CRYOGENIC ENGINE UPGRADES

New Technology Comes To Piston Engine Overhauls

By Bill Cox

Photography By James Lawrence

A cryogenic engine overhaul is the latest innovation in top-line engine overhaul and replacement.

One of the most common debates in general aviation is whether the glass is half full or half empty. These days, it seems many pilots argue on the side of half-empty.

The cynics suggest that aeronautical innovation has been stalled for the last 30 years, and that aviation technology hasn't kept pace with automotive boat, snowmobile or even dog sled progress.

It might seem aircraft piston engine technology has suffered a similar fate. Engines such as the Lycoming O-320, IO-360 and IO-540, along with the Continental O-470, IO-520 and IO-550 have sometimes been assailed as antiquated designs. Even the newest of them is at least 30 years old.

Engine manufacturers and overhaul shops have similarly been criticized for rebuilding the same, old, heavy, relatively inefficient powerplants, and the process of overhauling and repairing them has often been assailed as old-fashioned and inefficient.

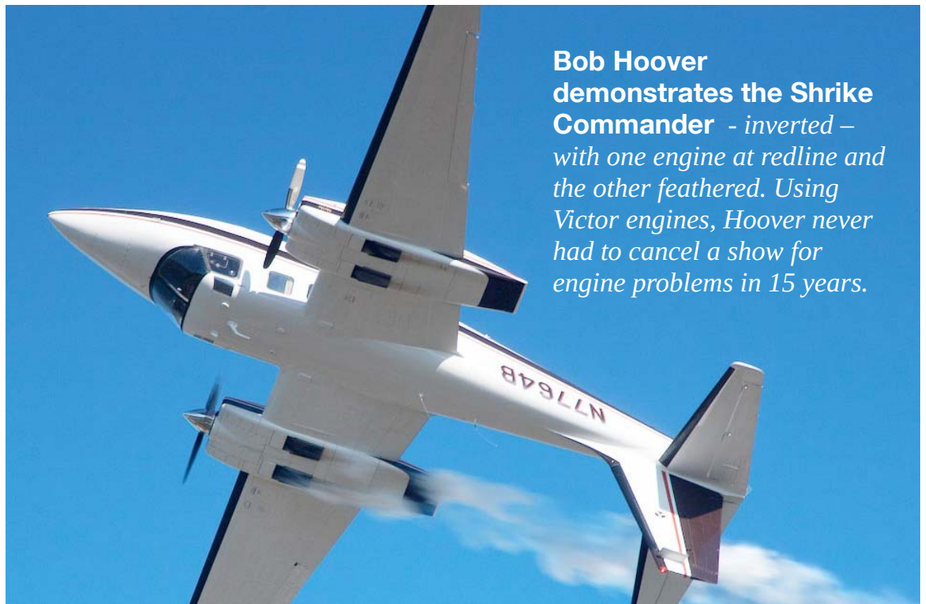
Ken Copeland's pristine E55 Baron, *equipped with Victor's cryogenic, series VII engines outperforms a stock airplane by a wide margin.*

Fortunately, there are a few shops that continue to strive for something better. They specialize in producing durable, high quality engines that can run well past manufacturer's TBO and provide pilots who prefer to fly behind the very best with that extra level of precision and reliability.

