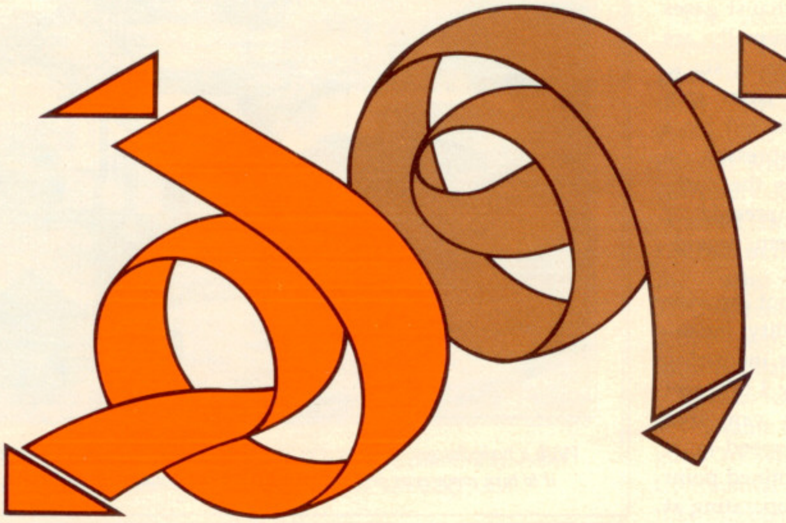
HIGH ASPIRATIONS

TURBOCHARGING THE AIRCRAFT

IN WITH THE OLD



OUT WITH THE NEW

Breathing new life into smaller lightplanes.

BY MARY F. SILITCH

Stuck under the icing level because your aircraft cannot climb through it quickly enough? Staggering off a short strip when summer temperatures reach 107°? Worried because the mountain peaks below you are higher than your aircraft's single-engine service ceiling? Turbocharging may be your solution.

General aviation pilots are reaching new heights these days, thanks to new developments—and new simplicity—in turbocharging. In the last few years, the number of turbocharged aircraft models has proliferated, reaching down almost to the smallest airplanes.

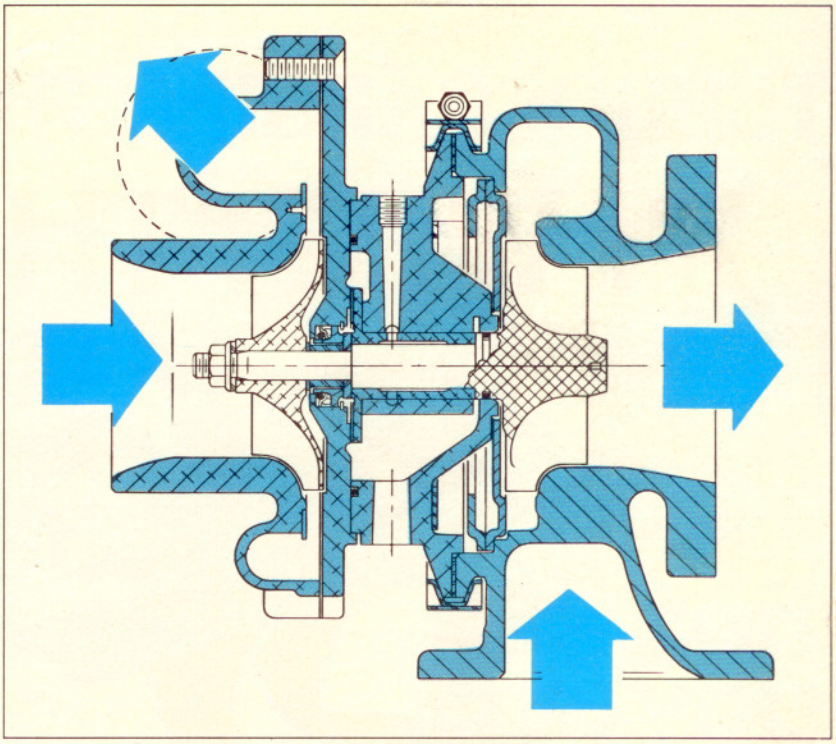
A glance at our list of light and high-performance singles and light and medium twins that now are turbocharged (we drew the line at more sophisticated cabin-class twins and pressurized models) will show that the 1980s should, indeed, be the age of turbocharging.

