of air that can be taken in on the intake stroke or pumped out on the exhaust stroke. The term used to describe how well the engine pumps air—the true value as compared to the theoretical 100%—is "volumetric efficiency." The best tuning can raise it above 100%, taking advantage of ram-effect manifold runners

- In the real world, automotive engines are not very efficient air pumps. The free flow of air into the combustion chamber is reduced on the intake side by the air filter, the air-flow sensor, the throttle valve, the EGR spacer, and the intake manifold and ports. Volumetric efficiency is further reduced by the restrictions of the exhaust system—exhaust manifolds, catalytic converters, mufflers and tailpipes. (See Chapter 10 for discussion of volumetric efficiency and its readout on some scan tools)

With these things in mind, it is easy to see that nearly all the hot-rodder's or racer's horsepower tricks have one common goal: to increase air flow through the engine by increasing volumetric efficiency at one part of the power curve (at the expense of other parts). The gains may be tailored to the middle rpm range to improve torque, or to the high rpm range to maximize peak horsepower, but the idea is the same. Higher lift and longer duration camshafts, larger valves, ported cylinder heads, aftermarket intake manifolds, low-restriction exhaust headers, and even dual exhaust systems all have the same job. They reduce air-flow restriction and allow atmospheric pressure to push more air into and through the engine. Superchargers and turbochargers have the same purpose, except that their job is to *force* more air through.

5.2 Fuel Metering

Naturally, when engine improvements allow increased air flow through the engine, the fuel system must compensate. It must deliver a proportionally greater amount of fuel to maintain the proper air-fuel ratio, or the engine will run lean.

The air flow and fuel delivery capabilities of the stock fuel-injection system have been chosen to correspond to the performance demands of the engine, including its volumetric efficiency. Modifying the engine changes the engine-volumetric efficiency and, therefore, the demands being placed on the original fuel-injection system.

In practice, this may or may not be a problem. Some of the stock Ford systems are quite flexible, able to compensate for some impressive flow increases. More on that later in this chapter.

For now, just keep in mind this fundamental question: When you modify the engine, does the increased air flow and increased demand for fuel exceed the limits of the stock fuel-injection system? If so, some fuel injection modifications may be necessary and worthwhile. Another question for owners of MAP systems—when you increase the intake air flow, does the EEC system know enough about the increased flow to add fuel properly? The answer to that is: seldom.

As for stock or only slightly modified engines, modifying the injection system to get more power is a different story. This is where significant power gains are elusive, and where it is easy to do more harm than good. Even the earliest, most basic Ford fuel-injection systems are precise and highly optimized, especially when compared to carburetors.

Higher system fuel pressure may also be a safety concern. With fuel lines and connections subjected to higher pressure, you have an increased risk of leaks or outright failure. To ensure reliability, the standard Ford parts are rated for pressures well above the normal operating range, but significantly higher fuel pressures may be a source of problems. This may be a problem if the pump is expected to operate above its designed delivery pressure.

Just "twiddling the knobs" on the injection system stands a good chance of reducing power—or fuel economy—and threatening exhaust emissions. Only after you get significantly more air into the engine will the fuel-injection system really require major modifications, or be able to benefit from engine mods.

5.3 Air-Fuel Ratio and Performance

In practice, the best set-up for clean exhaust and the best set-up for maximum power are slightly different. I'll discuss the differences in detail later in this chapter. For now, just remember that maximum power output demands a slightly richer air-fuel mixture—more fuel for a given amount of air.

Adjustments to fuel mixture would, at first glance, seem to be one aspect of fuel injection that is perfect for fine-tuning to increase power output. To some extent, Ford is already ahead of you. Ford fuel-injection and engine-management systems recognize full-throttle operation as a special condition with special requirements. Under normal, part-throttle running conditions, these systems precisely adjust the air-fuel mixture for good performance with minimum exhaust emissions. Then, at wide-open throttle, they provide a richer mixture—more fuel—to meet the brief demand for maximum power. Emissions increase at wide-open throttle, but the tradeoff is acceptable because of the short periods of time spent at full throttle.

As discussed in Chapter 2, all engines need a proper mix of air and fuel to achieve complete combustion. For a warm gasoline engine at part throttle, the ideal (stoichiometric) air-fuel ratio is about 14.7:1—approximately 14.7 kg of air are required for complete combustion of 1 kg of gasoline. The ratio is the same whether you're talking kilograms or pounds.

The stoichiometric ratio, however, is not necessarily the optimum ratio for peak power or for minimum fuel consumption. The graph in Fig. 5-3 shows the relationships between power, fuel consumption, and air-fuel mixture. Peak power is achieved with a slightly richer air-fuel mixture, approximately 13:1. Minimum specific fuel consumption is achieved with a slightly leaner mixture, about 15:1. In boosted engines at full throttle, where extra fuel is injected for cooling, air-fuel ratios can be as rich as 10.3:1 to 10.9:1.

At part-throttle, the fuel-injection system operates in a narrow range around what is approximately the stoichiometric air-fuel ratio, 14.7:1. As the graph in Fig. 5-3 shows, this provides the best compromise between maximum power output and minimum fuel consumption. Operating in this narrow range is essential for minimizing exhaust emissions.

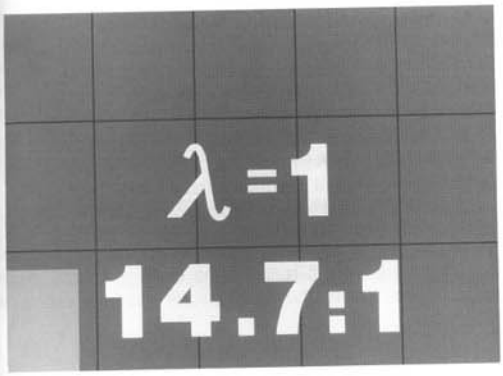

Fig. 5-2. For warm gasoline-fueled engines at part throttle, most complete combustion occurs at ideal ((stoichiometric) air-fuel ratio of about 14.7:1—approximately 14 kg air for every 1 kg fuel.

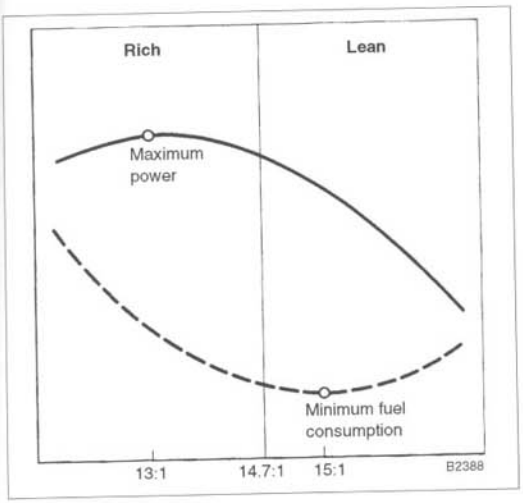

Fig. 5-3. Power and specific fuel consumption both vary as a function of air-fuel ratio

5.4 Add More Fuel?

In theory, it is possible to fine-tune the air-fuel mixture, either to maximize power or to minimize fuel consumption. This is tempting, of course, but take a closer look.

First, as I said, most systems already provide some kind of mixture enrichment at full throttle, so some of what you could hope to gain by optimizing the mixture for maximum power is already there.

Second, reconsider the curves on the graph. In the areas of interest—near the maximum power point and the minimum fuel consumption point—those curves are relatively flat. Even if the system can be adjusted to deliver the perfect mixture (just at the point of maximum power), the gain promises to be pretty small. There are no huge amounts of horsepower to be unlocked here! And if you miss and go too rich, its easy to end up de-tuning instead of improving! Of all the methods that try to optimize the air-fuel mixture for peak power, the ones that provide more gain than pain are likely to have extensive dynamometer testing and road testing behind them.

5.5 Closed-Loop Systems with Oxygen Sensors and Catalytic Converters

All Ford fuel-injected cars and trucks are equipped with one, or even two oxygen sensors and catalytic converters. The relatively clean exhaust resulting from combustion at the stoichiometric ratio is necessary for proper operation of the catalytic converter. For all cars, any significant deviation from 14.7:1 increases engine exhaust emissions dramatically because the catalytic converter cannot convert. As the mixture becomes rich, hydrocarbons (HC) and carbon monoxide (CO) go up. As the mixture becomes lean, oxides of nitrogen (NO_x) increase very rapidly. See Fig. 5-4.

