TAILORED MAINTENANCE SCHEDULES

It's vital to check, and check again, as one problem can often lead to another

The NSI aircraft engine is based upon the EA-81 Subaru car engine. This liquid-cooled, horizontally-opposed, four-cylinder injected engine is fitted with a purpose built geared reduction drive system that has proven to be problematic. This example is fitted to LAA Inspector David Hunter's Cvjetkovic CA-65 which, incidentally, was started in 1974 and may win a prize for the LAA's longest build. Note the alternator mounted at the top of the engine *(see arrow)* which is belt driven. David has collected most of the UK's NSI spares and is a fount of knowledge about the type. *(Photo: Malcolm McBride)*

I remember once, in a lonely psychology lecture, being taught about a theory, which went by the rather low-tech name of 'Hassles and Uplifts'. As I remember it, the creator of the theory had thought up some sort of index against which a list of small daily difficulties could be scored. The theory (as far as it could be counted as such) assumed that small, virtually unnoticeable failure events (hassles) could be scored and that the individual's cumulative score should give an indication of the level of stress they were suffering. Looking back, it amazes me that I actually paid real money to do this course.

The course, compulsory for other reasons, was lonely because I was the only male student, which naturally introduced a certain 'standing' stress level. The male lecturer, who was a smashing sort of chap, also suffered rather from this excess of femininity; he, sadly, had a benign (but inoperable) brain tumour that increased in size as his blood pressure rose. His level of consciousness was inversely proportional to his mean blood pressure. In other words, when he got excited he completely forgot where (and probably who) he was. I recall him staring, zombie like, into an imagined place beyond the classroom walls. It must, however, have been quite a good place, as his blood pressure soon dropped again, evident by his return... sometimes he wasn't aware that he had been anywhere.

I was never quite sure whether having one hassle event increases the chances of having another one. I suppose this could be described as 'horrible feedback' and, anecdotally, is exactly what seems to happen to me. Certainly things seem to fall to bits in waves, but there often seems to be no common ground between the individual failure events. Why, for example, would the heater in the bathroom fail in the morning and in the afternoon, the handle on the head separate from the pump's plunger on a boat over a hundred miles away? What secret force is at play that, after dealing with two consecutive failures, I should then be faced with a flat battery on the car? Naturally, there is one common denominator that cannot be ignored. Me. When I think about it, hassle accumulation, horrible feedback, they're all theories. Fact – if you don't do regular maintenance, things break!

With regard to my recent failure events (and, yes, there were others) none of them were that critical in the scheme of things. A new heater for the bathroom, a new battery for the car... easy fixes. Even the potential possibility of a flooded boat was averted by a bit of quick thinking and the rapid re-drilling/tapping of the plunger attachment. The issue with maintenance on aircraft is often that any failure, even very small ones, can lead to disaster. A blocked filter (the reason for the overheating of the bathroom heater) in an aeroplane could lead to an engine failure and a field landing, as could a battery failure. I dread to think what might happen if a primary attachment failed because a loose bolt wasn't discovered and replaced or repaired.

Over the last few years, we at LAA Engineering HQ have been giving a great deal of thought to the most suitable way of managing a Permit aircraft's maintenance requirements. We don't think that a 'one size fits all' approach is a sensible way to manage the requirements of the LAA's diverse fleet of aircraft. None of our aircraft are operated commercially and generally their annual flying time is low. The great problem is that, historically, maintenance schedules have been based primarily on hours flown and check cycles are often geared to engine hours. The *Light Aircraft Maintenance Schedule (LAMS)*, which forms the basis for most light aircraft manufacturers' schedules, was primarily designed around the hours flown by aircraft operating in the flying schools and with light commercial operations. In these operations, 'normal' usage would probably amount to at least 50 hours a month, which fits neatly into the engine oil/filter change cycle and so the Check 1 (50hr)/Check 2 (100hr) maintenance check was born. The Check 1 was a thorough (panel on) check – brakes and tyres, oil and filter change. The Check 2 required the aircraft to be put onto jacks and have all the panels removed. This was and is quite a big check in the scheme of things and pretty much all of the airframe would be inspected. Plus, in addition to a complete visual check of the engine, the sparking plugs would be removed, pressure checked and gapped and the ignition system checked and re-timed. It would be normal practice during the 100hr check to carry out a compression check on the engine.

