Grob G115E Tutor, G-BYVO

AAIB Bulletin No: 1/2002	**Ref: EW/C2001/07/03**	**Category: 1.3**
INCIDENT		
Aircraft Type and Registration:	Grob G115E Tutor, G-BYVO	
No & Type of Engines:	1 Lycoming AEIO-360-B1F piston engine	
Year of Manufacture:	2000	
Date & Time (UTC):	12 July 2001 at 1120 hrs	
Location:	3nm northwest of Cosford	
Type of Flight:	Training	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	No damage to aircraft	
Commander's Licence:	Student RAFVR Military	
Commander's Age:	20 years	
Commander's Flying Experience:	40 hours (of which 5 were on type)	
	Last 90 days - 6 hours	
	Last 28 days - 5 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot and investigation by the RAF, VT Aerospace and the AAIB	

History of the flight

The training flight by the University of Birmingham Air Squadron Pilot was planned for aerobatic (excluding spinning) and forced landing practise. The student pilot had previously flown and performed aerobatics in the Bulldog trainer before he had converted to the Grob Tutor type, and this was his first solo flight in the Tutor. The aircraft had previously been operated that day and so the engine was already warm and started easily. All ground engine checks were normal and the fuel mixture was adjusted to best power mixture (BPM)). The aircraft fuel tanks were approximately two thirds full.

After a normal take off, a small mixture adjustment was made at 2,000 feet agl to increase the fuel flow from around 53 litres per hour to achieve the placarded 56 litres per hour for BPM. The aircraft was levelled at Flight Level (FL) 50 and the propeller set to 2,500 rpm. The indicated airspeed was increased to 100 kt and the engine manifold pressure set to 19 inches. The pilot reported that the manifold pressure gauge was slow to indicate the new power setting, although the engine had responded normally. He then carried out some steep and maximum rate turns for 10 minutes, during which the engine indications were normal.

The aircraft was then climbed and aerobatics were performed for some 20-25 minutes, during which the engine indications were again normal. The pilot then initiated a stall turn to the left, pulling up at around 125 kt with the throttle fully open and the engine at 2,500 rpm. At about 70 kt the pilot applied left rudder, but as the nose dropped through the horizon there was a change in engine note which sounded as if the engine was slowing down. However, as the aircraft pulled out of the dive the engine recovered, but in view of the engine's behaviour the pilot decided to discontinue his aerobatics and return to RAF Cosford.

He nevertheless decided to perform his intended practise force landing (PFL) during his return flight to RAF Cosford, and so at around FL40 he closed the throttle and retarded the propeller pitch lever to LOW rpm. He reset the altimeter to the regional pressure setting, which gave an altitude of 3,300 feet amsl. He then completed the drills for a simulated mechanical engine failure, visually checking the relevant engine indications and controls. He then informed Cosford ATC of his intended PFL and gave his location as 4nm to the north of the airfield. The controller passed the wind direction and strength. The pilot then positioned the aircraft for his selected field and performed the landing checks; he switched the auxiliary fuel pump ON and left the fuel selector selected to 'Both', with the fuel mixture set at BPM. As the aircraft turned crosswind at around 3,000 feet amsl, the pilot noted that the cylinder head temperature (CHT) gauge was indicating 95°C and so he performed the 'full engine warm' procedure. The propeller pitch lever was moved fully forward to fine pitch, the throttle was then opened fully and the nose of the aircraft raised into the climb attitude. The engine accelerated normally to full power and after some three seconds the pilot closed the throttle and retarded the propeller pitch lever back to the LOW pitch setting.

He continued the glide descent at 75 kt, selected the first stage of flap (take off flap) and at around 2,300 feet amsl he performed an 'engine response' check. This was carried out in the same way as the 'engine warm' check, except that as the throttle reached the fully open position he immediately closed it again. The engine responded normally. He commenced the final turn towards his selected field at around 1000 feet amsl, and at 800 feet on the approach he decided to commence his go-around.

He duly moved the propeller lever forward to the HIGH pitch setting, opened the throttle and raised the nose. However, the engine responded with a 'spluttering noise' which he compared to the noise of an engine start on the ground if the engine failed to 'pick-up'. He checked that the throttle was fully open and that the propeller pitch lever was set to HIGH. He pressed the starter button.

