With Malcolm McBride
Airworthiness Engineer

FUEL PUMPS, CARB RUBBERS AND FILTERS

Disparate issues this month, though they are all related to the tricky subject of inspections and maintenance

Welcome, as always, to this September edition of Safety Spot. The nights grow longer and the days? Well, as I write this it is actually rather cold for August and I might have just seen a spot of rain, though the coming weekend is forecast fine as an Atlantic high pressure is due to drift across our island. Let's hope that it remains in place for the LAA Rally. By the time you read this, I expect you'll know whether it has!

This month's Safety Spot is thanks to all of you who have kindly contributed your stories and pictures. I try to collate then into themes as you know but, as you peruse the images, you'll detect a rather disparate bunch of subjects in this edition. Though a bit of a mish-mash of issues, if there is a central theme to it, I think the fuel pump sits close, though within them all is the tricky subject of inspection and maintenance. They all have a lesson embedded within to share.

Before we get into the fuel pump stories it would be worth spending a couple of minutes thinking about the lessons to learn from unrelated pictures. Three sports flyers, Tom, Nick and Leo, have come across real problems in the field, but thanks to a healthy dose of good fortune, none of the issues led to a reportable accident.

LAA inspector (and LAA Board member) Jim McKenna and a couple of pals operate a Cessna 172 and though not an LAA Permit machine, Jim sent this picture showing a failed exhaust which, after checking just about everything else, was found to be the cause of a severe low rpm engine vibration. Jim comments: "The left can supplies the carburettor heat on this installation and although heat was available its effectiveness could not be determined. Towards the later stages of failure it was evident that CO contamination was a potential safety threat." Of course the other great worry with exhaust system failures like this is the obvious fire hazard.
The engine installation on a 172, like many aircraft these days, is difficult to inspect fully during a pre-flight inspection so it is essential that your Tailored Maintenance Schedule builds-in regular 'cowls off' inspections so that early signs of this type of failure can be spotted and problems rectified before they become life-threatening. *(Photo: Jim McKenna)*

Cumbrian Jabiru J400 flyer, Tom Pullin, sent us this picture showing a 'good' oil filter (on the right) and a bad filter (shown left). Tom explained that his aircraft got covered with oil during a post-maintenance ground run because the oil filter wasn't sealing correctly. Initially he thought that the threads had been cut at an incorrect angle and the filter wasn't seating as it should but, on further inspection, he saw that the flange which connects the base to the bowl was faulty. *(Photo: Thomas Pullin)*

DUFF FILTER

Take a look at Tom Pullin's picture of a badly-made oil filter. After doing an oil and filter change, Tom did a ground run, brought the engine up to operating temperature and then removed the engine cowls of his Jabiru J400 to check all was well within. Because he took the trouble to do this he spotted the oil leak. Had he gone flying without doing this it is very likely that the engine would have run out of oil and seized. Tom was pretty annoyed that he'd been sent a duff oil filter but, because of good engineering practice, the actual cost, a bit of time cleaning up and a few litres of oil, was relatively low.

ROTTEN RUBBERS

BMAA flyer, Nick Brownlow, flies a Skyranger 912S from Sturgate airfield near Lincoln. Luckily, Sturgate has an 820 metre runway so, when his engine started to misbehave badly during take-off, he had plenty of room to land straight ahead.

When he opened the cowling everything looked OK so he naturally began a fault-finding exercise. Engine fitters, an eclectic bunch, might tell you that, "If you're getting compression, and you're getting fuel and there's a spark firing off at the right time, the engine should work." Nick was beginning to lose faith in this maxim when, after changing the CDI and spark leads with no improvement, he decided to check the fuel side of the bargain.

Thinking that the rough running might be because a jet was blocked, he started to remove the carburettor and set about undoing the attachments. Low and behold, halfway through this exercise, the carburettor fell off. "Honest guv, it came off in me 'ands."

Having established the fault, he set about replacing the attachment rubbers. Nick commented that he'd replaced these rubbers two years ago and that they've only flown 65 hours. The UK Rotax agent, CFS, agreed and replaced these obviously defective mountings free of charge, so well done to them.