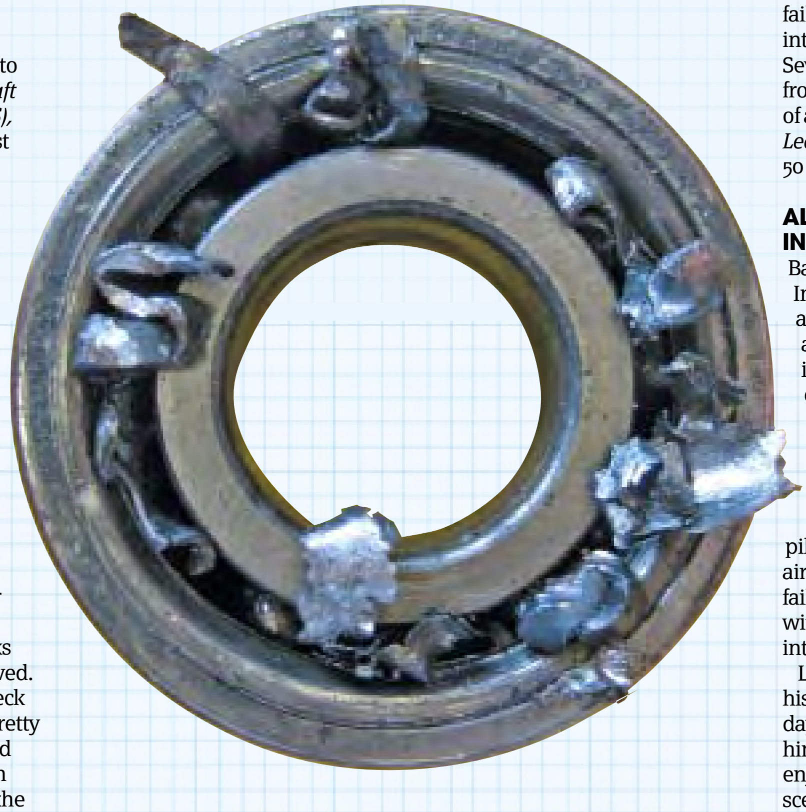
You can see the inspection issues presented by an aircraft doing an annual average of 30 hours (or less). Simple arithmetic will tell you that a full Check 2 wouldn't be due until sometime in the fourth year of operation and clearly for any aircraft, this is simply not enough checking!

To solve this issue in a way that hopefully understands and takes account of the fact that each aircraft is an individual machine operated in an individual way, the LAA is developing the concept of the tailored maintenance schedule. We envisage that this schedule will be based upon the LAA's recently published *Generic Maintenance Schedule* and include specific items required by the aircraft's manufacturer. Over time we will expect each aircraft to have its own Maintenance Schedule, which will be created and then followed by the aircraft's owner. Naturally, each check item on the schedule will need to be carefully thought through, but the schedule in itself needn't be overly complex or burdensome. As an example, I will take you through the decision process I might make if I were operating a simple type and I only do about 15 hours a year; there are quite a few LAA machines operating in this zone.

> "The issue with maintenance on aircraft is often that any failures, even very small ones, can lead to disaster"

Let's say that the only maintenance check I carry out is at the Annual. We'll take oil/filter change as an example. The engine on my imaginary machine is getting old and is running 'on condition'. I certainly think that it would be wise to change the oil filter during the annual check, not because I think that the filter's operation is likely to be compromised in any way, but because I think I would like to check that there is no metal showing in the element, which might mean it's time to do an overhaul. The oil itself though should be good for between 50 and 100 hours. Mmm, I need to think about that. My decision would probably be that I would change the oil every three years; this would be a good compromise between its useful operational life and the degrading effects of time. Personally, I think that I would complete a big (100hr) equivalent at least every three years, even though the aircraft had not officially reached even a Check 1.