The days of aviation superchargers and clumsily controlled first-generation turbochargers are past, and aircraft manufacturers that phased out earlier turbo models are reentering the market with improved products. Mooney Aircraft Corporation now has the Turbo 231, and Beech Aircraft Corporation, which produced only 132 turbocharged Bonanzas from 1966 to 1970, is back with the Model A36TC.

The new popularity of turbocharging on the lower end of the product line will take many a pilot into unfamiliar territory—there will be new responsibilities and new hazards. Previously confined to altitudes below 12,500 feet because of lack of horsepower or lack of an oxygen system, they will be trying the upper reaches to 20,000 or 25,000 feet. Pilots will find this environment as hostile to the human body as it is to the nonturbocharged engine (see "The Pilot at Altitude," p. 47). A different tack must be taken when obtaining a weather briefing for higher-altitude flight (see "The Weather on Top," p. 63); plus, some new regulations must be remembered. And there are a few new twists to engine management that must be considered.

Where does the extra energy come from that allows turbocharged aircraft to reach higher altitudes? A normally aspirated engine develops power when a mixture of fuel and air is burned. The density of air in that mixture is a major factor in power production, and normally aspirated engines lose power as they climb into less dense air. The air at sea level, for example, has a density of 0.0765 pounds per cubic foot. At 10,000 feet, the density is only 0.0565 pounds per cubic foot. Since the ratio of fuel and air remains constant, the available horsepower is reduced in direct proportion to the reduction in air density, and the engine develops less power as it climbs higher. Rate of climb drops off; and, if the aircraft keeps going higher, it will be unable to sustain a climb, as it reaches its service ceiling.

A turbocharger, or turbosupercharger, basically provides the engine with air that has the density of sea-level air even at higher altitudes. This is accomplished by directing the exhaust gases from the engine, which normally are discharged through the exhaust stack, into a turbine wheel. The gases spin the turbine, which is connected by a common shaft to an air compressor. As the turbine turns, it drives the compressor, which delivers compressed air to the engine induction system, providing the necessary denser air.



With a turbocharger, the flow of exhaust gas (from lower right) is directed into the turbine, causing it to turn compressor (at left). Compressor sucks intake air from left and directs it to manifold.

Even turbochargers cannot provide an engine sea-level capability indefinitely. With turbine speeds increasing about two percent for every 1,000 feet of altitude, turbochargers can spin more than 80,000 rpm, so speed must be controlled. The predetermined point at which a turbocharger is operating at maximum capability is the critical altitude for that engine. The engine develops its rated horsepower until this altitude; continued climb will cause engine performance to drop off.

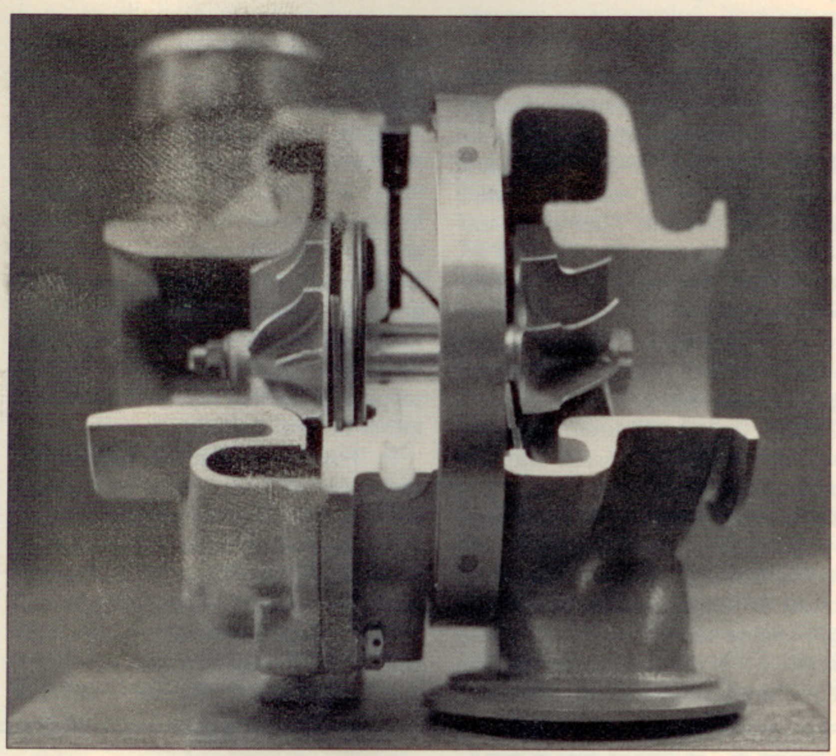
Incidentally, the terms turbocharger and turbosupercharger refer to the same concept; a supercharger, on the other hand, refers to a different device. Superchargers have an impeller that runs off a mechanical shaft, normally driven by the crankshaft or the engine accessory gears. The induction manifold pressure is increased by a centrifugal impeller.

