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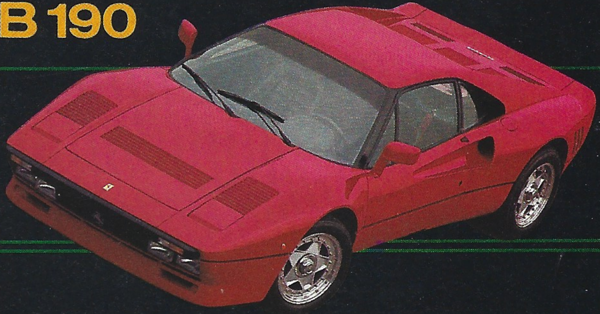


DRIVER'S REPORT: *400-HP GTO FASTEST FERRARI EVER!*

AUGUST 1984

TOMORROW'S MUSTANG?

4WD Turbo Ghia

SUPRA SURVEY: THE OWNERS TALK

Ford Mustang GTP

Quick is only half the story; look closer and you'll see Ford's blueprint for the rest of the century

Road American Raceway, Elkhart Lake, Wisconsin, Aug. 21, 1983: Out of the rain and mist of a sudden summer storm, whistling up the hill from the final turn to the soggy checkered flag, comes a low-flying blue-and-white bullet of a race car. On its nose, the familiar Ford oval; over its swept-back windshield, the words "Mustang GTP."

Squint your eyes, stretch your imagination . . . it does look *something* like a Mustang. Much lower and wider and longer of nose, and capped by a small, rounded bubble of a cockpit and a huge aerodynamic rear wing. As it flashes by and disappears into the downpour, you can just make out the message written across its twin-pontoon tail: "Have you driven a Ford . . . lately?"

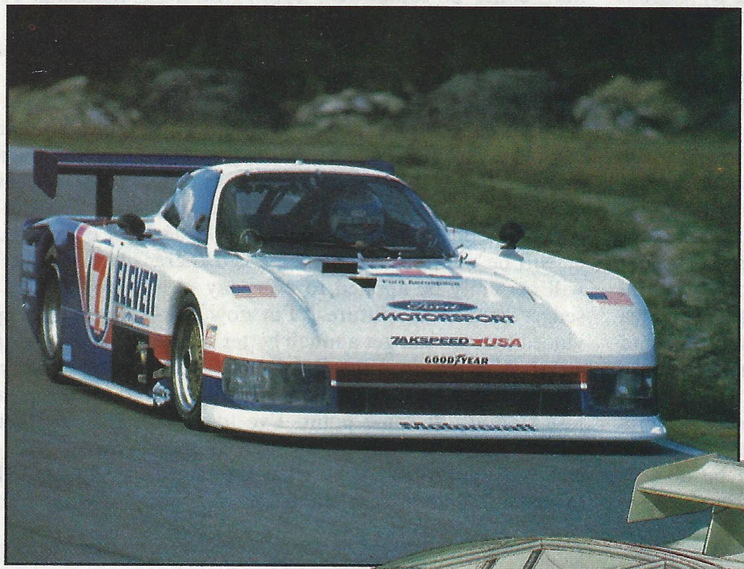
The fact that Ford's brand-new, fresh-from-the-box turbocharged 4-cylinder GTP (Grand Touring Prototype) had beaten the awesome turbocharged 6-cylinder Porsches and V-8-powered Lola and March prototypes that have dominated recent IMSA (International Motor Sports Association) road racing competition its first time out is certainly significant to the racing community. More important to you and me, however, is the car itself—who built it and why, how and of what it's constructed, and how it relates to our own automotive future.