Remove the Converter?

All Ford fuel-injected street-driven cars are originally equipped with oxygen sensors and catalytic converters. At the track, you might remove the converter to reduce back pressure. But never remove the oxygen sensor. At the track, I've watched them tune the mixture for the race, using the oxygen sensor. Some people report the 5.0L converter back-pressure is important for better low-speed torque for the launch. Before you pull the converter, remember the whole system is tuned for that back pressure. Removing the converter may add speed but increase your ETs.

On the street, you retain the converter for reasons of emissions and inspection. In addition, these feedback systems provide driveability and fuel economy advantages—their ability to continuously fine-tune the air-fuel mixture to match different conditions, even different fuels. What's more, the computer maps of air-fuel ratios and timing are set for the exhaust-system back-pressure of the stock exhaust with its converters.

I've covered the functional details of these systems in other parts of this book. In the context of high-performance modifications, however, here are some important things to remember.

The original fuel-injection system meters fuel to air in the best proportions possible, based on its various inputs. In closed-loop operation, the oxygen-sensor feedback system monitors the exhaust and continuously makes additional fine adjustments to the air-fuel mixture. The exceptions (open loop operation) occur principally at two times. One, the engine operates open loop during warm-up when the oxygen sensor is not yet up to operating temperatures. Two, more important for performance, it goes open loop at full throttle when oxygen sensor control is bypassed in favor of a slightly enriched mixture.

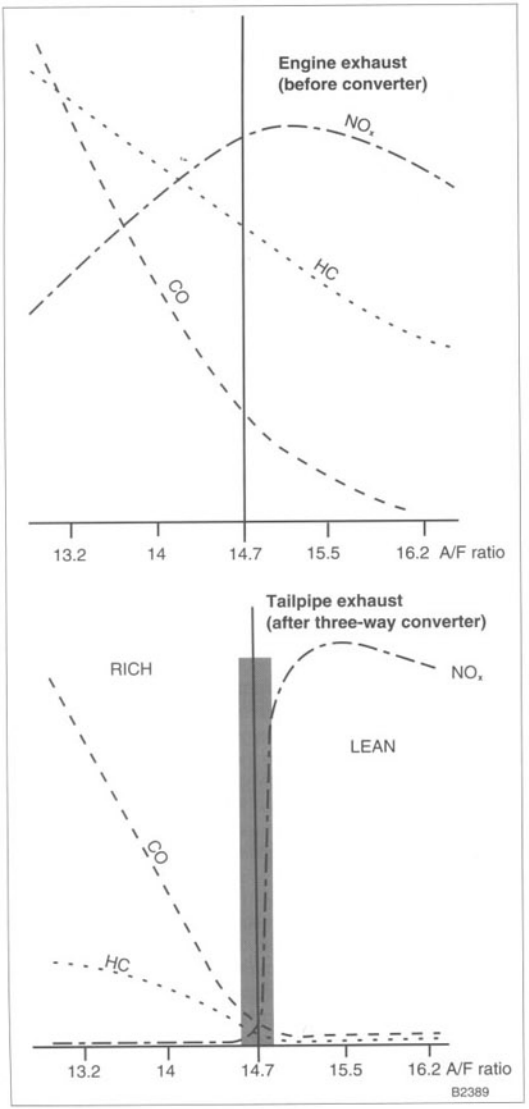

Fig. 5-4. Stoichiometric air-fuel ratio, 14.7:1, results in most complete combustion and minimizes harmful exhaust emissions when engine has a catalytic converter. Notice inevitable increase in exhaust emissions as mixture deviates from 14.7:1.

Remember, even if you modify the system to make it capable of providing more fuel, in most part-throttle operation, the oxygen-sensor system will still do just what it was designed to do. It continuously adjusts the air-fuel mixture to approach the stoichiometric ratio, the narrow range around 14.7:1. In short, no gain, except (maybe) in open-loop operation at full throttle.

Normally, this self-correcting capability—automatically keeping the mixture near the perfect stoichiometric ratio—is very desirable. Minor system modifications may make the mixture a little too rich at low and mid-range rpm. The oxygen-sensor system in closed-loop operation will tend to correct back to the stoichiometric ratio and preserve driveability, exhaust emissions control, and fuel economy.

The problems come when fuel system modifications force the system to the limits of its normal range of adjustment. The system constantly senses an over-rich mixture. When it tries to adjust more lean, it reaches the limits of its adjustment range. In such a case, the modifications and the resulting rich

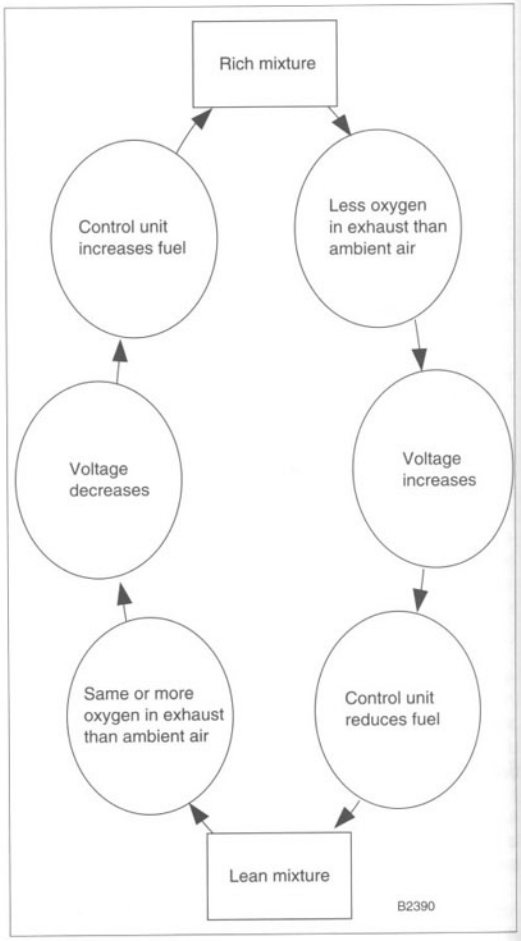

Fig. 5-5. In closed-loop operation at part throttle, engine control system will continuously try to correct air-fuel mixture to a stoichiometric value—no matter what modifications have been made to increase fuel delivery.

mixture will override the oxygen sensor's ability to correct, and will wreak havoc on fuel economy, driveability, and exhaust emissions. It may even hurt performance.

This situation can affect the performance and driveability of unmodified engines with high mileage and wear. Mixture control is addressed in 1986 and later Ford fuel injection/engine control systems with adaptive control. Instead of working within a fixed range of feedback control parameters, adaptive systems are able to accumulate data during operation. They adjust the center of their operating range according to the needs of the individual car, to this individual driver, even to the fuel of this fill-up.

5.6 Ignition

Ignition timing is another performance factor that goes hand-in-hand with fuel delivery. As you know, all Ford EEC systems and most MEC systems control fuel delivery and ignition timing in one electronic control unit. Conservative fuel-mixture control in the name of low exhaust emissions may also be accompanied by conservative ignition timing curves, primarily because of the manufacturer's concerns over the quality of available gasoline. Many tuners of fuel-injected cars usually advocate revised ignition timing specifications to further unlock the performance potential of revised fuel control. With 92-octane premium fuel, try advancing base timing to 12 to 14 degrees BTDC. Do not try higher-octane racing fuels to advance timing further. These fuels burn too slowly and may actually reduce power and increase carbon build-up.

As I described previously, some Ford ignition systems provide an Octane Switch so you can advance or retard ignition timing by a few degrees. With or without an Octane Switch, two other options are available: 1) advance base timing, 2) modify with an aftermarket ignition system.

For those engines with knock sensors, neither EEC-IV nor MECS engine controls advance spark timing toward the early limits of knock sensing. (Some European engine-control systems do that kind of advance).