The basic turbocharger (manufactured for aircraft only by Rajay or Garrett AiResearch) is simple; the complexity comes in when controls are added. These are installed by either the engine or the airframe manufacturer. Some means is needed to limit the flow of compressed air to the engine to avoid overboosting the powerplant. Some turbochargers are regulated by a wastegate, which determines the amount of exhaust gases that reach the turbocharger. With the wastegate (a butterfly valve located between the engine system and the turbine) open, the exhaust gases are vented before they reach the turbine, and the engine performs as a normally aspirated powerplant. During climb into less dense air, the wastegate is closed gradually, directing more and more of the exhaust gas into the turbine, turning the turbine and increasing the manifold pressure. In early turbocharger designs, the pilot manually controls the turbocharger from the cockpit by a cable system, much like a second throttle, making it easy to misuse the device by forgetting to position the wastegate properly. Leaving the wastegate closed on takeoff or for a go-around results in an overboost when full throttle is applied.

Later, automatic systems were developed, in which the wastegate position is controlled by air pressure and oil pressure. The pilot sets the throttle to the desired manifold pressure. The automatic controller uses engine oil pressure to adjust the wastegate and thus control the output of compressed air to maintain the given power. The Lycoming TIO-540 series engine, for example, has a density controller, which, according to Lycoming, "maintains a set power output at full throttle, regardless of variation in altitude and in temperature above or below standard temperature." The automatic systems are not alike, so you must go by the book when operating them.

The introduction of automatic systems did little to reduce complexity. And since complexity often equals expense, the systems were installed on the more expensive airplanes.

True simplicity arrived when Ed Austin of Teledyne Continental devised a fixed-orifice, manually controlled system. Instead of a movable wastegate, the device has a fixed opening through which a percentage of the exhaust gases escape. The size of the opening is preset and is not adjustable in flight; it determines the critical altitude of the engine. The rest of the exhaust gases go into the turbine whenever the engine is running, and the amount available is determined by the throttle setting. A pressure-relief or overboost safety valve, located between the compressor and the engine, helps provide protection against inadvertent overboosting. The pilot controls the system through throttle use and must be careful not to exceed the manifold pressure limit. Austin noted that there have been no known failures of turbochargers with the ground-adjustable system. Although it is possible to overboost, the safety valve prevents any serious overboost, he said. (Do not be misled by the term *ground adjustable.* Austin said the opening can be changed; but the engine is certificated



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Cutaway of Rajay turbocharger shows turbine at right and compressor at left, connected by a shaft in center. Compression of intake air delivers denser air to the engine, increasing power.

to a certain critical altitude, and any change outside specifications is not legal.) Lycoming uses the ground-adjustable-opening concept on the Turbo Seminole's TO-360-E1A62 engines.

The manufacturer's more common manually controlled system has a wastegate valve that is adjustable in flight, through a mechanical interconnect with the throttle. Since the wastegate can be changed in flight, higher critical altitudes are possible, according to Lycoming. As the throttle is advanced slowly, the wastegate closes to force more exhaust gas to the turbine. The throttle/wastegate interconnect system also has a relief valve in the induction system, to help prevent overboost, and it has more moving parts than the fixed-opening system.