BEND IT, SHAPE IT

Staying on carburettor mount rubbers, ubiquitous on microlight-based engine designs, Devon LAA'er Leo Collier sent in a picture of a failed rubber from his Jabiru 2200 engine quite some time ago, but I never got around to using the picture. I've checked the database and Leo still flies his Echo. Leo, in his accompanying email wrote:

"Dear Malcolm, I think that the important requirement to inspect induction system should emphasise that to inspect them properly you have to take the rubber fitting off the engine.

"To inspect the rubber you need to bend it to make sure it's still flexible; only then can you see cracks in the rubber. I would not have thought about doing this, had this not been pointed out to me by Roger up in Norfolk during an engine service!"

LAA Inspector and Jabiru engine specialist Roger Lewis, who used to be the Jabiru engine's UK agent, has moved on now and lives in France, rather dating Leo's email, but his advice still holds good. I spoke to Leo who explained that he checks these rubbers carefully every 50 flying hours as part of his Tailored Maintenance Schedule (see photo below).

So, to fuel pumps. I have three pump failures to discuss, two fortunately occurring on the ground and one resulting in a field landing. The first tale concerns a Schools Build-a-Plane Rans S6 built under the watchful eye of midlands engineer, Graham Elvis. ›

BMAA Flyer, Nick Brownlow, kindly sent us these pictures of a failed Rotax 912 carburettor attachment fitting. As you can see, the metal attaching plate is, or at least should be, bonded onto the formed rubber sleeve that attaches the carburettor; as evidenced from the corrosion on the metal plate, this fitting has been failed for some time. This type of failure has occurred before on 912 engine installations and Rotax have had several goes at improving the component over the years. *(Photo Nick Brownlow)*

Tecnam P92 Echo flyer, Leo Collier, sent us this picture of a carburettor attachment rubber that has failed. Leo's P92 is powered by a Jabiru 2200 engine and a hole in the rubber like this is very difficult to spot without removing the rubber itself. Because of the reduced manifold pressure at this point in the induction system, fresh air can enter the manifold through the hole, weakening the mixture and causing loss of power and, under some circumstances, higher than normal running temperatures. Had this been on a two-stroke engine it would probably have caused an engine seizure. A tell-tale symptom for this kind of problem that's worth remembering is an increased idle rpm. *(Photo Leo Collier)*

RANS S6E – JABIRU FUEL PUMP FAILURE

Graham is a regular attendee of the lectures held at Cosford and, as he explained during a recent telephone chat, about five years ago, after a lecture given by the Royal Aeronautical Society, a call for volunteers was made to help with the RAeS' Schools Build-a-Plane project.

Graham, a member of the Wolverhampton and Birmingham RAeS branch, has been a 'supervisor' with the project ever since. Their first aircraft, the subject of this story, was nationally number three to fly in this laudable Boeing-sponsored initiative. If you get the opportunity, pop over to their aircraft outside the LAA 70 Marquee at the Rally and shake their hands.

The idea of the Schools Build-a-Plane project is to offer children the opportunity to get hands-on experience working with tools on a real project. When each aircraft finally achieves its full Permit to Fly, the children get the chance, if they want to – and who wouldn't? – to fly in an aircraft they helped to build. The aircraft is then sold to finance the next project for a new group of children.

You will of course know that all new-builds go through a rigorous test programme before getting their full Permit and, during the ground running phase of this aircraft, any small snags are detected and rectified. This is normal and, perhaps, re-emphasises the importance of full engine ground-run checks after any engineering work on the engine or its associated systems. The snag that was possibly related to the eventual failure of the pump was listed in the worksheets thus:

"Oil leaked from the pump flange on the first engine run – one of the two screws was not clamping the flange due to "bottoming out". We cleaned out the female thread in the block and all was well."

This may be important as the pump may have been operating at an incorrect angle to the push rod, perhaps dislodging or disturbing the mechanism within the pump.

After all the ground run snags had been cleared down, the aircraft was given a final inspection and made ready for its first test flight. Head of the LAA's Coaching scheme, Jon Cooke, was delegated to carry out the test flight programme and he duly began taxi trials. These trials are designed principally to test the aircraft's steering, brake effectiveness and general pre-flight ground handling characteristics.

