Streak Shadow SA, G-TTOY

AAIB Bulletin No: 5/2004	Ref: EW/C2003/09/05	Category: 1.3
Aircraft Type and Registration:	Streak Shadow SA, G-TTOY	
No & Type of Engines:	1 Rotax 618 piston engine	
Year of Manufacture:	1996	
Date & Time (UTC):	17 September 2003 at 1815 hrs	
Location:	Old Sarum, Wiltshire	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - 1
Injuries:	Crew - None	Passengers - None
Nature of Damage:	Undercarriage and slipper (fuel) tank damaged	
Commander's Licence:	Private Pilot's Licence	
Commander's Age:	44 years	
Commander's Flying Experience:	2,300 hours (of which 320 were on type)	
	Last 90 days - 56 hours	
	Last 28 days - 8 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot, and follow up AAIB technical investigation of failed landing gear fitting	

Synopsis

During the take-off run, a weld connecting the right stub axle to the right landing gear strut, failed. The end of the strut contacted the ground and twisted rearwards, the aircraft veered to the right and came to rest just off the runway. Fuel leaked from the slipper fuel tank located beneath the fuselage, as a result of the rearward twisting of the landing gear having crushed, and holed, the top of the slipper tank. The investigation revealed the very poor standard of this weld on this aircraft, and on eight other examples examined, suggesting that many other aircraft might be similarly affected.

History of the flight

Having run over a slight bump on the grass surface during the early part of his takeoff from Runway 24 at Old Sarum, the pilot felt the right landing gear start to collapse. He decided to abandon the takeoff and held the wing clear of the ground for as long as possible using aileron. However, as the speed decayed the leg folded back and the aircraft veered to the right and came to rest just off the edge of the runway, with fuel leaking from the external slipper tank located beneath the fuselage.

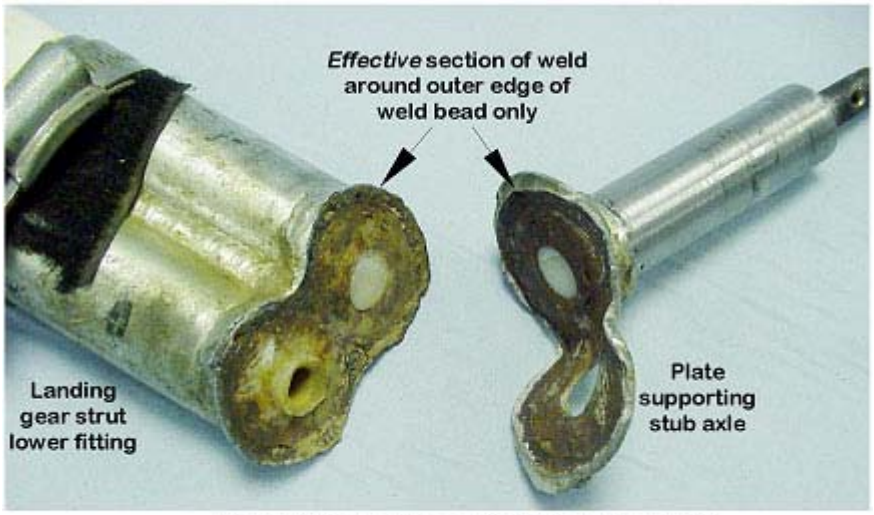
After shutting off the ignition, battery, and fuel the pilot and his passenger evacuated the aircraft carefully to minimise the risk of igniting the spilt fuel.

Failure examination

Initial examination of the aircraft showed that the right main wheel and brake assembly had separated from the landing gear strut at a welded attachment between the stub axle and the strut lower fitting. As the aircraft settled, the exposed end of the strut dug into the grass, wrenching the lower end of the strut rearward and upward, causing the landing gear to twist at its attachment to the lower fuselage. In so doing the landing gear cross member was forced downward, breaking through the top edge of the box-shaped slipper tank that hangs immediately below the landing gear fixings, allowing fuel to escape.

