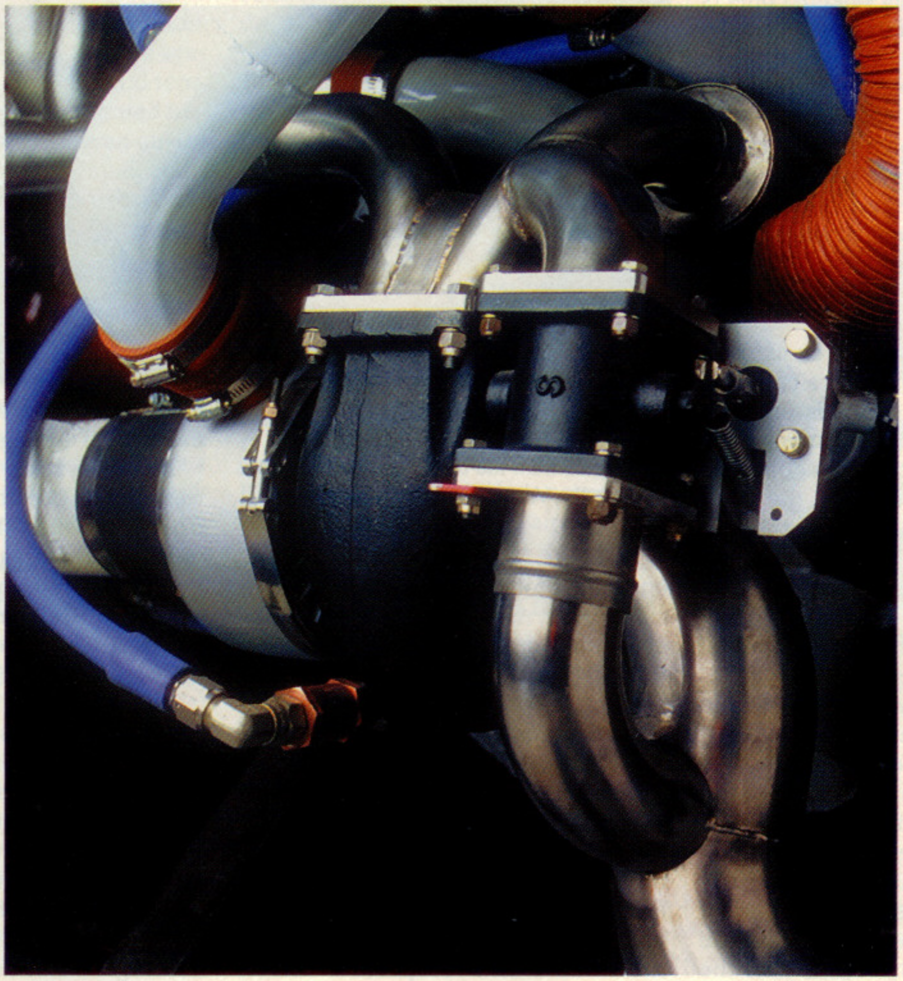
AOPA'S 2001 BONANZA SWEEPSTAKES



Up, up, and away

Turbonormalizing improves an airplane's utility

BY STEVEN W. ELLS

You can take this one to the bank—installing a turbonormalizer will improve an airplane's utility. This was demonstrated following the installation of a Tornado Alley Turbo (TAT) Whirlwind II turbonormalizer system on the Superior Air Parts Certified Millennium engine in the AOPA Sweepstakes Bonanza.