by Gary Witzenburg

PHOTOGRAPHY AND ILLUSTRATIONS COURTESY OF FORD MOTOR COMPANY

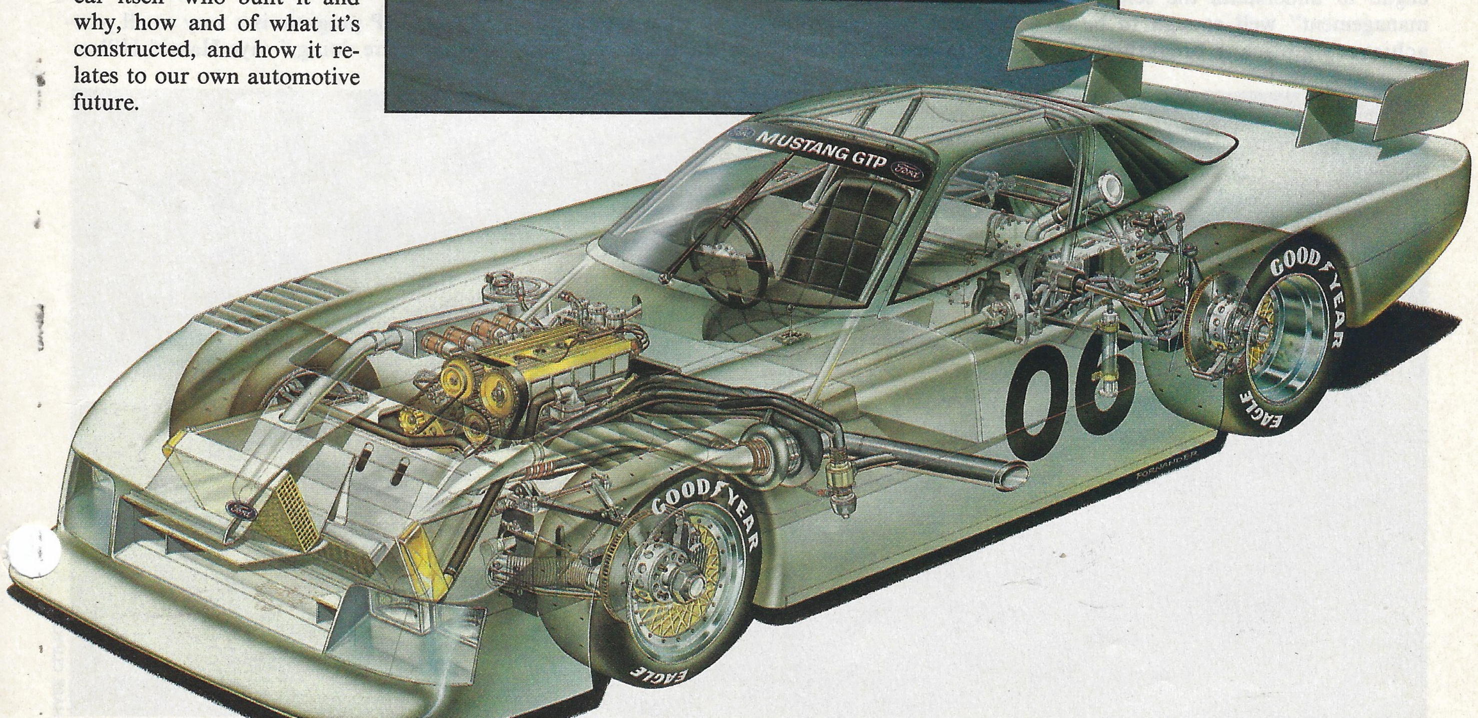
Ford's GTP racer, first off, is a unique and radical machine the likes of which has never been seen in this country or any other. It is, says Ford Chairman Philip Caldwell, "a clear, unmistakable example of U.S. technological prowess—the leading edge of technology development—which should discredit the notion that innovation and sophisticated technology do not reside in America."

It is a corporate statement of direction, a design, engineering and materials showcase, an important technological testbed and a window on our automotive future. It embodies the efforts and considerable talents of Ford's styling and racing departments, as well as the company's highly respected Aerospace and Communications affiliate and a group of its high-tech materials suppliers. And its technology hits squarely on just about every facet of the Ford production car of the late 1980s and beyond—computer-aided design (CAD) and manufacturing (CAM), advanced lightweight materials and adhesives, small but powerful turbocharged 4-cylinder engines and state-of-the-art aerodynamics.



Unlike any other modern race car of its type, the Ford GTP has its engine mounted up front instead of behind the cockpit. The tiny twin-cam, mechanically fuel injected, all-aluminum 1.7-liter turbo-four that powered it to that auspicious first victory developed an incredible 600 hp at 9000 rpm and 368 ft-lb of torque at 7500 rpm. It drove a rear-mounted 5-speed transaxle through a filament-wound carbon fiber driveshaft and propelled the 1770-lb "Mustang" to an estimated 210-mph top speed.

By the end of the 1983 season, a more powerful 2.1-liter engine (based—loosely—on the overhead-cam, electronically fuel-injected 2.3-liter four currently found in



Ford's T-Bird, Cougar, Mustang, and Capri turbos) had replaced the European-built 1.7-liter. And a revolutionary *plastic* engine (also 2.1 liters) being developed by Polimotor Research Inc. of Fairlawn, New Jersey, may find its way into service by next year.

