Getting FAT

There's more than one way to increase engine power

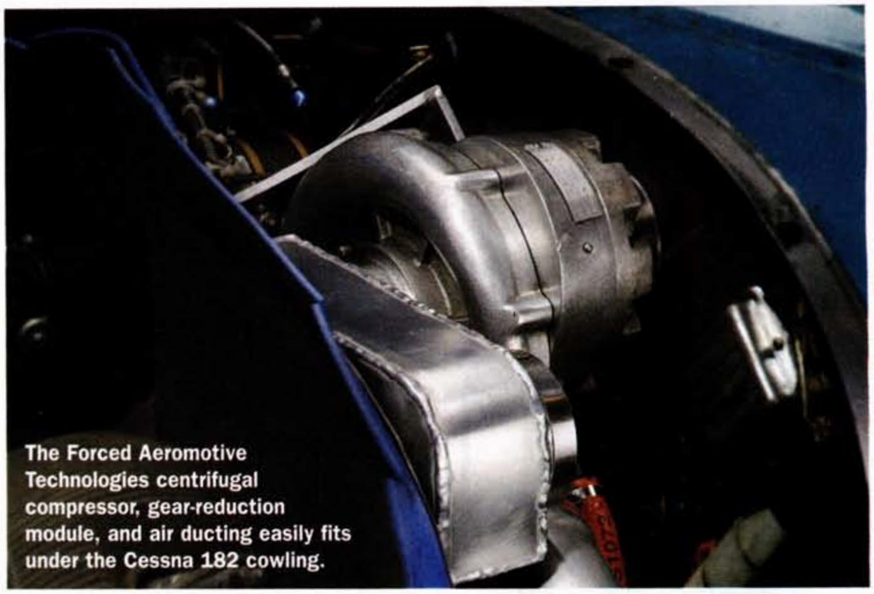
BY STEVEN W. ELLS

The maximum rate-of-climb table in Rod Sage's 1966 Cessna 182 owner's manual indicated that an unmodified airplane would climb at 655 feet per minute at a standard day density altitude of 10,000 feet.

Yet we had just taken off from Runway 16 at the Leadville, Colorado, airport where the density altitude was 11,200 feet and our initial climb rate was more than 1,000 feet per minute. After reducing propeller rpm to 2,350 and pitching the nose down slightly to get a cruise-climb airspeed of 105 mph—a move that improved the forward visibility and engine cooling airflow—we were still climbing at 500 feet per minute. Why did this 182 climb so much better than the book said it should? Because the supercharger installed under the cowl was demonstrating that there's more than one way to increase engine power.

Power helps airplanes leap tall mountains, haul loads out of deep canyons, and safely operate in the thin air of impressive true airspeeds. What pilot hasn't begged for more power at some time in his flying career—what pilot hasn't begged for more power within the past six months?

Forced Aeromotive Technologies (FAT), a small company based in the Denver area, has a solution in the form of an FAA-approved bolt-on supercharger system. Recently approved, this system is being installed by supplemental type certificate (STC) on Cessna 182E through -P models (1962 through 1976). Up until the FAT supercharger was introduced, the only avenue to more power for Cessna 182 owners was swapping the original 230-horsepower engine for an engine with more horsepower. There are STCs for 260- and 300-horsepower conversions.



The Forced Aeromotive Technologies centrifugal compressor, gear-reduction module, and air ducting easily fits under the Cessna 182 cowling.

Adding power

The power output of every normally aspirated piston engine fades the minute it climbs. The steady decline of engine power results from the decrease of atmospheric pressure with increases in altitude. Less pressure equates to a less dense air charge entering the engine's combustion chambers.

To understand how much this affects airplanes, consider a rule of thumb from James Embree's out-of-print classic *The Axioms of Flight: The Rules of Thumb for Pilots.*

Embree's rules say that fixed-pitch-propeller-equipped airplanes must add 15 percent to the takeoff distance for every 1,000 feet of density altitude up to 8,000 feet. A takeoff at 7,500-foot density altitude adds 112 percent of the sea-level takeoff distance. The Embree rule for constant-speed-propeller-equipped airplanes adds a 12-percent increase for each 1,000 feet of density-altitude increase up to 6,000 feet and 14 percent for every 1,000 feet above 6,000 feet. The constant-speed propeller does improve performance—the takeoff run is only 90 percent longer for the same 7,500-foot density-altitude takeoff.

Savvy aviators will point out that changes in density altitude also affect propeller efficiency and the amount of lift generated by airflow over the wing.