The ground taxi checks were successful and the aircraft took to the air for the first time. Apart from the normal tweaking, the aircraft performed well and, apart from a small carburettor issue, no other issues were reported.

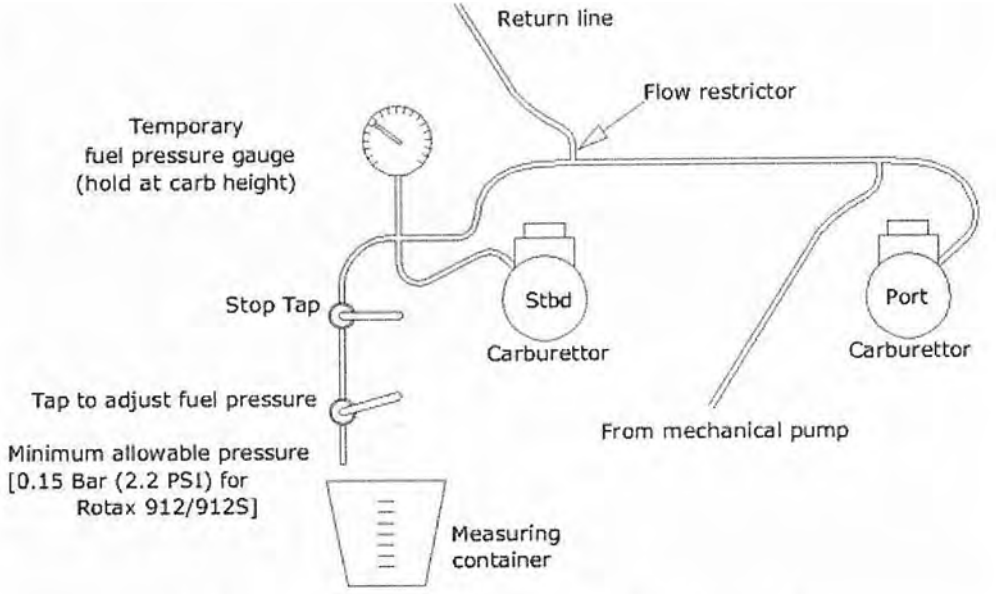
Then, after about five hours of testing Graham reports the following:

"A sudden loss of power was experienced at rotation, resulting in an aborted take-off. After extensive trouble shooting it was found that the fuel pump had failed.

"We could not reproduce the effect consistently on the ground until we raised the nosewheel approximately 10 inches to simulate the climb attitude. The engine would then run

(Right) **LAA flyer Graham Elvis sent us an excellent report into the causes of a serious loss of power incident he suffered in a Rans S6 back in 2015. In the end he established that the problem was a malfunctioning fuel pump… another unusual failure mode. In this case the rocker arm 'jumped' out of the slot in the diaphragm pull-rod leaving this tell-tale witness mark.** *(Photo Graham Elvis)*

(Left) **This picture shows a dismantled Jabiru fuel pump and you will no doubt be able to see how the pump functions just by studying the image. Importantly, this type of pump uses a pushrod to operate the main lever-arm (not visible) held in-situ in the casing (top of picture) and relies on spring pressure plus crankcase pressure to pressurise the fuel.** *(Photo Malcolm McBride)*



Fuel flow checking set-up for Rotax 912 series engine

(Left) **One of the most common causes of engine failures on homebuilt aircraft is inadequate fuel flow leading to fuel starvation or vapour lock – so begins the advice on how to carry out a fuel flow check in the LAA Technical Leaflet on the subject (TL2.20). This picture, taken from the TL, shows one set-up for checking the flow rate of a Rotax 912 installation. If you haven't found the online Technical Leaflet library yet then it's worth a browse. Go to the LAA's website (*www.laa.uk.com*), hover your cursor over the section 'Aircraft & Technical' which will open up another menu box. Click on 'Data Library' and a whole world of fascinating information for the LAA owner will be revealed.** *(Photo LAA Library)*

happily at 2600rpm but at 2900rpm (flat out) it would lose power after about 10 seconds. It ran perfectly with the fuel pump bypassed (gravity only) so the pump contributed significant resistance to the flow in its failed state."