The car's chassis tub is constructed of a Nomex-core carbon (graphite) fiber composite, an extremely strong and lightweight material developed by Ford Aerospace for communications satellites and other spacecraft. Nearly all of its underside is an aerodynamic tunnel that works with the smooth and almost flat upper body surface to create the effect of an upside-down airplane wing as air rushes through it. The resulting "downforce" increases with speed, pulling the car to the ground for tremendous cornering traction in high-speed turns.

Even the wind-tunnel-contoured windshield is high-tech. Flush-mounted at a wind-cheating 25° from the horizontal, it's made of a super-thin lightweight glass/vinyl/glass laminate pioneered by Ford's glass division, yet it's distortion free and strong enough to withstand the tremendous air pressure and constant sand and debris thrown up by other cars at 200mph.

How does all this relate to future production passenger cars? Let's explore the GTP's features with some of the key people involved in the program. Donald Kopka, Ford's design vice president, points out that the car's aerodynamic design really began with the company's experimental Probe I car of several years ago. The idea of shaping a vehicle's contours in the wind tunnel is nothing new, of course; but only recently, driven by the quest for fuel efficiency, have the industry's aero engineers begun to understand the science of "air management" well enough to be able to achieve significant breakthroughs.

Probe I led to Probes II and III, each aerodynamically slicker than the one before; then last year's Probe IV (a compact-sized 4-door sedan), which achieved the almost unbelievable drag coefficient (Cd) of 0.15—better than the average fighter aircraft! It took some expensive, far-from-production technology (spoilers that automatically deploy and a suspension that lowers the car and adjusts its angle of attack into the wind as speed increases, for example) to achieve that number; and GM, for one, is now into the mid-teens as well. But Probe IV *was* the first reasonably practical automotive shape to shatter the 0.20 Cd threshhold, and Kopka hints that Probe V may come in somewhere below the 0.1 mark.

Michael Kranefuss: "If you want a place to get your technical message across, it's road racing"

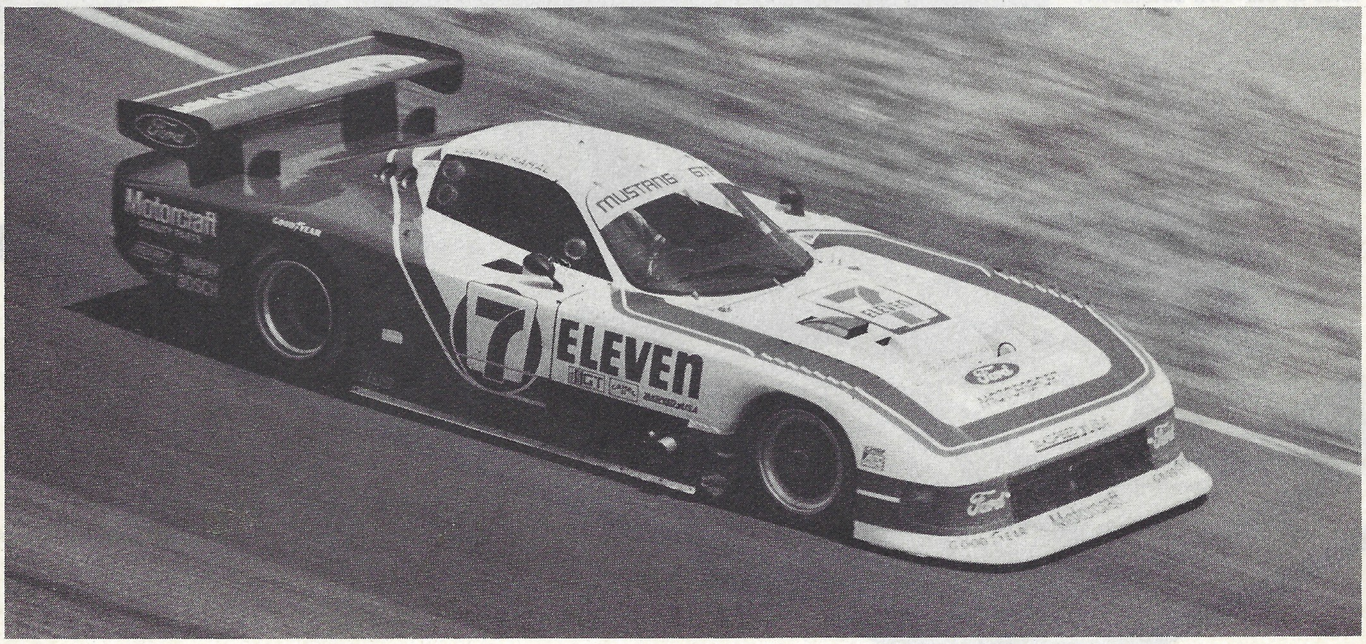
He cautions, however, that there's a lot more to air management than just low drag. Engine and brake cooling, interior ventilation, the way dirt is deposited on windows, headlamps, and taillamps, and especially high-speed stability—all are crucial factors in the aero equation. And that is one practical way in which the GTP racer will be useful, for lessons learned there will certainly be applied to everyday passenger cars in the future. "I'm now convinced that we can get a much better Cd on a car than on an aircraft," Kopka says. "But if it gets too aerodynamic, it starts to lose stability at some point. I've told my people to make Probe V as slick as they can, but then to pay back what they need to make it a very, very stable car. I don't care if the Cd ends up higher than Probe IV's so long as it's a better car in terms of overall air management."

