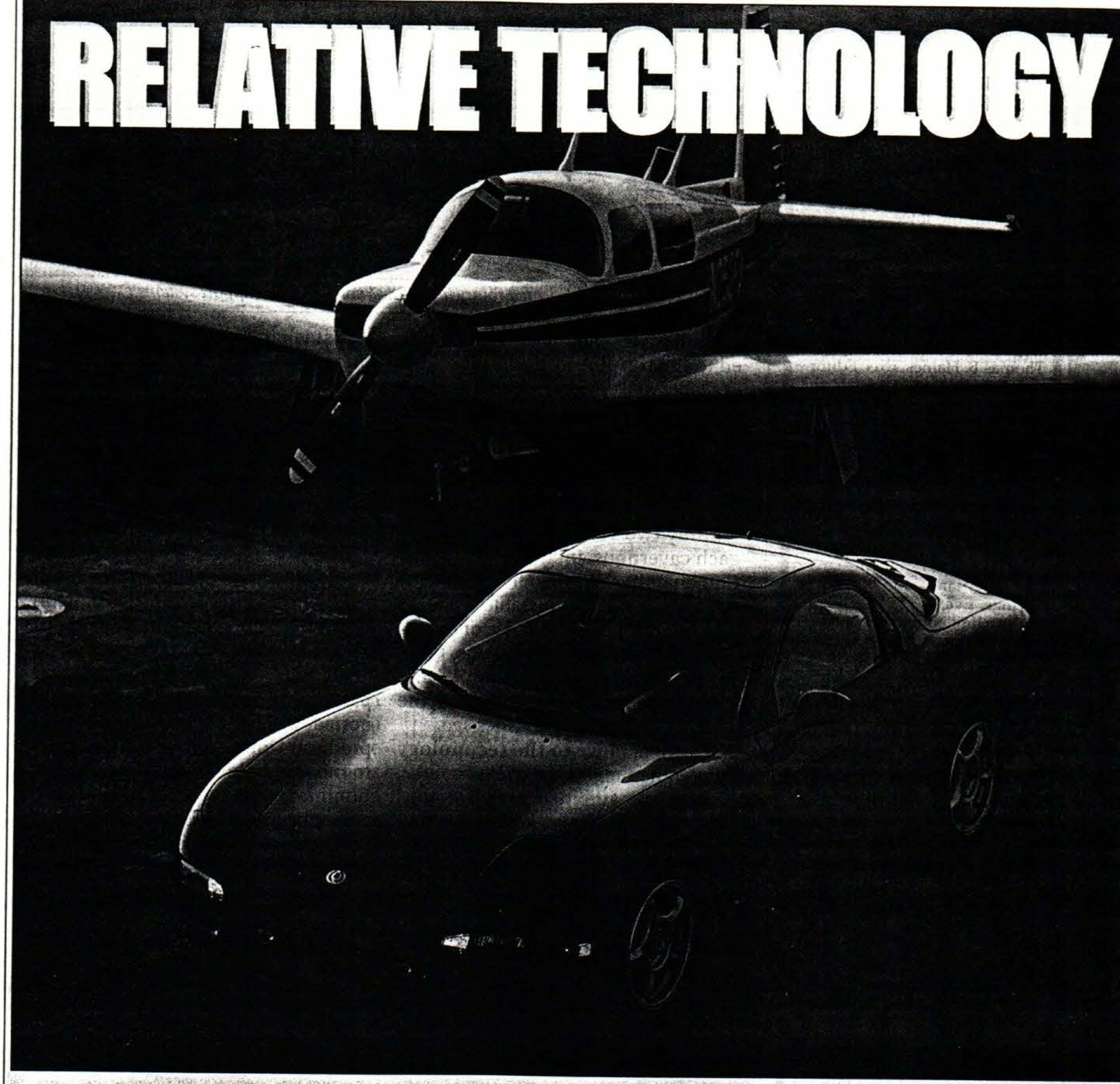
ENGINUITY

RELATIVE TECHNOLOGY



