Jet Provost T3A, G-BVEZ

AAIB Bulletin No: 8/2003	**Ref: EW/C2002/08/04**	**Category: 1.2**
INCIDENT		
Aircraft Type and Registration:	Jet Provost T3A, G-BVEZ	
No & Type of Engines:	1 Bristol Siddeley Viper MK102 turbojet engines	
Year of Manufacture:	1960	
Date & Time (UTC):	18 August 2002 at 1830 hrs	
Location:	Humberside Airport, South Humberside	
Type of Flight:	Private	
Persons on Board:	Crew - 2	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Nil	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	47 years	
Commander's Flying Experience:	9,000 hours (of which 500 were on type)	
	Last 90 days - 240 hours	
	Last 28 days - 80 hours	
Information Source:	AAIB Field Investigation	

Synopsis

The aircraft was carrying out a flight test with both the pilot and observer using oxygen supplied by the aircraft's integral oxygen system. On climbing through FL240, the pilot became unconscious due to a disconnection in his oxygen hose at the break point with his ejection seat. The ejection seats had been de-activated and were not equipped with their emergency oxygen bottles. The observer managed to control the aircraft, descending it sufficiently for the pilot to regain consciousness and subsequently to return to their departure airfield for a normal landing. Recommendations are made regarding risk assessment of the limitations and procedures after changes to the design standard of ex-military aircraft and for a review of their air test schedules.

Aircraft Description

The aircraft is a single-engined turbojet powered ex-military trainer fitted with two ejection seats in an un-pressurised cockpit. Both seats had been deactivated although their associated seat-back parachutes remained usable. The aircraft had an integral oxygen system that was serviceable but the emergency oxygen bottles had been removed from the ejection seats.

The aircraft was operated on a 'Permit to Fly' with conditions applied. These conditions specified that the aircraft must be maintained by an organisation approved in accordance with BCAR A8-20 and operated in accordance with CAP 632 (Operation of 'Permit To Fly' Ex-Military Aircraft On The UK register). No altitude limits were specified within the Permit conditions or the Flight Manual but in military service the aircraft type was occasionally flown to an altitude of 30,000 feet to demonstrate to students some characteristics of high altitude flight. Hypoxia recognition training in a barometric chamber and classroom education on the recognition and management of decompression sickness were pre-requisites for flight at high altitude.

History of Flight

The aircraft was due to undertake a flight test to renew its Permit to Fly. The pilot carrying out the test was accompanied by an observer whose task it was to note and record the various instrument readings required. The observer had no flying qualifications and sat in the left-hand seat in order to read the main instruments more easily.

Since the test involved flying above 10,000 feet, both the pilot and the observer were wearing oxygen masks connected to the oxygen hoses attached to their ejection seats. The pilot stated that as part of his pre-flight check he visually checked the oxygen hoses were properly connected. He also checked the Standard Warning Panel (SWP) by means of the test switch on the instrument panel; amongst the various captions are two labelled 'OXY', one for each seat. These captions should illuminate during the SWP test and at any time if either of two 'pull apart' connections between the pilots' oxygen masks and their oxygen supply hoses are not established. All seemed satisfactory and the aircraft departed Humberside Airport to carry out the flight test.

The pilot requested permission from ATC to climb to FL250 to conduct the initial part of the test, but he was cleared only to FL240. ATC also gave the pilot instructions to remain inside radar coverage and clear of controlled airspace. The aircraft began its climb with the relevant information being recorded every 5,000 feet for the air test. As the aircraft approached FL240, the observer noticed that the aircraft began to roll to one side, the roll becoming progressively steeper. The pilot's face was obscured by his helmet's dark visor and oxygen mask, but he was sitting upright with his hands on the controls. The observer spoke to him but, getting no reply, took the controls and attempted to fly the aircraft himself.

The aircraft had been on a northerly track approaching Airway L975. ATC repeatedly passed instructions to try to turn it onto a southerly heading but no reply was received and the aircraft flew through Airway L975, later crossing the coast and flying out to sea. At first the controller suspected the aircraft had experienced an electrical failure and contacted the ATC Distress and Diversion cell, but when its flight path became erratic, he was concerned that there might be a problem with the crew's oxygen. The aircraft's transponder was unserviceable and contact had been maintained throughout the flight by primary radar alone. The pilot's previous report to ATC, however, had informed them that he was passing FL140 in the climb.

The observer managed to maintain control of the aircraft and descend to about FL210. At this point the pilot became conscious and took the controls putting the aircraft back into a climb. The aircraft continued its ascent to approximately FL270, the pilot rapidly falling unconscious again. The observer, realising the pilot was hypoxic, continued to fly the aircraft and put it into a descent in the hope that the pilot would once again regain consciousness. The pilot did indeed 'come round' but it took about half a minute before he was coherent enough to take control, during which time the observer ensured the aircraft was not put back into another climb. The pilot stated that he had no recollection of events after approaching FL240, until he was aware of the aircraft descending again through approximately FL150.