Today's typical GTP racer is highly stable at speed due to its huge tires and aerodynamic wings, but recent emphasis on tremendous downforce for faster cornering pushes its drag way up into the 0.6 to 0.8 range, says Kopka, which slows it down on the straights. By contrast, the new Ford GTP achieves equal or better downforce with a Cd of just over 0.5. Because its engine is up front, there's room for a larger and more effective aerodynamic tunnel in the rear and less need for drag-inducing wing area on top. The bottom line is incredible cornering and braking plus competitive straight-line speed with less brute power.

Is downforce really important to a passenger car? "Yes, it is," says Kopka. "We measure it now, and we have good downforce on all our cars. Obviously you don't need much, just enough to keep it solidly on the ground to improve the stability and handling. Probe IV is definitely tuned for that." Can you apply the upside-down wing technique underneath? "Sure. It won't be as distinct as on a race car; you won't see it as much. But you basically start with a clean underbody and then handle the various shapes in a way to give some negative lift.

"You can do it with dams and spoilers, of course, but the more you build it in the better. That's what we're trying to do. I predict that you'll see fewer and fewer air dams and spoilers on production cars in the future—that these things will become integrated into the basic design. The idea is to keep most of the air out from under the car, then control what does go under there."

"The GTP program is a very small part of what we're doing," says Harold Hilles-



MARK CLIFFORD

land, supervisor of materials and processes at Ford Aerospace and a former sports car racer himself. "Yet the enthusiasm is very high. It's something exciting and different for us. We show the car parts along with our spacecraft parts at open houses, for example, because our families can relate to them better."

Ford Aerospace is the world leader in advanced composite materials for spacecraft, according to Hillesland. "We started using graphite epoxy in about 1967, because it's very lightweight—30% to 40% lighter than conventional aluminum—and very dimensionally stable. For example, you can't have a communications satellite antenna moving with temperature as it passes from sunlight to shadow because it would defocus. And there's a very high premium on weight in a spacecraft, so you get two payoffs. We've been building and flying composite spacecraft parts since 1970, and we currently have more than 34,000 graphite parts in orbit, all functioning well. Over 4000 of the parts, or 27% of the total weight, of our current large satellites are graphite."

Simply speaking, a "composite" is two or more materials combined to form a new material with a specific desirable set of properties. Fiberglass, for example, is a composite—fine glass fibers molded into lightweight plastic—and much stronger than the unreinforced plastic would be. Carbon fiber composite, as its name implies, is similar in concept but many times stronger since carbon (a close relative to diamond) is one of the hardest substances on earth. Compared to steel, carbon fiber gives equal strength at one sixth the weight, and the epoxy/imide resin into which it's woven is itself much stronger and more temperature resistant than conventional plastics. Like rope, however, these fibers are strong only in tension (pulling), so multi-directional strength must be achieved through layers of fibers pointing different ways. "We cross-ply them to carry specific loads," Hillesland explains, "so a given component may be strong in two directions but not the third. We put the strength in only where we need it."