Naturally the non-functioning pump was changed, fuel flow checks carried out and the aircraft returned to service. Graham commented that when he examined the failed pump he found a number of things he wasn't happy with, notably the screws holding the two halves of the pump together were barely tight – 'finger-tip on a screwdriver' – though no fuel was leaking from the joint.

A lesson here, if there is one, might be that before you fly an aircraft it is necessary to check absolutely everything; trust nobody. It may be that the person originally assembling this pump was, during its assembly, distracted halfway through. Who is ever going to know?

So, this last tale relates to a failure in a system on a new aircraft, the next fuel pump tale relates to an old aircraft being flown by a new owner while making his first flight in the aircraft. This time the failure ended up with the aircraft in a field, fortunately without damage.

JABIRU SK – FUEL SYSTEM MALFUNCTION

I know that I started this month's Safety Spot by explaining that I'll be telling the tale of three fuel pump failures but, on reflection, this isn't exactly true. The pump in this tale sits at the centre of the story but it didn't actually fail, rather the opposite. The engine failure was actually caused because the pump was working rather too well. Intrigued? Let's start from the beginning.

I got a telephone call from Devon LAA'er, Robert Nicholson, who had found himself in a bit of a fix with his new acquisition, a Jabiru SK. Robert explained that he'd had to land the aircraft in a field near to his home strip at Farway Common because of a severely 'surging' engine. Now this happened on Robert's first flight in the aircraft so it has to be said that he did very well indeed getting the aircraft back on the ground during the exercise, which he described as rather harrowing.

Flying a new type of aircraft is, as you would imagine, a time of increased risk. Though I love the experience of learning new tricks and exploring new devices, it's always sensible to get the advice and help of somebody who has specific knowledge under his or her belt before embarking off on one's own.

Robert had previously built a Eurostar aircraft and had flown the machine regularly for ten years or so, so he was pretty clued-up when it came to very light aeroplanes. He liked the look of the Jabiru SK when it came up for sale so, after inspecting it on the ground he decided to buy it, subject to a test flight with the previous owner.

As it turned out, for mostly weather-related issues, this dual flight never took place and the aircraft, now at Robert's strip, sat waiting for good weather and an instructor to arrive at the same time! Frustration got the better of him and, on a nice morning, he took to the skies on his own.

Perhaps because he'd recently carried out a full biennial review flight, he soon got the hang of the Jabiru and, once his heart rate had returned to near normal, he began exploring the aircraft's handling characteristics. Then the engine started to misbehave and rather than have the engine actually stop, Robert elected to land in a sizable field and seek help. This was a good decision as it turned out and, once he'd secured the aircraft, he got on the telephone to local LAA Inspector Robin King.

> 'Before you fly an aircraft it is necessary to check absolutely everything. Trust nobody'

Eventually, after searching every imaginable possibility as to the cause of the engine surging, Robin found the problem – a blocked crankcase breather bottle. Robin explained, when I asked him to send me a picture of the blocked bottle. He said:

"Unfortunately, we cleaned it all up before I took the attached picture of the sludge. However, the picture of the emulsified sludge in the container is as it came out, albeit with a little avgas to help its removal.

"I managed, finally, to clear the sludge using 120psi from my compressor. It's conjecture just how long it takes for a near as dammit solid mass of emulsified oil to build up but I can assure you it was very solid, certainly solid enough to block the breather at the top of the catch tank and the main breather. It really did release its first pressure pulse in one great glop to the underside of the fuselage - it was almost comedic.

"I've now done an oil and filter change and conducted a compression test – finding that all cylinders were normal."

What appears to have happened here, primarily to lack of maintenance in the past, is that the crankcase breather has blocked which results in a steadily increasing crankcase pressure. This increased pressure is due to what engine fitters describe as 'piston blow-by'. That's when some of the combustion gas from the top of the cylinder pushes past the piston rings into the engine's crankcase, or sump. That's why the system is vented, to release the gas, and the bottle is there to catch the minute particles of oil contained in the gas.