The creation of an individual, customised maintenance schedule will require the owners of LAA machines to seriously think about the maintenance of their aircraft. This can only be a good thing. Naturally, no schedule needs to be set in stone, that would rather defeat the object and as specific technical issues come to light, these can also be included. LAA member Gary McKirdy had an incident some time ago when the failure of the alternator put him into a difficult situation over the Severn Estuary. Lessons learnt from this failure led to the issue of an *Airworthiness Information Leaflet (AIL)* requiring checks every 50 hours.



You can see that this alternator bearing is way past its sell-by date. The AAIB investigators felt that the bearing failed due to lack of lubrication; it looks like the first component to fail was the bearing's cage, which rapidly led to a complete seizure. Interestingly, the seizure of the alternator was enough to drag the engine to a complete stop. Naturally enough, the heat generated by the frictional forces between the belt and the pulley created a fair amount of smoke which exacerbated the problems in the cockpit. Because the NSI reduction system employs an unusual sprag type drive gear in the reduction drive, the propeller can freewheel after the engine stops. It was noted that a freewheeling propeller creates far more form drag than a static (or slowly rotating) one which can lead to alarmingly high descent rates. *(Photo: Malcolm McBride)*

ALTERNATOR FAILURE IN NSI EA-81 ENGINE

Back in 2007, the Air Accidents Investigation Branch investigated a crash involving a Europa aircraft. As a result of their investigations, they made a couple of recommendations. One was to up the engine inspection regime; this was done by issuing an AIL. The other recommendation was about offering advice to pilots about the performance of aircraft after suffering an engine failure when they were fitted with a freewheeling propeller – intrigued? Read on...

LAAer Gary McKirdy was flying his Europa with a friend one July day in 2006. A friend accompanied him and by all accounts they were enjoying the North Somerset scenery from their lofty seats situated at 3,500ft. Gary had recently completed a complete rebuild of the airframe following a previous accident and this was one of the aircraft's first flights following repair.

The first sign of trouble was the appearance of smoke in the cockpit. This was followed by a burning smell. The aircraft yawed and the nose dropped and although the propeller was ➧

With Malcolm McBride
Airworthiness Engineer

still rotating due to the type of reduction drive used on the engine, Gary noticed that the engine had stopped.

Gary is an experienced glider pilot and under normal circumstances, he wouldn't have been fazed by an engine-out with plenty of height below him. There were two aspects to this particular situation though that he wasn't happy with. The first we have mentioned, smoke. The other was that Gary noticed that the elevator response was severely reduced; I think that you would agree that the potential for fire coupled with a flight control reduction would be considered a scary moment for any pilot, regardless of experience.

Gary checked that he was below Vf (flap limiting speed) and dropped the gear. I can hear your mind whirring… remember, the Europa's flaps automatically deploy when the single undercarriage wheel is lowered. He then did the usual forced landing checks: mags, master switch, fuel all off. The smoke had now cleared but he couldn't get to grips with the extremely high descent rate, which he later estimated to be over 2,000ft per minute!

Naturally, field choice was limited but Gary managed to line up into a small 290 metre field; a little fast and worrying about hitting the far hedge, he decided to raise the gear and belly flop the aircraft, hoping to reduce the run on. The tips of the still freewheeling propeller hit the ground and the blades broke off. The aircraft hit the far hedge at quite a lick and was seriously damaged. The cockpit remained intact and Gary and his friend exited the aircraft through the doors, thankfully with only minor injuries.