Fuel and Spark Timing

It's to your advantage to use the lowest octane fuel that does not provoke pinging in your engine. If you've pushed the timing and the engine control toward pinging, consider your options:

- Pump gas with higher octane. If 92 octane premium unleaded sells for about 20 cents a gallon more than 87 octane regular unleaded, you gain about 5 octane points at a cost of about 4 cents per octane/gallon
- Octane Enhancers. Generally alcohol-based, they can raise the octane rating of premium fuel by as little as 0.1, and as much as 2.2. Some enhancers take advantage of the methanol pump-octane rating of 101. But recall from Chapter 3 that methanol additions of over 10% can lead to real trouble with fuel system corrosion as well as engine-control system problems. And excess octane slows burning to lose power

Too often, we limit our thinking of modifications to the Mustang tire-burner on the street or on the track. But many of these mods will help the owner of a Bronco, Explorer, Aerostar or an E/F series light truck increase power for trailer pulling.

6. Bolt-ons and Modifications

Each of the Ford fuel-injection systems you've already read about in this manual has its own unique features and characteristics. I'm considering only fuel-injected engines. Most of the available modifications apply to 5.0L engines, some to the 2.3L turbo, and some to the Mazda engines in the Probe, and the 1.6L Mazda engine in the '91 and later Capri.

I'll describe the most popular fuel injection/ignition system modifications, and give a cross-section of the methods employed by experienced tuners. In line with the legal and the moral "green" aspects of the '90s, I'll identify those mods that are certified street-legal as we go to press.

The efforts of tuners are not only interesting and exciting. They also provide valuable insight into how the experts think about the problems, and how they approach solving them. These insights, combined with your knowledge of the system basics, should help you to decide which modifications hold promise for your application.

Some of these modifications are well-known and well-tested. I can give you a fairly accurate idea of the results, if any, that you might expect. For many others, the results are much less certain. I've described these modifications and the theories by which they are supposed to work. I make no recommendations.

6.1 Mass Air Flow Conversion

Mass Air Flow (MAF) sensors are stock in most late-model Ford cars and trucks. Interestingly, MAF began with the 1988 California 5.0L H.O. engines. But Manifold Absolute Pressure (MAP) sensors were stock in 1988 49-state 5.0L and in many other Ford engines between 1988 and 1992. The MAP system (also known as Speed-Density) is quite different from MAF, in spite of the similarity of the initials. MAF is generally superior for street and for track, so most tuners will begin by recommending changeover from Speed-Density to MAF. If you had to do it from scratch, it would be a major mod. But Ford Motorsport has seen the need and provided a complete kit.

SVO Kits

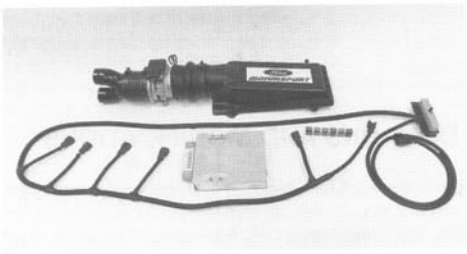

Fig. 6-1. MAF kit for F-series truck includes jumper wire harness to convert gang (bank) injection to sequential (SFI), and new EEC-IV control unit. Not street-legal in California as we go to press.

Ford Motorsport kits include the MAF sensor, a matching computer, the hoses, and the harness. You can order one of four kits:

- '88 49-state Mustang, Manual transmission
- '88 49-state Mustang, Automatic transmission
- '88 and later F-series 5.0L truck, Manual transmission
- '88 and later F-series 5.0L truck, Automatic transmission

Each is a neat bolt-on, available from most Motorsport dealers and tuners. Truck kits include a special overlay wire harness that converts your two-bank ganged injectors into sequential (SFI). Not street-legal in California.

Compared to Speed-Density, this MAF Conversion kit provides two benefits:

1. Better idle quality and overall vehicle performance. Even if you don't change anything else, it can react faster and more accurately to the changes in air flow as you accelerate and decelerate.
2. Versatility required when your performance mods change the air flow. Without changing the engine control or the fuel pressure, you can expect to handle up to 320 horsepower. Then the injector dwell is 100%—they're open all the time. You can expect good driveability even as you change the mass of air drawn into the engine for each stroke by changing:
   - Camshaft
   - Cylinder heads
   - Throttle bodies
   - Intake manifolds
   - Headers
   - Exhaust systems
   - Axle ratios
   - Turbo/supercharger

Speed-density systems do not measure air flow directly. Instead, the computer looks at the speed signal (rpm from TFI) and the calculated air density (MAP and Air Charge Temperature (ACT) and barometric pressure (BARO), plus data from its memory) to calculate the air flow. More on this in Chapter 4. Many performance mods—not only to the engine, but to the exhaust and even the axle ratios—defeat the accuracy of those calculations. They change the real air flow to be different from the calculated air flow. MAF measures the real air flow.

6.2 Increasing the Air Flow

One logical place to start is where the air comes in, the air filter. Suppliers like K&N Engineering and Hypertech offer replacement low-resistance air filters. See Fig. 6-2. They're widely used, reducing the obvious restriction of the original air ducting and filter. They're easy to add (5 minute installation) and they're certified street-legal. They claim horsepower increases up to 15.

Fig. 6-2. Low-resistance air filter (here coupled with larger Mass Air Flow sensor) increases air flow. Filter requires cleaning and oiling at regular intervals.

Among the hot Mustangs, most increase air flow from the stock 60mm throttle body, following Motorsport options of larger MAF sensor, throttle bodies, and EGR spacer plates. Among your options:

- 77mm MAF sensor with high-capacity air filter from Motorsport increases air flow without degrading idle quality. For max performance mods. Not recommended for stock unmodified engines. Certified, E.O. #D-242
- 65mm Throttle body. See Fig. 6-3

- 67mm EGR Spacer is machined to be compatible with 65mm Throttle body. It is compatible with stock manifolds or Motorsport manifolds.
- Motorsport Upper and Lower Intake Manifolds. They must be used together.

The intake manifolds add to the effect of your enlarged MAF sensor, throttle body and EGR spacer. Each tubular runner is 42 mm (1.65 in.) in diameter. You can use production fuel rails, sensors and wiring harnesses. You'll gain power, and look good underhood, too.

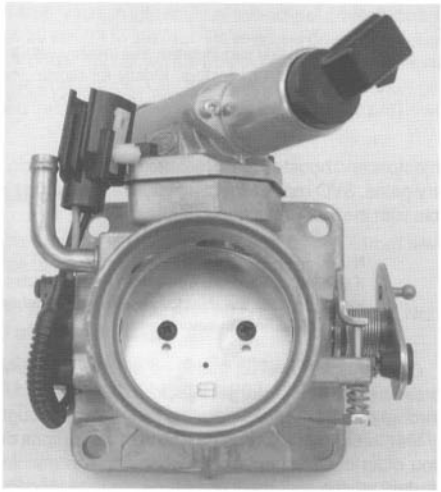

Fig. 6-3. 65mm Throttle body "High Flow Hi Po" from Motorsport flows about 10% more air than a production 60mm. Comes complete with TPS and Throttle Air Bypass–ISC valve. Not certified for street use.

Saleen offers an upper intake manifold to increase the flow. Saleen represents you'll have no problem passing a smog test. In fact, if you buy this intake manifold installed in a modified Saleen Mustang, available from selected Ford dealers, the car is EPA Certified as passing complete Federal/California tests.

For other intake manifolds, look to BBK, Edelbrock, and several others.

Charlie Bruno of Charlie's Mustang in Silicon Valley is one of several tuners I talked to. His "50 horsepower" conversion increases air flow in several ways:

- MAF conversion from Speed-Density
- Enlarged EGR and upper manifold to 70mm with polished runners

Fig. 6-4. GT-40 intake manifold (here with 65mm throttle body) can mean big horsepower gains. By themselves they are not street-legal, but Ford sells a full GT-40 kit (including valve train components, heads and ring and pinion set) that is 49-state legal.

Fig. 6-5. Aftermarket tuners such as Steeda and Saleen offer Mustangs with with mods that pass certification tests as complete vehicles, although many parts may not be individually certified.

- JBA rockers to increase lift by .030 in. and dual valve springs
- JBA shorty headers
- No change to injectors or to control module

Doug Baker of JBA (J. Bittle American) of San Diego, told me he doesn't touch the control module, or the injectors. The stock settings seem to handle the increased air flow. As Doug put it, "The 5.0L is very production—you can really improve

the engine to build performance into the many compromises of the production engine."