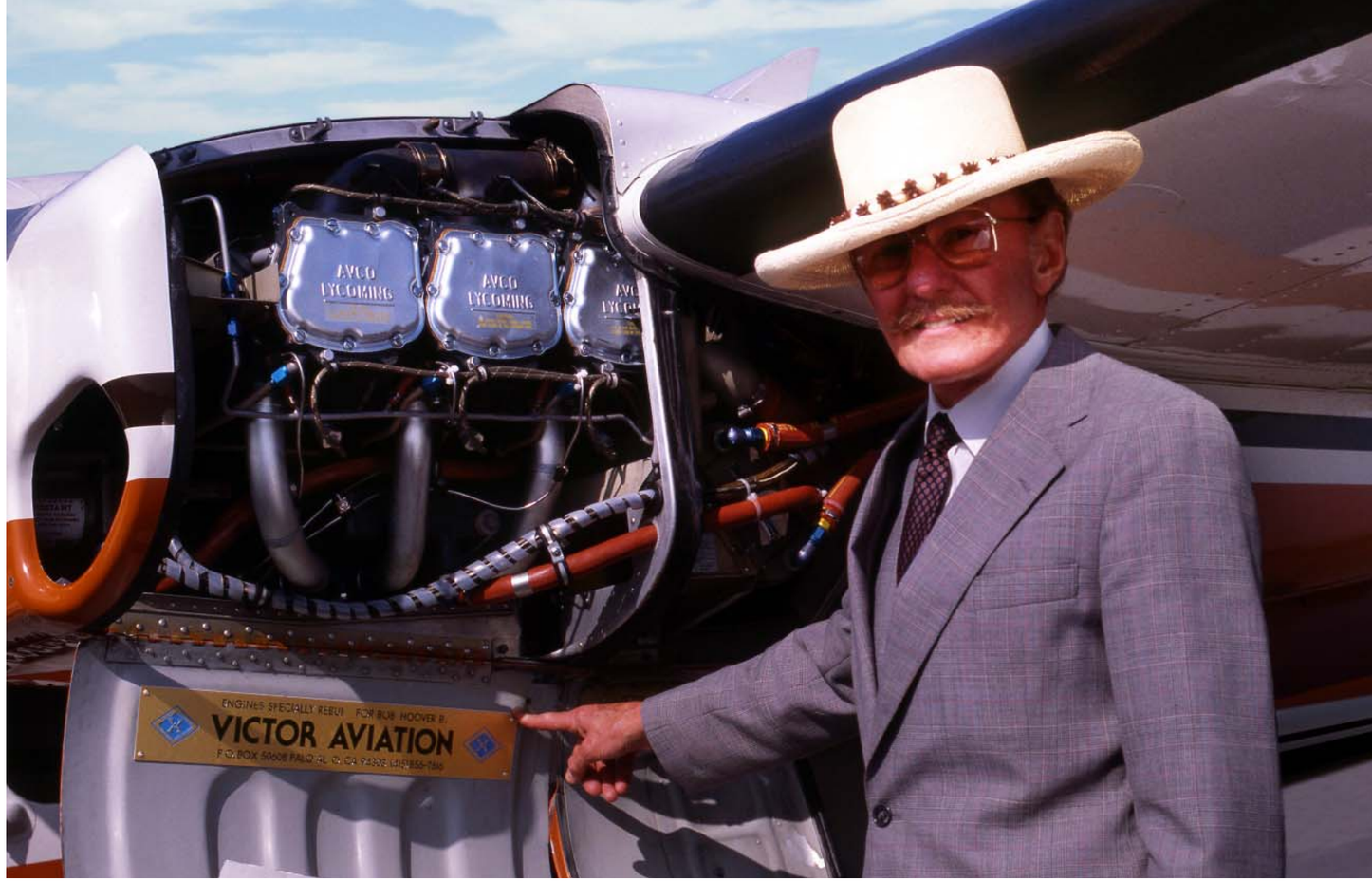
Kenneth Copeland of Fort Worth, Texas is one of those pilots. Copeland operates a number of aircraft in conjunction with his worldwide religious organization, Kenneth Copeland Ministries. One of his fleet of airplanes is Copeland's personal machine, an E55 Beech Baron, that's been in service with the ministry for 20 years.

Recently, when the Baron was two hundred hours past TBO and still running strong with Victor engines, Copeland decided to take it back to Victor Aviation in Palo Alto, California for a pair of cryogenic XR Black Edition VII engine upgrades. Victor Sloan, president of Victor Aviation, has long been a proponent of expanding the technological envelope on precision engine overhauls. His shop at Palo Alto Airport has been dealing in extreme overhauls for 37 years, all within FAA guidelines, but often utilizing new techniques for improving reliability and advancing the state of the art.

Victor's overhauls include work on aircraft belonging to some of aviation and auto racing's most knowledgeable pilots and engineers. Retired airshow pilot Bob Hoover had at least two sets of engines on his Shrike Commander overhauled at Victor's shop, simply because Hoover



Bob Hoover demonstrates the Shrike Commander *- inverted – with one engine at redline and the other feathered. Using Victor engines, Hoover never had to cancel a show for engine problems in 15 years.*



Legendary Air Show Pilot Robert A. "Bob" Hoover *is a former United States Air Force test pilot, known for his wide-brimmed straw hat and wide smile. In aviation circles he is often referred to as "The pilots' pilot." Over Bob's flight career he has earned some of the most prestigious awards such as Distinguished Flying Cross, Soldier's Medal for Valor Air Medal with Clusters Purple Heart and Croix de guerre.*

was convinced they were the best piston engines available. As Hoover put it "In my business, I couldn't afford anything less than the best."