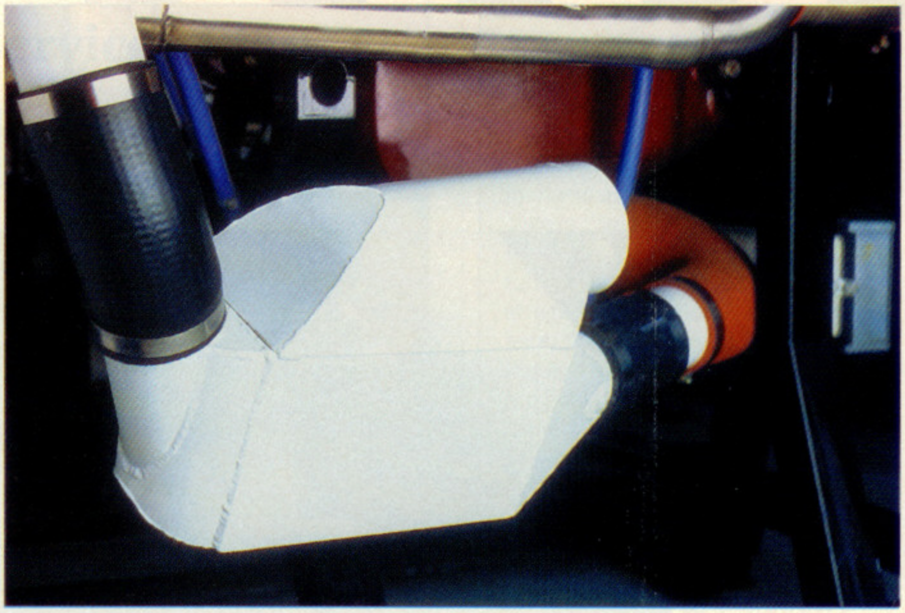
Turbonormalizing the sweepstakes Bonanza had the same effect on our 1966 Beech V35 Bonanza that Viagra apparently has had on Bob Dole—the sweepstakes Bonanza can now keep up with airplanes half its age. Before we describe what was done, let's talk about why it was done.

Turbonormalizing will allow the winner of the sweepstakes Bonanza to more fully utilize the airplane. Even at 35 years old, the standard V35 Bonanza is very capable. An airplane with a service ceiling above 16,000 feet, cruise speeds above 165 KTAS, and a still-air range of more than 750 nm (on 74 gallons) is cer-

PHOTOGRAPH BY MIKE FIZER

tainly very useful, but the installation of a turbonormalizer *transforms* this good airplane into a great—indeed, a twenty-first century—airplane.

A turbonormalizing system collects engine exhaust gases that are normally pumped overboard. These gases are used to indirectly drive an air compressor. This compressed air artificially creates sea-level atmospheric air pressures when it is pumped into the engine. In this way the engine can develop full power (300 horsepower) at altitudes up to and above 20,000 feet msl.



Cool ram air enters the intercooler housing through the orange flexible ducting. Compressed air from the turbo, now cooled, exits through the black hose to enter the engine.

The building blocks

A turbocharger consists of an exhaust gas-driven turbine wheel in a cast-iron scroll housing and a compressor wheel in an aluminum scroll housing, with both wheels mounted on a common rotating shaft. The housings, the shaft, and the two wheels make up the turbocharger assembly. The center shaft is supported in a bushing that is constantly lubricated by circulating engine oil. The turbocharger is a component of the turbonormalizer system.

The Tornado Alley Turbo Whirlwind II system replaces the original exhaust system with a heavy-duty stainless steel system. Exhaust gases are collected from the engine cylinders and are routed to the turbine wheel inlet.

At low altitudes, where the air is denser, the compressor doesn't have to compress a lot of air to maintain the manifold pressures necessary for the engine to produce 65-percent to 75-percent power. As the airplane climbs, the air pressure decreases, so the compressor must deliver more air. A turbonormalizer system increases the amount of compressed air that is delivered to the engine by controlling how much of the total exhaust gas bypasses the turbocharger. This bypass route is controlled by a butterfly valve called a *wastegate.* Closing the wastegate increases the amount of exhaust gases being forced past the turbine wheel. The resultant higher rpm of the turbine and compressor wheels increases the amount of compressed air delivered to the engine.

In this system the position of the wastegate is controlled by the absolute pressure controller. This controller monitors the pressure from the compressor output and maintains a constant air pressure in the "upper deck" of the system by adjusting the position of the wastegate.

The upper deck is the part of the turbonormalizer system that is located between the compressor outlet and the engine throttle plate. The controller is designed to maintain the upper deck pressure at two to three inches of pressure above the maximum manifold pressure the engine would ever need. This type of system works the turbocharger a little harder than some "on-demand" systems, since the components of this system are adjusted to always maintain 33 to 34 inches of upper deck pressure, but this is offset by the fact that there's never any turbocharger lag or spool-up time. A pressure relief valve (pop-off valve) is mounted in the ducting between the compressor outlet and the engine, and is designed to open if the controller malfunctions and allows upper deck pressure (and consequently manifold pressure) to increase beyond safe limits.