For your 5.0L engine, JBA offers roller rocker arms, headers and other goodies beyond this book. Most are for track so check to verify which are certified street legal.

You can see that increasing air flow has many dimensions, and your considerations are interrelated. How much horsepower can you get from:

- What size MAF?
- What size throttle body?
- What manifold?
- How about smoothing the manifold? Porting?
- Supercharger? Turbocharger?

6.3 Increasing the Fuel Injected

The Ford Motorsport high-flow fuel pump replaces the stock in-tank pump. It includes the in-tank filter, the internal pressure-relief valve, and the discharge check valve. It delivers up to 110 liters (28 gal) per hour against the standard regulator pressure of 39 psi (270 kPa). This pump increases delivery, not fuel pressure. I advise safety considerations in working with the fuel tank. This is not a user-friendly job.

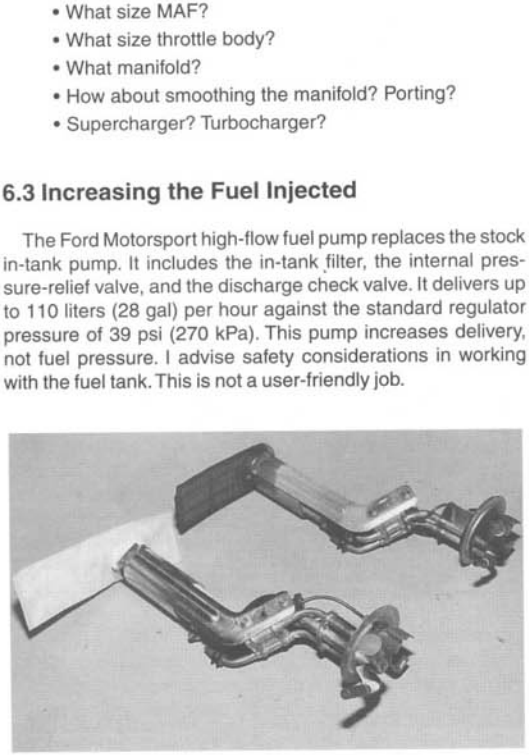

Fig. 6-6. High-Flow fuel pump (lower) from Ford Motorsport increases delivery from 88 to 110 liters/hr to eliminate high-end fuel starvation in modified 5.0L H.O. engines. Not recommended for use with Nitrous Oxide. CARB No. D-308. Street Legal.

For race applications, you may want increased fuel delivery at mid-range to high rpm. Try the SVO kit of high-flow injectors, delivering 25 lb/hr. These work best with revised MAF sensors, trimmed for high flow rates. Stock injectors at normal fuel pressure can deliver 19 lb/hr. That calculates to 320 horsepower, maximum.

To achieve significant fuel delivery increases without extremely high fuel pressures, you may also want to install larger injectors. At near-stock fuel pressures, poorer fuel atomization from larger injectors is a drawback, but a combination of larger

Fig. 6-7. You can increase fuel delivery with this kit of 24 lb/hr injectors. Strictly for racing. Require MAF special calibration. Not certified for street use.

injectors and boosted fuel pressure can produce big fuel delivery gains. SVO replacement injectors are electrically compatible with the stock injection system.

NOTE —
If you install injectors other than Ford-manufactured, be sure the injector impedance matches the original Ford injectors.

Once more, however, this is no simple fix. Increasing fuel pressure or installing larger injectors will increase fuel delivery throughout the engine-operating range, even though it is really only needed at high rpm. So, with modifications of this type, you must make a corresponding change to maintain correct air-fuel mixtures at the low and middle rpm ranges. You may: 1) alter the inputs to the computer, 2) reprogram the computer, or 3) alter its outputs.

6.4 Turbocharging/Supercharging

Increasing the air flow by turbo/supercharging falls in two categories:

1. Are you adding a turbo or supercharger to a non-turbo engine? For those engines that breathe naturally, you may hear the term "Naturally-Aspirated."
2. Are you increasing the flow from a factory-installed turbo/supercharger? Ford has delivered thousands of Original Equipment (OE) turbos. Ford introduced domestic superchargers in the T'Bird Super Coupe (SC).

Boosting a Non-turbo Engine

Bob Stelmaszczak of Ford told me that it's not as simple as some people say. The boost system must complement the engine and the fuel-delivery system. You might increase the high-end power, then wonder what happened to your power around town. You might fire up the engine, then wonder why it starves at high outputs.

According to George Spears of Spearco, the stock fuel pump delivers enough fuel at zero boost to maintain 350 horsepower at an air-fuel ratio of 12:1. But at 7 psi boost (45 in. Hg MAP), the pump delivers only enough fuel for 320 hp. That's because the pump is delivering against the higher regulated fuel pressure, raised by the regulator to inject against the higher MAP.

Even if you dramatically increase the engine power output (and you can), you must consider how long your drivetrain will last unless you modify that—clutch, transmission, final drive.

Further, you must get the power to the road. After you can smoke the tires, you run into limits of two-wheel drive. Acceleration transfers weight to the rear. Rear-wheel drive, as in Mustangs and T'Birds, puts down the power better than front drive, as in Probes and Capris. OK, add horsepower, and then get ready to add traction bars, slicks, shocks, and stuff to put down the power.

Turbo Add-ons

Turbo kits and add-on accessories are available from several sources (addresses listed in the Appendix):

- Car-Tech, Dallas TX. Also high-flow fuel pumps. Not certified for street use
- Spearco, Panorama City CA offers intercooler kits and accessories for many Ford factory turbo/supercharged engines (2.3L, 3.8L) as well as for use with aftermarket superchargers such as from Vortech (described below). See Fig. 6-8.
- Turbo Technology of Tacoma WA offers a TurboNetics T04 water-cooled turbo with special wastegate and an intercooler for the 5.0L. See Fig. 6-9. Not certified for street use

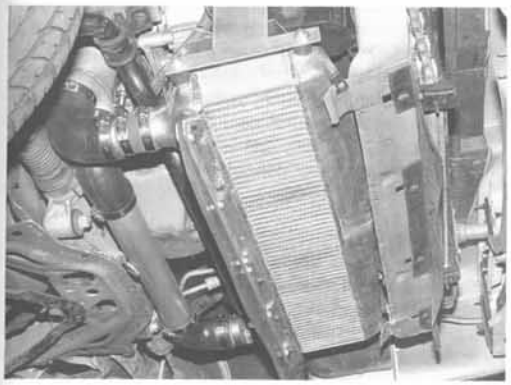

Fig. 6-8. Intercooler from Spearco is designed to work with 5.0L Supercharger kit from Vortech.

Fig. 6-9. Turbo Technology T04 water-cooled turbo.

Remember that forced-air induction raises the intake air temperature, reducing the air-fuel mixture density and the available power. Any turbo system will benefit from intercooling to reduce the intake air temperature, and Spearco offers a number of options depending on whether you want to intercool an OE turbo system or an aftermarket or custom system.

In most cases, intercooling will reduce the temperature of the air charge by a minimum of 100°F, with only about 1 psi of pressure drop. On one system designed for the factory 2.3L Turbo Thunderbird/Cougar, Spearco claims an air charge temperature reduction of 130°F and a horsepower increase of 18–20%. This system was originally designed for Ford SVO.

Supercharger (aftermarket)

Best known are the Paxton blowers from Paxton Superchargers in Santa Monica CA. They are street legal, CARB Exemption # D-195-8, P/N 10018, and kits are designed for the 5.0L engine in Mustang, Mark VII, Bronco, and F-150 (also 5.8L and 7.5L). You can also bolt on the Paxton supercharger kit for the 4.0L V-6 in the Explorer, Ranger, or Mazda Navaho. See Fig. 6-10.

As engine displacement increases, supercharger requirements also increase. In most cases it may be easier to fit dual turbochargers instead of one large unit. Paxton has a twin-supercharger kit for the big 7.5L engines as shown in Fig. 6-11.

Vortech V-1 Gearcharger turns up to 63,000 impeller rpm for 6 psi boost to add 100 horsepower, if your drivetrain can take it. Kit includes special Fuel Pressure Regulator to increase fuel pressure according to boost. Vortech Gearcharger at 8 psi boost delivers 317 hp, and 418 ft lbs torque. You'll need a new pulley, fuel pump, ignition retard, high-flow air filter. Both are street legal, CARB certified for 50 states.