An old saying, on this occasion without the magic ring of truth is, 'There's no smoke without fire'. A subsequent inspection of the engine revealed that the cause of the engine failure was that the main bearing in the alternator had failed catastrophically and, as a consequence, had seized. The smoke had come from the alternator drive belts (which hadn't broken), the resulting friction dragging the engine to a standstill. I don't blame Gary one bit for his decision to get the nose down and get on the ground quickly; smoke in the cockpit would have a similar effect upon me. But with hindsight, the outcome may have been better if a more measured approach had been taken.

The AAIB later commentated that the fact that the Subaru is fitted with twin alternator belts, a design feature that introduced some system redundancy, may actually not be an altogether good idea.

Let's take a look at the technical aspects of this event. As we do so, it would be worth thinking about whether the lessons learnt in this failure could affect the Maintenance Schedule for your aircraft. The engine fitted to this Europa was the NSI Propulsion Systems EA-81. Although there were a fair number of these Subaru conversions initially fitted to UK Europas, most have now been/are in the process of being re-engined. There are two LAA Europas still flying with the NSI units. As far as I am aware, the only other LAA machine fitted with this engine is LAA inspector David Hunter's Cvjetkovic CA-65, although this aircraft hasn't flown yet.

Personally, I like the EA-81 engine. It's a little heavy for its power but the flat four configuration makes for a neat front of firewall fit. The problems with the NSI conversion seem to have been centred on the reduction drive that had a history of failure in service. One of the product's Unique Selling Points of this conversion was the unusual torsional vibration damper, called by NSI the Linear Cam Device (LCD), which claimed to remove the need for rubber damping between the crankshaft and the propeller. This device was actually a sprag clutch, similar to those found in helicopter rotor head assemblies. In the helicopter, this device disconnects the rotor from the engine should the engine RPM drop below the resulting geared RPM of the rotor. In other words, the blades are able to freewheel and therefore auto-rotate in the event of an engine failure.

This freewheeling action wasn't the purpose of NSI's LCD, but if the engine RPM is allowed to drop below about 1,500rpm, it is the result. At high engine RPMs, the propeller is directly coupled to the engine through the gearbox and the engine/prop combination behaves completely conventionally. At low engine RPMs, the cams in the LCD free and the naturally pulsating torsion force, generated at each cylinder firing and transmitted through the crankshaft, is smoothed out. Under normal operation the propeller would generate the usual braking effect during a power reduction. If the engine failed however, the propeller would be de-coupled from the engine and would be able to freewheel, just like the helicopter rotor head during an auto-rotation.

It is probably clear to the reader that the resultant RPM of the propeller will be proportional to airspeed and that, as the propeller RPM is increased, so will the effective disc area and therefore drag. Bear in mind that the propeller disc area presented by the 64in Warp Drive propeller is likely to be about 22 square feet worth of profile drag – that's a pretty big air-brake! You can see why there was both a very high descent rate and a reduction in elevator authority. Both these effects would have been mitigated if, immediately following the engine failure, the speed had been reduced to minimum sink. Although, in this case, the smoke entering the cockpit would have thrown a spanner in the decision-making works.

I was taught the 'currency rule' when it came to engine failures – either real or simulated; 'You've either got money in the pocket (speed) or money in the bank (height)'. The primary requirement, just after the engine failure, is really thinking time. To get this you need initially to trade speed for height, then get the aircraft's descent rate down to the lowest possible value. This speed will be minimum sink. When you've sorted out where the wind's coming from and selected a field, then you would be better off going for range and this speed will almost certainly be a little higher. Early on during the 'get to know you' phase in the relationship between the pilot and his aircraft, the performance he/she can expect at these two speeds should be established.

