Aviation Safety Investigation Report 199401106

de Havilland Aircraft Tiger Moth

01 May 1994

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Aviation Safety Investigation Report

199401106

Occurrence Number: 199401106 **Occurrence Type:** Accident
Location: Luskintyre
State: NSW **Inv Category:** 3
Date: Sunday 01 May 1994
Time: 1355 hours **Time Zone** EST
Highest Injury Level: Fatal
Injuries:

	Fatal	Serious	Minor	None	Total
Crew	2	0	0	0	2
Ground	0	0	0	0	0
Passenger	0	0	0	0	0
Total	**2**	**0**	**0**	**0**	**2**

Aircraft Manufacturer: de Havilland Aircraft
Aircraft Model: DH-82A
Aircraft Registration: VH-UNA **Serial Number:** A17-610
Type of Operation: Non-commercial Pleasure/Travel
Damage to Aircraft: Destroyed
Departure Point: Luskintyre NSW
Departure Time: 1355 EST
Destination: Luskintyre NSW

Crew Details:

Role	Class of Licence	Hours on Type	Hours Total
Pilot-In-Command	Commercial	572.0	1200

Approved for Release: Thursday, July 18, 1996

1. FACTUAL INFORMATION

1.1 Sequence of events

The aircraft had been flown from Brisbane to Luskintyre to carry out a series of joy flights over the weekend. At the completion of those flights it was configured for a wing-walking demonstration in which, during flight, a person would stand strapped to a demountable frame installed above the fuel tank on the upper wing centre section.

The aircraft was refuelled during the morning prior to the accident. Two local flights were flown before the wing-walking frame was installed. The wing-walker, who was also a Tiger Moth pilot and was experienced with this routine, was strapped into the frame. After starting the engine, the pilot boarded the aircraft, taxied to the eastern end of the airfield, turned, and commenced a takeoff to the west.

After lift-off, a climb was made at a low airspeed. At approximately 150 ft above the ground, the aircraft's engine lost power. The aircraft commenced a turn to the left, the turn continuing to develop until the aircraft's nose dropped. The aircraft then descended steeply into the ground, caught fire, and was destroyed. Both pilot and passenger were fatally injured.

The accident occurred within the confines of the airfield and no other property was involved.

1.2 Crew information

The pilot held a commercial pilot licence. He had 1,200 hours flight time, of which 570 were on Tiger Moth aircraft. Both his pilot licence and medical certificate were valid.

The wing-walker also held a pilot licence and was endorsed on the Tiger Moth aircraft.

Both crew members were experienced with the wing-walking routine.

1.3 Site, aircraft and wreckage information

The weather was fine with a light breeze from the north-west. Weather was not considered to be a factor in the accident.

There were no known unserviceabilities with the aircraft prior to the flight. The aircraft was properly certificated and the maintenance release was valid. The last periodic maintenance inspection was performed in December 1993 and was valid for 12 months or 100 hours, whichever was the sooner. The aircraft had flown approximately 30 hours since that inspection.

The airframe was extensively burned, and had suffered impact and heat distortion. It was not possible to definitely establish pre-accident serviceability. However, the wreckage examination disclosed an apparent anomaly with the flight control system in that the right rudder control horn was fractured. Specialist metallurgical examination determined that the fracture had occurred after the horn was affected by the post-accident fire.

The engine was extensively damaged by impact and fire. There was no evidence of power interruption from water contamination or mechanical damage, and evidence of sufficient fuel supply was obtained. However, during a strip inspection it was found that an unmodified fuel needle valve was fitted to the carburettor.

1.4 Engine examination

The carburettor contained a fuel needle valve of a design that the manufacturer had declared obsolete in 1957. The needle fitted to the carburettor was Part Number CH 28696 and should have been replaced by Part Number CH 46155 in accordance with Gipsy Major Modification G1136. The modified needle was introduced to obviate sticking of the needle. This was accomplished by increasing the side clearance between the needle and the housing to 12-15 thousandths of an inch (0.012-.015 in). The original had a maximum clearance of two thousandths of an inch (0.002 in). The British manufacturer of the carburettor had declared the modification to be "highly desirable and strongly recommended to be embodied not later than the next complete overhaul provided parts are available". Existing needles were able to be modified, and new needles were manufactured. After consideration, the Australian regulatory authority at that time did not make compliance mandatory for Australian-registered aircraft.