Fig. 6-10. Paxton centrifugal supercharger is belt driven. Adds up to 45 horsepower to 5.0L Mustangs. Street legal. CARB # D-195-8.

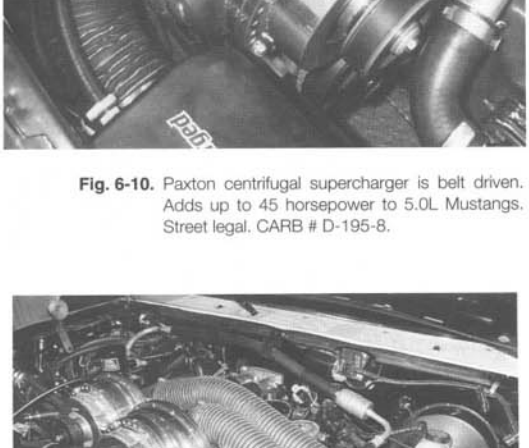

Fig. 6-11. Paxton twin-supercharger kit for large-displacement engines provides over twice the volume of air over single 5.0L unit. Kit pending CARB exemption.

Fig. 6-12. Vortech belt-driven centrifugal supercharger. Street legal. CARB # D-213-1. Also available for 5.8L.

Adding Performance to Your OE Turbo/Supercharger

Consider changing the supercharger on your Thunderbird 3.8L Super Coupe (SC) or Cougar XR-7. Ford Motorsport offers a high-flow supercharger that clips 1/4 mile times and increases speed.

Two major improvements increase flow, about 7% volumetric efficiency with less heating of the air:

- A smaller drive pulley spins the rotors faster while reducing inlet temperature
- The Teflon-coated rotors can be made with tighter tolerances because they seat themselves in the casing. One SAE engineer told me this: If you keep reducing tolerances of metal rotors in a metal casing, pretty soon they touch, and at those speeds, they fuse. But when Teflon-coated rotors touch, the Teflon wears down quickly and soon there are much closer tolerances without danger of metal-to-metal contact

6.5 Nitrous Oxide (N_2O)

Nitrous Oxide injection is popular because it is a blast, and it is cost effective. Nitrous Oxide (N_2O) is a simple gas of 2 Nitrogen atoms combined with 1 Oxygen atom. N_2O is compressed to a liquid under high pressure. During operation, it is released as a gas at the throttle body. N_2O systems provide extra oxygen and add extra fuel to combine with the oxygen, with little or no effect on the fuel-injection system or the control module.

Normally operated only at full-throttle, and only for a few seconds at a time, it has little or no effect on emissions, drive-

ability, or long-term fuel economy. For the short term, you'll burn lots of fuel to make lots of power. Tom Wilson of *Super Ford* advises, "Nitrous makes it too easy to destroy your engine with too much power. Stay with a small system unless you plan some serious engineering."

N_2O can be jetted to deliver all the power your drivetrain can handle, all the power you can put to the road through the tires. For a few seconds, your car or truck will "leap tall buildings in a single bound."

The instantaneous blast of power results from two ways of increasing power:

- Added oxygen is like adding extra air flow, like a turbo or supercharger. If you add N_2O to a turbo/supercharger, it's like having two of them in series. What's more, adding extra oxygen and fuel just as the throttle goes full open tends to reduce turbo lag
- When the compressed N_2O liquid at 800 psi (5500 kPa) changes to a gas at the throttle body, it cools the incoming air by as much as 60 degrees, increasing the air mass. Remember, the engine burns pounds of air, not cubic feet

Nitrous Oxide Systems Inc. in Cypress CA offers systems for the Ford 5.0L and the 2.3L fuel-injected engines, including the #5115 Stage II kit shown in Fig. 6-13. This system can be made 50-state legal with an additional kit, #0015 (CARB EO #D-266), that includes a special Wide Open Throttle module that senses throttle position and releases a progressive charge of N_2O.

A fogger nozzle delivers extra fuel to the throttle body combining the N_2O and the fuel in a gaseous vapor. An actuating solenoid controls the flow of Nitrous Oxide. A separate solenoid controls fuel flow. A full-throttle switch actuates both solenoids after being armed by a cockpit switch. "Armed" is a good word because the N_2O injection can seem like some kind of explosion somewhere behind you, and on your pistons.

Installation of a kit can be relatively simple. The extra fuel is drawn from the fuel rail through a fitting installed in the pressure-test port under regulated pressure, normally 39 psi (270 kPa). If you install an aftermarket system, be sure you mount it down stream of the air-flow sensors (MAF or VAF). N_2O can damage either sensor.

Several different kits are available for the 5.0L from The Nitrous Works. The simplest is calibrated to gain 125 hp, working with either the stock throttle body or the Ford Motorsport 65 mm throttle body. No vehicle or fuel system modifications are required. An adjustable kit provides up to a claimed 175-hp gain, with a larger fuel pump. A dual-staged kit is claimed to give gains up to 250 hp. See Fig. 6-14

Some cautions:

- Be aware of the results of adding this kind of power; operating at high cylinder pressures, engine detonation is a real possibility: is it protected by a knock sensor? Does it need retard of base spark timing? Usually yes. Does it need a high-output ignition system? Yes
- Avoid grease or oil near the bottle, fittings and solenoids; the oxygen in N_2O could make a nasty fire
- Upgrade your clutch, or prepare to replace it

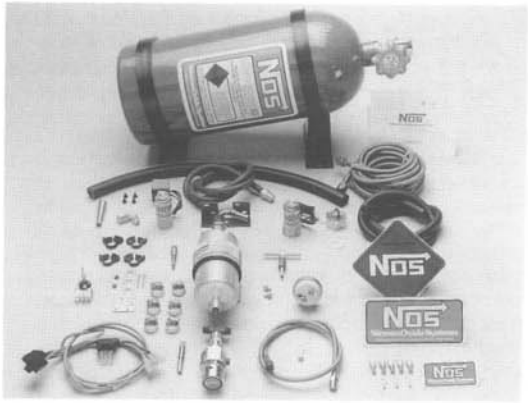

Fig. 6-13. Nitrous Oxide Systems claim up to 150 additional horsepower with their Kit #5115. Addition of special Kit #0015 can make installation 50-state legal.

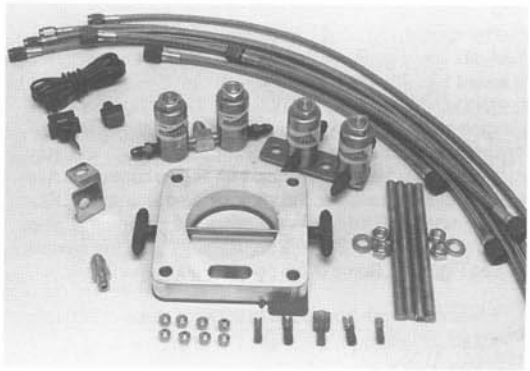

Fig. 6-14. The Nitrous Works kit #13025 is claimed to give horsepower gains of up to 250.

6.6 Engine Control Modification

You'll find plenty of offers from aftermarket chip changers for chips to plug into your EEC control module. This is not the way to modify EEC control. Opening the EEC module to change the chip is now in most cases against EPA regulations. It's also a good way to make your engine run worse or even ruin it. The only Ford Motor Co.-accepted way to modify the engine controller is by interfacing with the EEC harness, not the control module. Rather than changing the chip, you use a special harness and an additional control module that modifies EEC output.

Some more evidence that plug-in chips are a bad idea: A recent report by CARB (California Air Resources Board) estimates installation of at least 100,000 performance chips in that state alone. In a recent SAE paper, EPA reported tests of several Aftermarket Programmable Read Only Memory (APROM) chips in performance cars and in light trucks. All increased emissions, some seriously so: HC up to 27%, CO up to 59%, NO_x up to 53%; fuel economy down slightly. Performance chips may (or may not) improve your performance, but they are such a threat to air quality that Ford soldered the chip in place beginning in 1985. I hear talk that future Emission Testing may learn from your own engine control module if you have removed your performance chip module just to pass the Smog Test. When I asked CARB engineers about this, they nodded and said, "Not yet, but we're working on it." Be aware of so-called "street-legal" chips, unless they include a CARB exemption order.