Hoover was famous for his dramatic Commander routine that involved running the engines to max power; then, shutting down one or both and performing loops, rolls and even dead stick landings with one or both props feathered. Hoover's airshow routine demanded ultimate reliability, as the engines often needed to start and stop every time on short notice.

The airshow pilot had never endorsed any product until flying behind Victor Engines, and after 15 years and 570 air shows of operating over 5,000 hours with Sloan's overhauls, he was happy to say, "I've never had to cancel

X-15 research rocketplane pilot Scott Crossfield *inspired Victor Sloan to pursue cryogenic engine overhauls. Crossfield installed a Victor Black Edition II in his personal aircraft, a Cessna 210.*

an airshow because of engine problems since starting to use Victor engines."

Former X-15 rocketplane test pilot Scott Crossfield, first man to bust both Mach 2.0 and Mach 3.0 also chose to overhaul the engine in his personal Cessna 210 using Victor's advanced engine processes. Like Hoover, Crossfield had never endorsed an aviation product, but he had no problem vouching for the reliability of a Victor Black Edition II engine in his own aircraft. "Whether it's Mach 2.0 or Mach .2, it's all a function of power," said Crossfield.

Gary Bettenhausen, a member of the famous Bettenhausen auto racing family and consistent Indy-car competitor at the Indianapolis 500 picked a Black Edition II engine for his personal aircraft and was proud of his choice. "At Indy, if you have engine problems, you drop out of the race, and in an aircraft, if you have engine problems, you drop out of the sky. I recommend Victor highly, and maybe we'll see him at Indy someday."

More recently, however, Kenneth Copeland Ministries had used Victor Sloan's services before. In fact, Victor Aviation had performed at least two dozen overhauls on Copeland's variety of aircraft, ranging from several Cessna 421s to Bonanzas and Barons.

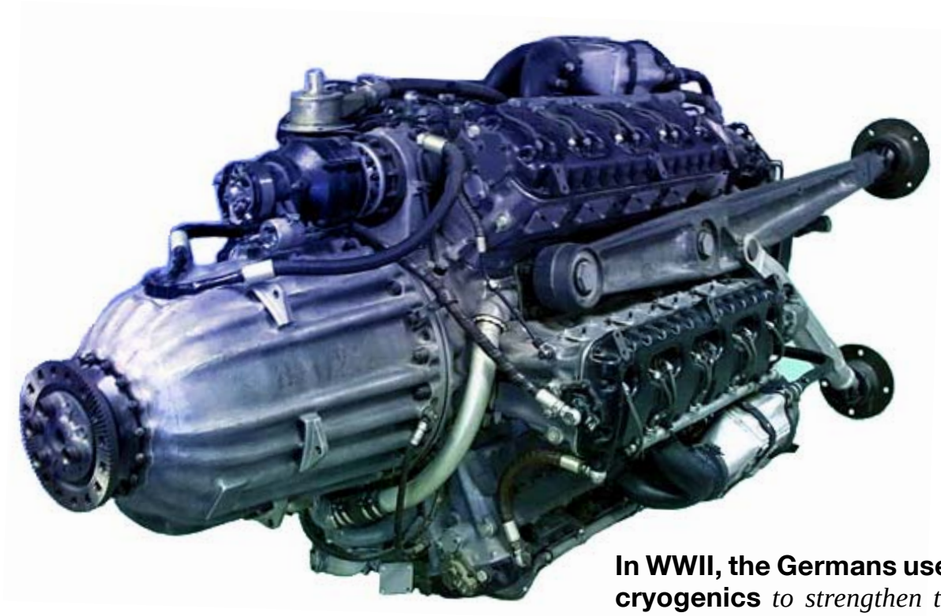
Sloan was especially eager to see the E55 come in for a double XR Black Edition VII overhaul. "The engines installed on that airplane were ones we'd previously overhauled 13 years ago as Black Edition II's. We were eager to examine them to see how they'd fared after 1,900 hours of hard service, 200 more than the recommended TBO," said Sloan.

In many respects, Copeland's Baron engines were ideal test cases as the E55 had been flown often, was never abused and was well maintained by Copeland's mechanics. Sloan felt it was "a great opportunity to flight and ground test a pair of engines that had been given the benefit of very meticulous maintenance."