However, he then realised that this was the incorrect drill and released the starter button, before retarding the throttle to a position some 2cm open. The spluttering sound stopped and he again pressed the starter button. He then saw that the propeller was windmilling and released the starter button. He recalled the drill for a windmilling propeller and moved the throttle open again. However, the engine started spluttering once more and so he decided to conduct a forced landing in his selected field. He switched off the auxiliary fuel pump, transmitted an RT call to Cosford ATC and switched OFF the battery master switch.

He landed with the flap still at the take off position and described the initial contact as 'very heavy'. The ground was rough and the aircraft came to rest without the use of the brakes. The pilot contacted Cosford ATC to inform them that he had landed safely. He then called his University Air Squadron on his mobile phone to report his forced landing.

Meteorological conditions

The synoptic situation at 0900 hrs UTC showed an unstable westerly flow covering the Cosford area with some deep convection covering England and Wales. The visibility was 30 km or more outside occasional showers in the area. The cloud was generally few scattered cumulus out of showers, with a base around 2,500 feet, but deteriorating in showers to broken towering cumulus, base 2,000 -2,500 feet. The following table shows the winds, temperatures and humidity from the surface up to 4,000 feet agl:

Height agl	Wind direction and speed	Temperature	Dew point	Humidity
Surface	260°/14 gust 20-25 kt	+14°C	+10°C	77%
1000 feet	270°/20 kt	+10.5°C	+8.5°C	87%
2000 feet	270°/25 kt	+9°C	+7.5°C	90%
3000 feet	270°/25 kt	+8°C	+5.5°C	84%
4000 feet	270·/30 kt	+7°C	+5°C	87%

The pilot stated that he had avoided flying through any showers during his flight.

Best power mixture setting procedures

For most engine installations the injector is set to provide an over-rich mixture during take off/landing phases to ensure engine operating temperatures well below the peak CHT. For this aircraft the manufacturer, assisted by the engine manufacturer, had developed the airframe/engine combination so as to ensure adequate engine cooling in all flight configurations, and the BPM setting procedure was intended to provide the best and most economical engine operation. The engine should be operated at 100-150°F below the maximum CHT. The use of BPM was described in the manufacturer's Aircraft Flight Manual. The pilot used the RAF Pilot Flight Manual, the content of which was taken from the manufacturer's Aircraft Flight Manual.

The BPM cockpit placard states a figure of 59 litres/hour at sea level (1032.2 mb) with full power applied in flight. However, because BPM is set up on the ground with the aircraft stationary, the maximum rpm cannot be obtained and so an approximation has to be applied. Experience has demonstrated that subtracting 4 litres/hour from the placard figure results in about the correct setting for BPM at full power on the ground. Thus with full power applied on the ground, the mixture is adjusted to set the fuel flow to the placarded value appropriate to the altitude, less 4 litres/hour. At sea level, a BPM fuel flow setting of 55 litres/hour corresponds to the placarded fuel flow of 59 litres/hour.

Engine failure checklists

From the RAF Pilot Operating Handbook (POH) for the aircraft the engine failure (non-mechanical) drill was as follows:

Immediate Actions

Check or set:

Speed	75 knots
Auxiliary fuel pump	ON
Throttle	CLOSED

Subsequent Actions

Below 1500 feet AGL	*Above 1500 feet AGL*
Attempt **Restart** if practical otherwise	Attempt **Restart**
Forced Landing	Decide by 1500 feet AGL on **Abandoning** or **Forced Landing**

Restart

RPM	HIGH
Mixture Control	RICH
Alternate Air	As Required (see Note 1)
Fuel Selector	Check/change selection
Fuel cock	ON
Ignition	BOTH

Propeller windmilling	*Propeller stationery*
Open throttle smoothly	Open throttle to about 2cm. Press Starter Button until engine starts (see Note 2) Check starter warning light goes out

If no start
Close throttle and decide between **Abandoning** and **Forced Landing**

Note 1: If intake icing caused engine failure, use alternate air until clear of icing conditions

Note 2: If engine does not turn using starter motor dive steeply to 130 kts and pull out sharply. Only attempt this if a successful forced landing or abandonment would still be possible if the engine fails to start.

Practise forced landing procedures

The engine failure is simulated in the PFL by closing the throttle and setting the propeller pitch lever to LOW, which more realistically reproduces the glide performance of the aircraft with an engine failure.

Advice is given in the RAF Student study guide to conduct the 'engine warm' check every 1,000 feet during the glide descent to keep the CHT above the minimum in-flight value of 65°C. This should be achieved by selecting full power, applying rudder to prevent yaw and selecting the climb attitude without trimming. Full power should be held for 3 seconds.