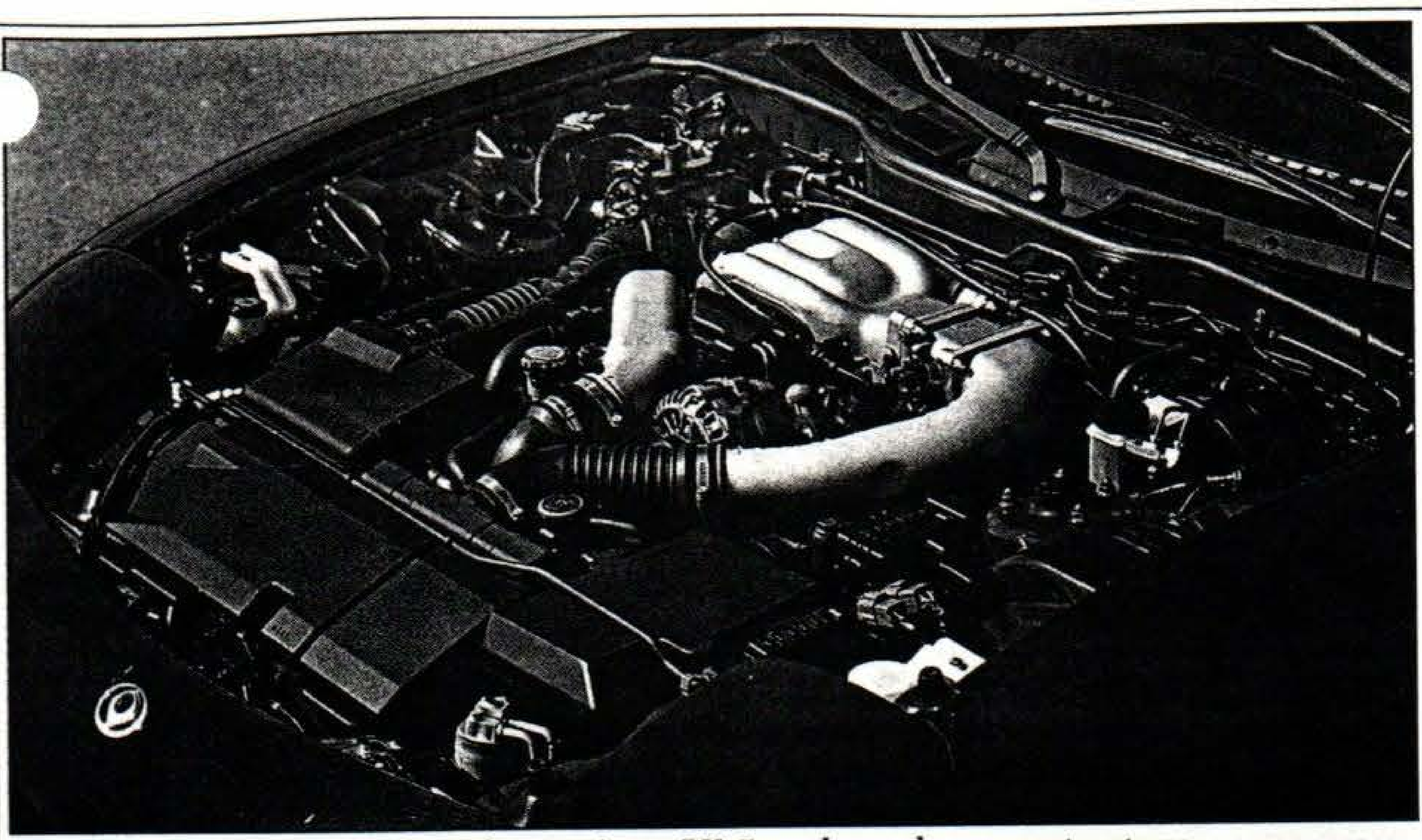
Aircraft engines: Are they appropriate technology or just stone age?