"We were surprised at how little wear was evident when we opened up those engines." said Sloan. "The Baron's Continental engines hadn't needed any major maintenance since the last overhaul so none of the engine's cylinders had been removed. When we disassembled the engines, everything looked pristine and well-preserved, a tribute to how painstaking the Copeland aviation division is about maintenance," Victor comments. "We could have easily just closed those Continentals back up, and they probably would have run another 1000 hours without problems."

For the new XR Black Edition VII overhauls, however, Victor incorporated technology that had

Victor Sloan *President of Victor Aviation runs the Cryogenics Laboratory. Innovating new methods to enhance the quality and performance of materials is a real art.*



In WWII, the Germans used cryogenics *to strengthen the Jumo 211D engines on the JU-87 Stuka dive bomber and the ME-209 fighter.*

never before been applied to general aviation aircraft engines. Victor Aviation has become one of the pioneers at incorporating cryogenic technology into aircraft engine rebuilding.

Though the concept of cryogenics isn't that tough to understand, the execution is a little more complex. Cryogenics isn't a new process. It's been around since before WWII, when scientists discovered that cold-soaking metals to extreme low temperatures improved their durability, hardened them and made them more resistant to wear.

Cryogenic processing of aircraft engine parts dates back to the 1930's and was reportedly used by the Junkers Aircraft Company on their Jumo 1,400 HP V-12 aircraft engines. These engines were installed in many German military aircraft such as the Messerschmitt ME209 and JU87 Stuka dive bombers used in World War II.

Trouble was, the prevailing pre-war technology wasn't sophisticated enough to take advantage of the new process. Cryogens such as liquid helium or liquid nitrogen were required to lower the temperature to -300 degrees F (not far from absolute zero), and those materials were scarce or unavailable in the 1930s.

A scientist named Ed Busch is credited with starting the modern cryogenic revolution when he established CryoTech in 1966. Busch originally

Cryogenics helped harden the JU-87 *dive bomber against the stress of shock cooling when the aircraft would dive vertically at idle, then go to full throttle to escape after delivering ordnance.*

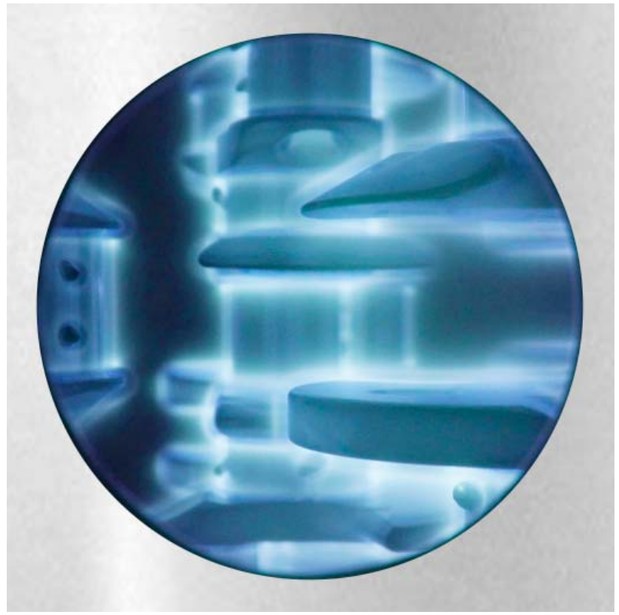
experimented with cryogenic tempering rather than heat treating metal tools and succeeded in creating high tolerance tools with life expectancies 200-400 percent greater than their previous endurance.

Other researchers discovered cryogenics had several applications in the manufacturing business. Solid metal components are not all created equal. Parts for a variety of products could be made more durable and constructed with greater precision by removing the residual stress in machined parts.

Victor began his research on cryogenic material property improvements in conjunction with his engine overhaul business, often working with agencies such as Stanford University, UC Berkeley, UC Davis, Boston University and the Massachusetts Institute of Technology.

NASA turbine blades *are being lowered into the cryogenic chamber for stress relief testing.*

Victor turns back the clock *and slows down the rate that atoms vibrate in a cryogenic atmosphere with Liquid Nitrogen. The results are tougher and more durable parts.*



Longer life and improved reliability of metals were of great interest to organizations as diverse as NASCAR, NASA and Boeing Aircraft, all of whom demanded extreme reliability from parts manufactured to unusually tight tolerances. NASCAR was well aware of the problems of parts breakage during auto racing and was interested in improving engine parts performance, not only on engines that were being pushed well beyond normal limits but on suspension systems that could break at high speed and send a car out of control.