Performance gains

The term *supercharger* may not be familiar to many pilots. A supercharger is similar to the more common turbocharger and turbonormalizer systems in one respect—compressed air from a centrifugal air compressor is ducted into the engine air inlet. The difference is in how the compressor is driven.

PHOTOGRAPHY BY MIKE FIZER

AIRFRAME&POWERPLANT

Turbocharger and turbonormalizer systems require specialized exhaust systems to collect and direct the total exhaust stream energy over a high-temperature turbine wheel. The percentage of the total energy in the exhaust stream that is directed to the turbine wheel, the rotational speed of the turbine wheel, and the pressure of the compressor discharge air are directly linked and are controlled by the position of a device called a *wastegate.*

At lower altitudes, where the air is more dense, only a portion of the exhaust gas energy is required to maintain the elevated manifold pressures required to boost engine power output. As a turbocharged or turbonormalized engine climbs into less dense air a greater percentage of the total exhaust energy is directed over the turbine wheel because the compressor must rotate faster in order to maintain the same manifold pressure.

These systems, if well maintained, are reliable and efficient, and do add a lot to an airplane's performance and utility. But they're heavy, and to compensate for the elevated under-cowl and compressor discharge temperatures engine manufacturers lower the cylinder compression ratios (making the engines less efficient) to provide detonation margins. They're also expensive to install, and they provide good service only when flown and maintained by well-educated and conscientious pilots and technicians.

The FAT supercharger system

The FAT system doesn't require any exhaust system changes nor are under-cowl temperatures elevated because the turbine is turned by a rubber belt driven by an accessory section pulley. The FAT air compressor speed is directly related to engine rpm and has been optimized through Forced Aeromotive's selection of drive-pulley-size multiplication factors and internal gearing in the supercharger compressor housing.

The result is 20 percent more pressure at sea level at takeoff. The price of a factory-installed system, which includes pilot training, is just under $20,000.

The FAT system adds 30 pounds to the aircraft empty weight. Since almost all the weight is located a few inches forward of the firewall, this moves the empty-weight center of gravity slightly farther forward.

The compressor is mounted on a welded bracket that is bolted to the aft end of the engine on the pilot's side. In order to clear the existing alternator installation, the alternator is rotated downward around its mounting bracket and held in this position by installing a longer drive belt-tensioning arm.

The original alternator drive pulley is replaced with one that has provisions for two belts—one for the alternator and one for the supercharger.

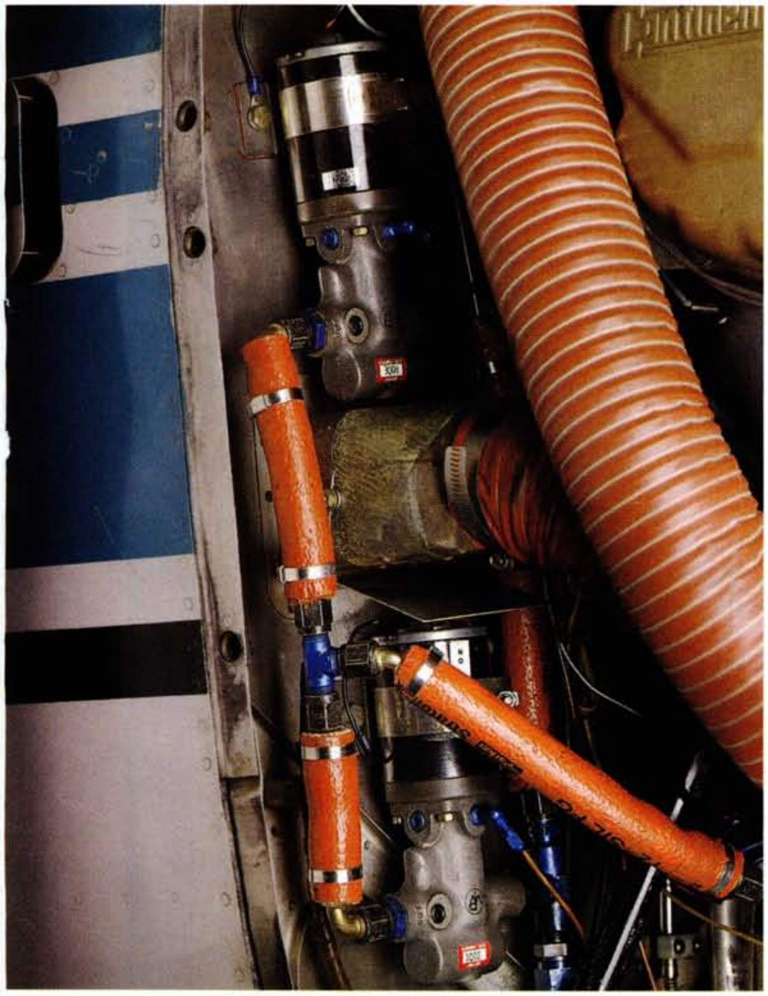
A lubricating oil line and return line to the supercharger are plumbed, dual firewall-mounted electric fuel pumps are installed and plumbed, and the filtered air hose to the supercharger and the pressurized air hose to the carburetor inlet are installed.

