BULLETIN ADDENDUM

The original report on this accident was published in bulletin 8/92 with a note that further information would be published when the results of certain investigations were known. The following comprises a summary of the original bulletin report, together with a report on the results of a detailed investigation into the aircraft fuel system and a limited engine examination.

AAIB File:	EW/G92/05/04
No & Type of Engines:	1 Blackburn Bombardier 20801 piston engine
Year of Manufacture:	1960
Aircraft Type and Registration:	Auster AOP 9, G-BDFH
Date & Time (UTC):	3 May 1992 at 1625 hrs
Location:	Fen Road, Milton, Cambridgeshire
Type of Investigation:	Aircraft Accident Report Form submitted by the pilot and investigation by an AAIB Inspector (Engineering)

Background

This aircraft suffered an engine failure during a short transit flight from Bourne Airfield to Cambridge Airport. Operation of the Ki Gas pump during the enforced descent resulted in a brief restoration of power, but the pilot decided to concentrate on the emergency landing rather than continue attempts to re-start the engine. The aircraft landed a little fast and passed through a hedge and into the next field, breaking the left landing gear.

The engine has now undergone a shock-load inspection during which, at the request of the AAIB, the ancillary drives to the fuel injector pump, the magneto, and the engine driven fuel pumps were specifically checked and found to be intact. There is no facility to bench test the injector pump, nor to bench run the engine, and therefore the engine can be test run only after it has been re-installed in the repaired airframe. In the interim, in view of the lack of any overt signs of a failure of the engine itself, the airframe fuel system was examined in detail by the AAIB. This addendum deals primarily with the results of that investigation.

Fuel system description

The fuel system on the Auster AOP Mk9 was, in its original form, a very simple system comprising a single fuel tank in the right wing which fed the engine directly via a fuel cock with positions, OFF, ON, and PRIME. A conventional bowl type fuel filter was mounted just forward of the engine firewall. The engine was fuel injected, with two engine driven Amal diaphragm pumps maintaining a positive pressure at the fuel injector pump inlet. Excess fuel from the injector pump outlet was returned to the fuel tank via a separate spill line.

The Mk9 fuel system was subsequently modified in a number of stages, which included a fuel tank in the left wing and a fuel collector tank with integral boost pump. It is understood that the latter modification was intended primarily to overcome fuel vapour locking problems which had been experienced during military operations in hot climates. Some aircraft, but not G-BDFH, were fitted with a long range fuel tank in the fuselage.

The arrangement of the left and right sides of the fuel system were essentially identical. Fuel flowed under gravity from each tank via a pair of take off points, located at the fore and aft inboard corners of each tank, and thence through standard 3/8" pipes to 'tee' connectors situated on the lower fuselage left and right sides. The flow from these tee connectors then passed through a pair of non-return valves (NRVs) before combining at another tee connector, the outlet of which was directed to the small cylindrical collector tank mounted centrally in the cockpit beneath the instrument panel. A vent line extended upwards from the domed top of the collector tank to the right wing fuel tank, and an impeller type boost pump was fitted into its base. From the collector tank, fuel passed directly to the fuel cock and thence to the engine compartment fuel filter, mounted just ahead of the firewall.

A fuel pressure switch in the outlet line from the fuel cock was connected to a fuel pressure warning light on the left instrument panel. The spill line from the fuel injector pump fed back into the right wing tank only.

The pair of NRVs appears to have been introduced as part of the modification to install the collector tank and boost pump, but their intended purpose is not at all clear at this time. The practical effect of these valves, however, is to cause a fuel imbalance to accumulate during normal flight because although fuel is drawn evenly from both left and right tanks, the excess from the injector pump is spilled back to the right tank only and the non-return valves prevent the tank levels balancing themselves up by cross feeding through the connecting pipework. As a result, an aircraft which starts a flight with full tanks might typically have 6 or more gallons remaining in the right tank when the left tank runs dry. It would appear, however, that the system will continue to deliver an acceptable supply of fuel from the right tank even after the left tank has been fully depleted.

Fuel system examination

Background

Shortly before the accident, the aircraft had been landed at Bourne with the intention of taking on fuel. However, fuel was not available and therefore the pilot decided to fly to Cambridge, a distance of about 5 miles only, which, at a burn rate of around 7.5 gal/hr, was well within the range of the

6 gallons or so of fuel remaining at that time. The engine failure occurred when the aircraft had about 2 miles to run to the destination airfield.

When the aircraft was subsequently recovered, about 5 gallons of fuel was drained from the left tank but there was no fuel in the right tank. Under normal circumstances, with only 5 gallons total fuel on board, the disposition would have been the opposite of that found, ie. all the fuel should have been in the right tank with none in the left. There appeared to be two possible explanations for this unusual fuel state.

Firstly, the non-return valve in the supply line from the left tank may not have been closing properly, thus allowing a post-accident transfer of fuel to take place from the right to the left tank due to the left wing low attitude of the aircraft (the left landing gear had broken).

Secondly, there could have been an obstruction of the left tank feed lines which so reduced the flow from the left side that the right tank ran dry (overcoming the normal imbalance in favour of the right tank due to the injector pump spill-back) whilst there was still 5 gallons in the left tank, allowing air to be drawn into the engine fuel injector system from the empty right tank.

The complete airframe fuel system was therefore examined in detail, with particular emphasis on the left tank non-return valve.