After Gary's incident, we asked LAA Pilot Coach Will Greenwood to simulate the event on a similarly equipped Europa. Will said that the descent was indeed spectacular, probably about 2,000fpm with both the gear and flaps down. I asked Andy Draper, the LAA's Europa guru, what he thought the sink rate under these circumstances would be with a conventional power unit. He thought that 700 to 800fpm would not be unreasonable, primarily because of the Europa's big flaps. I would bet you could easily halve this (and double your thinking time) with a clean airframe being flown at a lower speed.

I spoke to Gary about his decision to pull the undercarriage up just before landing and he explained that he felt that this didn't really reduce the landing run; in fact it may have extended it a bit. In the Europa, as opposed to a conventional glider, when you pull up the gear you also get rid of the braking action of the flaps. When you add the fact that propeller braking was lost because it disintegrated when the tips hit the ground, I can appreciate his point.

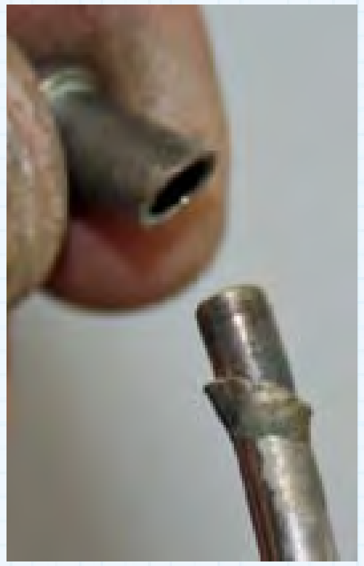
To summarise, I think that the following lessons should be learnt from this unfortunate incident. Firstly, maintenance scheduling. This is always a difficult call with an LAA aircraft. In this case the bearing failed through lack of lubrication. Because there was no specific service history for the alternator, it is impossible to establish the hours it had run. The total airframe/engine hours on the subject aircraft was recorded as 76 – not even to Check 1, although the aircraft was nearly ten years old! Another general lesson that may be taken from this incident is that because the airframe had undergone a lengthy repair, the engine had been sat about doing nothing for quite some time. Whether this contributed to the bearing failure itself will never be known, but it is certainly worth considering limiting the duration of early flights after a long lay-up for any reason.

As previously stated, the alternator fitted to the NSI Subaru engine is now required to be checked each 50 hours, but when did you last check the bearings in your alternator? Does it even figure in your maintenance schedule? If it doesn't, perhaps it should.

The second lesson that rings out loud is that it is very important to establish the actual performance in the glide of the aircraft that you're flying. Know your minimum sink speed and the speed at which you'll get best L/D, and practise this. OK, the NSI's freewheeling propeller is an unusual feature, but when you think about it, all aircraft have their own unique selling points – in this case the aircraft comes down pretty rapidly when you stick the nose down. If there really was a fire, that might be quite a good thing!

INJECTOR PIPE FAILURE SUPERIOR XP IO-360 A1A2

Many thanks to LAA Inspector Roy Sears for sending me the photo of the broken fuel delivery pipe end fitting found at the fuel injector nozzle connection on



This failed IO-360 fuel injector pipe was found on a Lycoming engine… it was a Superior IO-360. Lycoming's *Mandatory SB 342F* describes checks for staining, dents, pits or nicks on these injector pipes each 100 hours. This failure was found by accident on a 300-hour powerplant. When designing a maintenance schedule on LAA types, which may include uncertified/unregulated components, it is necessary to think outside the box when deciding what (and when) things need checking. Factory advice may be very limited, but lessons from the past shouldn't be ignored just because of lack of a legal applicability chain. *(Photo: Roy Sears)*

an IO-360 fitted to a Van's RV-7. Very graciously, Roy gave all the credit for this excellent SPOT to the aircraft's owner/builder Mark Elliot, so very well done to him. I spoke to Mark to ask him what it was that led to this discovery… I was wondering whether the 2010 Lycoming SB (No. 342F), which requires checks on these stainless steel fuel lines each 100 hours, had prompted him to have a closer look. He explained that he had never heard of the bulletin, which is fair enough as this, officially at least, isn't a Lycoming engine.