The control module is designed to give you performance, economy, driveability, emission control, and more. It provides air/fuel ratios to prevent destructive detonation, and limits engine speed to 6250 rpm to help prevent other kinds of damage. But, with the right kind of know-how, and the willingness to risk the engine or the drivetrain, you may be one of those enthusiasts who can push beyond the built-in boundaries. You may want to explore an "extender," an add-on engine control module that simply plugs in between the vehicle harness and the EEC-IV control module: Ford SVO now offers the Extender, a chip module that allows you to make adjustments from the driver's seat. See Fig. 6-15. Some of the possible adjustments are:

- Maximum rpm from 6500 to 9300, in steps of 200 rpm
- Air-fuel ratio from 9.5:1 to 14:1, at engine speeds above 4200 rpm

The Extender is designed to work with 5.0L MAF systems only (49-state). As we go to publication, Ford is working on a CARB Exemption Order, but don't see it as a problem since air-fuel ratio is affected only above 4200 rpm. That's well above the speed at which emission tests are done.

The Extender is a simple plug-in installation, with two knobs on it for mixture and redline adjustments. Note that the Extender does not affect ignition timing, so it is not recommended for use with turbo or nitrous modifications.

Some chips may give you a greater kick in the back, with a great power surge as the turbo spools up. It feels good, but you can expect drivetrain problems down the line. The programming of the stock chip makes the power come on quickly, as fast as the drivetrain can handle over time. Keeping the stock torque-curve flat may reduce the exhilaration factor, but may keep your car running longer. And it may be just as fast as the hop-up chip. What's your decision?

Unfortunately, it is difficult to hold a computer chip-module or "black box" in your hand and be able to tell what it can and cannot do, or what the tradeoffs or undesirable effects might be. The word is that some chips are "smoke and mirrors." There is plenty of opportunity for a small gain in one area—full-throttle acceleration, for example—at the expense of driveability, fuel economy, and exhaust emissions. Try to find out as much as possible about the product. It's real results that count.

Ford SVO Extreme Performance Engine Control (EPEC) System

Ford SVO recently released a new system intended to maximize engine performance. The Extreme Performance Engine Control (EPEC) System allows the owner to recalibrate *all* engine parameters, from air-fuel ratio, to spark timing, to add-on nitrous systems and engine speed limiters. The EPEC system installs in the EEC-IV wiring harness and is controlled by a laptop computer (owner-supplied) running Windows software. The system also has a data-acquisition feature to check the effects of recalibrations.

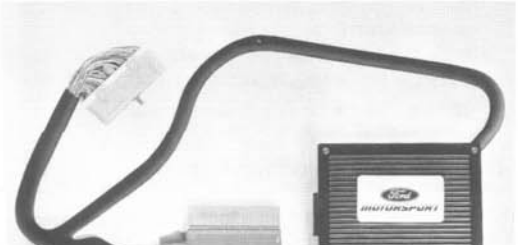

Fig. 6-15. SVO Extender is extra control module that installs between EEC-IV module and wiring harness to give additional air-fuel ratio control and redline adjustment.

Fig. 6-16. Ford EPEC system installs between EEC-IV module and wiring harness and interfaces with a laptop computer to give total control over the calibration of air-fuel ratio, spark, and other parameters.

Fig. 6-17. This 1989 Mustang GT hatchback pulls an 11.94 quarter mile at 113.26 mph. Modifications include GT-40 intake with 65mm throttle body and the stock MAF sensor ported to 61mm.

The EPEC System puts an unprecendented amount of control in a tuner's hands—Ford warns that destroying an engine is possible if the system is not used carefully. Currently the EPEC system is available for many MAF sensor controlled models (such as 1988–93 Mustangs), with plans to offer a MAP sensor (speed-density) version in the future.

6.7 Ignition System Mods

When you talk ignition system mods, start with "MSD," for Multiple Spark Discharge. Autotronics Controls Corporation of El Paso TX makes all sorts of ignition goodies for the aftermarket. Glen Grissom, formerly of MSD, tells me they work closely with Ford Motorsport for ignition-system mods. MSD builds the SVO racing ignitions under the Ford label.

The CD unit (CD in this case stands for Capacitive Discharge) draws battery power, steps it to 300 to 450 volts, then stores the raised-voltage energy in a capacitor. When the spark signal arrives, the capacitor energy is delivered to the coil where it is transformed into several-thousand volts to fire the plug.

The CD ignition tends to pay off for serious engine mods, delivering a reliable spark:

- Higher compression ratios
- Richer air-fuel mixtures
- Higher cylinder pressures resulting from supercharging/turbocharging
- Nitrous Oxide injection

The multiple sparks show up more at lower revs so you're likely to see the results in better starting, reduced plug fouling, better fuel economy, and lower emissions.

Autotronics offers just about every ignition mod up to and including a system for a Land Speed Record (LSR) holder. I'll concentrate on those parts for Ford fuel-injected engines, both street and track: ignition control, rev control, timing control, boost retard, knock sensors and alerts.

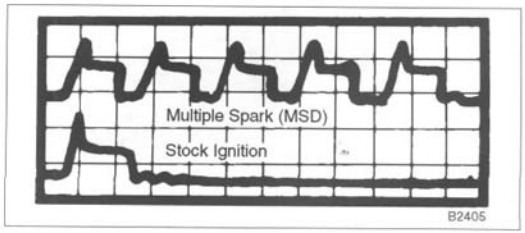

Fig. 6-18. MSD is a capacitive discharge (CD) system, producing sparks over 20 degrees of crankshaft rotation. At low rpm, that means multiple sparks.

The Ford Motorsport MSD kit provides improved capability to fire wet, fouled plugs. See Fig. 6-19. It is recommended for competition and all-out racing. With the ignition coil and wiring harness, it connects directly to all Ford TFI-IV (Thick-Film Ignition—EEC) systems. It does not apply to DIS (Distributorless Ignition Systems).

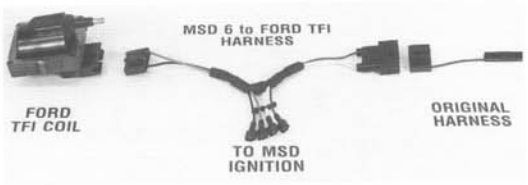

Fig. 6-19. Motorsport MSD kit provides simple installation of control unit to Ford TFI coil.

The Rev Control protects your engine from overspeed caused by a missed shift or loss of traction. The Soft-Touch gets its name because it limits revs smoothly to the selected rpm without backfires or engine roughness. When the limit is reached, it drops one cylinder at a time, then fires that cylinder the next revolution, dropping another cylinder. You adjust the rpm limit with a plug-in module, such as 6,000, 7,000, 8,000, but the Rev Control will not extend the rev limit already in the EEC control module. Some ignition controls provide a built-in rev control.

The MSD Adjustable Timing Control allows dashboard control to advance timing toward the ping point, and to retard timing for bad gas, or for extra heavy loads in your truck.

You may be able to hear the ping, or other noises may cover it—wind, road, engine noises. Or your car may have noise insulation between you and the engine. If so, you may need an Engine Knock Monitor, with a knock sensor to bolt to your engine. On the dashboard readout, you'll see green for light knock, yellow for moderate and red for "Back off, bud!" Remember, light knock is probably the point of maximum engine efficiency so a monitor can be a real help. You will need to use the sensitivity adjustment to tune the sensor to match your engine.

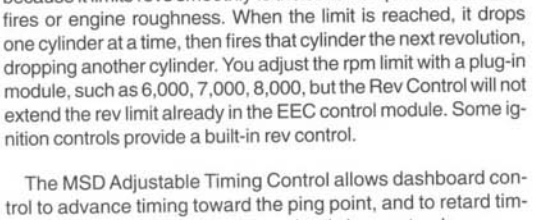

Fig. 6-20. Engine-knock monitor kit provides a readout of knock vibrations picked up by knock sensor you attach to engine block.