During the late stages of a PFL, if the CHT is above100°C only an 'engine response' check should be carried out (as stated in the RAF Pilot Study Guide). This is carried out to confirm that the engine will respond normally when power is applied for the overshoot and without applying excess thrust which could disturb the glidepath of the aircraft. This response check is carried out by selecting the propeller pitch lever to HIGH rpm, opening the throttle to confirm a smooth engine response without hesitation or rough running, and then retarding both the throttle and propeller levers.

Investigation of the engine failure

The aircraft was dismantled and returned to RAF Cosford where its maintenance organisation investigated the cause of the engine failure. The aircraft was re-assembled with no adjustments made to the engine control or mixture settings. A forward facing filter intake located in the bottom of the engine cowling supplied induction air. In the event of blockage of this filter, warm air could be inducted from around the engine be pulling the 'ALTERN AIR' push-pull control in the cockpit. Examination of the air filter found it to be clean and dry when the aircraft was examined after recovery form the field. The aircraft was then refuelled and an engine ground run performed.

The engine started normally and all indications were normal, apart from a slightly low fuel pressure indication initially. However, the fuel pressure indications increased to normal after a short period, and it was considered probable that the initial low fuel pressure indications may have been due to the retention of some air in the fuel system after all fuel had been drained from the aircraft prior to its dismantling for recovery to RAF Cosford. The engine ran smoothly at idle (700 rpm), and was then accelerated to warm the engine to within normal operating limits. After setting BPM, the engine idled normally at 800 rpm. The engine then performed satisfactorily throughout the full range of operation during the ground run, with all recorded parameters within limits.

Further checks were then performed on the engine units.

The fuel injector system comprised a set of injector nozzles, one per cylinder inlet port, with an associated flow divider and a control unit incorporating fuel metering and airflow measurement sections. As the throttle is opened, the increased airflow through the throttle body induces a pressure differential in the airflow metering section which applies a force to the regulator valve. This is balanced by a force generated by the fuel flow through the fuel metering section to provide the correct fuel-to-airflow ratio. The idle control valve is connected to the throttle linkage and effectively reduces the area of the main metering jet to provide accurate metering of the fuel in the idle range.

The fuel injector assembly was removed and bench tested satisfactorily, with the measured fuel flows within limits. Strip inspection of the fuel injector assembly revealed scores on the surface of the idle control valve and a nick on its rim. There was also a considerable quantity of blue/green residue around the venturi and on either side of the air diaphragm. This type of residue had been found in injectors previously and was thought to be residue from the fuel dye. The engine manufacturer did not consider such residues caused engine response problems (see later). The injector nozzles were removed and tested satisfactorily for fuel flow and spray pattern.

Some debris was found in the injector filter and the main fuel filter which was sent to the aircraft manufacturer for analysis. The debris consisted of steel, steel alloy, stainless steel, aluminium, brass, cadmium and plaster. The manufacturer considered this to be 'general filter contamination' and the amount was 'not thought to be significant'.

The engine cylinders were checked for compression and found satisfactory.

The magneto timing and switchleads were checked and no faults found. The spark plug leads were checked for continuity and insulation and found satisfactory. With regard to the spark plugs, the No 4 cylinder lower plug appeared fouled with oil, and all the plugs appeared to have been running slightly rich. All plugs were found to have electrode gaps which were greater than the maximum allowed, and when tested all appeared to have poor sparking characteristics. However the engine had reportedly been ground run satisfactorily with these spark plugs.

Previous history of engine stoppages

Since the introduction of the Grob 115 'Tutor' into service with the RAF there have been a number of 'undemanded engine stoppage' and rough running occurrences reported to the CAA. Of these, four engine stoppages had occurred in flight, including this incident, and all of the three previous stoppages had occurred during stall turn manoeuvres. In these three events the engines had restarted in flight, without any pilot intervention in two of these incidents.

In this incident, the stall turn manoeuvre had been accomplished by pulling up at 120 kt to establish a vertical climb,and allowing the speed to drop to 70 kt, before left rudder was applied to yaw the aircraft through 180° until it was pointing vertically downwards. Full throttle had been used for the manoeuvre, as normal, and 2,500 rpm was maintained throughout the manoeuvre. There have been reports of reductions in propeller rpm as the airflow through the propeller disk reduces in the vertical part of the manoeuvre. The other reported incidents involved a deliberate reduction in power during right hand stall turns.