Mark has created a Maintenance Schedule that requires him to conduct a 25hr check cycle (a good idea on fairly low-usage machines in my view) and during this check, he always gives everything a good tug (another good idea). It was during one of his 25hr checks that he felt some looseness at the injector connection and took things apart to investigate.

I enjoyed my conversation with Mark, a seasoned builder who has previously built a Taylor Monoplane and a Pietenpol Air Camper, the latter having (rather coincidentally) the first Subaru engine fit. Mark, who had completed his RV-7 from a quick-build kit in 2007, explained that the end fitting had failed at 170 hours, some five years after original fit.

This SPOT highlights the difficulties in establishing what actual inspection requirements to use when designing a maintenance schedule. Mark's approach to check everything is a good one, but wouldn't necessarily find a problem hidden from view. This particular issue was known about by the original engine manufacturer who has issued *Factory Service Bulletins* directed at their original owners. The Superior engine is the same in many ways as the engine that it's based upon, the Lycoming, but many of the models are only available to the experimental market. These, quite often being built to customer specifications, may contain unusual ignition or fuel systems or even major structure changes, for example specialist barrels.

The Lycoming SB that covers checks on these fuel injector pipes came about because there had been instances of support clamps being omitted after service or repair; when you think about it an injector pipe on an engine is an injector pipe on an engine… it shouldn't matter really who built it, previous service experience still applies if. The biggest problem can be laying your hands on the information.

FUEL LEAK IN RV-7A

Mark Elliot's experience with the failure of the flared fitting was unusual in that there was no obvious fuel leak; this is especially true when you bear in mind that this part of the fuel system is operating at high pressure. LAA Inspector Tony Troughton's experience was slightly different when he was asked to investigate a persistent fuel smell in the cockpit by the new owner of an RV-7A, as there was a clear blue stain around the fuel tank outlet fitting.

Tony drained the tank and unscrewed the AN fitting and, honest guv, it just came off in his hands. What appears to have happened is that the builder wasn't sure about how this particular type of AN fitting

LAA inspector Tony Troughton sent me these two pictures showing what he discovered while searching for the source of a cockpit fuel smell. For some reason (not discovered), the fitting was made without a flare and was able to be pulled out without much trouble, hence the leak! The smaller picture shows a correctly made connection (which includes the flare at the end of the pipe). As a aside, I hope that you can see the blue staining on the pipe in the picture on the left. This is a dye added to aviation fuel. I couldn't remember whether this dye was added to the fuel so that leaks could be more easily seen or for fuel identification purposes. Both Ken Craigie and Barry Plumb put me right on the matter – it's the latter. Thanks to Barry for the acres of literature he's just sent me on the subject! *(Photo: Tony Troughton)*

Trevor Villa, BMAA Inspector and LAA member, sent me this picture of a lift strut/wing connection on a Jabiru UL he was asked to inspect. You can see clearly that the corrosion has become established in this fitting and may be beyond recovery. *(Photo: Trevor Villa)*

worked and had failed to flare the end of the pipe during the assembly. He or she had pushed the end of the pipe into the fitting and secured it with plumber's tape and it was glued in place with a fairly liberal dose of bathroom sealant. Mmm, not quite the method described in AC 43 or CAIPS.

This particular RV-7A had done over 300 hours since its original build back in 2006 and the leak hadn't been spotted during the previous four annual inspections, which is rather worrying. Tony decided to do a complete review of the fuel system and all the other connections were correctly made. Personally, I think that the correct mindset to adopt when going through an annual inspection is the 'never take anything for granted' one. Well done Tony, good SPOT.