Looking through the lower left engine access panel, the silver scroll of the compressor side of the turbocharger can be seen. Filtered inlet air is delivered to the turbo via ducting from the front of the engine compartment. The compressed-air ductwork can be seen exiting the top of the scroll.

MIKE FIZER (TOP); STEVE ELLS

The system operation is simple. The pilot adjusts the throttle to select the manifold pressure he wants, and the system automatically maintains a constant upper deck pressure, which maintains a constant manifold pressure.

Intercooler

Compressing air raises its temperature. Since we would like the air to be sea-level dense, and as near standard temperatures as possible, sophisticated turbonormalizing systems have an air-to-air radiator in which the heated, compressed air from the compressor is cooled by ram air before it enters the engine. This device is called an *intercooler,* and the Tornado Alley Turbo system has a very efficient one mounted below the engine on the right side.

After the initial acquisition costs of a turbonormalizing system, are there any other costs involved? Yes, there will be slightly higher costs associated with a turbonormalizer system, especially during an engine overhaul, when the turbo components (including the exhaust system) should also be overhauled. The Tornado Alley system is designed for long life, uses proven components, and shouldn't have any trouble matching engine TBO numbers before needing overhaul.

Some new powerplant management techniques (we will get to Tornado Alley's method in a moment) will have to be adhered to, and the pilot will have to learn about hypoxia, the use of oxygen, and high-altitude operations. Is the engine overworked or stressed because of the installation of a turbonormalizer? The potential exists to abuse a turbonormalized engine, primarily if the pilot always insists on going as fast as possible. As pilots get used to the system, they will learn that a turbonormalized airplane can easily climb above the thick, draggy air of lower altitudes to where even conservative power settings yield impressive speed gains. TAT likes to tout the advantages gained from its system at lower altitudes. True airspeeds are increased, and safety margins rise as power-robbing conditions such as high ambient temperatures or high airport elevations are simply no longer a problem.

Lean-of-peak operations, if correctly performed by the pilot, result in lower temperatures than rich-of-peak operations.

Before Tornado Alley Turbo

In 1994, *AOPA Pilot* reported on flying George Braly's turbonormalizer-equipped 1967 V35 from Orlando, Florida, to Ada, Oklahoma (see "Higher Flyer," March 1994 *Pilot*). Braly started Tornado Alley Turbo Inc. after acquiring the turbonormalizing STCs for the Beech Bonanza and the Cessna 185 from FliteCraft Turbo, of Pagosa Springs, Colorado. Before Tornado Alley upgraded the original FliteCraft installation, cylinder head temperatures (CHTs) in Braly's Bonanza often exceeded 400 degrees Fahrenheit during climbs to altitude. Low-altitude performance also suffered when ambient temperatures were high.

Braly, an engineer by training, cooled the installation down with the Whirlwind II upgrades. Changes include a new composite airbox and alternate air door relocation, a cooling kit for the number-2 and number-6 cylinders (this mod cools these two cylinders by 30 to 35 degrees), cowl louvers adapted from current A36 Bonanzas, and a set of baffle louvers to enhance cooling airflow past the cylinders.

The original intercooler has been replaced with a more effective "Rammer" unit that, combined with changes in the under-cowl plumbing and clever tricks such as recessing the landing light for more airflow, has effectively doubled the volume of air passing through the intercooler. The result is improved hot-weather takeoff performance, cooler CHTs, and safer detonation margins. All of the Whirlwind II upgrades can be retrofitted to earlier installations.

The TAT method of powerplant management

The Whirlwind II upgrades include a set of turbo GAMIjectors (Braly is also the chief engineer at GAMI). GAMIjectors are flow-matched fuel-injection nozzles that equalize the power output among all cylinders. Tornado Alley believes that long engine life is directly related to lowering engine temperatures. As a result, each new owner of a Tornado Alley system undergoes training in how to fly the TAT way.

The TAT method of setting power for climb involves setting the throttle wide open, reducing the prop rpm to 2,500 after the airplane is cleaned up for climb, and then using the mixture control to adjust the turbine inlet temperature (TIT) to a target temperature. The target TITs are 1,280 to 1,300 degrees from sea level to 10,000 feet; 1,260 to 1,280 degrees from 10,001 to 17,000 feet; and 1,240 to 1,260 degrees (with engine rpm increased to 2,600 rpm) when climbing above 17,001 feet. If the TAT procedure is followed, climb speed targets are 115 to 120 KIAS up to 10,000 feet, 115 KIAS up to 17,000 feet, and 105 to 110 KIAS above 17,000 feet.