Here's an unusual picture. This tar-like substance was, after rather a lot of persuading, removed from the crankcase breather bottle of a Jabiru SK. It was clear that this bottle hadn't been cleaned out for quite some time and this lack of maintenance ended up with the pilot force landing into a field. The owner did a good job in getting the aircraft down without damaging anything, especially as this was the first time he had flown the type. We think that there are lots of wider lessons to. learn from this incident. *(Photo Robin King)*

Now, an increased pressure in the crankcase will increase the pressure acting on the fuel pump diaphragm and the fuel delivery pressure will increase. Take a look at the accompanying pictures and you'll see what I mean. Remember that the fuel pressure from this type of pump is related to the spring pressure, flow is a function of the frequency of operation.

In Robert's case, the pressure built up so much that the fuel pressure reached a point where fuel was forced past the float valve in the carburettor. Regular readers will remember that we've seen this before on some Rotax installations fitted with incorrect return line restrictors. Naturally, once the float valve become inoperative the engine will essentially flood with excess fuel and stop.

I've just spoken to Robert who has engaged the expert services of Jim Greenshields to go through the finer points of flying the Jabiru SK and tells me that first he's going to go through the aircraft with a fine-tooth comb to make sure there are no other maintenance, perhaps lack-of-maintenance, issues lurking!

So, what of the last fuel pump failure. Well, the engine of this aircraft stopped whilst at the hold waiting to take off and a gang of blokes had to push the aircraft back to the hangar to find out why. Here's the story.

JODEL D119 – MECHANICAL AND ELECTRICAL FUEL PUMP FAILURE

I first heard about this event when LAA Inspector David Bonsall called for advice about a fuel issue he'd come across on a Jodel operating from Netherthorpe. He wasn't sure that the T-piece connected to the carburettor was correct, and wondered whether we had any drawings of a 'standard' fuel system installation on the Jodel before he started to investigate the cause of the recent engine failure.

Naturally, we have lots of installation drawing here at LAA Engineering HQ but I couldn't find one for this particular airframe.

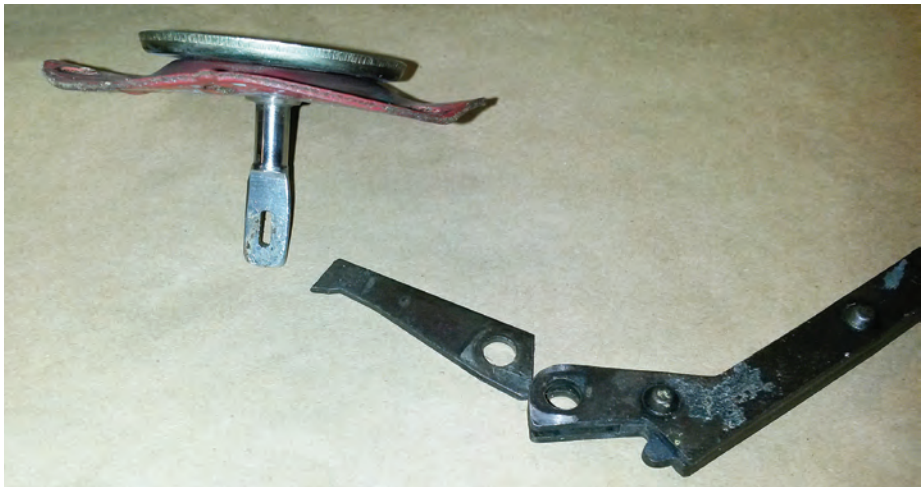
Dave explained that the pilot, who had owned and operated this aircraft for many years, had taxied out for a local flight but, whilst waiting for the runway to clear, had suffered a complete engine failure and, despite many attempts, the engine refused to start. Dave promised to find out why and, when he discovered the answer, would let me know what he found.

A couple of days later Dave rang and explained what had gone wrong. It seems that the root cause of the problem was that the hook that attaches the pump's drive arm to the diaphragm pull-rod had broken off, rendering the pump inoperative. Fortunately, the aircraft is equipped with an electrical back-up fuel pump for this eventuality, though this had also stopped working.