NASA was interested in Victor's cryogenic work in conjunction with space programs where the failure of a single part out of several million could cause the loss of a multi-billion dollar shuttle or rocket component. NASA satellites and the recent James Webb Space Telescope (JWST) are specifically designed to operate in a cryogenic temperature range, from +185 to -388 degrees F. Understanding the effects of vibration and shock on components and their ability to withstand the environment of space is a vital concern. Sloan has also been contracted to harden wind-tunnel blades at NASA's Ames Research transonic and supersonic wind tunnel facility a few miles south of Palo Alto. Victor's cryogenic testing and processing programs have assumed an important role in advancing space system developments.

Boeing needed high strength materials to support construction of ever larger and more efficient airliners, a discipline in which a major failure of a critical part could cost hundreds of lives. Airliners operate in very cold temperatures, sometimes as low as -70 degrees F at 41,000 feet. Materials subjected to these extreme conditions must be of very high purity. Victor's cryogenic testing and treating enhances performance for Boeing aircraft by conditioning the parts to cryogenic temperature ranges.

The process begins by placing engine parts in a large vacuum insulated cryotank, designed specifically for the task of creating a liquid nitrogen, non contact atmosphere. The process is computer controlled and usually consists of slowly adding the cryogen and lowering the temperature inside the tank to about -300 degrees F. Parts may be maintained or cycled in a super-cold state for 24, 48 or even 72 hours, depending on the material being tested. During Victor's patent pending cryogenic testing and treating processes, materials are monitored real-time using ultrasonic's to test for any material property or stress component changes.

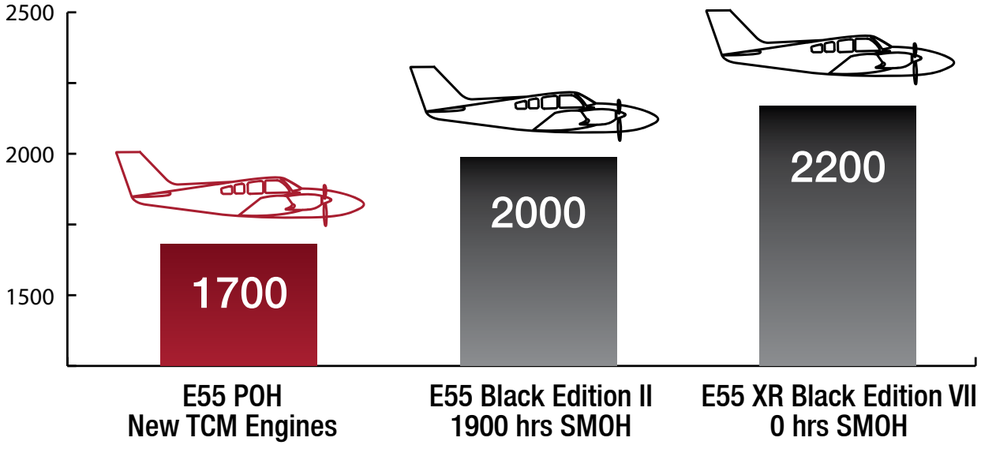
Then, the parts are slowly returned to room temperature or sometimes subjected to a heat-treatment phase that raises them to +300 degrees F for a calculated period of time. Following the testing and treating process, materials are tested for property conformance using techniques such as X-ray diffraction ultrasonic's and Rockwell hardness. This alternating cold and heat-soaking technique can improve engine parts performance, making them less susceptible to wear or fracturing.