> The supercharger had the same effect as chopping 5,000 feet off of the density altitude.

Flight-test results were impressive.

One of the side benefits of the FAT supercharger system is slightly elevated carburetor inlet air temperatures. Raising the temperature of the inlet air improves fuel atomization. This causes a smoother-running engine since power output from individual cylinders is more evenly matched. According to Rod Sage, the engineer on the Forced Aeromotive supercharger project, certification instrumentation revealed that a 35- to 50-degree F rise above OATs (outside air temperatures) is common.

Any increase of inlet air temperatures decreases an engine's detonation margin so it's common to install an intercooler (air-on-air radiators) on turbocharger and turbonormalizer systems. Intercoolers reduce compressor discharge air temperatures before the hot air enters the engine. The combination of elevated under-cowl temperatures and the increased compressor rpm necessary to maintain discharge pressures at higher altitudes can cause inlet air temperatures to approach 200 degrees F.



To offset the effects that the slightly pressurized inlet airflow has on the carburetor fuel level, two firewall-mounted electric fuel pumps (the second is for redundancy) provide increased fuel pressure.

Since the FAT system wasn't designed to maintain sea-level manifold pressures above 5,000 feet msl, supercharger temperature increases are small in relation to the other types of systems.

Although there's scant evidence to indicate that the installation of a FAT system would lead to temperature-induced detonation problems, Sage agreed with an FAA certification suggestion to restrict FAT-modified airplanes to 100-octane fuel. Lower-octane fuels such as 80-octane and auto fuel (when its use is approved under STC) have less resistance to detonation. Better to be safe than sorry.

How does the system work? Join Sage and me for an early morning flight from Denver's Centennial Airport to the airport at Leadville.

The Leadville certificate flight

Centennial Airport is 5,883 feet above sea level—this explained why the manifold pressure gauge read 24 inches before engine start.

Takeoff required a modified pretakeoff engine run-up procedure (see "Pilot Training for an Equivalent Level of Safety," page 172) and increased pilot attention during the initial power application since the maximum manifold pressure is limited to 28 inches—pilots are trained not to firewall the throttle. At 1,000 feet agl the manifold pressure was reduced to 24 inches to follow the suggested climb power setting in the owner's manual.

As we climbed out throttle was continually added to maintain 24 inches—the supercharger system provided sufficient boost to maintain the climb-power manifold pressure until reaching 10,500 feet msl. This pressure was maintained at 2,350 rpm.

We headed west toward the magnificent mountains of the Continental Divide and Leadville's Runway 16.

Pattern altitude at Leadville is 10,727 feet msl. Leadville, at 9,927 feet msl, is one of the highest public-use airports in the United States. As we cleared the last ridge, the OAT gauge read 42 degrees F—a whopping 19 degrees F above standard-day temperatures. Sage remarked that it was unusual to not have more wind—a fact verified as

Pilot training for an equivalent level of safety

Boost systems usually have an automatic method of protecting the engine components from the effects of overboosting. Overboosting raises manifold pressures too high, which force-feeds the engine more fuel and air than it was certified to withstand. The most common method is a spring-loaded valve (pop-off valve) that is calibrated to open when the boost exceeds a predetermined level that is approximately two inches greater than the maximum certified manifold pressure. The FAT system was certified without this valve under the provision that each operator would receive training specific to the FAT system.

Pilots are trained to keep manifold pressures below the redline value of 28 inches during takeoff.

Since the FAT system pipes air into the carburetor, and since this air is pressurized in relation to the relative air, a provision was required to maintain the proper carburetor fuel level.

The fuel level in a carburetor is dependent on the fuel pressure at the carburetor inlet, and the pressure of the air entering the carburetor, especially since the air pressure is connected (vented) into the float chamber. There's a balance—fuel pressure versus air pressure. This tried-and-true balance is upset when a FAT system is installed.

When pressurized (in relation to the ambient) air enters the carburetor, and the float chamber of the carburetor, it pushes down on the fuel level in the carburetor. This upsets the level, causing too much fuel to enter the induction system. To counteract this tendency, Sage designed a fuel pump system utilizing two firewall-mounted electrical fuel pumps that increase the pressure of the fuel in the carburetor. The balance between the fuel pressure and the inlet air pressure is reestablished and proper fuel metering takes place.