The ATC controller reported eventually regaining radio contact, although the pilot's transmissions were initially described as unintelligible with the aircraft continuing to fly erratically. The controller passed the pilot his position as 5 nm east of Flamborough Head whereupon the pilot stated he was returning to Humberside. The controller stated that he continued to carry out radio checks with the aircraft but it was not until the pilot reported being at 2,500 feet that the pilot's voice became completely intelligible again.

The aircraft made an uneventful landing at Humberside Airport. Upon inspection of the cockpit, it was discovered that the pilot's oxygen hose (the right hand seat) was disconnected at the break point connector between the seat and the cockpit floor. This connection cannot easily be checked once the seat is occupied and it could be affected by items firmly stowed between the ejection seat pan and the cockpit wall.

Integral oxygen system description

Oxygen is stored in a single 2,250 litre cylinder in the nose of the aircraft. From the cylinder, high pressure gaseous oxygen is fed to an automatic line valve on the left cockpit wall. If the pilot forgets to turn on the line valve, a barometric capsule opens the valve between 8,000 and 9,000 feet altitude. Oxygen then flows from the line valve to a regulator in front of the left seat from which a low-pressure supply is taken to an economiser behind the left seat. Outflow from the economiser is then fed to the left seat oxygen connection. Low pressure flow also passes from the left regulator via another regulator in front of the right seat to an economiser behind the right seat and from there to the right seat oxygen connection.

Both regulators include a twin flow indicator comprising two glass tubes each containing a small ball which rises into view when oxygen is flowing to the economiser. A single ball indicates normal flow whereas two indicate the high flow recommended at altitudes above FL250.

The oxygen hose from each economiser contains a break point between the aircraft and the ejection seat which is designed to separate during ejection. An electrical sensor should illuminate the associated 'OXY' caption if this break point is disconnected. At the user end of each hose is a connector for the pilot's oxygen mask which also has a similar sensor to illuminate the 'OXY' caption if the pilot's mask is not connected or if no blanking plug is fitted when the right-hand seat is unoccupied. The system is designed so that for the pilot to be receiving a supply of oxygen, at least one ball should be visible in the relevant twin flow indicator and the amber 'OXY' warning on the SWP should be out.

Emergency oxygen bottles

The aircraft design is such that if the integral oxygen system fails in flight then an emergency supply of oxygen is available from a small cylinder attached to each ejection seat. It was intended that a separate hose connected each cylinder to the seated pilot's mask. This arrangement had a dual purpose. Firstly it provided oxygen automatically during ejection from the aircraft until the pilot separated from the seat at or below a nominal 10,000 feet. Secondly, the emergency oxygen bottle acted as a back-up for the integral oxygen system. It could be turned on manually during flight by pulling an emergency operating knob located on the front of the seat pan on the right-hand side. When selected, the emergency system provided an unregulated flow of oxygen for a duration of approximately 10 minutes. This would have been sufficient to allow time for the aircraft to be descended to an altitude of 10,000 feet or below.

The AAN (Airworthiness Approval Note) for G-BVEZ endorsed by a CAA surveyor revealed that because the ejection seats on this particular aircraft had been de-activated, the Authority was content that the emergency oxygen bottles and connectors were not fitted.

Analysis

It is clear that irrespective of when the hose became disconnected, the pilot found himself unknowingly flying above 10,000 feet without an adequate supply of oxygen. Due to the insidious nature of hypoxia he remained unaware of his incapacitation to the extent that he became unconscious. At this point, there was nothing that could be done to restore an oxygen supply and the observer, who was not a qualified pilot, did well to control the aircraft as skilfully as he did. Without emergency oxygen bottles, the only solution to the problem was to descend the aircraft back to a safe altitude. Fortunately, the observer was able to maintain control and manoeuvre the aircraft to an altitude low enough for the pilot to recover sufficiently to regain control and commence a descent back towards the airfield. It was not until some time later, however, with the aircraft at 2,500 feet, that it appears he had recovered fully.

The cause of the pilot's hypoxia was the break in the oxygen hose connection supplying his mask. This occurred at the break point between the seat and the aircraft which, for the right-hand seat, is situated in the narrow space between the edge of the seat and the side of the cockpit. This is a difficult area to inspect but should there be a break in the connector, the pilot would expect to see a warning on the SWP.