Detailed examination of the detached stub axle and the mating part of the landing gear strut showed that separation had occurred as a result of a fracture through a weld line. This weld joined a steel plate supporting the axle stub to twin tubes which form the body of the landing gear lower fitting. Although the externally visible part of the weld appeared normal, the effective cross-section at the interface between the weld bead and the plate was extremely narrow, typically around 1 mm or less, around the whole of the weld circumference. It was apparent that the fitting would have been significantly weaker than intended as a result. Figure 1 shows the failed lower fitting from G-TTOY, and Figure 2 illustrates the general layout of the landing gear and the form of construction used in the failed lower fitting.

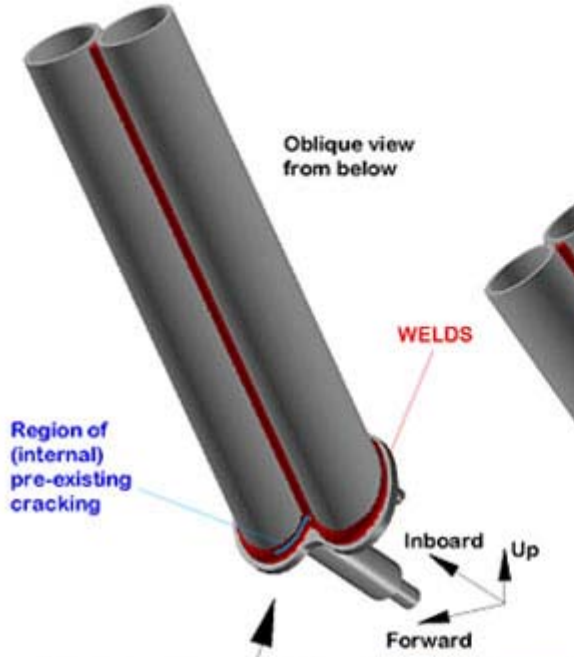
Figure 1: Weld failure of lower fitting on G-TTOY



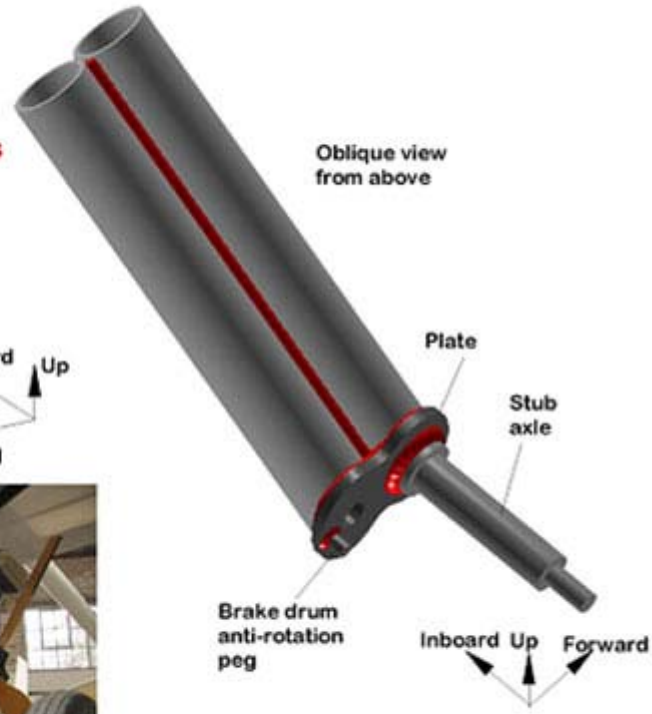
Weld failure of lower fitting on G-TTOY

Figure 1

Figure 2: Landing gear strut lower fitting, showing form of construction



CFM Shadow landing gear configuration
(slipper fuel tank not installed on example shown)