BY MARC E. COOK

WE live in a world of high technology. From wristwatch televisions to cellular telephones to satellite navigation, innovation surrounds us like a silicon fog. And yet with all the technological breakthroughs, we in general aviation, if one discounts the onslaught of exciting new avionics, have received precious few of the these space-age plums—a situation ever more evident when you peek over the fence at *that other* form of transportation: the automobile.

Walk onto just about any new-car dealer's lot, and you will find cars bubbling over with technology. You can find cars with high-specific-output engines employing four valves per cylinder, computer-controlled ignition, and fuel injection; you also see antilock brakes, air bags, and automatic transmissions with "fuzzy logic." Today's car buyer can dip into a veritable witches' brew of technology. More-

PHOTOGRAPHY BY LONNA TUCKER



The sophisticated rotary in an RX–7 nestles under support systems.

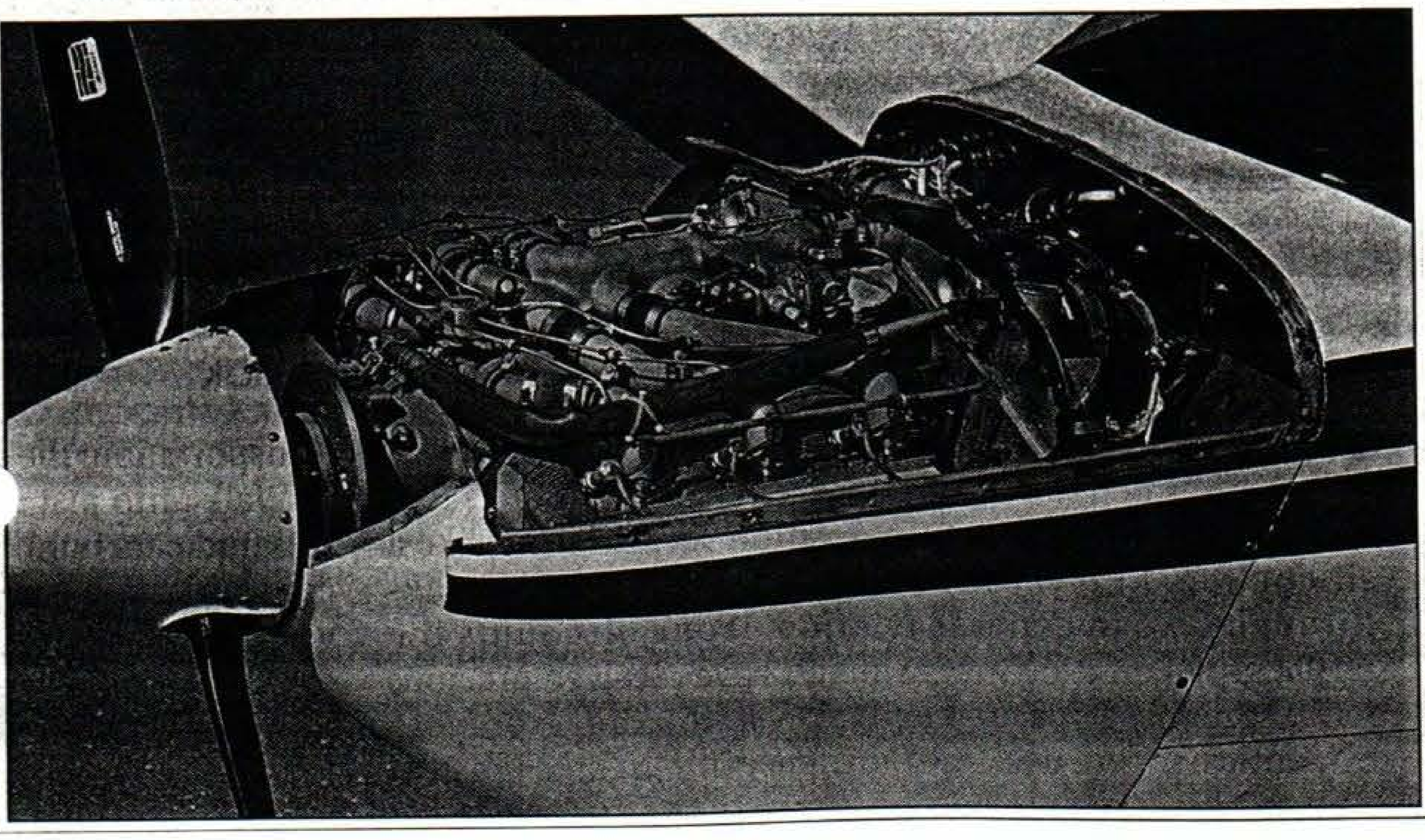
over, these techno tidbits aren't limited to the top-line offerings; they are available well down the model lines.