The remainder of the reported events had occurred on the ground. Four events were reportedly due to one faulty injector unit that over a period had been fitted to three different aircraft. The same injector was also involved in one of the airborne incidents. Two occurrences were ascribed to an internal 'catastrophic' failure of the impulse coupling within magnetos causing debris to be distributed around the accessory gearbox and engine. A related magneto modification has been introduced and some 50% of the fleet had been modified, including this aircraft.

Fuel contamination had been identified in six of the cases, but the source of the debris had not been identified. The use of a 20 micron filter between the engine driven fuel pump and the injector inlet was under investigation by the manufacturer. Scoring of the injector idle control valve had been found in some of the incidents, including this one. A hardened valve seat has been developed to minimise damage to the valve by debris, and a trial is to be carried out with modified units fitted to a few aircraft.

The maintenance organisation and the aircraft manufacturer have agreed to check all fuel filters and strainers to assess the extent of the debris problem in the Grob 115 RAF fleet, with any significant contamination returned to the manufacturer for analysis.

There have also been incidents of the inlet air filter becoming saturated with water. One such event was reported where the engine ran down after landing during the roll-out. A new type of induction air filter has been tested by the manufacturer with the intention of making it available for fitment by December 2001.

Finally, several engine problem events were believed to have been caused by flexing of the throttle control lever bracket. As a consequence, strengthened brackets have been fitted to new-build aircraft, and a fleet retrofit programme has been completed.

Safety actions

The RAF have made a number of recommendations as part of their unit inquiry into this incident:

The Inquiry recommended that:

> All pilots to be reminded of the drill for restarting/recovering a failed (non mechanical) engine.
>
> A review of Tutor FRC emergency drills be undertaken.
>
> A review of the use of the engine control levers during PFL and glide approaches to be made.
>
> All aircrew are reminded of the importance of making a PFL only to a suitable landing area.

The Inquiry further recommended that the Maintenance Organisation provided assurance that:

> Action would be taken to eliminate debris from the fuel injector system and to minimise the damaging effect of debris in the injector.
>
> Action would be taken to prevent the tendency of the air induction system to collect and retain moisture.
>
> Action would be taken to ensure the correct setting of spark plug gaps.
>
> The aircraft manufacturer has been asked to confirm the engine operating criteria, particularly regarding air/fuel mixture control, during take off and go-around, together with a supporting explanation.
>
> An investigation will be undertaken to discover if liquid fuel on both sides of the air diaphragm affects the correct operation of the fuel injector system.
>
> An investigation will be undertaken to discover how such a variety of debris gets into the fuel system.
>
> A check will be carried out on the Tutor fleet fuel filters and strainers to assess the full extent of the debris problem, following which appropriate debris control measures should be devised.

Discussion

Although this University Air Squadron student pilot had previously flown and performed aerobatics in the Bulldog, he had only 4:40 hrs on the Grob Tutor and this was his first solo flight on this type. In the conversion training that he had received, he had demonstrated all the required exercises including stall turns and PFLs. The pilot reported a 'change in engine note' associated with the stall turn to the left. A reduction in propeller rpm was not uncommon during stall turns, and there have been three reported occurrences of engine stoppages during such manoeuvres. However, in these cases the engines had recovered and subsequently ran normally.

There was evidence in this case of scoring on the idle control valve. Similar evidence had been found during the investigation of the previous engine stoppages. Any debris which may have lodged between the idle valve faces could have given rise to an over rich mixture. In this context, it was notable that the condition of the spark plugs appeared consistent with a 'rich running' engine. Such debris may then have been flushed out with subsequent movement of the mixture control; however no debris was found lodged in the flow divider or the injector nozzles.

Debris might also have caused the idle valve to have held open slightly and so have affected the idle and mixture setup. If any such debris had then been dislodged, it might have resulted in a fuel mixture that was too lean. However the engine ran at idle satisfactorily subsequent to the forced landing without any change in the idle and mixture settings.

As stated previously, in response to such fuel contamination debris related concerns the maintenance organisation and the aircraft manufacturer have agreed to check all fuel filters and strainers to assess the extent of the debris problem in the Grob 115 fleet, and the use of a 20 micron filter is being pursued by the manufacturer. In addition, a hardened injector idle control valve seat has been developed to minimise the damage to the valve caused by debris and a trial is being carried out with a modified unit being fitted on a few aircraft.