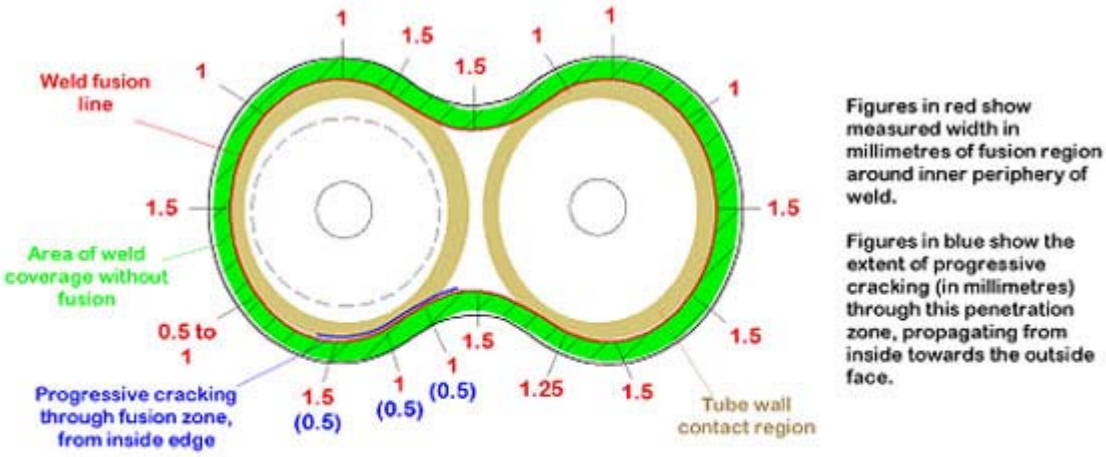
Landing gear strut lower fitting, showing form of construction

Figure 2

This connects with, and is bonded to, the lower ends of a pair of composite rods that function as spring-struts, and which are attached to the lower fuselage. The stub axle, which is welded directly to the forward end of the plate, supports a conventional wheel and cable-operated drum brake. A short peg welded to the rear end of the plate provides anti-torque reaction for the brake assembly.

The failed weld was subject to specialist metallurgical examination, from which it was established that, although the coverage provided by the weld bead at its interface with the plate was adequate, the weld itself had failed to fuse properly into the plate, except at the very inside edge of the bead. This had resulted in the effective working section being very narrow around the whole of the weld line. A small region of the fracture surface at the bottom of the fitting exhibited corrosion and other features consistent with progressive fracture prior to final failure. The fracture had propagated from the inside towards the outer surface of the weld bead. Although this had not penetrated right through the (already very narrow) working section, it had evidently weakened the joint sufficiently to allow it to fail under relatively benign loading conditions. Figure 3 illustrates the approximate width of the working section of the weld around the periphery of the plate joint, and also the approximate position and extent of the region of pre-existing, progressive, fracture.

Figure 3: Sketch illustrating the position of the weld coverage



Sketch (not to scale) illustrating the position of the weld coverage which actually achieved fusion into the plate (red), and the approximate extent of progressive cracking (blue)

Figure 3

So far as could be established, there have been no prior reported instances of failure of this kind on the Streak Shadow. However, it was a cause for concern that the failed component displayed no external sign of poor weld quality, or of the progressive cracking which had weakened the fitting prior to failure. An attempt was therefore made to determine whether these defects were confined to G-TTOY, or were possibly more widespread.

Eight scrap Shadow landing gear lower fittings were obtained, which had originally been fitted to aircraft involved in unrelated landing accidents or incidents. Each of these was cut to produce two vertically orientated section-planes through the plate welds, aligned with the centres of each of the tubes that form the body of the fitting. After polishing, the welds connecting the plate to the housing, and the stub axle to the plate, were studied to assess the quality and security of the joint. It was found that every one of the eight samples exhibited significant weld deficiencies, including a lack of adequate fusion similar to that on the fitting from G-TTOY and also a lack of weld penetration, resulting in a reduced load-bearing section at the affected joint. Table 1 at Figure 4, shows the results of this study.

Figure 4: Survey of weld quality on 8 sample landing gear fittings

Table 1: Survey of weld quality on 8 sample landing gear fittings

	Forward (axle) tube								Rear (blank) tube			
	Weld 1		Weld 2		Weld 3		Weld 4		Weld 5		Weld 6	
Sample	X	Observations	X	Observations	X	Observations	X	Observations	X	Observations	X	Observations
A	2	RP	2	RP	3.5		3		3		2.25	RP
B	2	RP	2	RP	3	RP + SWF	2	RP + SWF + P	1.5	RF + SWF	1	RP
C	1.5	RP	1	RP	3	RP	3.5	RP + P	2	RF	2	RF + P
D	1.5	RP + P	1	RP + SWF	3	RP + SWF + P	3	RP	1.5	RF	1.5	RP
E	2	RF	1.75	RP	3.5	RF + IF	5	SWF	2.5	RF	1.5	RP
F	3		2	RP	3.5		3		3.5		3	RP
G	1.5		3	RP	3		2.5		2		2	RP
H	1.5	RF	1.5		4.5	IF	4.5	SWF	1	RF	2.5	P