The engine was last overhauled in Griffith, NSW during 1982. There was no record of the fuel needle valve modification being incorporated nor was a mandatory requirement in force in 1982 for the modification to be incorporated. Since this accident, other engines in service on Australian-registered Tiger Moth aircraft have been found fitted with the obsolete fuel needle valves.

The carburettor needle and the needle valve seat exhibited signs of particulate contamination which appeared to be compacted dust or dirt.

There were no defects found in the remaining component parts of the engine or its accessories.

1.5 Video recording

A visitor to the airfield filmed both the preparation for the flight and the flight itself on a hand-held video camera. The video recording (with sound) revealed that the engine was operating normally during the takeoff and initial climb but then lost power. The engine continued to run with the spluttering, staccato beat typical of an engine of this type at idle power. The recording also showed that right aileron and left rudder were applied for much of the period after the engine lost power.

Information was provided to the investigation team suggesting that an independent examination of the video recording had found evidence that the pilot's arm could be seen waving out of the cockpit, and that he was probably trying to grab flailing rudder cables. It was also reported that the recording indicated that the rudder was jammed to the left by the tail skid.

However, the video recording showed that the aircraft was normal in all respects as it taxied and lined up and took off. Had the rudder jumped over the skid keepers and been jammed, the pilot would not have been able to effect a straight takeoff. The wreckage examination did not show any marks on the skid or the rudder to indicate that the rudder was restricted, and the skid itself was free to rotate in its tube housing. Because the skid was free to rotate in its housing, even if the rudder had jumped over the keepers, the rudder would still have been able to travel side to side had the pilot applied pressure to the control bar. However, total movement in one direction would have been slightly reduced.

The flailing rudder cables were supposedly from the failed right rudder control horn. Metallurgical examination did not support this hypothesis and the wreckage examination did not show any other areas of distress within the rudder control system.

The video recording was digitised to aid enhancement. The images in the early part of the accident sequence, purported to be of the pilot's arm, were found to be images of the cowl-mounted air cleaner scoop and the propeller. An image adjacent to the fuselage in the area of the left wing root, noticeable on frames immediately prior to impact, was found to be the left cockpit door which was open throughout the flight. Both images were affected by pixel flare. (Pixel flare is the merging of the dots that make up the screen picture and is very evident in an image that is fast-moving on a screen.)

Specialist examination determined that the recording of the accident was of such a quality that even with enhancement it was not possible to detect the control cables.

1.6 Wing-walking

Wing-walking was prohibited in Australia until 1989 when Civil Aviation Regulation 250 was amended to relax this total prohibition. Regulations were drafted to allow wing-walking stunts in special circumstances under vigorously controlled conditions. Flying Operations Instruction 27-2, Issue 1, dated 21 April 1989, was raised to specify those circumstances and conditions.

Flying Operations Instruction 27-2 approved wing-walking stunts only at the following venues:

(i) an Authority-approved air display as detailed in Flying Operations Instruction 27-1;

(ii) a commercial film production; or

(iii) practice sessions for either of the above.

The wing-walking stunt on the day of the accident was for the benefit of a welfare group with whom the pilot and wing-walker were associated. The event was not an Authority-approved air display, nor was commercial filming undertaken. The Flying Operations Instruction did not contain guidance for approving the event as a practice session and there was no evidence that the pilot had been granted blanket approval to use this sort of event as a practice session.

The Flying Operations Instruction contains a requirement that the flying display be previewed and approved by the Authority. The preview is to be an assessment of the display sequence flown by the display pilot, with the aircraft fitted with the approved wing-walking structure containing a dummy of equivalent weight to the intended wing-walker. Although there has been verbal advice to the Bureau that an assessment was made, the Civil Aviation Authority files available to the investigation did not contain evidence that the Authority had formally assessed and approved the sequence flown by the pilot. There is no evidence that an assessment had been made of the performance and handling characteristics of VH-UNA when configured for wing walking. The Flying Operations Instruction required such an assessment to be made.

Neither the Civil Aviation Authority files nor those files held by the pilot contained any evidence that the pilot had applied to the Authority for permission to install the frame assembly and carry out wing-walking. Accordingly, there was no evidence that the pilot had been formally apprised by the Authority of its requirements. Although there was no formal record of the stunt being assessed and approved, the stunt had been incorporated into some airshow programs approved by the Authority.