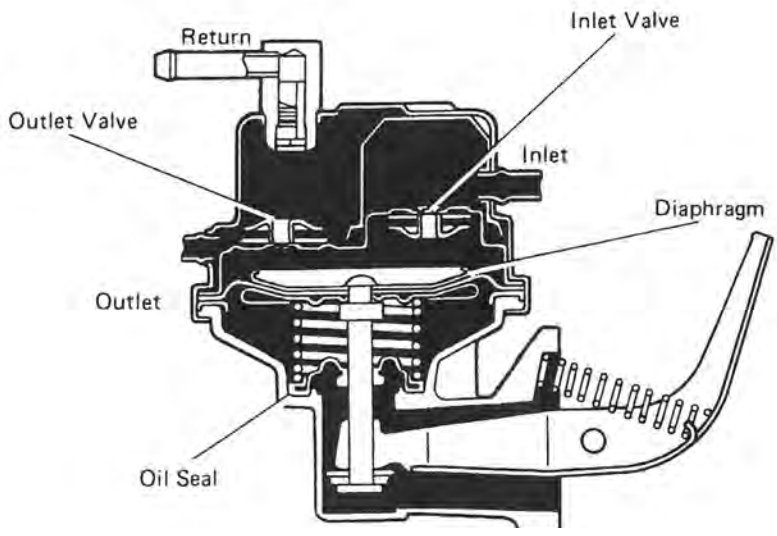
Actually, Dave got the engine started quite quickly by tapping the electrical pump with a spanner after working out that the engine wasn't getting any fuel into its carburettor. This fuel pump CPR brought it back to life, though only temporarily of course.

Dave, naturally, replaced both pumps ›

(Above) **LAA Inspector David Bonsall sent this picture showing an unusual failure mode of a fuel pump. The pump on the left is a perfectly serviceable item and he's included this to show what the removed pump should look like. The dismantled pump on the right, showing the diaphragm and the rocker arm, stopped working because the connection between the inner arm and the diaphragm failed.** *(Photo Dave Bonsall)*



(Above) **Here's a close-up showing the failed AC pump's inner arm/diaphragm failure; the broken end of the rocker-arm hasn't yet been found.** *(Photo Dave Bonsall)*



(Above) **This 'how it works' picture of a rather generic AC mechanical fuel pump shows well the basic mechanics of this type of pump. Note that the fuel pressure produced is a function of the main spring pressure plus the pressure in the spring chamber.** *(Photo LAA Library)*

'If you have a problem in flight, divert to the nearest landing site as soon as safely possible'

and the engine is now working normally. But we were both surprised that these pumps should fail at the same time and we agreed that this was a lucky escape for the pilot, had this happened shortly after take-off, the story may have been very different.

What seems to have happened here is that the pilot had got into the habit of starting his engine with the electrical stand-by pump switched on and, for some reason, of leaving the electric pump on for the whole flight. Whilst, with this type of installation, there's no immediate harm done to the other fuel system components by leaving this pump on, it does mean that, if the main mechanical fuel pump fails, as it had in this case, the pilot wouldn't be aware that the engine is only running on the (essentially) emergency stand-by fuel pump.

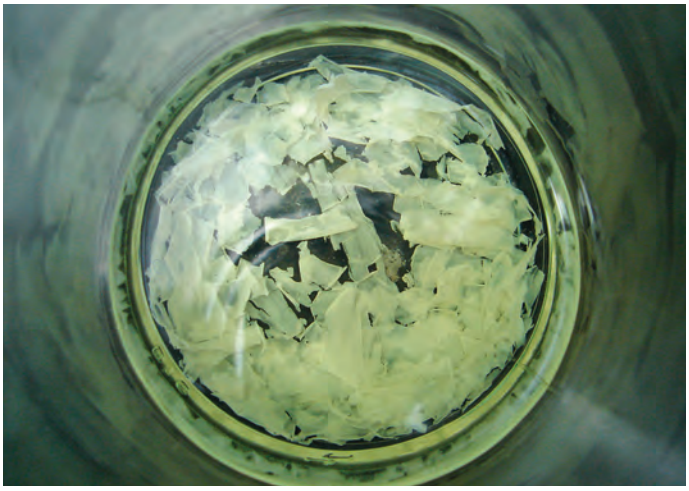
Also, the fuel output from these small, essentially automotive, pumps normally only just meets the minimum fuel delivery requirements for an engine at full power.