With both manual systems, the pilot must advance the throttle as the aircraft climbs, as with a normally aspirated engine, to keep the desired manifold pressure. He also must make throttle changes carefully, to keep within MP limits.

No matter what kind of turbo system your aircraft has, it will take you higher than the normally aspirated engines that have been so prevalent in the past. But is turbocharging merely the new status symbol, the thing to have this year? Or is it truly a useful device that extends the capabilities of your aircraft and your own operations?

One initial consideration is cost—turbocharging is more expensive. For the new Cessna Turbo Skylane fixed-gear model, you will be paying $10,750 more base price—$62,250—than for a plain Skylane. (Included with the Skylane turbo package are more standard items, such as a fuel-flow/manifold-pressure gauge, a fuel pump and oxygen-system plumbing, in addition to the turbocharging system.) Buying a Piper Turbo Saratoga for $82,760 will cost $9,060 more than a Saratoga. The difference between a normally aspirated Beech Bonanza A36 and an A36TC is $12,000.

Beyond initially higher prices, higher maintenance costs must be considered, especially if you plan to operate one of the more complicated automatically controlled turbo systems. The type of use to which the aircraft will be put must be considered also. If it will serve as a rental or a club aircraft, it may not receive the thoughtful operational care that turbochargers demand.

Not everyone agrees that turbocharging means higher maintenance costs. Dan Bellas, general manager of Rocky Mountain Piper in Broomfield, Colorado, said they have operated rental turbocharged aircraft for five years and have found no unusual problems. "Maintenance on a turbocharged aircraft is no more than on a nonturbocharged aircraft, provided it is operated properly. If you are rough with the power, make long power-off descents, touch down at the airport and immediately shut off the engines, you'll have problems. Proper pilot technique is the key to low maintenance."

The recommended time between overhaul (TBO) for turbocharged engines is on the upswing. Although there still are a few engines with 1,400-hour TBOs, there are an equal number with 1,800-hour recommended intervals. And Cessna just announced that the Lycoming O-540-L3C5D, in the new Turbo Skylane and the Turbo Skylane RG, has had its TBO extended from 1,400 hours to 2,000—which equals the highest TBO for a normally aspirated engine.

Cessna sets TBOs for turbochargers at the same number of hours as the engines to which they are attached. A Continental spokesman agreed, saying that turbochargers generally match the life of the engine. "If there is a TBO understood for turbochargers, it's the same as for the engine," said Ed Austin. "If operated properly, turbochargers have an extremely long life." He noted that some have outlasted their original engines and have been mated to new powerplants. Piper defers to component manufacturers' recommendations about TBOs.

Lycoming does not list separate TBOs for turbochargers, but notes that the turbocharger may have to have carbon removed before the engine TBO is reached.

As noted before, turbochargers operate at extremely high speeds—80,000 to 100,000 rpm. And turbocharged engines produce extremely high temperatures, as anyone can attest who has flown, say, a Turbo 310 at night and looked out to see the white-hot glow from the turbocharger. Maintaining rated horsepower longer and the added heat of the compressed air account for the rise in temperatures. Under such conditions, any careless operation obviously could be detrimental to the turbocharger and to the engine.

The service difficulty reports available from the Federal Aviation Administration (and from AOPA's Oklahoma City office) could help you pinpoint possible problem areas of a particular airplane model in advance, and they could give your mechanic guidance in what to watch for on inspection or if a malfunction occurs. The reports from June 1974 to October 1980 show that one Cessna Turbo 206 suffered a cracked No. 5 cylinder, causing the crankcase to crack. Overboosting was thought to be the cause. There were six other instances of cracked crankcases, but no probable cause was given.

Perusal of the Piper Saratoga readout shows nine instances in which the turbo oil-sump tank or inlet port was cracked or separated or had broken loose, and there were six different wastegate problems. Twelve Turbo 210s had sheared, worn, broken or galled turbine shafts. Two Cessna Turbo Skylane RG exhaust-stack flanges were cracked under the clamp, which hid the problem from view—a good thing for a mechanic to be aware of.