1.7 Aircraft performance

The Tiger Moth is a low powered, high drag aircraft. During the investigation it was found that a wing-walker would increase the drag by 27%. This increased drag would reduce the aircraft's maximum cruise speed from 75 kts to 58 kts.

The wing-walking frame fitted to the accident aircraft was manufactured for and fitted to Tiger Moth VH-GVA in January 1990. This aircraft was subjected to flight tests (supervised by the Civil aviation Authority) to assess, in accordance with Flying Operations Instruction 27-2, its performance and handling characteristics. The investigation found no evidence that any performance calculations were made prior to the flight tests.

During the initial flight test, VH-GVA was fitted with a propeller having a 4 ft 6 in pitch. On a subsequent flight, with a 4 ft 2 in pitch propeller fitted, the rate of climb improved and it was established that the particular aircraft/engine/propeller/pilot combination achieved a best initial climb speed of 53 kts. The maximum attainable straight and level speed was 63 kts. The normal climb and cruise speeds are 59 kts and 75 kts respectively. The accuracy of the test results could not be determined as there was no requirement to calibrate the instrument system on the aircraft prior to the tests.

The flight tests found that before being fitted with the frame, VH-GVA accelerated from 50 kts to 70 kts in 12 seconds. With the frame fitted and a dummy installed, the aircraft took 24 seconds to accelerate from 50 kts to its maximum straight and level speed of 63 kts. There was also a noticeable rudder buffet that was later found to be reduced if the wing-walker stood with feet apart.

The wing-walk frame was later sold to the pilot of VH-UNA, who fitted it to his aircraft in February 1992, in accordance with an engineering order approved by the design engineer involved with the original installation on VH-GVA.

Along with the engineering order, the pilot received a copy of Civil Aviation Authority letter V131/24/34, dated 28 March 1990, which required among other things that for all wing-walking flights the propeller fitted to the aircraft should be of 4 ft 2 in pitch. The propeller fitted to the aircraft at the time of the accident was Part Number DH5220/H/26 and of 4 ft 11 in pitch. There was no record of a fine-pitch propeller having been fitted to VH-UNA since the wing-walking frame was initially fitted in 1992.

There is no regulatory requirement for the owner of an aircraft to inform the Authority of any approved modification being fitted to an aircraft. Also, for this particular modification, there was no requirement for the flight manual to be amended to detail the conditions surrounding the installation of the modification. Consequently, the Authority's file for the aircraft did not contain details of the fitting of the frame to the aircraft.

The first entry in relation to the wing-walking equipment occurred one year after installation when an airworthiness survey of the aircraft found irregularities in the procedures used during installation. Certification for manufacture of the frame had not been made and weight and balance considerations had not been addressed. The Authority's file did not contain a copy of the Authority's own letter that required a fine-pitch propeller to be fitted, nor did the survey disclose that an incorrect propeller was installed.

The design engineer who completed the original work on VH-GVA and authorised the installation onto VH-UNA is based at Bankstown, and his file was held in the Bankstown, NSW office of the Authority. The aircraft was based at Archerfield, Qld and its file was accordingly held in the Archerfield office of the Authority. There is no system within the Authority requiring that modifications approved by a design engineer be reflected on the file for the aircraft concerned. Accordingly there was no opportunity for the Archerfield-based officer carrying out the survey on the aircraft to check the configuration requirements prior to conducting a survey.

The first flight of VH-UNA after it was modified was conducted with the accident pilot in the frame. The pilot on that flight stated that he had difficulty climbing out of ground effect and that he was only able to attain a climb speed of 45 kts. The accident pilot is reported to have later stated that he had developed a slow flying technique that gave a climb performance acceptable to him. This technique is evident from videos taken at previous airshow performances which show the attitude difference between the accident aircraft and another Tiger Moth during takeoff.

1.8 Incorporation of modifications

The carburettor manufacturer recommended that the modified fuel needle be introduced at the next overhaul after 29 April 1957, and parts were made available to accomplish that requirement. The manufacturer's recommendation was not made mandatory by the then Australian Department of Civil Aviation. From 1957 to 1988, aircraft owners and operators were required to incorporate only those modifications made mandatory by airworthiness directives promulgated by the Department and its successor organisations.