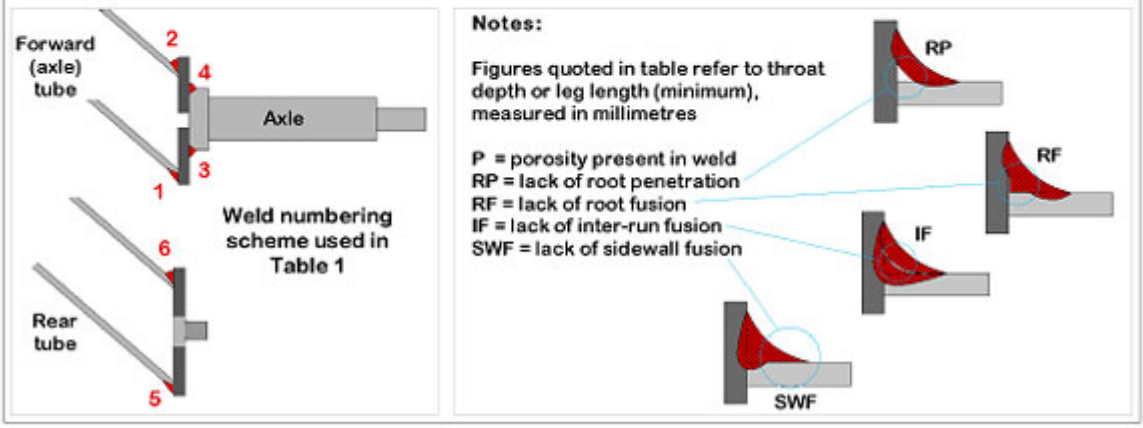
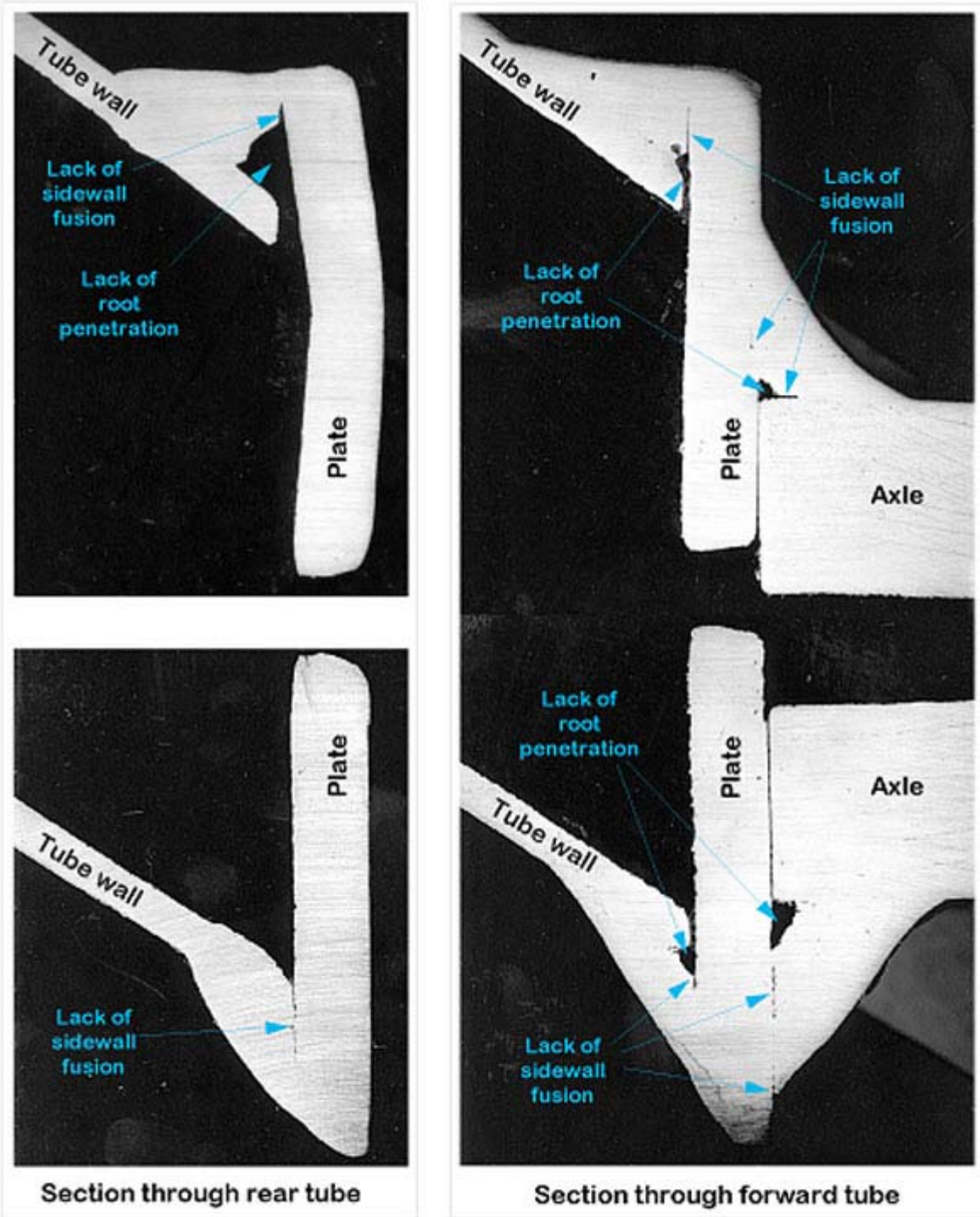