Cost and complexity considerations may be outweighed by practical need. The most dramatic evidence of the benefits to be derived from turbocharging shows up in comparing the single-engine service ceilings of twins that are normally aspirated with those that are turbocharged. As Rocky Mountain Piper's Flite Center manager, Mike Murrell, pointed out, "The single-engine service ceiling of the normally aspirated Piper Seminole is 4,100 feet, 1,500 feet below the field elevation here at Jeffco Airport." Turbocharged, the Seminole has a 12,500-foot single-engine service ceiling.

Ceiling figures, Murrell said, are based on a fully grossed airplane climbing to that altitude. "In this part of the country, with minimum en route altitudes (MEAs) at 14,000 to 15,000 feet, you're not going to be at full gross at cruise. If you are already above your single-engine service ceiling, you may drift down a bit, if you lose one engine; but you are probably going to be able to stay at your MEA, even though it's above your service ceiling. That's a strong point out here—turbocharging gives all-weather capability across the mountains."

Archie Trammell, director of AOPA's Air Safety Foundation, agreed. "On a flight, say, from Colorado Springs to Grand Junction, you really shouldn't fly a normally aspirated twin IFR, because if one engine fails, you're going to come down into the mountains," he said. "Some pilots won't fly a nonturbocharged twin IFR in the mountains for that reason. They would rather be in a single."

In Trammell's opinion, one of the most important aspects of turbocharging is that it gives the pilot more capability in dealing with icing. "Several times in my [Cessna] 182, I just haven't been able to get above the icing level or couldn't get above it fast enough. Turbocharging would have helped."

A comparison of the rate of climb of

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Aircraft	Engine/ Turbocharger	Recommended TBO (hr)	Rate of Climb (SL) (fpm)	Cruise† (kt)	Range† (nm)	Service Ceiling* (ft)	1981 Base Price	Fuel Consumption† (gph)
Maule M-5 210C	Lyc TO-360-C1A6D 210 hp/ Rajay direct link	1,200	1,350	148	625	25,000 (18,000)	$38,299	12 (60% @ 10,000)
Cessna Turbo Skylane	Lyc O-540-L3C5D 235 hp/ AiResearch throttle/wastegate interconnect	2,000	965	158	745	20,000	$62,250	14.3
Piper Turbo Arrow IV	Cont TSIO-360-F 200 hp/ Rajay fixed orifice	1,800	940	167 (65%)	720 (65%)	20,000 (17,000)	$64,520	12.7
Mooney M20K 231	Cont TSIO-360-GB 210 hp/ Rajay fixed orifice	1,800	1,080	192	950	24,000	$66,125	11.1 (@ 24,000)
Cessna Turbo Skylane RG	Lyc O-540-L3C5D 235 hp/ AiResearch throttle/ wastegate interconnect	2,000	1,040	173	875	20,000 (14,300)	$75,950	14.5
Cessna Turbo 206 Stationair 6	Cont TSIO-520-M 310 hp/ AiResearch automatic controller	1,400	1,010	167 (80%)	690	27,000 (14,800)	$78,400	16.5
Piper Turbo Saratoga	Lyc TIO-540-S1AD 300 hp/ AiResearch throttle/wastegate interconnect	1,600	1,170	165	682	20,000 (14,100)	$82,760	16.5
Cessna Turbo 207 Stationair 8	Cont TSIO-520-M 310 hp/ AiResearch automatic controller	1,400	885	161 (80%)	525	26,000 (13,300)	$87,750	16.5
Piper Turbo Saratoga SP	Lyc TIO-540-S1AD 300 hp/ AiResearch throttle/ wastegate interconnect	1,600	1,120	177	730	20,000 (16,700)	$97,680	18.7
Cessna Turbo Centurion T210	Cont TSIO-520-R 310 hp @ 2,700 rpm/AiResearch automatic controller	1,400	930	196	815 (80% @ 20,000)	27,000 (17,300)	$99,700	16.5

the Piper Turbo Saratoga SP and the Saratoga SP, both of which have Lycoming 540 series engines, shows greatly increased rates for the turbocharged version. Using standard-day, gear-up, gross-weight figures, we get a 650-fpm climb for the Saratoga SP at 6,000 feet, 1,020 fpm for the Turbo model. Up at 10,000, the Turbo is still making a healthy 840-fpm climb, while the Saratoga is lagging at 450.