By direct comparison, aircraft piston engines are about as high-tech as bowling balls and as sophisticated as root-beer floats. We make due with large, slow-turning engines that employ two valves per cylinder for each cavernous, inefficient combustion chamber. We also live with cantankerous and unadjustable magneto ignition and the most basic of carburetors or fuel injection systems. From a pure technology standpoint, airplane engines should have gone the way of the Dodo bird decades ago.

There is more to the technology debate than meets the eye, of course. We have our admittedly unglamorous powerplants for some very good reasons, chief among them packaging efficiency and reliability. What works in the Lexus doesn't necessarily work in a Cessna.

Just what is the state of the art in automobile-dom, and how does this technology compare to that in general aviation? Let's consider the following vehicles not so much as direct competitors, but as emblems for certain duties, be they by highway or airway. Examine thus the Mooney 252 and Mazda RX–7 and the Beech A36 and Lincoln Town Car. And while surely the sports-car-versus-sedan argument will rage, let's look at the vehicles more in terms of the powerplants—a pair of high-output turbocharged engines designed to make the most of tight packaging requirements, and a pair of normally aspirated mainstream thrust producers intended to be most things to most people. (That there are two Continentals here—okay, three if you count the Lincoln—is no indictment of Lycoming's technology. The current Mooney TLS has a turbo engine as sophisticated as the 252's, and in the grand scheme of internal combustion, an IO-550 Continental is quite similar to an IO-540 Lycoming—even the inventor of the four-cycle engine, old Nikolaus August Otto, would agree.)

The Mooney's TSIO-360 wears a tuned induction system—a decent advance for aircraft.