In designing the GTP tub, Hillesland's group put the basic dimensions and loads (supplied by Bob Riley, Ford's brilliant racing designer) into its CAD/CAM system, used finite element analysis to test each component for strength and torsional stiffness right on the computer screen, then had the system draw full-size mylar prints, scribe aluminum templates, and even machine-finish certain graphite parts. The completed tub is made up of more than 20 separate panels bonded together by space-age adhesives, which are highly developed "modified" epoxies with outstanding "peel" strength as well as tensile strength.

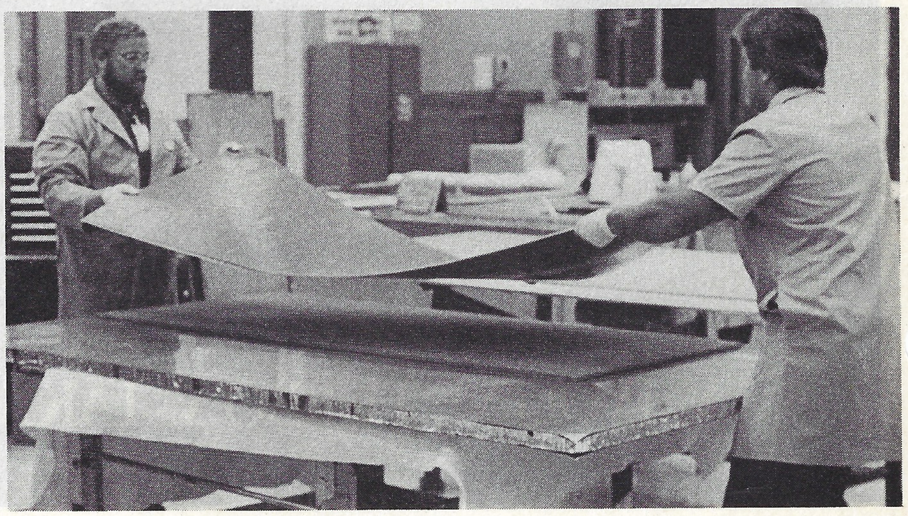
Each panel is one or more sandwich-like layers (plies) with the stiff graphite fiber composite as the bread and super-light Nomex honeycomb the filling. The number of plies in each panel depends on the strength and stiffness required in that specific area. Twelve plies are used in the driveshaft tunnel, for example, where the highest stiffness is needed, and a layer of ballistic Kevlar (flak-jacket material) is bonded in to further protect the driver in case the driveshaft breaks. In contrast to most other pure race cars, whose torsional strength comes almost entirely from tubular steel rollcage/chassis structures, the Ford GTP's composite tub is so stiff its rollcage is strictly for driver protection.

Graphite body panels have brought the arcane art of "vacuum bagging" to autodom

The top, front, and rear structural panels and those around the fuel cell also are very strong, while lightly loaded areas such as the dashboard, seatback, and side sills require just one or two plies. Suspension and powertrain mounting points are reinforced with high-density graphite blocks, many with threaded metal nut plates molded on. "What we've done is tailor it," Hillesland explains. "It's a very lightweight structure with stiffness only where it's needed."

Since the bottom of the tub is also the top of the aerodynamic tunnel, it must be extremely smooth and precisely curved for optimum airflow. This panel's contour is achieved by literally sucking it against a template with a vacuum (negative air pressure) before its bonding adhesives are dry; and its super-smooth surface is a layer of Tedlar, a thin plastic film supplied by DuPont. (Nomex and Kevlar are also DuPont products and trademarks, though the Nomex honeycomb core is built and supplied by Hexcel Corporation. Other suppliers donating materials to this festival of space age synthetics include Celanese, American Cyanamid, and Fiberite Corporation.)

Ford engineers prepare one of many carbon fiber/Nomex honeycomb composite panels that make up the Mustang GTP tub.