Because the system's automatic wastegate controls the engine manifold pressure, and the prop governor controls the engine rpm, the pilot's workload is reduced to flying the airplane—and adjusting the mixture as necessary to maintain the target temperatures. If any CHT goes above 380 degrees during the climb, the mixture is adjusted as necessary to bring the CHT back down to 380.

The TAT cruise

Cruise engine management consists of running the mixture lean of peak (LOP). This is accomplished after leveling out, closing the cowl flaps, and accelerating by performing the *big pull.* The big pull consists of grabbing the mixture knob and smoothly pulling it back until the fuel flow needle is indicating approximately 15 gallons per hour on the lean side of peak. After a short period of time, the mixture is slowly richened until peak EGT is found, and then leaned again until the turbine inlet temperature is approximately 80 degrees F lean of peak.

Up until GAMI came on the scene with its finely tuned fuel-injection nozzles that made lean-of-peak operations practical, the most accepted practice was to run one of these engines with the mixtures set somewhere between 100 to 50 degrees rich of peak to keep temperatures down. According to extensive testing by Tornado Alley, its method keeps TIT, EGT, and CHT temperatures even lower than rich-of-peak methods, and TAT believes cool temperatures are the key to long engine life. In spite of a great deal of solid evidence to support GAMI's methods, not everyone is con-

CONTRIBUTORS

AOPA would like to thank the following companies that donated or discounted their products and services to refurbish the Sweepstakes Bonanza or otherwise assisted in the project.

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vinced. Sometimes this is because of a reluctance to let go of old ideas, and sometimes it's because opponents don't realize how thoroughly GAMI and TAT test their ideas.

The Carl Goulet Memorial Test Cell

Braly and his staff in Ada, Oklahoma, have built one of the most sophisticated airplane engine test cells on the planet. Rather than guessing what goes on inside the combustion chamber, they devised a way to sample the combustion chamber pressures and display a smorgasbord of data from their test-cell engines. What have they learned? That lean-of-peak operations, if correctly performed by the pilot, are safe, result in lower temperatures than rich-of-peak operations, and do not result in destructive detonation.

These facts are borne out by years of test-stand study. For a look at TAT's plans for the future—and you can bet they're not resting on their laurels—go to the Web site (www.taturbo.com). If you want to take a look at some of the data being gathered, go directly to the test-stand Web site (www.engineteststand.com).

Why turbonormalize?

Turbonormalizing expands an airplane's operating envelope. Because ample power is always available, climbing up out of icing temperatures becomes possible. When selecting a cruise altitude there's a whole band of airspace between approximately 10,000 and 17,500 feet where traffic is generally light, because it's too high for normally aspirated airplanes and too low for turbine-powered airplanes. One result is that direct IFR flight plans are often approved. Again, this translates into a more efficient way to fly.

The turbonormalizer, because it can easily provide sea-level manifold pressures up to flight-level altitudes, allows the pilot to pick up some "free" airspeed by climbing up to altitudes where the atmospheric drag is reduced. The combination of less drag and robust power results in higher true airspeeds, and only slightly higher fuel-consumption numbers. During the first testing and adjustment flights of the sweepstakes Bonanza, true airspeeds of 215 knots at 17,500 feet were observed with a fuel burn of 18.5 gallons per hour. The hottest cylinder head temperature was 358 degrees F during the 215-KTAS flight.

The result

The TAT method of climb and cruise operation is designed to keep cylinder head temperatures below 380 degrees F. This is a full 80 degrees below the manufacturer's redline. These methods have been thoroughly tested, and are in keeping with the goal of the AOPA Bonanza Sweepstakes project. Once we realized all the benefits and weighed them against any liabilities, the installation of the Tornado Alley turbonormalizer system was a no-brainer. It's a new century, and this system transformed a 35-year-old airplane into a twenty-first century speed demon. AOPA

i Links to additional information about the AOPA Sweepstakes Bonanza may be found on AOPA Online (www.aopa.org/pilot/links.shtml). Check the Web site (www.aopa.org/sweeps) for weekly updates on the project. E-mail the author at steve.ells@aopa.org