The SWP test allows each of the system's lamp filaments to be tested for continuity but the test switch does not check the integrity of the detection circuits or power supplies. The pilot had checked the SWP and because all the warning lights had illuminated on pressing the test switch, he had assumed his mask was connected to the integral oxygen system. Thus, after his visual check of the connectors and regulator, and in the absence of any warning lights, he believed that his oxygen system was functioning properly. However, a subsequent test of the Standard Warning System (SWS) revealed that the fuse in the 'OXY' warning circuit had blown and that a break in the hose would not have triggered a warning on the SWP.

Pre-flight oxygen checks

The pre-flight check of the oxygen system listed in G-BVEZ's Aircrew Manual is designed to detect just such an occurrence. It states the following:

On both left and right oxygen regulators:

1 Ensure locked ON (left regulator only), check contents and connections; SWS caption out.

2 Disconnect mask tube from ejection seat tube. Check SWS OXY caption is illuminated and amber attention-getters operate.

3 Re-connect supply; check OXY caption out and cancel amber attention-getters.

4 Select *(regulator)* emergency switch ON and check oxygen flow. Switch OFF.

5 Select HIGH FLOW and check flow.

6 Select NORMAL FLOW and check flow.

Thus had either the fuse been blown or the hose been disconnected prior to takeoff, this would have been detected by carrying out the specified check. However on this occasion the full check was not completed.

Physiological Aspects

Flight at high altitude carries with it the risks of hypoxia and decompression sickness.

Hypoxia only becomes a problem for healthy individuals above an altitude of 10,000 feet. It is associated with, amongst other symptoms, a loss of judgement and impairment of consciousness ranging from confusion to full unconsciousness.

The onset of hypoxia may not be immediately apparent but pilots should be aware of the symptoms and be prepared to take immediate remedial action. The time available between recognising the symptoms and remaining sufficiently unimpaired to take appropriate action is termed the time of useful consciousness. This may be as much as 20 to 30 minutes at 18,000 feet, reducing to about two to three minutes at 24,000 feet. At 30,000 feet, the upper limit required for the flight test, it would have been between 45 and 75 seconds.

Decompression sickness is associated with exposure to reduced atmospheric pressure at altitude and is characterised by nitrogen coming out of solution within the body and forming small bubbles within the body tissues. This can result in painful joints, problems breathing and ultimately collapse.

Decompression sickness does not normally occur at altitudes below 18,000 feet but the risk increases with altitude and the time of exposure above 18,000 feet. Once identified, those affected should, where possible, be placed on 100% oxygen and the aircraft must be landed as soon as possible. Further medical treatment should then be sought immediately.

Risk management

The aircraft was designed to be operated with fully functioning ejection seats and oxygen systems. Moreover, the Aircrew Manual (formerly Air Publication 101B-2303A-15) and to some extent, the aircraft's limitations, were devised on the assumption that these systems would be fully serviceable before takeoff. Operators choosing to fly the aircraft with one or both oxygen systems partially or fully disabled, or with deactivated ejection seats therefore restrict the aircraft's utility and potentially the safety of those onboard. Equally, those choosing to make use of these systems must ensure they have been adequately trained and that the appropriate procedures are followed. (Guidance on this subject is contained within CAP 632).

Consequently, it would seem logical that when flying an unpressurised aircraft and relying on only a single source of oxygen it is important to remain at an altitude where:

a. The risk of decompression sickness remains low and

b. The time of useful consciousness is adequate to descend the aircraft to a safe altitude should the oxygen supply fail.

Time of useful consciousness

According to the United States Naval Flight Surgeon's Manual, Third Edition 1991, at an altitude of 25,000 feet the time of useful consciousness would be between two and three minutes. Allowing one minute for a pilot to recognise hypoxia, check the contents and connections of the main oxygen system, and subsequently to declare an emergency and receive clearance to descend, the occupants might have only one more minute of useful consciousness in which to descend to a safe altitude. In a Jet Provost, one minute would be insufficient time in which to descend to an altitude where oxygen is no longer a necessity.

At 22,000 feet altitude, the time of useful consciousness is increased to between five and ten minutes. With a stabilised descent rate of 3,000 ft/min, an aircraft could be descended to 10,000 feet in four minutes without any need for high g or high speed manoeuvres. Allowing one minute for the same recognition and decision process, from 22,000 feet a pilot could descend to a safe altitude without losing consciousness. Therefore, an upper altitude limit in the order of 22,000 feet seems sensible for an unpressurised aircraft equipped with a single oxygen system. Should an alternative supply of oxygen be available, then the time needed to descend is increased allowing flight at higher altitudes. However, at these altitudes the risk of decompression sickness then increases, especially above 25,000 feet.

