The green machine

GA industry research has produced a remarkably quiet and fuel-efficient light aircraft, as ***Pat Malone*** *reports*

This is the most environmentally-friendly light aircraft in the world, a machine which incorporates every modification possible to make it burn less fuel more cleanly while making less noise.

It is a research aircraft for Hjelmco Oil, the Swedish company responsible for the development and production of unleaded avgas, which was featured in the December issue of *General Aviation*. Not only can the plane use unleaded fuel but it's capable of burning fuel containing up to 30 percent ETBE, an ethanol-derived ether obtained from non-fossil fuel sources.

The four-bladed prop is an off-the-shelf Hoffman product and the silencer is an expensive but readily-available Liese model. The Lycoming engine requires no modification, and every mod on the aircraft has a Swedish STC, written in English and accepted by EASA. It should therefore be possible to put the aircraft and equipment on the G-register without let or hindrance from the CAA – in theory, anyway.

Hjelmco Oil's chairman Lars Hjelmberg spent 180 hours working on the STCs and has given them gratis to the Swedish company Labro, which intends to market the mods.

The aircraft is a standard Piper Cherokee 162 with a Lycoming O-320 D3 engine. Lars Hjelmberg bought it in 1989 with the intention of using it to test his company's unleaded 91/96 avgas, then in development. Later he determined to make it as environmentally-acceptable as possible, a decision which led to a continuing programme of experiment and improvement.

Hjelmco's research, and the fact that many Swedish aircraft have been modified in a similar way to the company's test aircraft, has been a significant factor in the Swedish government's decision to levy no duty or VAT on avgas – a situation which is now threatened by the European Commission's tax demands. If the EC's diktat prevails, further development of new fuels is likely to be unaffordable at this level.

Fuel

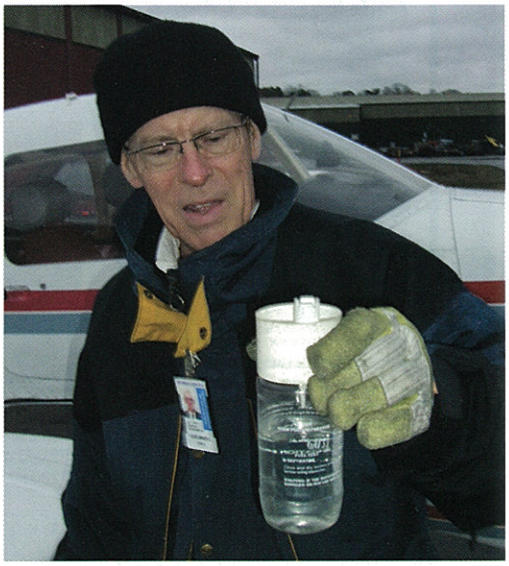
Lars chose the Cherokee because it had a 91/96 engine – although he had a wide range of options in making his choice. For the full story on the company's development of unleaded fuel see the December issue of *General Aviation*. Suffice it to say that it is approved for most light aircraft engines, including Lycomings of up to 180hp, the 235 and 260hp Lycoming O-540s, all Continental 100 and 145hp engines, and all Rotax engines. No engine modification is required, although a Textron-Lycoming approved oil additive is put in every 50 hours to help the oil stick to the metal. In Sweden, Hjelmco now has 70 percent of the avgas market.

Once the aircraft had been ferried to Sweden Lars had to find an instrumentation system that was accurate enough to make the sort of temperature, fuel flow and engine performance measurements he needed. "Avgas burns slower or faster depending on the components you put in it," Lars says. "Obviously if you start getting detonation you need to know exactly when and where it happened. The main point is that you have to be very accurate. We went to a company called Masten in the United States and created a bespoke system that gave us precise cylinder head temperature measurements on each cylinder, with exhaust gas temperature at the manifold and in the silencer. We have precise fuel flow measurement and digital oil temperature readout, together with digital engine RPM gauge."

The only evidence on the panel is the digital RPM gauge at top left, digital MAP (added later during prop experiments) at top right and the flight computer on the far left under the yoke, where the pilot can dial through all the parameters to see at a glance how the engine is performing, as well as fuel flow and remaining endurance to the minute.