The injector also contained a considerable quantity of 'fuel dye residue' around the venturi and on either side of the air diaphragm. If the engine is overprimed, fuel can run down the intake pipes into the manifold where it can accumulate on the sharp edges of the venturi and gain access to the venturi suction side of the air diaphragm. When the fuel evaporates it can leave residue from the fuel dye which has the same viscosity range as engine oil. The engine manufacturer had been aware of this problem and had conducted an engine test with oil in the area of the venturi suction side of the air diaphragm. However, this test had not produced any detectable change in engine response as a result of such contamination.

The pilot warmed the engine once during the idle descent from above 3,300 feet to around 800 ft where he made the decision to go-around from his PFL. Normal procedures required the engine to be warmed every 1,000 feet during descent to prevent plug fouling and to maintain CHT above the minimum permitted in-flight temperature of 65°C, but the pilot reported that the CHT had been above100°C at that stage. He did, however, carry out an engine response check, but the short duration of this check would not have warmed the engine significantly.

His use of the starter button when the propeller was windmilling was not the correct action, and would have had the effect of disabling the right magneto. In addition, the pilot did not select the fuel mixture control to rich; making this selection would have improved fuel flow, especially if debris in the injector had caused too lean an idle/mixture setting.

No evidence was found to suggest that the induction air filter had been saturated. A new induction air filter, which should be less susceptible to water contamination, has been tested by the manufacturer for fitment by December 2001. The pilot had closed the throttle at FL 40 and the engine had responded normally during the descent down to 1000 feet amsl. It may be seen from the meteorological aftercast conditions table information that the air temperature increased from +7°C at FL 40 to +10.5°C at 1000 feet agl, with respective dew points of +5°C and +8.5°C and a humidity of 87% at both heights. It would therefore appear from these conditions that although the dew point may have been only some 2 degrees lower than the air temperature at both levels, the air temperature was some 3.5°C higher at the lower level. It would thus appear that if the intake conditions at FL 40 were satisfactory for normal engine operation, with no apparent symptoms of intake filter icing, then they should have also been satisfactory at the lower levels with higher air temperatures.

On the basis of these findings, it was not possible to assign the cause of this engine failure with any certainty. However, the balance of the evidence on the spark plugs appeared to indicate that this engine had been running 'rich' for some time, and the debris contamination found in the fuel system had induced scoring of the idle control valve surfaces, which has also been found in the other engine stoppage incidents. Such debris and scoring could have produced a richer fuel mixture than normal which may have induced the engine symptoms during the stall turn manoeuvre when the aircraft slowed to the stall at the peak of the manoeuvre. In this context it was notable that there have been reports of reductions in propeller rpm as the airflow through the propeller disk reduces in this part of the stall turn manoeuvre. Piston engines generally can withstand a higher degree of overfuelling at higher power/rpm settings. It was also notable that the three previous in-flight engine stoppages had occurred during such stall turn manoeuvres. However, in each of these three previous cases the engines had restarted in flight, and without any pilot action in two of these incidents.

The pilot would have been better advised to have returned directly to RAF Cosford after his concern over the engine response during the stall turn, without attempting a PFL. However, he appeared to have prepared his aircraft for the PFL in a competent manner and there was no indication that his lack of engine warming bursts of power at 1000 feet intervals during his descent had allowed the engine to over-cool, since he reported that the CHT had been above100°C, well above the minimum permitted in-flight temperature of 65°C. The question arose, therefore, as to why the engine would not pick up when he applied the throttle for his go-around. If his earlier engine symptom had been related to over-fuelling, the only apparent factor which may have increased this tendency might have been his (correct) selection of the auxiliary fuel pump to ON before he commenced his PFL (this pump is not switched on for aerobatics). However, he later carried out a full engine warm check and an engine response check, during which the engine responded apparently normally on both occasions. The only additional change that he made prior to the go-around was to correctly move the propeller pitch control lever fully forward to the low pitch/high rpm setting before he opened the throttle. If over-fuelling was responsible for the spluttering response that then occurred, it may be that the engine had been suffering from an increasing tendency towards this from the time that the auxiliary fuel pump had been switched on. Such over-fuelling or 'flooding', if indeed this did occur, may also explain why the engine could not then be restarted in the time available before the pilot had to commit to a forced landing.

However, notwithstanding the difficulty in determining with certainty why this particular engine stoppage had occurred, it appeared from these findings and the recommendations of the associated RAF unit inquiry that all of the known possible sources of such engine problems would be addressed by the manufacturer and the maintenance organisation to improve future engine reliability on this trainer type.