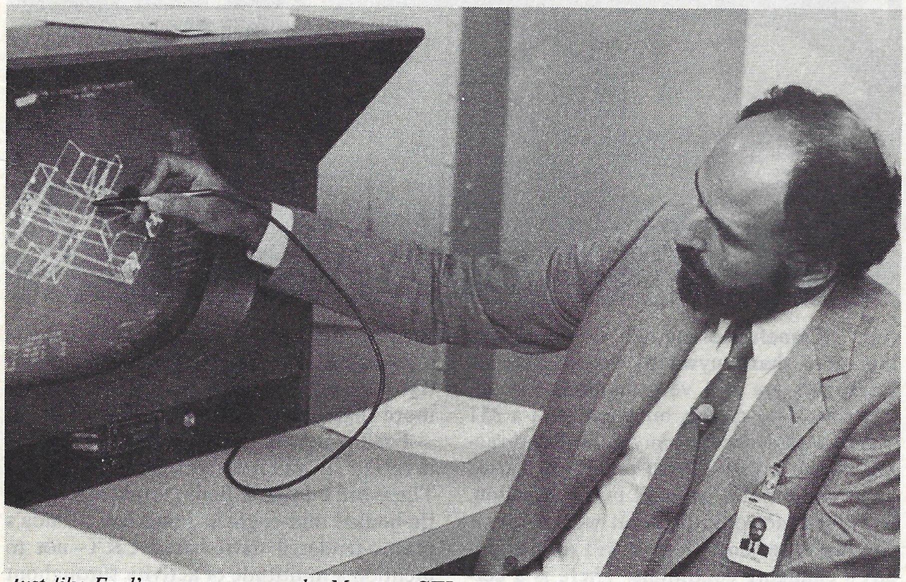


Nomex was chosen over aluminum honeycomb as the sandwich material primarily because it's lighter, secondarily because it's fire retardant (protective driving suits are made from it) and has better (safer) crush properties. The whole carbon fiber tub, in fact, is an excellent safety device in itself because it will crush and break but not deform around a driver and trap him (like metal can) in case of a crash. One other interesting material used for safety reasons is a high-temperature quartz cloth called Nextal, which is bonded in around the engine compartment to form a protective firewall. "Nextel will take a couple thousand degree fire on one side and you can put your hand on the other," says Hillesland.

Asked how much weight carbon fiber saves over aluminum, he estimates (unofficially) about 60% to 75% with equivalent stiffness—the Ford GTP tub weighs a bit over 100 lb versus 350 or so for an aluminum one. Carbon fiber construction also has significant advantages in repairability, whether to fix crash damage or to repair and reinforce any area that may fail under the rigors of racing. "We've come up with some very good quick-cure resin adhesives," he explains, "so instead of holding something together with racer's tape, you simply bond it. It cures to 80% strength in just five minutes at room temperature." Or, as designer Riley succinctly puts it, "just saw a piece out and glue in another piece."

Ford is satisfied that there is a future for high-tech synthetics in engine applications

The car's original fiberglass outer body panels (which bolt onto the tub and are quickly and easily removable) are being phased out in favor of graphite to save even more weight as development continues. The graphite ones are made by a process called "vacuum bagging," common in the aircraft and aerospace industries, which uses a vacuum to suck a "pre-preg" composite cloth (already impregnated with a small amount of epoxy resin) against the mold, yielding strong but very light panels. Steering, suspension, and brake components are mostly aluminum, as are the engine, transaxle, and bell housing. But a lot of these pieces, too, are good composite candidates for the future. If you're getting the idea that carbon fiber composites may be ideal for certain applications on production vehicles, you're dead right. The major problem, as always, is cost—from $18 to $1000 or more per pound, depending on the quality and the strength required.



Just like Ford's passenger cars, the Mustang GTP coupe made extensive use of computer-assisted design and modeling techniques.

☑ SPECIFICATIONS

Ford Mustang GTP

GENERAL

Vehicle type	Front-engine, rear-drive, 2-pass., 2-door coupe

ENGINE

Type & displacement	L-4, liquid cooled, 2097 cc (128 cu in.)
Induction system	Mechanical fuel injection turbocharger
Max. power (SAE net)	700 hp @ 9500 rpm
Max. torque (SAE net)	440 lb-ft @ 7300 rpm

DRIVETRAIN

Transmission	Hewland 5-sp. transaxle

CHASSIS

Front suspension	Independent, unequal-length upper and lower A-arms, coil springs, Koni shocks, anti-roll bar
Rear suspension	Independent, unequal-length upper and lower A-arms, coil springs, Koni shocks, anti-roll bar
Brakes, f/r	13.0-in. discs/13.0-in. discs
Steering type	Rack and pinion
Turns, lock to lock	2.3
Wheels, f/r	16 x 11.0 in./16 x 14.0-in. modular aluminum-magnesium
Tires, f/r	23.5 x 11.5-16/27 x 14-16

DIMENSIONS

Curb weight	900 kg (1990 lb)
Wheelbase	2668 mm (105.0 in.)
Overall length	4520 mm (178.0 in.)
Overall width	1984 mm (78.0 in.)
Overall height	1067 mm (42.0 in.)
Power to weight ratio	2.8 lb/hp
Fuel capacity	120.8 L (32.0 gal)

Hillesland worked with Ford Research several years ago to build a car completely out of composites, but the 1979-1982 recession put an end to that particular program. Commercial trucks, where weight-saving is paramount and cost-saving not as crucial, are the best near-term candidates for composite springs, suspension control arms, and the like (the new Corvette already has fiberglass leaf springs front and rear), and carbon fiber driveshafts may soon be phased into passenger cars as well. "A graphite composite driveshaft is cost competitive," he points out, "because with the stiffness of the material and its light weight, you can eliminate the center U-joints and center bearings."