"I'm glad I did it in 1989 rather than today," says Lars, "because such equipment would never now be certified by EASA, not without enormous cost. It was expensive to get everything to the STC stage in Sweden, but it was affordable."

During the testing process Lars had unleaded 91/96 in one wing and 100LL in the other, so comparison testing was just a matter of switching tanks. "It's important to make comparisons under conditions that are as near identical as possible," he says. "Over the course of half an hour the pressure changes, the humidity and the temperature change, but when you can test simply by switching tanks you can compare combustion with as much accuracy as is attainable."



Top: Lars Hjelmberg's Piper Cherokee, the world's most environmentally-friendly light aircraft
Above: Lars takes a fuel sample - and returns it to the tanks, of course
Left: wing-top fuel filler is placarded for both 100LL and unleaded 91/96

The unleaded 91/96 was introduced in 1991, and Hjelmco later ran a series of emissions test in conjunction with aviation authorities in Switzerland and Germany. They showed that the number of particles emitted was far lower, and that their mass was up to eight times less. 100LL particles are on average twice the size as those from 91/96 unleaded, and they are far greater in number – four times as many at low power, significantly more at high power. At some regimes of flight, notably a lean cruise setting, particle emissions from the unleaded fuel are negligible. This is largely a function of the cleanness of the fuel and the efficiency of the burn.

The downside is that when combustion is effectively too good, undesirable toxic

components called carbonyls are produced. Although there are only microscopic quantities of carbonyls, and the reduction in particles far outweighs the increase in carbonyls, it's worth minimising their production by not trying to achieve perfect combustion with clean fuels. A richer mixture can give you a less efficient fuel burn – leaning off can raise the temperature inside the cylinder by up to 100 degrees Fahrenheit.

Because of European moves towards the enforced incorporation of ethanol in fuels, Hjelmco has been researching biofuel additives. "Ethanol is useless in GA engines," says Lars. "It simply can't provide the energy and has many other problems. We have been working with an ether called ETBE which we have derived from ethanol, and which we have found can meet the requirements for aviation fuels. This Cherokee has been the test aircraft for that fuel, and we have been able to take the ETBE content up to 30 percent with no serious degradation of performance."

The American Society for Testing and

Materials Standards, which created the ASTM D910 standard to which avgas is produced, is preparing to investigate ETBE, and Lars Hjelmberg has been appointed chairman of the task force working on the project.

Noise

Having sorted the fuel, Lars decided to see just how environmentally-friendly he could make the aircraft, and began to address the issue of noise. "People around airports don't see if your fuel is clean, but they can hear noise," he says.

The three sources of noise from an aircraft are engine, propeller and airframe. Roughly speaking the prop accounts for perhaps half the noise, the engine and airframe a quarter each. There was little that could be done about the airframe – the Cherokee came with the 'speed kit' which included flush riveting.

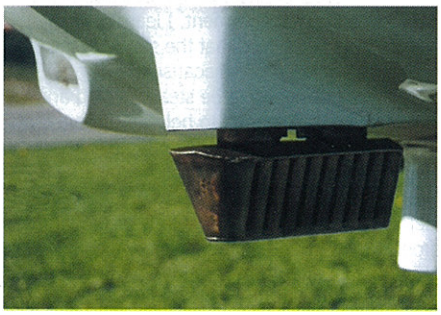
First they tested silencers. One was the Gomolzig – the German one with the long pipe beneath the aircraft. "We had problems on two counts," he says. "First, the metal blanked the transponder signal at some angles, and second, it exhausted directly beneath the pilot's seat where the aircraft metal is thinnest, and we had internal problems with noise and vibration. Better for the people outside, but bad for the pilot."

So they turned to the Liese silencer, which operates on a different principle. Also a German product, it has internal louvres which baffle some of the sound to the point where sound waves override and cancel each other out. No power required. With the Liese installed, engine noise was reduced by 65 percent, which equated to seven or eight decibels. As a component of overall noise, it meant a two decibel reduction.