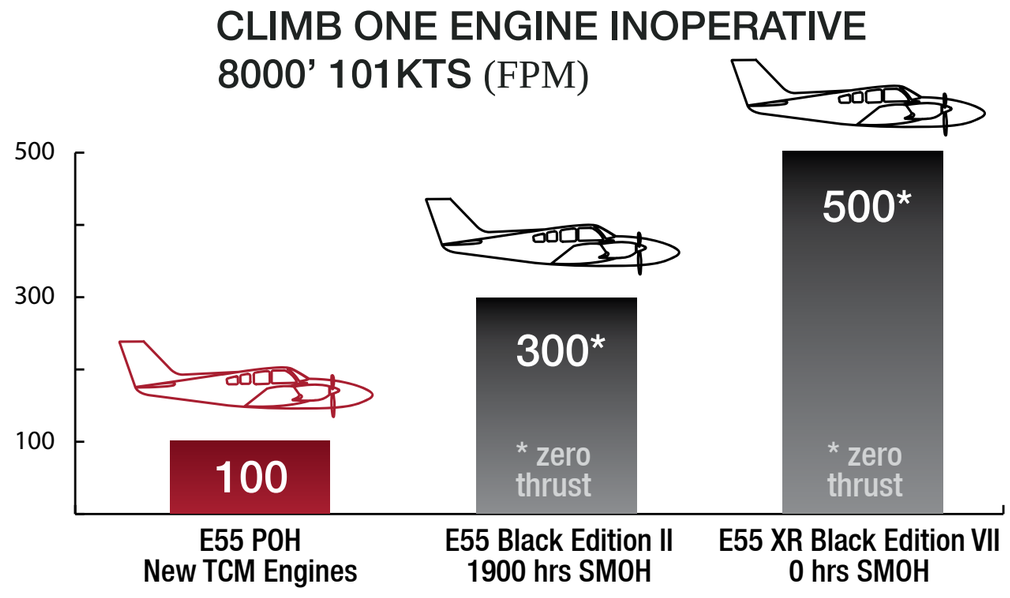
Victor can measure the quality of engine parts *using innovative electromagnetic acoustic techniques; then evaluate how they're improved employing cryogenics.*

The result is an engine constructed to such fine tolerances that it's bound to run smoother and more efficiently than most other piston aircraft powerplants.

I flew Copeland's Baron with the 1900-hour Black Edition II engines and again two months later immediately after the cryogenic XR Black Edition VII overhauls had been completed. Outside air temperatures were comparable on the flights, the airplane was flying with half fuel both times and there were two pilots up front to record the numbers.

With enhanced reliability and improved performance, *Kenneth Copeland's E55 Baron offers rapid transit for up to six people.*

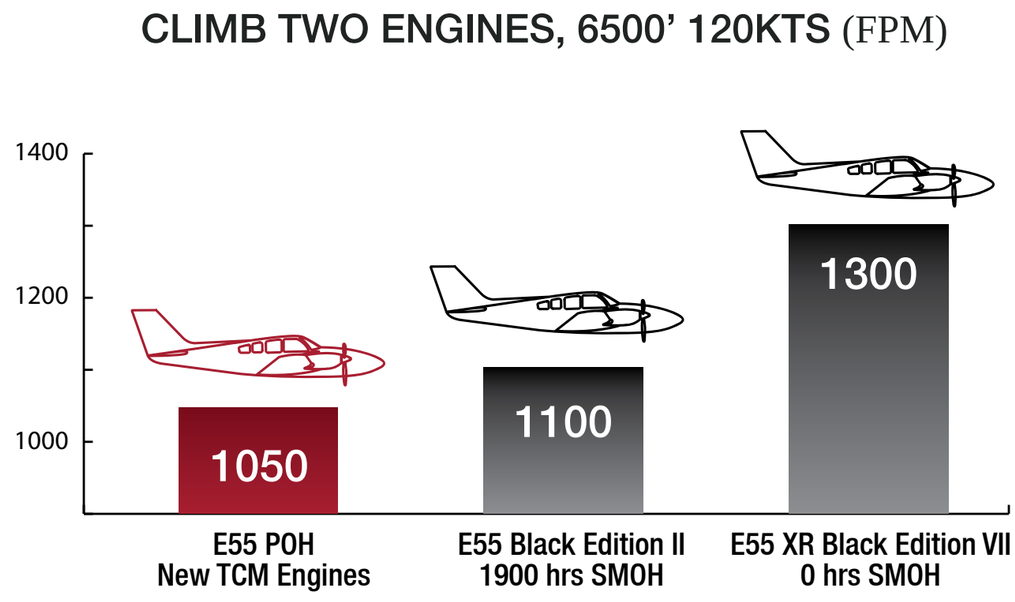




Here's A Quick Synopsis Of The Two Flights:

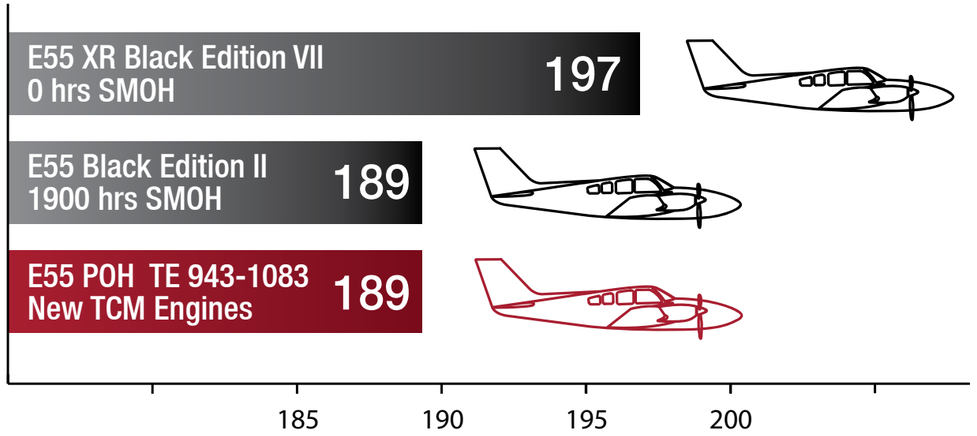
Initial climb was about 2200 fpm at the cryogenic–powered Baron's 101 knot Vy, slightly better than the over-TBO airplane's 2000 fpm. Using a cruise climb of 120 knots, this carried through to 1300 fpm at 6500 feet on the overhauled version, 1000 fpm on the engines over TBO. Similarly, there was a pronounced difference in single-engine climb.

With the left engine at zero thrust, the new cryogenic overhaul provided 500 fpm whereas the original, over-TBO Black Edition II engines managed more like 300 fpm. It was also notable that the 1900-hour Victor engines outperformed the Beechcraft POH for single engine and double engine climb performance.



Performance of the “Power-By-Victor” *Baron topped the stock Baron’s specifications on all tests.*

RECOMMENDED CRUISE POWER: 10000’, 2300 RPM (KTAS)

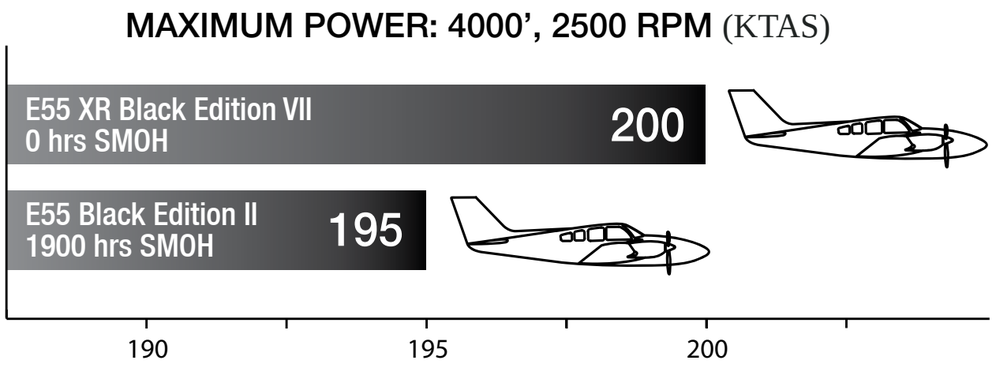


Results were even more impressive at cruise. Up at 10,000 feet with full throttle and the props dialed back to 2100 rpm, the “before” Baron turned in 143 knots IAS for 165 knots true. The “after” airplane realized 155 knots IAS for 176 knots true.

Descending to 8000 feet for some max cruise checks at 2300 rpm and full throttle, we saw 155 knots indicated for 177 knots true before the XR Black Edition VII overhaul, 174 knots IAS for 196 knots true after the cryogenic treatment. That’s a 19 knot improvement.

Another interesting aspect of the Baron’s improved performance was obvious when we compared it to Beech’s pilot handbook. At 10,000 feet with 2300 and 20 inches dialed in, the POH suggested I should have seen 158 knots indicated for 189 knots true. Instead, the cryogenic XR Black Edition VII engines increased performance to 165 knots indicated for 197 knots true. The speed improvement was all the more notable considering that Copeland’s Baron was fitted with vortex generators that normally subtract a few knots from cruise performance.