Figure 4

Figure 5 shows a series of section micrographs from one typical sample, in which both types of deficiency are clearly evident.

Figure 5: Section micrographs through welds in one of the sample lower fittings (not G-TTOY)



Section micrographs through welds in one of the sample lower fittings (not G-TTOY)

Figure 5

Discussion

Implications of the failure

The weld quality in the lower strut fitting both on G-TTOY and the other examples examined, was very poor, resulting in a weak joint with a minimal working section and significantly reduced static strength in the finished component. The progressive propagation of a small crack into this marginal working section, albeit only over a small length of the weld and only part-way through the working thickness, was sufficient to cause the component to fail under relatively benign conditions.

Given that the failed component appears to have been installed on the aircraft from new, is perhaps surprising that it did not fail sooner than it did. The fact that it did not do so suggests that, in the absence of progressive cracking, the static strength of this particular fitting (on G-TTOY) was just about adequate under normal operating conditions. Consequently, it would appear that the progressive cracking was a significant causal factor in the failure; however, it is equally clear that the poor weld quality was the primary cause of the failure.

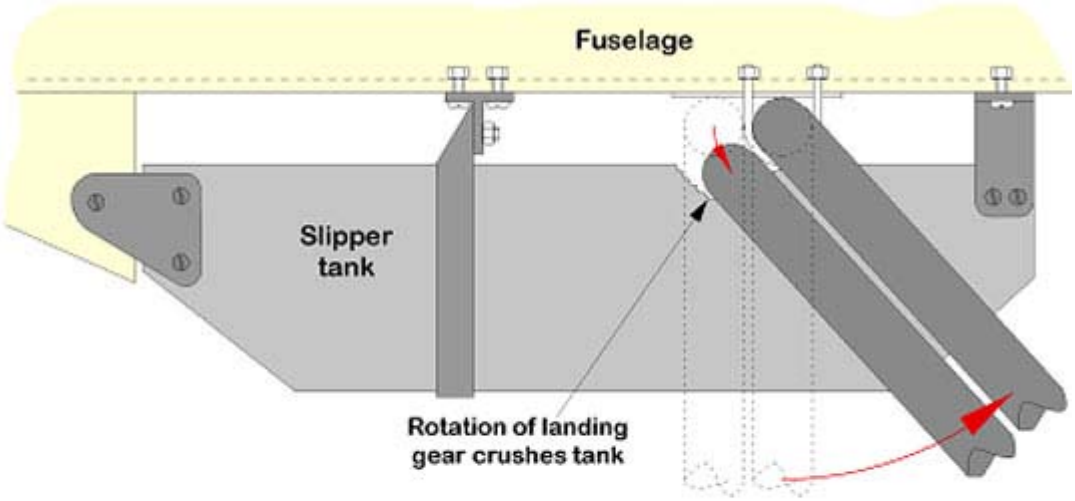
The presence of similar weld defects on every one of the eight samples studied suggests that a significantly large number of these fittings installed on other Shadow aircraft, possibly a majority, are likely to have similar defects and may not meet the strength criteria against which the aircraft was certificated. Indeed, it is entirely possible that many may fail, like the fitting on G-TTOY, under conditions that fall comfortably within the expected operating envelope for the aircraft.