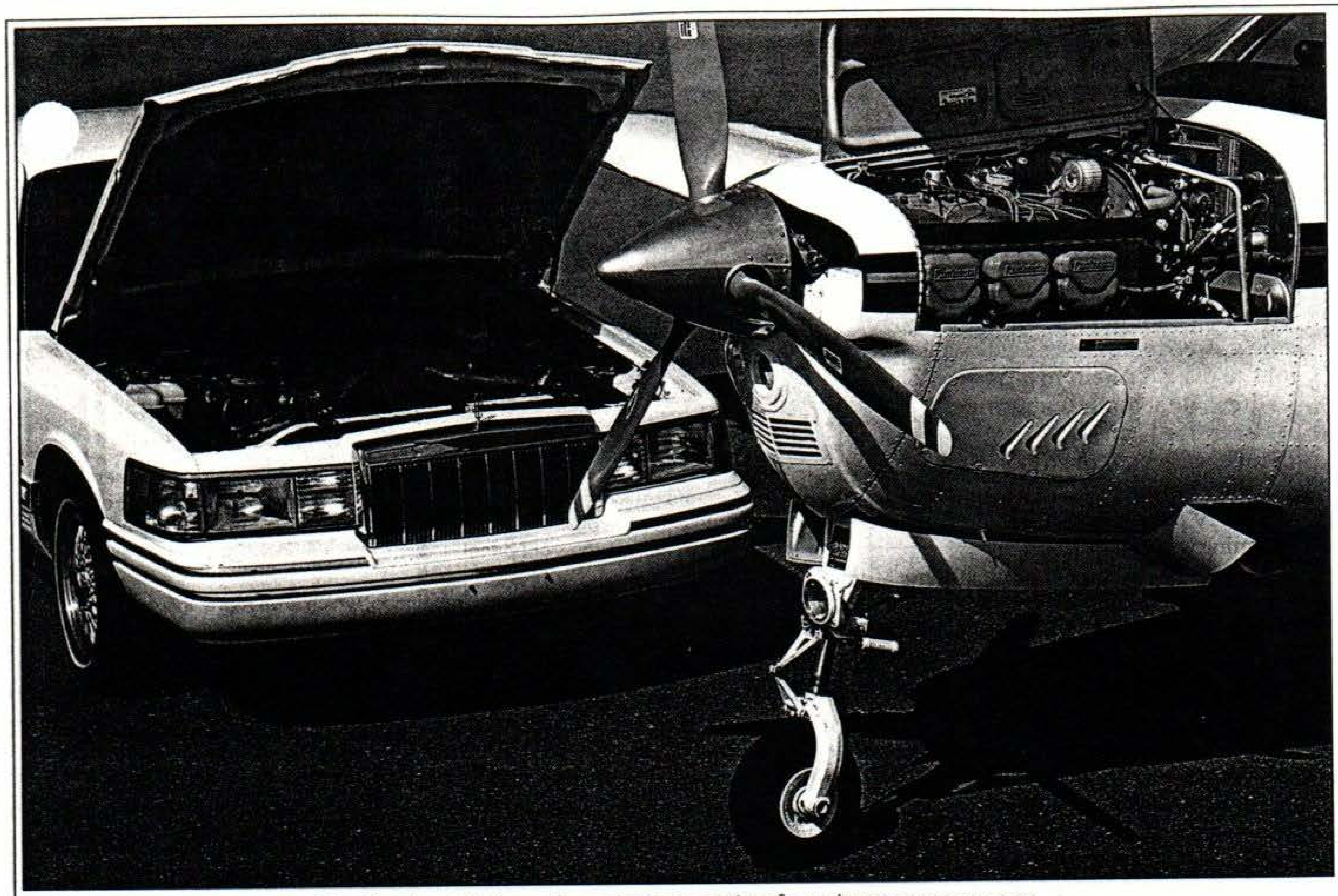


If a take-all-comers set of specifications gets you all warm and stoichiometric, feast your techno glands on the 1993 RX–7's twin-rotor Wankel. In a very small package, this rotary represents the highest expression of the type, producing a stunning 255 horsepower from a swept volume (roughly analogous to displacement in a Wankel) of 1.3 liters, or about 80 cubic inches. It has by far the highest horsepower-per-liter measurement of any automotive engine in production, including some with very expensive Italian names beginning with "F" or "L."

How the rotary gets such power makes a superb study in thermodynamic efficiency and, for lack of a better term, volumetric chutzpa. A pair of Hitachi turbochargers pump up to 10 psi of boost through a grill-mounted intercooler, resulting in that 255 hp at 6,500 rpm and a kidney-punching 271 foot-pounds of torque at 5,000 rpm. Together, the turbos have enough volumetric capacity to run an airplane engine of nearly four times the rotary's displacement. Another aspect of the RX–7's engine power potential is in the very nature of the Wankel. Each three-sided rotor has machined in its faces in effect three combustion chambers, so for each revolution of the rotor, there are three power events taking place, as opposed to one every other revolution in a piston engine. The output shaft (you really can't call it a crankshaft) turns at three times the rotor speed, so you get one power event per rotor per output-shaft revolution, still twice as many as a conventional four-stroke.

An ingenious engine-control scheme uses the two turbos sequentially to help take the peaks and valleys out of the power delivery. At low rpm, only one turbo receives exhaust gas, which, because of its low mass, can be spun up quickly. By itself, this single turbo wouldn't have the capacity to fulfill the engine's needs at peak speed and power, so at about 5,000 rpm, the second turbo comes on line. Don't confuse this with twin turbo systems as on, say, the Piper Malibu, which uses both turbos all the time, each feeding one bank of cylinders.