Changes to the Civil Aviation Regulations initiated in 1988 made the aircraft owner responsible for deciding what modifications should be carried out. The regulator still retained the capacity to issue airworthiness directives.

Civil Aviation Regulations current at the time of the accident required that aircraft maintenance be carried out in accordance with the applicable provisions of the aircraft's approved maintenance data; that is, in accordance with the manufacturer's instructions specifying how maintenance should be carried out.

The Authority's airworthiness officers interviewed during the investigation disagreed as to whether the effect of that requirement would mean that Modification G1136 would need to be incorporated at next overhaul. One view was that it is impractical to catch up with 50 years of modifications on old aircraft such as the Tiger Moth and that "ancient" modifications could be ignored. A contrary view was that although many older aircraft could be grounded by the requirement, all modifications required by the manufacturer should be incorporated, regardless of the age of the aircraft.

1.9 Pilot reaction time

The time between the first engine splutter and the aircraft commencing a left turn was 3.5 seconds. The time between that first splutter and ground impact was 5.8 seconds. If VH-UNA was climbing at 50 kts, the rate of loss of airspeed after an engine power interruption is estimated to be 5 kts per second. The aircraft has a stall speed of approximately 40 kts. Therefore the pilot would have had just two seconds to apply corrective action before the aircraft stalled. There is evidence that the aircraft had on at least one occasion attained only 45 kts, which would allow even less time to react to an unexpected emergency situation.

The Royal Air Force Institute of Aviation Medicine, Farnborough, UK carried out two experiments on pilot response times to emergencies presented in flight simulators. The experiments were conducted in the wake of an airliner accident in which the pilot took 5 seconds to react to an unanticipated emergency situation.

The first experiment involved a measure of the time taken to apply brakes after presentation of locked controls at rotation of a fixed wing aircraft. The second involved the time taken for helicopter pilots to depress the collective lever after the presentation of a double engine failure.

The mean reaction time was 3.4 seconds in the first experiment and 3.08 seconds in the second. Although these response times appear long, the fact that they were measured in a simulator in which pilots were expecting emergencies, makes them, if anything, conservative estimates of the response times likely to occur in actual flight. Even in this simulation some pilots took 7 seconds to react to an emergency they would have been anticipating.

2. ANALYSIS

2.1 Introduction

Shortly after the aircraft became airborne the engine lost power, possibly because the carburettor fuel needle became jammed in the housing sometime during taxi prior to takeoff. If this had occurred, when the pilot applied take-off power the jammed needle would have limited the amount of fuel able to flow into the fuel chamber to replace fuel being used for take-off power (that is, the needle would have remained in its pre-takeoff, idle power position). With the fuel being used at a rate greater than it was being replaced, it would only be a matter of time before the engine lost power. Possibly contributing to the event was a fuel needle valve of obsolete design coupled with the presence of some particulate contaminant.

Although the manufacturer had recommended the fitment of a different fuel needle valve, it was not mandated at the time by the Australian regulatory authority. At the time of the accident there was some confusion as to whether legislation required the installation of the modified valve.

2.2 Aircraft handling

It has been established that the pilot had developed a procedure to fly the aircraft at a very slow speed to obtain a rate of climb that was acceptable to him. The investigation was not able to establish precisely what speed was used, nor what rate of climb was attained. With the very high drag occasioned by the wing-walker, the high-nose attitude and the low forward speed, any loss of power such as occurred on this flight would have led to a very rapid loss of airspeed to a point where control would have been lost unless almost instant corrective action were taken. The most effective corrective action would have been to immediately lower the nose to maintain airspeed. It is not known why this was not accomplished.

The video recording showed that a substantial left rudder deflection and an application of right aileron occurred immediately after power was lost. The left rudder deflection occurred almost simultaneously with the wing-walker adopting the crouched position.

On a previous flight in VH-GVA, it was found that the position of the wing-walker could effect the airflow over the tail of the aircraft, which resulted in rudder buffet if the wing-walker did not stand with feet apart. The investigation was unable to determine whether the position adopted by the wing-walker after the loss of power resulted in the left rudder deflection. The effect of the wing-walker adopting a crouching position is not known but it could be that some airflow disturbance was generated that may have caused the left rudder deflection.