During preflight both electrical fuel pumps are tested and both are turned on for takeoff and landing. During normal flight ops, only one pump is required.

If both electrical pumps fail, or if all electrical power is lost, an overly rich fuel mixture will result since the balance between carburetor float-bowl air pressure and increased fuel pressure has been upset.

In this instance the pilot is taught to open the throttle and then to manipulate a "boost cutoff" valve in accordance with a placard on the instrument panel. This valve chokes off the amount of supercharger air delivered to the carburetor. The goal is to reduce the air pressure to normally aspirated levels. This restores the balance between the fuel pressure and the air pressure in the carburetor float bowl. The engine then runs as if the FAT system has been removed. ***—SWE***

we picked up the Leadville ASOS: "Winds 020 at 3, density altitude 11,200."

After applying two more of Embree's rules of thumb—add 4 percent to the stopping distance for every 1,000-foot change in field elevation and add 4 percent for every 15 degrees F deviation above standard temperatures—we knew that a safe landing could be made on Leadville's 6,400-foot-long runway.

After picking up my "Certificate of Pilotage" for successfully landing at "North America's Highest Airport," as Leadville calls itself, Sage and I taxied back to the end of Runway 16 for the takeoff.

Pilots who fly normally aspirated airplanes up into Colorado's Rocky Mountains learn to apply the rules of thumb noted above—in our case, with a constant-speed prop, we would increase standard day sea-level takeoff distances 12 percent for each 1,000 feet of density altitude up to 6,000 feet, and 14 percent for each 1,000 feet of density altitude above 6,000 feet density altitude. A Leadville takeoff for a normally aspirated version of our airplane on that hot June day would have required 142 percent more runway than a takeoff in the same airplane at sea level.

The supercharger installed in the FAT-equipped airplane had the same effect as chopping 5,000 feet off of the airport density altitude. At an indicated altitude of 13,000 feet the manifold pressure still indicated 21.5 inches.

The certain knowledge that a 500-fpm climb was readily at hand at altitudes as high as 15,000 feet goes a long way toward increasing a pilot's comfort levels when flying in the high country.

The low fuel pressure light (top), alternator inoperative light (center), and fuel pressure gauge are panel-mounted components of the FAT system.

Temperatures and pressures

Although the airplane we flew that day was not equipped with an engine monitor, Sage supplied certification flight- test data showing that temperatures recorded during an 18-minute, full-throttle, and full-rpm climb at the best-rate-of-climb (V_Y) speed from a pressure altitude of 1,659 feet to a pressure altitude of 12,252 feet shouldn't cause any temperature concerns. Beginning-of-climb OAT was 72 degrees F.

This data shows that all temperatures were well below the manufacturer's suggested limits with the highest cylinder head temperature only touching 411 degrees F (maximum limit 460 degrees F) during a two-minute period through 6,000 feet before dropping to finally stabilize at 378 degrees F. The highest oil temperature recorded was 199 degrees F (maximum limit 225 degrees F), and the highest measured supercharger case temperature varied between 35 degrees F to 45 degrees F above the outside air temperature.

Sage's stated goal when he started designing the FAT system nine years ago was to produce a simple bolt-on-style system that would provide the pilot with 65-percent power at 12,500 feet. He's done it.

Since there's never a free lunch in aviation, the question will arise regarding the cost of driving (in horsepower) the supercharger. FAT sales pamphlets boast that the system is very efficient—that it only costs approximately 4 horsepower to drive the system in cruise. Calculations seem to verify this claim.

Based on my one test flight, the altitude cruise power available is boosted approximately 4,000 feet. FAT claims a 5,000- to 7,000-foot boost in altitude performance. Based on the high OATs experienced, and the fact that the airplane tachometer indicated 50 rpm low, these claims appear realistic.

Rod Sage

Rod Sage, the man who has spent nine years of his life and a lot of his own money to develop the Forced Aeromotive system, says that a supercharger system answers the need for more power without the offsetting liabilities of an exhaust-gas-driven system.

It's lighter, there isn't any need to shoehorn a hot, complex, and possibly leak-prone exhaust system under the cowl, engine time between overhauls isn't reduced, and it costs less.

For right now, FAT system installations must be carried out at the FAT facility in Denver. Downtime, which includes training, is one week. After the FAA grants FAT's parts manufacturer approval (PMA), kits will be available. FAT systems are warrantied for six years or 1,800 hours. AOPA

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