The once touted plastic engine now seems to be a back-burner program at Ford, according to Matthew Holtzberg, president of Polimeter Research Inc. "They have one complete racing engine," he says, "but they are moving slowly and cautiously." Holtzberg adds, however, that he has other customers who are moving more quickly on it, and he expects to begin limited production sometime this year (mostly for non-automotive—marine and military—applications) and hopes to be building some 5000 composite engines annually within five years.

Holtzberg's work with automotive composites began in 1973 with suspension components and certain engine parts. Since then (though there have been problems and setbacks) he has sold thousands of composite pushrods and connecting rods to the high-performance market, and that success gave him ideas about the entire engine. Ford was interested enough to lend some parts support, so early efforts centered on Ford's 2.3-liter overhead-cam four. At one stage of development, a 100-hp Polimotor version with a fiberglass block was made of 90% composite parts and weighed just 168 lb versus 341 lb for its iron-block production counterpart. Only the crankshaft, camshaft, valve springs, exhaust valves, cylinder liners, piston crowns, and certain bushings, bearings, bolts, and threaded inserts were metal. The current twin-cam 2.1-liter fuel-injected Polimotor racing engine has a carbon fiber-reinforced plastic block, develops nearly 350 hp (without turbocharging) at 10,000 rpm and weighs 152 lb.

You might rightly question how plastic parts can take the high loads and extreme temperatures inside a running engine. As Holtzberg explained last year to an International Motor Press Association (IMPA) audience: "We've taken a very simple approach. This [holding up an engine valve] is a modular valve with an aluminum head. Since half the weight of the valve is in its stem, we do that in composite. Where the heat is, we put metal. In some of the pushrods, we put metal ends where the loads are greatest. We put the composites where they perform well and save weight."

In other words, the cylinders are metal lined, the valves that extend into them are metal tipped, and the bonds joining metal to plastic are far enough away from the highest heat that high-temperature (600°-plus) adhesives and the composites themselves can take it. The aluminum valve heads, for example, are not simply "glued" flat-surface to flat-surface. They have aluminum extensions that are internally bonded well up inside their composite valve stems.

The lighter an engine's moving parts, of course, the higher its rpm capability and therefore its power potential. Holtzberg added that 18 versions of the carbon fiber block engine, some of them turbocharged, had been built as of late 1983 and that continuing development (aluminum cylinder liners instead of iron, for example) could pare its weight even further.

He points out that the most likely near-term applications are marine (because the basic block will never corrode), military (where cost takes a lower priority than performance), and perhaps some lightweight racing engines—maybe from Ford, maybe someone else. Longer-term, when the material costs come down and weight-saving moves up again on auto makers' priority lists, composite engines should have good possibilities in passenger cars. "It takes seven to 10 years for a new iron engine to be built and run," he says. "It may take 10 or 15 years for the plastic engine." As he told the IMPA group: "It is expensive, but it's cheaper than titanium. Essentially it's a material that's about as strong as a forged steel alloy, but 75% lighter."