One of the reasons for undertaking the study of other fittings was to establish whether or not it might be possible to identify those fittings at risk of failure by non-destructive means. The results suggest that it would not be possible visually to identify poor quality welds in the fitting simply from the external appearance of the weld bead *per se,* or from the physical characteristics of the joint overall (bead width, profile etc). Neither would it have been possible visually to detect, either directly or indirectly using dye penetrant or comparable techniques, the progressive internal cracking which had propagated partially through the weld on G-TTOY. Eddy current or similar techniques could potentially be employed to detect the sub-surface weld defects; however, even if viable, such techniques would require significant development resources and the skilled use of equipment which probably, would not be readily available to the majority of Shadow owners.

Fuel tank fracture

The slipper fuel tank on G-TTOY was fractured in the accident due to rotation of the main part of the landing gear at its attachment to the fuselage, and the attendant leverage imposed on the upper corner of the tank. The latter was restrained by its fore and aft fixings to the fuselage and, more significantly, by the support strap which passes underneath it. This crushing action, illustrated in the sketch at Figure 6, is an inevitable consequence of the method of landing gear attachment and the slipper tank position and its method of attachment.

Figure 6: Slipper fuel tank damage resulting from rotation of landing gear in its mounting



Slipper fuel tank damage resulting from rotation of landing gear in its mounting

Figure 6

Safety recommendations

Whilst the probability of failure appears to be relatively low under benign operating conditions, it is likely that a significant number of lower fittings may fail under conditions only marginally more severe than those routinely encountered in every-day use. Such a failure during landing or takeoff would be likely to lead to loss of directional control, and possible collision. If fitted with a slipper tank, fuel spillage is also a likely outcome, with the attendant risk of fire, particularly in the event of a collision. The manufacturer of the CFM Shadow, Streak Shadow and Starstreak Shadow microlight aircraft ceased trading in August 2002. Since June 2003, the CAA have been working with the BMAA and the PFA, who have taken on responsibility for the continued airworthiness of these aircraft, with respect to airworthiness issues relating to the landing gear design.

The following recommendations are therefore made:

Safety Recommendation 2004-02

The UK Civil Aviation Authority, in conjunction with the British Microlight Aircraft Association (BMAA) and the Popular Flying Association (PFA), should review the adequacy of the main landing gear lower fittings currently in service on Shadow aircraft, in light of the evidence suggesting that significant numbers of these are likely to contain weld defects which significantly reduce their static strength compared with that assumed at the time of certification.

Safety Recommendation 2004-03

The UK Civil Aviation Authority, in conjunction with the British Microlight Aircraft Association (BMAA) and the Popular Flying Association (PFA), should review the adequacy of the slipper fuel tank mounting arrangement, insofar as this makes the tank vulnerable to fracture and leakage of fuel during any incident which causes a rearward rotation of the gear about its attachment to the fuselage.

On 30 December 2003 and 12 January 2004, the CAA issued Mandatory Permit Directives, Nos. MPD No: 2003-019 R1 and MPD N0: 2004-002 respectively, which essentially prohibit the use of the underfuselage 'slipper' tank, which should be removed or disabled before further flight. Should that be the only fuel tank fitted, then further flight is prohibited pending solution of the landing gear problem. On 11 February 2004, the CAA issued a Letter to Operators/Owners (LTO) of the subject aircraft, which drew attention to the MPDs and the background to the landing gear problem. In this

LTO they also state *'The safety risk associated with continued operation of these microloght aeroplanes with the existing undercarriage design is unacceptable. Following a meeting with BMAA and PFA, it was agreed that a modified/new undercarriage must be available and installed on all affected microlight aeroplanes by 31 March 2004 in order to allow their continued operation.'*