In practice, the RX–7's sequential turbo system works beautifully. Mazda's rotaries have never been



Two Continentals show off—mainstream engines for mainstream conveyances.

known as particularly torquey engines, especially at very low rpm, and the new RX–7 powerplant is no exception. Right off idle, the engine feels a tad soft, but by the time the tachometer swings around to 2,000 rpm, the primary turbo is up to speed, and the car is off like a shot. This roller-coaster ride of internal combustion continues unabated to the engine's 8,000-rpm redline. Considering that power is mated to a car weighing just over 2,800 pounds, the amusement-park analogy remains true: The RX–7 is capable of 0- to 60-mph times of about five seconds and a top speed of nearly 160 mph.

And if you thought that high-technology engines were anathema to American cars, it's time for you to take a look at Detroit iron again. While the Lincoln Town Car won't emerge in the next millennium as the greatest step since the Model A, it is an important car. Ford in this model introduced the first of a new generation of engines, modular powerplants that can be produced in four-, six-, and eight-cylinder variants, with single- or double-overhead camshafts. This is a significant break from the traditional American engine and a sure sign that U.S. automakers are ready to stand toe-to-toe with the rest of the world.

> *The Lincoln's engine is as smooth and civilized as the Lady Diana's PR agent and moves the Town Car with aplomb.*

In the Town Car, the 4.6-liter V-8, with one camshaft per bank of cylinders and two valves per cylinder, makes 210 hp; compare this to the previous Town Car motor, which made 50 fewer hp from a 4.9-liter engine. Moreover, the new-for-1993 Lincoln Mark VIII sports a four-cam, 32-valve version of this modular engine with 280 hp. Ford took the opportunity with this new series of engines to improve durability, reduce the assembly time, and to boost efficiency. Specific fuel consumption of the engine has been improved significantly over the old engine. Also, as is true of the Mazda's powerplant, the Ford V-8 sports computer-controlled fuel injection and ignition systems and oxygen sensors in the exhaust system to help the microchips maintain ideal fuel/air mixtures.

In practice, the Lincoln's engine is as smooth and civilized as the Lady Diana's PR agent and moves the outsized Town Car with aplomb. It is virtually vibration free; you are vaguely aware of something like an engine going about its duties on the other side of the Town Car's vast firewall.

Given the large dose of technology to be found in the Lincoln's and Mazda's engine bays, how could the Mooney 252's TSIO-360 or the Beech A36's IO-550 hold a spark plug to the auto engines?

Let's start with the Mooney. In its own way, the TSIO-360-MB engine is quite sophisticated, with an automatic wastegate controller, a durable Garrett turbocharger with a listed temperature limit of 1,750 degrees Fahrenheit, an intercooler, and a neat, effective tuned induction system. Where the Continental shines is in weight: With accessories, the engine is less than 400 pounds, while the Mazda's tips the scales at 346 pounds without oil, water, or clutch. Add another 150 pounds for the turbo system and plumbing, and you can see where the TSIO-360's mostly aluminum construction pays big weight dividends; the Mazda engine has cast-iron exhaust manifolds and core.

In practical aircraft terms, the -360's slow reciprocating speed also buys a weight savings: To make the Mazda engine work with a propeller, it would absolutely have to have a reduction drive, which adds mass, weight, and complexity and saps a bit of power, too.

Engineering types often blame the aircraft-engine makers for never advancing the breed, but that myth can be debunked by looking at the Mooney's evolution from 231 to 252. In the older airplane, there was just a crude ground-adjustable wastegate, a small turbo, and an inefficient induction system, all of which added up to the airplane's propensity to run hotter and use more fuel than the 252's powerplant. The 252 engine is more complex and expensive, sure, but it is undeniably a better powerplant.

Evolution has worked its subtle spell on the Bonanza's IO-550 as well. An outgrowth of the common IO-520, the -550 produces 300 hp at 2,700 rpm without the need for fancy materials or wave-of-the-hand magic. As installed in the A36, though, it gets an altitude-compensating fuel pump that makes mixture control during the climb-out a simple matter: Leave it full rich. You need only lean during cruise. What's more, the IO-550 seems to have much better fuel specifics than the -520 and is happier running near the lean end of the envelope. Why this is so remains something of a mystery, even to Continental: The engineers just shrug and claim that their goal was to increase the engine's power, not improve its overall characteristics, as seems to have happened.