If you are using this Engine Knock Alert timing control to adjust according to the indicated knock, you are operating "open loop." You must recognize the difference between this and a closed-loop system that, sensing the detonation, retards the spark timing in milliseconds. I have yet to find an aftermarket knock sensor kit that operates closed loop.

Within that limitation, the ignition system can be set up so that maximum spark advance is close to the most efficient power point. The timing adjustment does not need the fudge factors and retarded timing that may be required when you must depend on your ears to hear the knock, and your fingers to react quickly enough.

With a knock-sensor system, preferably original equipment (closed loop), there is some advantage to buying higher octane gasoline. The better fuel is more resistant to detonation, and the knock-sensor system will allow more spark advance for more power.

7. QUESTIONABLE TRICKS

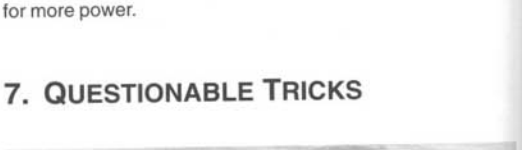

Fig. 7-1. Don't do this: Opening the EEC control module to make modifications (such as the installation of performance chips) can at the very least violate EPA regulations, and at the worst cause your engine to run poorly or ruin the control module. Stay away from modifications that have you open the control module.

Modifications that attempt to trick the electronic control module by manipulating its input signals may produce some performance gains under full-throttle acceleration. But these modifications might also result in less-than-perfect air-fuel mixtures under other operating conditions.

Wolfgang Hustedt, Bosch Motorsport Manager, told me, "Don't try to fool the computer. Can you enrich by playing games with the sensors? That's kid stuff that seldom gets results. The effect of the sensors on the enrichment is usually

linear, so if you want rich at speed, you'll probably get too much rich at lower speeds." In other words, any marginal improvement may well be accompanied by problems elsewhere.

Steve Dinan, President of Dinan Engineering, an aftermarket tuning firm in Mountain View, California, told me, "...power gain is elusive. Somebody can show you tests with more power at one point on the curve, but you don't know that you are losing somewhere else. You might gain peak power, but driveability glitches can develop, such as poor idle, loss of low-end torque, and high HC (hydrocarbon exhaust emissions). Some of the most involved work we do is trying to restore driveability to a (car) that has been fooled with for a little gain at one point of the curve."

7.1 Fool the Coolant-Temperature Sensor?

As you have seen, the variable resistance of the coolant-temperature sensor is an input to the computer. At lower temperatures, the higher resistance signals the computer to call for more fuel. They'll tell you that adding resistance to this circuit will trick the computer into thinking the engine is cold, so enrichment is added. I don't see any professional Ford tuners trying this old trick.

Here is the problem. Computers are programmed to operate within a certain band of resistance values of the coolant-temperature-sensor circuit. Instead of enriching the mixture, a radical change in resistance might cause the computer to revert to Failure Mode Effects Management (FMEM), lighting your Check Engine light. Some systems simply operate based on the last "normal" temperature signal. This won't work closed loop.

Even if it worked open loop, it would be a bad trick. Over an extended period, the extra fuel could cause wear of the rings and cylinder walls. The big caution in a set-up like this is to watch for too much enrichment on cars equipped with catalytic converters. Too much fuel will send converter temperatures soaring—in some circumstances high enough to light the car on fire!

7.2 Install Lower-Temperature Thermostat?

Some tuners recommend low-temperature thermostats. It's true that a cooler engine takes in cooler air—more pounds for more power. Sounds good, but lower coolant temperatures do not lower the temperature of intake air by the same amount.

There is one possible gain from a cooler thermostat: lowering head temperature may reduce probability of detonation. That means you can advance the spark timing for increased power. Except for the track, this is not one of your better ideas.

Most engines are designed to operate with a coolant temperature of around 95°C (200°F). Unfortunately, lower coolant temperature will increase cylinder wall wear and, in cold climates, affect driveability. What's more, the cooling system operates with greater efficiency at the stock 200-degree temperature. So the lower-temperature thermostat could lead to overheating at high powers.

When I investigated this some time past, the Eveready engineers told me some NASCAR racers run 100% glycol in the cooling system so they can run the engine at higher temperatures. And in Europe, Honda found its racing engines operated more efficiently if they raised the air temperature. Something about lean-burn efficiency. How about that! Pass on cool thermostats.

7.3 Disconnect Fuel-Pressure-Regulator Vacuum Line?

This is one of the worse ideas, trying to improve performance by defeating the line that modifies fuel pressure according to manifold pressure. As you know, the system is designed to operate with constant relative fuel pressure. At WOT, the regulator will give you maximum fuel pressure, even with the vacuum line connected. At less than WOT, the injector pulse times are calibrated for properly-reduced fuel pressures. Disconnecting the vacuum line causes rich running only at part throttle. What a scheme to foul plugs!

7.4 Convert from MAF to MAP?

Unfortunately, some tuners want to change your Mass Air Flow (MAF) sensor to a Speed-Density system, operating from MAP. Apparently, they cannot stand the thought of the restriction of the stock MAF, a reduction of air flow that is so small it is measured in milligrams. They forget that Ford, once committed to Speed-Density, has almost completely changed engine control to MAF. Motorsport offers a kit for your aftermarket changeover to MAF.

The Speed-Density conversion is usually bad news. Because the MAF sensor signals control of fuel and ignition, some converters find the engine will not run at all; others find detonation and poor driveability. Check this out all the way before you try converting MAF to MAP.

7.5 Remove EGR (Exhaust Gas Recirculation)?

If you're tempted to block off the EGR flow, hold it. I know, dumping partly-burned gasses back through the combustion chamber seems a power-robbing game. When EGR first appeared in 1974, blocking off the EGR was probably the only thing that kept some engines running. But today, in these fuel-injected engines, people who know don't do it for two reasons:

- The engine-control already shuts off EGR under high-performance conditions, also at idle and during cold operation
- The rate of fuel injected and the spark advance are calculated for EGR under part-throttle conditions. If you block off EGR, you stand of good chance of experiencing knock and wasting fuel. You might even reduce your power output, and you are dirtying the air

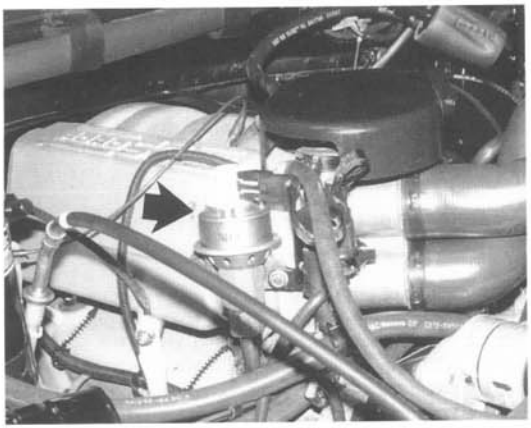

Fig. 7-2. Disabling EGR valve (arrow) control may lead to engine knock and poor fuel economy.

7.6 Add-On Injectors?

One approach to providing needed fuel enrichment to modified engines is to leave the existing fuel system untouched and add a separate system with the capability to meter additional fuel. See Fig. 7-3. The controller considers input signals of rpm and MAP to determine the activation point. Tuning is required to determine the gain, the percentage of injector capacity to be used. Unfortunately, some controllers do not correct for coolant or air temperature, so the air-fuel ratio may be off. In my opinion, you're asking for driveability problems, particularly in northern climates, if you add injector(s) that do not provide for temperature compensation.

Fig. 7-3. Add-on fuel injector (arrow) can supply fuel for high demand situations, but precise control of air-fuel ratio is difficult .

8. Mazda Engine Control System (MECS)

HKS of Torrance CA, and of Shizuoka, Japan, specializes in performance mods for Japanese engines, including the turbo 1.6L in the 1991 and later Capri, and the turbo 2.2L in the Ford Probe. These include: fuel-system components, boost controls, air induction and exhaust systems, intercoolers and ignition systems. Systems come in several stages of tune. Those that are Smog Legal show "EC" (Environmentally Conscious) in the Part #. Typical power boosts from stock Probe GT with 2.2L turbo:

Street			
	HP	**Boost (psi)**	**Mods**
Stock	145	10	—
Legal 1	159	10.5	Intake and exhaust upgrades
Legal 2	164	10.5	Above, plus intercooler upgrade
Off-Road			
Stage 1	169	11	Intake and exhaust upgrades
Stage 2	178	12	Above, plus wastegate control
Stage 3	187	12	Above, plus intercooler upgrade
Stage 4	222	15.5	Above, plus power-chip module

The HKS power-chip module, known as a Programmed Fuel Computer, Stage IV Off-Road, really adds horsepower, based on serious engine mods. It is adjustable with internal dipswitch, and can even be cockpit controlled with an additional mod, the Graphic Control Computer.