Fuel efficiency and higher airspeeds are other reasons to operate a turbocharged aircraft. Corporate transportation consultant Richard E. Rose explained that, although the engine is developing more power at a higher altitude and using a greater amount of fuel than a normally aspirated engine of the same horsepower would use, it can get you to your destination quicker. "What would appear to be a disadvantage," said Rose, "is one of the biggest benefits of the turbo system. A pilot's ability and training, along with proper maintenance, can provide a fuel savings per mile traveled. You not only can get there faster, but you can use less fuel doing it. One trip of 305 miles that I have made hundreds of times, for example, worked out like this: In a Cessna 210, unturbocharged, speed at 10,000 feet was 166 knots, total time was 1.83 hours, fuel consumption was 14.9 gallons per hour, for a total fuel burn of 27.3 gallons. On the same trip in a Cessna Turbo 210, speed at 17,000 was 198 knots, trip time was 1.54 hours, fuel consumption was 17.1 gph, and the total fuel used was 26.3 gallons." So while the fuel consumption per hour was higher, the total amount of fuel used was less.

Mooney has done a number of comparisons of turbo and nonturbo models, which show the advantages, for example, of the Turbo Centurion over the Centurion. At 12,000 feet and 75-percent power, the Turbo 210 gets 176 knots and 16.3 gph; the Centurion flies 162 knots at 12.3 gph. Mooney also compared the performance of the Mooney 201 with that of the Turbo 231 (the 231 has 10 more horsepower). At 12,000 feet and 75-percent power, the 201 gets 160 knots and burns 9.6 gph; at 18,000, the Turbo 231 gets 182 knots burning 11.3 gph.

You do not have to dwell in the higher elevations of the west to appreciate the extra zip of turbocharging. This summer, when Midwest temperatures hovered at almost 110°F for weeks, and density altitudes at Wichita rose from the field elevation of 1,384 feet to more than 5,000 feet, Cessna test pilots flying both normally aspirated aircraft and their turbocharged kin could testify to the difference in performance. As one Turbo 206 operator on the East Coast said, "Every day is a standard day with turbocharging."

But the benefits of turbocharging are not free. There are requirements for oxygen (see "Oxygen To Go," p. 53),

A listing of nonpressurized turbocharged production light aircraft.

Aircraft	Engine/ Turbocharger	Recommended TBO (hr)	Rate of Climb (SL) (fpm)	Cruise† (kt)	Range† (nm)	Service Ceiling* (ft)	1981 Base Price	Fuel Consumption† (gph)
Piper Turbo Seminole	Lyc TO-360-E1A6D 180 hp/ AiResearch fixed orifice	1,800	1,290	183	785	20,000; SE: 12,500 (17,100; SE: 4,100)	$112,160	24.2
Beech Bonanza A36TC	Cont TSIO-520-UB 300 hp/ AiResearch automatic controller	1,400	1,150	199 (31 in/ 2,400 rpm @ 25,000)	654 (see cruise)	25,000 (16,600)	$125,750	16.7 (see cruise)
Piper Seneca II	Cont TSIO-360-E/EB 200 hp/ Rajay fixed orifice	1,800	1,340 SE: 225	190	787	25,000; SE: 13,400	$129,980	23.6
Piper Turbo Aztec F	Lyc TIO-540-C1A 250 hp/ AiResearch automatic controller	1,800**	1,470 SE: 225	210	947	24,000; SE: 17,000 (17,600 SE: 4,800)	$165,960	27.4
Cessna Turbo 310	Cont TSIO-520-B 285 hp/ AiResearch automatic controller	1,400	1,700 SE: 390	223 (73.6%)	1,242	27,400; SE: 17,200 (19,750; SE: 7,400)	$188,000	31.2
Piper Aerostar 601B	Lyc IO-540-S1A5 290 hp/ Rajay automatic controller	1,800	1,800 SE: 240	257 (@ 25,000)	1,024 (65% @ 15,000)	30,000; SE: 8,800 (21,200; SE: 6,300)	$251,480	29.7 (65% @ 15,000)
Beech Baron 58TC	Cont TSIO-520-L 310 hp/ AiResearch automatic controller	1,400	1,418 SE: 270	241 (25,000 33 in/ 2,400 rpm)	1,026 (see cruise)	25,000; SE: 13,940 (18,600; SE: 7,000)	$259,000	37.08 (see cruise)