That these two aircraft engines work well in their roles—and that myriad other models do, too—is a result of them being mature designs. We've had decades to iron out the wrinkles, improve the materials, and improve the engines. They are also designed from the start for the role, an advantage auto engines thrust into airplanes do not share. Take duty cycles, for example. If you were to drive the RX–7 so as to use 75 percent of its rated power continuously, you'd spend more time in court fighting speeding tickets than driving. You also probably

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This idea of duty cycle is also influenced by how much power the engine produces. True of cars and of airplanes, the more power made from a given size engine, generally speaking, the shorter the life. Which is why the typical aviation engine's output of 0.5 hp per cubic inch is both technologically dismal and emotionally comforting.

When one has finished weighing the pros and cons of aviation-engine technology, a few items stand out. The aircraft piston engine, in the most basic sense, is highly optimized for its role: It is light for the power, simple, and reliable. A large-displacement, slow-turning engine is still the least expensive and most efficient way to turn a propeller.

But there are areas in which we could see some tremendous improvements in the engines' efficiency and reliability. First, you get rid of the magneto. Yes, it will run all by itself in the event of a catastrophic electrical system failure, where other types of ignitions might not. But the magneto is cranky, none too reliable, and its timing cannot be changed in flight; better fuel specifics and easier starting could be ours with electronic ignition. Cars have been using it for more than two decades and rarely does the black box fail. Homebuilders, unencumbered by the Federal Aviation Administration's love of the old spark-thrower, have been experimenting for some time with electronic ignitions, with excellent results. A separate, small battery can be used as a backup power source.

Fuel delivery systems could be improved, too. Most fuel systems in light airplanes are very simple, leaving the mixture control in the hands of the pilot, hands occasionally too busy with other chores to do the best management. Electronic fuel injection (or even just electronic control of existing mechanical systems) could relieve the pilot of much work and some confusion. A small processor could employ an oxygen sensor to keep the mixture ideal for the existing flight conditions.

Finally, we could find better ways of shedding the engine's heat than by air cooling. While light and simple, cooling by ram air is not particularly efficient in that it produces a good chunk of the airplane's total drag, and that it doesn't cool as evenly or consistently as other methods, particularly liquid cooling. (A few motorcycles tried oil cooling, using unusually large oil capacities and ingenious flow patterns to keep the internals cool. This method is heavier than liquid cooling.) Rotax in its 912 four-stroke has an excellent idea, cooling the cylinder heads with liquid and the cylinder sleeves by ram air. Continental has been cautiously promoting the liquid-cooled Voyager engines, which show tremendous promise, especially in high-horsepower applications.

Of course, many of these suggestions have been tried in the Porsche-powered Mooney PFM. That airplane, frankly,

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failed, but not directly as a result of its technology. It entered the market in perhaps the worst of times, and it was heavier, slower, and more expensive than a 201. In time, the airplane probably could have been tweaked to get the speed out of it, and continued production of the engine/ airframe combination could have reined in the price. And had the certification process not required an almost egregious degree of electrical duplication, the airplane surely would have been lighter.

Shortcomings aside, the PFM reaped some real benefits from the technology. Thanks to the sophisticated fuel delivery and ignition systems, the airplane started readily, hot or cold, and it had very good fuel specifics. The single-lever power control made engine management a real no-brainer.

The PFM's failure in the marketplace left many pilots saying, "We told you so—if it isn't broken, don't fix it"—which is a sentiment only half-true. While the basic engines we have today are well suited to their roles, an infusion of technology into the fuel delivery, cooling, and ignition systems could net useful gains without having to dismantle the mechanical infrastructure. Let us not turn a deaf ear to technology's siren song just because it didn't transform the airplane engine overnight. □