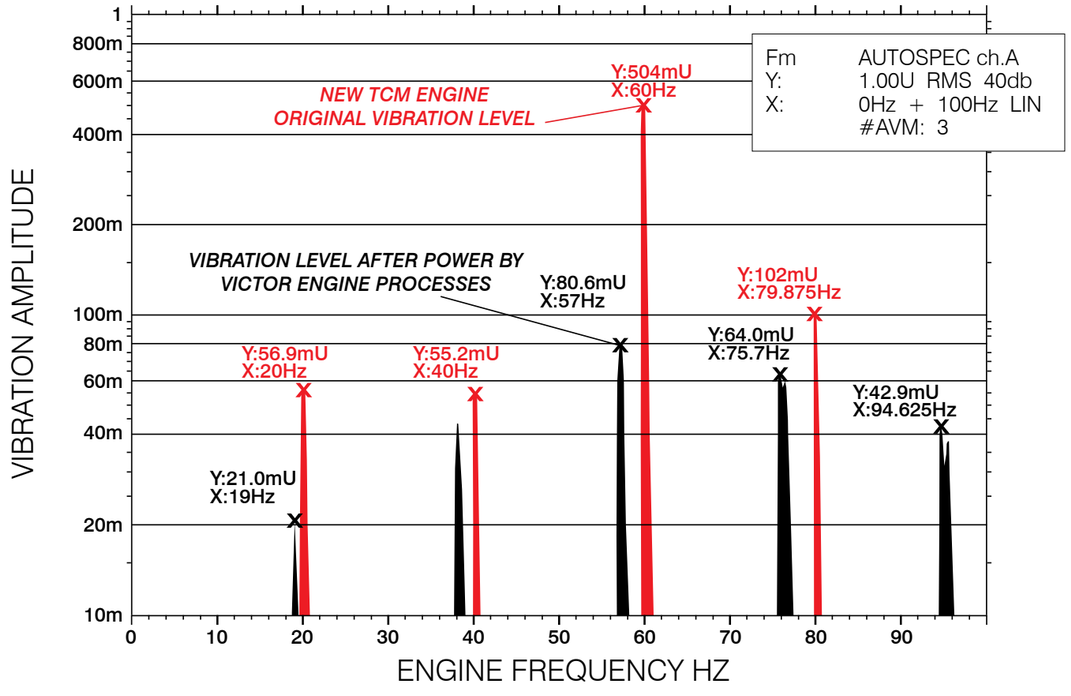
Throttled back to 2100 rpm and 21.5 inches at 8000 feet, book speed was advertised at 149 knots for 171 knots true. We saw 153 knots for 177 knots true. In short, the Baron scored well ahead of book in every parameter.



We also recorded fuel burn at 4,000 feet using full rich mixtures and full throttles. The initial flight test with the 1900-hour engines installed had produced 195 knots true airspeed. After the cryogenic series VII engines were installed the Baron delivered 200 knots true airspeed. We then reduced power by four inches manifold pressure to realize the same 195 knots true airspeed. The reduction in fuel burn was four gph per engine or eight gph total.

Pretty obviously, an engine that runs smoother and more efficiently burns less fuel to deliver the same power. Extrapolated over 1700 hrs to TBO, this could equate to fuel savings of $88,400 based upon using an average fuel cost of $6.50 per gallon. We’re well aware that Baron owners don’t normally fly at full throttles and 4000 feet, but the message is clear. Victor engines will pay for themselves over time.

Before engines are released *at Victor’s shop they go through extensive state-of-the-art vibration analysis testing and thrust load performance testing.*



A month following my "after" flight, Kenneth Copeland had his chance to fly his E55, and he was suitably enthusiastic but hardly surprised. "I hadn't flown this airplane for a while before the latest Victor overhauls, and when I saw the specs on the "old" parts he'd removed from the engines at 1900 hours, they were so close to optimum, I wouldn't have been reluctant to fly the airplane anywhere. For me, starting the engines was like shaking hands with an old friend that had suddenly become younger," Copeland commented.

"I've been trying to tell people for years about the reliability and power of Victor's engines, and even though I'm a preacher, people still don't believe me," Copeland laughs. "This is the third set of engines Victor has overhauled for me on this airplane, and the performance he promised has been very accurate."

Kenneth Copeland *of Kenneth Copeland Ministries in Ft. Worth, Texas is a highly experienced pilot with just about every flight rating available, including a Cessna Citation X type rating. "My E55 Baron with Victor's new cryogenic series VII engines plays a vital role in providing the fast, reliable transportation needs of our ministry," says Copeland.*

> *Put together a team such as Hoover, Crossfield, Bettenhausen and Copeland, combine their collective recommendation with Victor Aviation's new cryogenic XR Black Edition VII engine and you have formidable corroboration of the most technologically advanced piston engine in the industry.*