SE (single engine) SL (sea level)

†Cruise, range and fuel consumption 75% power (with 45-minute reserve) at 20,000 ft., max fuel, unless otherwise noted.

*Figures in parentheses are for normally aspirated versions.

**Engines without larger main bearing dowels may not exceed 1,500 hours before overhaul.

and regulations govern the equipment you must carry and the ratings you must hold. For flight above 12,500 feet above mean sea level (unless you are within 2,500 feet of the ground), you must have a transponder with Mode C, or automatic altitude-reporting, capability. Above 18,000 feet, where altitudes are translated into flight levels, you must operate under instrument flight rules at an altitude assigned by ATC. Your aircraft must be equipped as required for IFR (naturally, a two-way radio for ATC communication is included), and you must have an instrument rating—a good idea even if you do not go as high as FL180, since it is easier to get caught on top. You also need high-altitude en-route charts above 18,000 feet. Above 24,000, if you are required to use VORs, you must have distance-measuring equipment (DME). Above 10,000, VFR minimums go up to five statute miles visibility, and you must keep your distance from clouds—1,000 feet above and one mile horizontally.

Minding the operational considerations of the turbocharger and the engine, however, is the most important of the constraints placed on the pilot of turbocharged aircraft. Turbochargers require, first of all, smooth throttle operation and careful attention to engine temperatures. The sequence of power adjustment is more important with turbocharged engines, also—when increasing power, enrich the mixture, increase the rpm, then manifold pressure. In decreasing power, reduce manifold pressure first, then rpm.

"One of the things I emphasize is very, very smooth operation of the throttle both going up and coming back—it's mandatory, absolutely mandatory," said Ken Johnson, Avco Lycoming's customer relations manager. "Equally important is very careful, smooth operation of the mixture control after you're set up for cruise."

With turbocharger turbine speeds running more than 80,000 rpm, there is a lag after the engine is started while the turbine builds up to speed, Johnson said. When it does build up, the manifold pressure will rise. If you set the manifold pressure initially to the desired limit, the turbocharger, when it gets to full speed, will make the MP go over the limit (unless the turbocharger has an automatic controller), causing overboosting. So any throttle application must be made carefully. "You must set the manifold pressure at a point somewhat below what you want to get," Johnson explained. "When the turbocharger comes up to speed, you then can make minor adjustments."

With the pilot-controlled systems, power will decrease as the aircraft climbs, just as it does with a normally aspirated engine. So you have to move the throttle in to increase manifold pressure. With an automatic controller, you set the manifold pressure and the system maintains that power setting.

"On a cold day or on the first flight of the day, if you have a turbocharger with a wastegate controlled by engine oil pressure and you advance the throttle at normal throttle rate without letting the engine warm up, you'll often get an overboost," said Paul Pendleton, propulsion certification engineer in the FAA's Wichita Engineering and Manufacturing District Office. "The pilot is supposed to observe the normal engine limits. If you overboost, you must pull the throttle and the mixture back."

Older supercharged engines did not have a relief-valve mechanism, noted Pendleton, and they would overboost frequently. But they did have an advantage: Fuel flow did not go up when an overboost occurred, so the engine would not flood out from being overly rich. "Today, with an engine in which oil pressure is coupled to the turbocharger control system," Pendleton said, "the fuel system tries to compensate for overboost, and it can overly compensate, flooding the engine. But if you allow the engine to warm up gradually to normal operating temperatures, you won't have that problem." Once an engine suffers an overboost, it often will need an overhaul and possibly a new crankshaft, said Lycoming.