The HKS Electronic Valve Controller (EVC) manages the wastegate to increase the time at max boost without increasing the max boost pressure. The electronic control maintains closer control over the wastegate than an air-operated boost control. We're talking Stage II, Off Road.

In addition, the dashboard controller allows boost increases over stock to 150%, 200%, 300%. I hope your engine and your drivetrain can handle that.

One simple mod improves air flow, using a low-resistance air filter as described earlier.

Another simple mod improves power by changing the exhaust. The HKS High-Flow Turbo Exhaust system is certified street legal. What's more, it does not affect engine timing, fuel enrichment or emissions because the engine-control module compensates for any changes. Reducing the back pressure at the turbo increases the pressure across the nozzle so the turbo winds up more quickly, reducing turbo lag. It might raise the max boost.

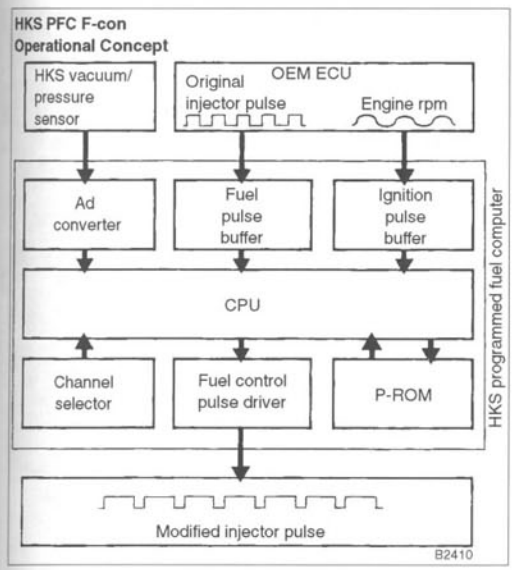

Fig. 8-1. HKS power-chip module reads OEM (Original Equipment Manufacturer) control module, modifying injector pulse times. Not Certified as street-legal.

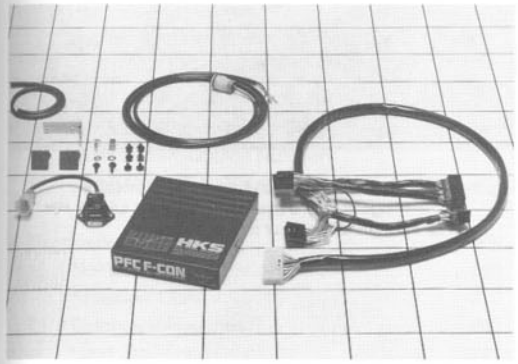

Fig. 8-2. HKS power chip module monitors Ford control module and modifies injector pulse times. Not certified for street use.

You can replace the stock intercooler with the upgrade intercooler for modest horsepower increases for both Probe and '91 and later Capri. With more cooling, you'll increase the peak horsepower (Probe about 6 hp, Capri about 8 hp), but with increased volume of the intercooler, you'll increase turbo lag. Street legal, CARB #D-186-1.

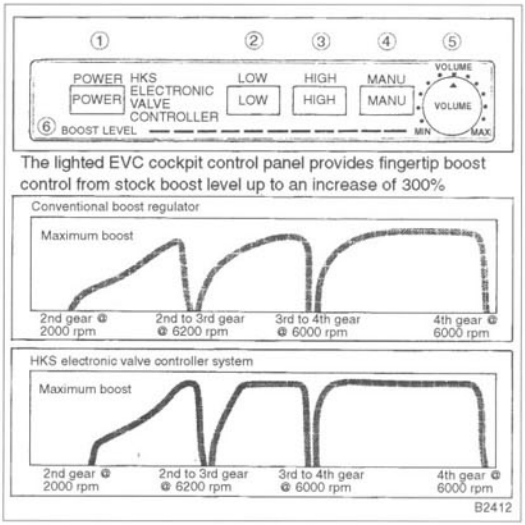

Fig. 8-3. Electronic monitoring of wastegate provides more time at max boost without increasing max boost pressure.

To improve low-speed driveability and throttle response, try the HKS Twin-Power Capacitive Discharge (CD) Ignition Amplifier. You may find an improvement in high-end misfire, particularly if you're increasing the boost.

Recalibrating the Volume Air Flow (VAF) Sensor

The Bosch Volume Air Flow (VAF) sensor is used in MECS-I engines, including 1991 and later 1.6L Capri, some 1.8L DOHC Escorts and Tracers, and 1989 and later 2.2L Probes.

From the factory, the relationship between the air-flow sensor mechanism (the flap) and the signal to the computer is precisely calibrated. But, you can recalibrate the mechanism by tightening or loosening the return-spring tension on the air-flow sensor flap to alter this relationship. Adjusting the spring tension will change the sensor-flap position for any given intake air flow. This produces a greater or lesser signal and, therefore, a leaner or richer mixture—in the range up to about 4000 rpm where the air-flow sensor is fully open.

Some very knowledgeable independent tuners have had success with this method, but remember that the VAF sensor is a sensitive, delicate device. Without knowing what you are doing, it is easy to do more harm than good. You must check the fine adjustments and their effects on mixture with an engine exhaust analyzer. Ford does not recommend or endorse any kind of internal VAF adjustment.

9. CONCLUSION

In this chapter I have presented a broad spectrum of ideas on the high-performance application of fuel-injection systems in Ford cars and trucks and on modification of those systems. The subjects have ranged from inexpensive modifications to street cars to extremely expensive custom electronic controls made for racing.

The fundamental messages of the chapter are these:

1. In the quest for more power, increased efficiency, or better fuel economy, the stock fuel-injection system is not necessarily the weak link. Sometimes the stock system is the best system, considering the limitations of the engine and the needs of the driver.
2. There are no "demon tweaks," no magic chip that can miraculously unlock vast amounts of horsepower. The need for fuel-injection system modifications depends directly on the needs of the engine. It all comes down to whether the needs of the engine exceed the capabilities of the injection system.
3. There is no substitute for knowledge—knowledge of the engine's requirements, knowledge of the engine control system's limitations, and an understanding of the real effects of modifications. I've devoted the first eight chapters to describing the detailed functions of each Ford fuel-injection system. Thorough understanding of these functions will be the first and most important step in figuring out what adjustments and modifications will pay off for your car and your individual needs.

NOTE —
See appendix for CARB Exemption Order List

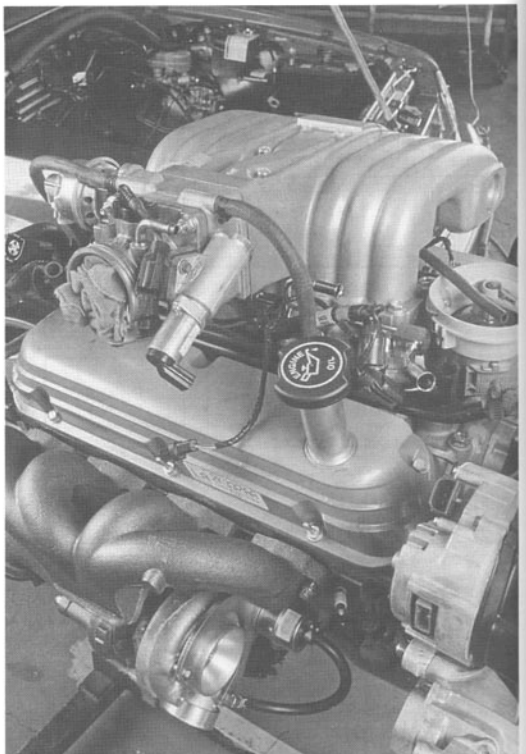

Fig. 9-1. All it takes for successful tuning is a thorough knowledge of engine management basics as well as the trade-offs of your modifications.