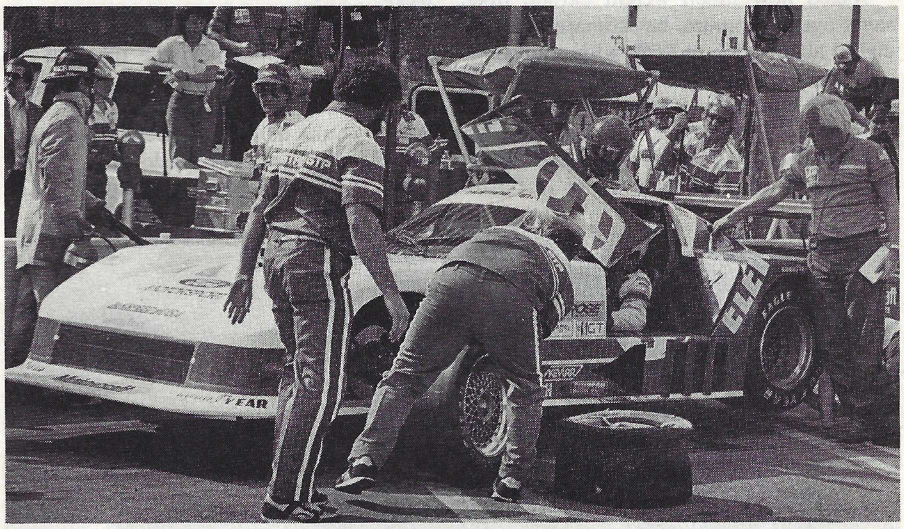
Why is Ford's GTP car so radically different, and why is the company putting so much time, money, and effort into a road-racing program in the first place? Michael Kranefuss, who directs the company's SVO (Special Vehicle Operations) racing group—and recently took over responsibility for all of Ford's motorsports activities worldwide—addresses both questions:

"One reason we wanted to race a small 4-cylinder was so we wouldn't have to have much of an engine compartment. Everyone is racing mid-engine cars; but a mid-mounted engine goes right in the middle of where you want your aerodynamic tunnel under the car, so you have to divide the tunnel. With a small engine in front, balanced by a transaxle, radiators, and other components in back, getting the optimum 50/50 weight distribution is fairly easy. And with a front-engine car, we can have a much longer and wider tunnel and therefore a lot more downforce. Bob Riley said that when he designed cars for Indy, where aerodynamic downforce plays such a significant role, he always wished that the engine wasn't where it was. Zakowski [Eric, president of Zakspeed Rennsport, Ford's European racing arm] had been wind-tunnel testing in Germany and came in with the same idea.

"If you want to get your technical message across, where you're headed in the future," Kranefuss continues, "it's road racing more than anywhere else. NASCAR stock cars are still very important to us, and so is drag racing, but there isn't a 351 V-8 in a passenger car anymore. Road racing makes a very strong point when used to promote not a product but a direction. Everyone, not only here but worldwide, is waiting to see how Detroit will react to today's changing conditions. There is a certain amount of expectation. Does Detroit consider itself technologically dead—or is there still life? This is something that very clearly talks about the new Ford Motor Company, which is very much technologically oriented and dedicated to product integrity. It's a combined corporate effort, with some budget from Ford Design, some from Aerospace, and quite a bit from SVO [over $1 million in 1983] to build the first four cars and about 15 engines."

Ford's plan is to continue the program through SVO and Zakspeed USA, a new branch of Zakspeed Rennsport set up specifically to develop the high-powered turbo engines and prepare and campaign two factory-backed cars in America. Like several other Ford motorsport entries, one of the factory GTPs enjoys 7-Eleven sponsorship for 1984. At least one carefully selected independent team may be racing a third GTP Mustang later this year, and both cars and parts will be sold to others in the future. "Why should all the people who are road racing here have to go to Europe to buy Porsches and Marches and Lolas?" Kranefuss asks rhetorically. "With all the technology around, why couldn't one U.S. manufacturer build something that can win and then make it available? Long term, I would like to see us doing what we've done in Europe, making all the bits and pieces we race available through our parts programs—engines, body, chassis, everything.

"Once you've got an edge, all you have to do is stay there. You just have to keep the development up. The Europeans, the Japanese, Chevrolet, Pontiac, all have



road-racing programs here because there is a change in car philosophies in this country. The whole theme is that we're a lot more than just a car builder."

Ford is not the only auto maker heavily involved in materials research, of course. There are Pontiac's highly innovative plastic-bodied mid-engined Fiero and Honda's plastic-fendered Civic-based CRX—not to mention a multitude of activity throughout the world's automotive and supplier industries involving everything from ceramic engine parts to belt-driven transmissions. And carbon-fiber composite tubs are already becoming fairly common in the mega-buck world of Formula One. The difference is that Ford is a mainstream American car maker using a radical race car (which at least looks vaguely streetable) for materials and aerodynamic and engineering development that will almost certainly find its way into production cars in the reasonably near future. It's also an exciting and highly visible showcase for the company's technical talents, and, as such, a highly effective publicity tool and image maker.

And if there's any truth at all to the old saw that racing improves the breed, Ford's Mustang GTP—probably the world's fastest testbed—portends an exciting automotive future for us all. MT