Careful monitoring and management of exhaust-gas and cylinder-head temperatures is essential, and more attention is being paid to this aspect of turbocharged aircraft operation. Pendleton believes that, with a turbocharged engine, an exhaust gas temperature (egt) gauge is a necessity. Although it is not a required instrument, most turbocharged aircraft are equipped with them. Some, such as the Mooney 231 and the Bonanza A36TC, have turbine inlet temperature (TIT) gauges. The TIT is marked in temperatures and has a redline limit—usually 1,650°F.

"If you don't have an egt, the only thing you have to go by to manage the mixture is the fuel-flow meter," said Pendleton. "It is important to see that the engine is receiving the amount of fuel that the manufacturer specifies."

Cylinder head temperatures must be monitored carefully as well, and Pendleton said care should be taken to make certain that the cht probe is on the hottest cylinder. Since both the cht and the egt indications may fluctuate in climb, Pendleton said that both must receive close attention.

Extra care should be taken with engines that were not designed originally to be turbocharged, Pendleton said. Some of these engines have higher compression ratios than they might have, had they been designed with turbocharging in mind, which makes them "difficult to operate detonation free." But he emphasized that cylinder head temperatures on all turbo engines must be watched to prevent detonation.

You don't have to fly in the West to appreciate turbocharging. It makes every day a standard day.

Detonation, unlike overboosting, is not discernible by the pilot; but it can destroy an engine, nevertheless. In contrast to the normally aspirated engine, which loses power as it climbs, the turbocharged engine actually can increase its power as it goes higher. It is possible, by leaning the engine out, to make it run hotter and generate more power than the engine was manufactured to deliver, said Pendleton.

"Engines are manufactured with a tolerance of three percent on either side of what we call spec power," Pendleton said. "If the engine were certificated for 300 hp, it could deliver up to 310 or down to 290 hp. If you had an engine that was on the low side of spec—say, that developed 290 and was rated for 300—by leaning it out, you could easily get to 310 hp. It would be running hot, really hot, and you would be on the verge of detonation. You would get more power, but your engine life would be reduced considerably.

"The most practical way to avoid detonation," advised Pendleton, "is to operate at least 50°, or more conservatively, 75°, on the rich side of peak at all power settings above 55 percent. Keep the cylinder head temperature at a reasonable limit by adjusting the cowl flaps, or whatever you need to do, and keep the fuel flow within the engine manufacturer's spec limits.

"Fuel flow is what really counts," said Pendleton. "Fuel-cooling the engine is what we call it." Pendleton acknowledged that keeping the fuel flow up goes against the current inclination to operate more fuel efficiently. "But pilots are only defeating the purpose by reducing the engine life when operating it too lean," he said. "They will get more power and the aircraft will go faster, but the engine will be on the verge of detonation."

The efficiencies of cooling also are illustrated by the results of modifications on the Turbo Saratoga. Its fuel consumption was 22 gph, and engine temperatures were extremely high; there was no cowl flap. Piper added fixed louvers and made other modifications to direct more airflow through the engine compartment. Temperatures dropped dramatically and fuel consumption was lowered from 22 to 16.5 gph at 75-percent power.

Careful operation on descent also is necessary to prevent a too-rapid cooling of the engine. Once on the ground, you should give the turbocharger time to spin down—while it still has proper oil lubrication—before shutting down the engine and thereby cutting off the oil supply.

And if you have to rev up the engine, to fit into a tight parking space, you should allow it to idle at about 1,000 to 1,200 rpm for a few minutes, to avoid the sudden cooling that can damage the turbocharger.

Since pilot management of a turbocharged system is the main key to its efficient operation, good training is essential, Lycoming's Ken Johnson said. At flight instructor courses, he urges the CFIs to stress careful operation of the throttle, as their students are more likely these days to be flying turbocharged aircraft sooner in their careers. Rocky Mountain Piper now has a special checkout and a 26-question written examination on turbocharged operation for prospective renters and new owners; no doubt more flight schools will add this to their curricula.

If you now are flying a turbocharged aircraft, or if there is one in your future, just remember to treat it even more gently than you would its normally aspirated predecessor, and you will keep flying higher and higher. □