The Liese is easy to attach to the exhaust pipe, it is small and weighs less than 1 lb, but it is expensive – made of titanium, it costs around £1500. It needs little looking after, although you must take it off every 50 hours and blow through it with an air hose to clear out metal particles from the exhaust which might otherwise burn and damage the silencer. Failure to do this has reduced silencer life on some Swedish aircraft to 500 or 700 hours, but Lars says: "I've had well over 1,000 hours out of this silencer and I've had no problems with it at all."

Then it was time to look at the prop. They removed the original two-bladed Sensenich and tried a number of alternatives, all four-bladed. While there is more drag on a four-bladed prop, making it less efficient, it dramatically reduces tip speeds, reducing noise by a substantial margin. Different diameters and pitches were tested in the hope of finding something that would give performance as close as possible to that of the Sensenich across the full speed range with far less noise. (Variable pitch was not an option because of engineering and certification difficulties).

The first model tested was a climb prop, but the pitch was too fine and the engine tended to overspeed. Normal range is 2200 to 2700 RPM, but with the climb prop on the engine operated at 2700 at 90kt. "It was good



in the climb, though," says Lars.

With a four-bladed Hoffman prop costing around £2,000 they obtained similar ground roll, take-off and cruise performance, with the RPM significantly different from those in the handbook, but well within the normal operating ranges. Lars says: "Typically, 2500 RPM in a Warrior is 75 percent power at 1,000 feet – that's max continuous. With this prop we get 75 percent at 2,425 RPM. That means you're getting that power output for a less noise. Furthermore, the diameter of the prop is 10cm less, therefore the tip speeds are lower, so you reduce noise there again."

The big surprise was that the prop gave the engine more power. Lars couldn't initially figure out where the free lunch was coming from – at the time the plane had no MAP gauge, and Textron Lycoming, who were following his experiments closely, suggested he fit one. He found that thanks to the natural turbo-charging effect of the new prop acting on the air intake, he was getting fully 1.8 inches more manifold pressure than without the Hoffman. Lars says: "This means we can maintain 75 percent power up to 10,000 feet. I can throttle back, lean off and it gives me lower fuel consumption. I can get 100 knots at 12,000 feet and be using 19 litres per hour – less than a Cessna 150 – where I was probably using 32 litres before."

Everything has a downside, and with the Hoffman prop they found that at low speed some parts of the blades are stalled, making it less efficient. During the take-off roll it appears to accelerate slightly more slowly through the first third, then once it gets above about 50 knots it accelerates more quickly. Tests show that despite the initial sluggishness it beats the Sensenich over a 50-foot obstacle.

However, you have to fly by the numbers because you can get off the ground when the prop is still relatively inefficient and find that it won't accelerate you out of ground effect, so you're hanging on the prop until either the earth curves out of your way or you put it in the hedge.

It's a composite prop and it wears differently from a metal one – you have to clean it regularly, but it's more easy to repair than aluminium and has the advantage that if you ding it, it won't shock-load the engine, it'll just shatter. Obviously it's not subject to metal fatigue, and it has no TBO.

The reduction in noise is impressive. Internally, I found it possible to conduct a conversation in normal tones without headsets, even in the climb – there's no additional soundproofing in the airframe. The engine itself has an almost electric quality, while the prop

Far left: four-bladed Hoffman is remarkably quiet and gives the Lycoming an extra 1.8 inches of manifold pressure
Left: digital MAP gauge was added during prop tests
Below left: Liese silencer weighs only one pound
Below right: STC is written in English

makes a bit of a din at full power when you're standing five yards from it, but it has none of the unpleasant rasping edge you get from a normal prop. Overall, the reduction in noise totals around seven-eight decibels.

Will we see aircraft like this in the UK? Many flying clubs won't move until the knife is at their throats because no noise complainant will recognise that you have taken pre-emptive action, or give you credit for it – they will always complain. Furthermore we have the problem of the CAA, which will certainly find a way of making certification an issue – and down at the Belgrano, where fleas are weighed on scales designed for elephants, that means prohibitive expense. ■