Aircraft abandonment

Although abandoning an aircraft at high altitude without a functional ejection seat is possible, the only oxygen supply available would be atmospheric. Thus once outside the aircraft at high altitude, a pilot could face a severe risk of hypoxia. If he opened his parachute too early, he might suffer low-temperature thermal injuries or lose consciousness during the long parachute descent. If he waited until he was nearer 10,000 feet before opening his parachute, he might lose consciousness in the free-fall descent and not recover in time to open his parachute.

Reasons for high altitude flight

Although this aircraft could be flown at high altitude using the integral oxygen system, the pilots within the ownership syndicate seldom if ever did so. They operated to a self-imposed limit of 10,000 feet and dispensed with oxygen masks, wearing boom mikes on their helmets instead.

According to the flight test schedule, the aircraft should have been climbed to FL300 (30,000 feet altitude). It was apparent from the schedule that the only reason for climbing above FL250 (25,000 feet) was to check the performance of the engine.

Air test schedule

In RAF service, the un-pressurised versions of the Jet Provost were flown as high as FL300 (30,000 feet) but not frequently and seldom with only one pilot on board. The flights to high altitude were part of a training syllabus that included exposing trainees to the high-altitude flight effects on aircraft speed, performance and control. The physiological effects of un-pressurised high-altitude flight were also experienced but only after comprehensive training and briefings to minimise the risks and discomfort to the aircrew.

It is likely that the flight test schedule used for G-BVEZ contained a requirement to test the engine at FL300 because of a legacy requirement from its original service role as a basic trainer. This requirement is probably unnecessary for the civil role now undertaken by the Jet Provost. Moreover, if the flight test schedule were capped at a level between FL200 (20,000 feet) and FL240, there would be no need for the air test to enter Class B airspace (all UK airspace above FL245) with its attendant complications.

Other aircraft types

Notwithstanding the recommendation in CAP 632 that *'the oxygen system be fully serviceable in all types of turbine powered aircraft whether or not the operator proposes to fly the aircraft above FL100'* the AAIB is aware that the operability of systems within some ex-military jet aircraft varies between individual aircraft of the same type and mark. For instance, the AAIB recently investigated an accident involving a foreign built ex-military jet trainer aircraft. The example had a pressurised cockpit and functional ejection seats but the integral oxygen system was placarded as inoperative. Consequently, the safe operation of some of these aircraft is no longer assured by adherence to a Flight Manual based heavily on the endorsement of the military Aircrew Manual.

Design standards and limitations

The Civil Aviation Authority considers that when permission is granted to operate an ex-military aircraft with some of the original equipment inhibited or removed, this represents a change in the design standard which is reflected in the aircraft's Permit to Fly. Also, in the case of G-BVEZ, although the operator had no intention of flying the aircraft above 10,000 feet, the Authority required the aircraft to be flight tested at high altitude because the design standard permitted it to be flown at high altitude.

Safety Recommendations

The AAIB considers that when an aircraft's design standard is changed, it may no longer be appropriate to operate the aircraft in accordance with the original military 'Aircrew Manual'. The Authority refers to this Manual within the aircraft's Permit to Fly and in the case of G-BVEZ, the Permit re-iterated some of the limitations specified in the 'Aircrew Manual' but added additional conditions which were not related to the design standard such as *'the aircraft shall only be flown by day and in accordance with the Visual Flight Rules'*. No upper altitude limit for the Jet Provost T Mk 3A is specified in the military Aircrew Manual whereas the emergency procedures in the Manual were formulated on the basis that the aircraft had separate main and emergency oxygen systems, and functional ejection seats. Consequently, some of the emergency procedures specified in the Aircrew Manual are no longer appropriate to the design standard of G-BVEZ.

The difference in design standard between the military and that permitted by the CAA for G-BVEZ did not materially affect the aircraft's airworthiness, but it did make its **operation** less safe for the crew, particularly at high altitudes. In cases where the Authority permits a change in the design standard of an ex-military aircraft which affects the safety of the occupants, it is appropriate that a risk assessment be carried out to determine whether the aircraft should still be operated throughout the original flight envelope and in accordance with the original limitations and procedures specified in the Military Aircrew Manual. Therefore, it is recommended that:

Safety Recommendation 2003-27

The Civil Aviation Authority should consider whether ex-military aircraft operated in accordance with a Permit to Fly and CAP 632 may still be operated in accordance with the original limitations and procedures specified in the Military Aircrew Manual after changes to the design standard that have an impact on the aircraft's operation.

Safety recommendation 2003-29

The UK Civil Aviation Authority should review the air test schedules of all ex-military aircraft on the UK Register to harmonise those schedules with any additional limitations placed upon the aircraft resulting from changes to the design standard.