Results of the fuel system examination

The whole of the fuel system from the NRVs forward to the engine compartment fuel filter was essentially full of AVGAS fuel, though it was not possible to say whether small pockets of air were present in either the collector tank or the filter bowl. The filter element was clean and unobstructed and there was no unusual debris in the filter bowl.

In excess of 1 litre of fuel was drained from the system via the lowest point in the pipework, at the connection to the left NRV, on the tank side. The fact that fuel flowed from the collector tank to the opposite side of the left NRV indicated that the NRV must indeed have been back-feeding.

Careful removal of the left NRV revealed that the inlet was partially obstructed by a slug of rubbery material. However, although this material largely filled the inlet port to the valve, the orifice was not completely obstructed and a limited flow of fuel through the valve could have taken place in either direction.

Dismantling of the valve revealed that this foreign material took the form of a long string or *sausage* of a soft and glutinous, translucent, rubber-like material which had worked its way into the valve interior and was holding the clack valve off its seating. The material had the general appearance of a silicone rubber compound which had become softened and swollen by prolonged contact with fuel.

Further examination of the fuel lines between the left fuel tank outlets and the NRV revealed a substantial obstruction in the lines. Blowing the lines through resulted in the forcible ejection of one large plug and one small pellet of a soft rubbery material, similar to that found in the NRV. This material would certainly have caused a significant restriction of the fuel flow from the left tank. The rest of the fuel system pipework was checked for obstructions and blown through in sections, but no further material, or obstruction, was found.

The fuel recovered from the left tank was strained through a fine filter to check for debris but nothing of significance was found.

Investigation of the rest of the airframe fuel system revealed that the left fuel tank gauge unit, which is bolted directly to the inboard wall of the tank by means of a flanged coupling, had been sealed to the tank cell with what appeared to be some form of clear silicon rubber sealant, similar to that sold commercially as a domestic bath sealant. Blobs of this material were adhering to the periphery of the outside flange, where the sealant had evidently been extruded whilst still soft, as the flange bolts had been tightened. Larger strips and blobs of this material, some of which appeared to be held in place only very lightly, could also be seen adhering to the flange on the tank wall interior. In contrast, the fuel gauge on the right tank was fitted with a rubber gasket seal which appeared to be original, and upon which there was no sign of any sealing compound. It is understood that the left fuel tank cell was removed for rectification of a slight leak approximately 2 years prior to accident, whereas the right tank had never been disturbed.

Similar rubbery material had been used as a sealing compound on the left tank filler attachment flange.

The material found inside the NRV and pipework was analysed using infrared spectroscopy and compared with beads of the sealing material removed from the left tank gauge attachment flange and the left tank filler cap sealing flange. A sample of clear room temperature curing (RTC) silicon rubber was also included for comparison. The spectra obtained from these samples were essentially identical, with characteristic peaks which indicated beyond any doubt that the material was a silicone rubber compound. The control sample of RTC silicone rubber also gave identical results, confirming that the material which was lodged inside the left fuel tank pipework and NRV was excess RTC silicone rubber used as a sealing compound on the gauge unit and the tank filler neck fitted to the left fuel tank

Possible causes of the engine stoppage

It was not possible to determine positively whether the material found in the NRV and pipework was responsible for the engine failure, but there are at least two ways in which this material could have caused the engine failure whilst leaving 5 gallons of fuel remaining in the left tank.

Firstly, had the restricted fuel flow from the left tank caused the right tank to run dry first, leaving the 5 gallons still remaining in the left tank, then the Amal pumps would have drawn air from the empty right tank in preference to fuel from the restricted left tank pipework. It would have required only a small amount of air to stop the engine, and the collector tank could subsequently have re-filled from the left tank after the accident, albeit at a slow rate due to the restriction. (The left tank remained above the collector tank level, even though the left landing gear had collapsed). The pilot turned off the fuel immediately after the accident and therefore the fuel filter bowl could not have refilled by this same mechanism. However, it is quite possible that some air was present in the filter (there was no way of knowing whether the filter was completely full). It is also conceivable that a small amount of fuel was able to work forward from the collector tank, sufficient to re-fill the filter bowl but not to re-prime the injector system, whilst the engine was windmilling during the descent. The second possibility, which is considered less likely, is that the fuel flow from the left tank was adequate, despite the obstruction, but another slug of the rubbery material (as yet unrecovered) temporarily obstructed an orifice somewhere downstream of the point where the feed from the two tanks join together, for example in the collector tank area. Such an obstruction could have effectively stopcocked the fuel supply, even with the lines completely full of fuel, stopping the engine, and then subsequently fallen clear. In this case, the presence of all the fuel in the left tank could be readily explained by gravity cross-feed past the left NRV, which was being held off its seat by the foreign material, during the period when the aircraft was lying left wing-down after the accident.

Silicone rubber in contact with petroleum spirits

Silicone rubber compounds of the kind sold as bath sealants are not suitable for use in environments in which they are likely to come into contact with petroleum spirits. The material softens, disbonds and swells, particularly in the presence of gasolene. A simple test carried out as a part of this investigation showed that a disc of RTC silicone rubber immersed in aviation gasoline for a period of 48 hours swelled to approximately twice its original size. Clearly, small beads of silicone sealant which drop off and find their way into pipework and valves can not only cause immediate obstruction, but the restriction can become more severe as the material swells over time.

A further update on this investigation will be issued if, during cleaning and repair of the fuel system or the subsequent installation and testing of the engine, further light is thrown upon the cause of the engine failure.