Naturally, all fuel systems are different, it is essential that every pilot understands how the system on the aircraft they're flying works. Some systems involve a tank, a filter, an on/off valve and some kind of fuel gauge but some require far more components to make the system work correctly.

Certainly, if you are flying an aircraft with more than one fuel tank, it is good practice to check that each tank can deliver fuel before setting off. If you have more than one pump, likewise, check each one before flying. In a pumped system I personally think that it's foolish not to have a fuel pressure gauge measuring pressure at the carburettor inlet.

For most small aircraft a normal technique might be to taxi the aircraft with the electrical fuel pump off and then, during the pre-flight engine checks, turn the electric pump on with the engine running at a medium power setting, you should see a small change (upwards) in

Here we show another failure mode of an AC mechanical fuel pump; you can see clearly that the slot in the diaphragm pull-rod – remembering that it's the spring on this type of pump that does the pushing – has failed, most likely because of the abrasive effect of iron oxide between the moving surfaces. *(Photo Malcolm McBride)*



(Left) **I almost guarantee that you couldn't guess what this picture shows. No, it's not a petri dish full of the latest horror bug or a creature from the depths of the mid-Atlantic ridge, though it does rather look like it might be! Thanks to Kitfox flyer, Milt Turner for sending us this picture of debris he found in his 'Mr Funnel fuel filter' after a recent re-fuel of his Kitfox. I think that we can be fairly sure that the fuel system would have been compromised had this muck found its way into the tank. First lesson, always use a filter when refuelling from a can.** *(Photo: Milt Turner)*

(Below) **After Milt Turner found the significant amount of FOD in his fuel filter, he decided to check-out where it came from and, after a bit of detective work, he established that the debris was actually the remains of the glue from the duct tape he used to connect an extension to his fuel delivery pipe. I think Milt would be better off using jubilee clips to join the two pipes together.** *(Photo Milt Turner)*

(Left) **This picture, taken from the web, shows how the Polarn pump works. From the sales literature I quote:** ***This pump simply connects to the top of most lever cap jerry cans and allows easy transfer of fuel. The pump pressurises the jerry can with several pumps and can be stopped easily with the air bleed. The pump can empty a jerry can in less than 35 seconds if used at full flow. The pump means the jerry can does not need lifting to fill the car. Save your back! Jerry can not included!*** **The pipe is 780mm long as delivered, though an extension is available – needed for the Kitfox.** *(Photo: 'Demon Tweeks')*

the fuel pressure.

Most aircraft flight manuals for this class of aircraft will suggest that you leave the pump on for take-off but, when at a safe height, this pump should be switched off and a check of the running fuel pressure made. If an engine starts running roughly during flight the action, after applying carburettor heat, should be to switch the stand-by fuel pump on and, if appropriate, change fuel tanks.

One further thing, though I'm not suggesting that this is the case in this latest event, it would be tempting, if you did have a mechanical fuel pump failure, to carry on flying with just the stand-by keeping fuel flowing to the engine.

No, No, No! That's a silly thing to do as this last story, I hope at least, makes clear. If you have a problem like this in flight, divert to the nearest landing site as soon as safely possible. Avoid the holes in the Swiss cheese lining up!

If you're reading this before the Rally, and I know that Brian is working hard to get *Light Aviation* out early, just so that you know, I'm looking forward to seeing you there. If you are reading this after the Rally, I hope that you had time to stop for a chat and, if you did, it was good to meet you! Fair Winds. ■

LAA ENGINEERING CHARGES – PLEASE NOTE NEW FEES HAVE APPLIED SINCE 1 APRIL 2015

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 450kg	£450
451-999kg	£550
1,000kg and above	£650
Permit renewal	
Up to 450kg	**£155**
451-999kg	**£200**
1.000kg and above	**£230**
Modification application	
Prototype modification	minimum £60
Repeat modification	minimum £60

Transfer		
(from CofA to Permit or CAA Permit to	LAA Permit)	
Up to 450kg	£150	
451-	999kg	£250
1,000kg 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 - No.16 February 2015		