LIFT STRUT CORROSION ON JABIRU UL

A while ago I was accosted in the office by LAA inspector (and Jabiru engine expert) Gary Cotterell, with an unexpected but

»

welcome surprise. Gary had just flown in to Turweston to have some breakfast en route to an on-site inspection – I know, it's tough at the top! Anyway, Gary fished around in the pocket of his flying suit and retrieved a lump of machined alloy that looked remarkably like a Jabiru strut-end fitting. I have recently received quite a few pictures from members who are concerned about the amount of corrosion they're finding on Jabiru fittings, so I have included one or two pictures for you to study.

"It's spiders," exclaimed Gary, pointing at the pretty bad case of corrosion in the strut end fitting. Now, when an LAA inspector declares the reason for some or other failure, however weird, I've learnt to hear them out. Sometimes it's even worth counting to ten before commenting. In this case, I was having a problem keeping a straight face. "I'm telling you," he continued, "whenever I see corrosion like this, there's evidence of spiders." I looked around at my bookcase. I've got a book about arachnids somewhere… now where? "I think that it could be the eggs, maybe they're acidic or something?"

I suggested, hoping to add some science to the exchange, that it's possible that acid could act as an electrolyte but, quite frankly, I was beginning to wonder whether the cold weather had affected Gary slightly. It's quite a distance from Norfolk.

"Don't be stupid!" Gary's face changed to a broad grin. "Chaps aren't taking their panels off so the spiders feel safe, you can always tell when panels have been off."

Fair winds! ■

Here's a picture of some light corrosion on a Jabiru strut after the paint had been removed. The owner noticed that the paint was chipping away from the surface and decided to investigate why. This sort of surface corrosion must be removed quickly and the surface re-protected. This strut is a highly-stressed structural member on this aircraft type and will be subject to stress corrosion cracking. It is well known that cracks can start at corrosion pits in the surface of a material and can lead to structure failure. *(Photo: Winston Lee)*

Here's a picture of an aileron turnbuckle sent to us by an LAA Inspector recently; he was worried that maintenance standards were slipping. I suppose, after a fashion, the wire-locking would work but I think that I would be hard pressed to score it for 'artistic merit'! Personally, I'm a bit more concerned about the other errors in this primary control cable attachment. Without pressing the corrosion point too hard, and let's not even think about the blobs of weld, this turnbuckle is not in safety as threads are showing. Perhaps that's the reason for the extra wraps of lock wire… just in case the screw pulls out of the barrel! *(Photo: LAA Library)*

This is the strut end fitting brought into the office by LAA inspector Gary Cotterell. You can, I hope, see that this end fitting is a write off. Corrosion like this is essentially an electrical process and electrons tend to discover a line of least resistance – this is why only one area of the strut is badly affected. Note that the corrosion products have actually been removed by bead blasting, which clearly shows how much material has been lost. The corrosion here is unacceptable not just because material, and therefore strength, has been lost but in some ways more importantly, each portion of corrosion can act as a stress raiser and may lead to local cracking and component failure. *(Photo: Malcolm McBride)*

LAA ENGINEERING SCALE OF CHARGES

LAA Project Registration	
Kit Built Aircraft	£300
Plans Built Aircraft	£50
Issue of a Permit to Test Fly	
Non-LAA approved design only	£40
Initial Permit issue	
Up to 390kg	£320
391 - 499kg	£425
500kg and above	£565
Three seats and above	£630
Permit renewal	
Up to 390kg	£105
391 - 499kg	£140
500kg and above	£190
Three seats and above	£210
Modification application	
Prototype modification	£45
Repeat modification	£22.50
Transfer	
(from CofA to Permit or CAA Permit to LAA Permit)	
Up to 499kg	£135
500 kg and above	£250
Three seats and above	£350
Four-seat aircraft	
Manufacturer's/agent's type acceptance fee	£2,000
Project registration royalty	£50
Category change	
Group A to microlight	£135
Microlight to Group A	£135
Change of G-Registration fee	
Issue of Permit Documents following G-Reg change	£45
Replacement Documents	
Lost, stolen etc (fee is per document)	£20
Latest SPARS - April 2009	