Another possibility is that left rudder was applied by the pilot in an attempt to execute a flat turn back towards the airfield. Yawing the aircraft in this manner would have rolled it to the left, a secondary effect which the pilot may have attempted to counteract by applying right aileron.

The Tiger Moth is fitted with differential aileron control which reduces the yaw effect of aileron application. Flying at slow speed, and thus at a high angle of attack, the downgoing left aileron would, even with differential aileron control, still increase the effective angle of attack of that wing beyond the stall angle, resulting in the rapid roll to the left, further yaw and nose-down attitude as seen on the video recording. The control positions seen on the video were those which, given low airspeed, could be expected to result in the aircraft entering a spin to the left.

2.3 Aircraft performance

The propeller fitted to VH-UNA had a pitch of 4 ft 11 in, a standard cruise propeller for that aircraft. The initial test on VH-GVA showed the aircraft to be performance-limited when fitted with a 4 ft 6 in pitch propeller. It was necessary to fit a fine-pitch propeller of 4 ft 2 in pitch to obtain a climb performance acceptable to that pilot. With a coarse pitch propeller fitted, VH-UNA would have been even more severely performance-limited than VH-GVA.

The pilot of VH-UNA possessed a copy of a Civil Aviation Authority letter that detailed the requirement to fit a fine-pitch propeller. It is not known why he did not comply with the requirement. However, had he fitted a fine-pitch propeller prior to departure from Brisbane, his cross-country cruise capability would have been degraded.

The Authority's procedures for recording that the wing-walking frame had been installed onto VH-UNA were deficient. Although the details were held on file in the Authority's Bankstown office in relation to the design engineer who approved the installation, they were not required to be copied to the aircraft file for VH-UNA which was held at Archerfield. The Queensland-based officer carrying out the survey on the aircraft would not have been aware from the data held on the aircraft file that the modification had been carried out some 12 months prior to the survey. Nor would he have been aware of the conditions surrounding the installation and operation of the wing walking frame. Accordingly the chance to detect the incorrect propeller installation was missed.

2.4 Organisational factors

The aviation system has a number of built-in defences which are designed to detect any hazards before they lead to an accident. In this case, when the regulations were altered to allow activities such as wing-walking, instructions were issued by the Authority to regulate the conduct of the activity. These instructions were, in effect, aircraft and event specific in that they required approval on an individual basis.

The pilot of VH-UNA had aquired the wing-walk frame which he subsequently fitted to his aicraft under the approval of an authorised person. There was no evidence that the Authority was aware of the fitment of the frame other than when the pilot was approved to take part in certain air displays. Accordingly the Authority did not carry out, as required by the Flying Operations Instruction, an airworthiness inspection, nor an assessment of the aircraft's performance.

Similarly, there was a requirement that the wing-walking stunt be previewed and approved by the Authority. Although the investigation received anecdotal evidence that this was done, no formal evidence of the preview having taken place was found. If the preview did take place it was apparently of a cursory nature in that it did not detect that there had not been an airworthiness inspection, nor an assessment of VH-UNA's performance.

Moreover, surveillance conducted by the Authority on the aircraft did not detect that the fitment of the wing-walking frame had not been completed as required and that the aircraft was fitted with an incorrect propeller of a coarser pitch.

When the pilot purchased the frame he obtained a copy of the engineering order relating to the fitment of the frame and an Authority letter that required the fitment of a fine-pitch propeller to the aircraft for wing-walk activities. He apparently chose not to fit the propeller. In so doing, he circumvented the protection afforded by the fitment of a fine-pitch propeller which would have improved the climb performance.

Following the poor climb performance obtained on the initial flight with the frame fitted, the pilot apparently developed a flying technique which involved operating at a slower climb speed. By using a lower climb speed, the pilot had almost entirely removed any margin of performance to allow adequate reaction time in an emergency.

3. CONCLUSIONS

3.1 Findings

1. The pilot held a current commercial pilot licence and his medical certificate was valid.

2. Both crew members had previous experience with wing-walking activities.

3. The performance of the aircraft was significantly degraded when carrying a wing-walker.

4. The extent of the performance degradation was not calculated during the initial approval process.

5. The calculations made as a part of this investigation showed that the Tiger Moth was probably not an appropriate aircraft for carrying out wing-walking stunts.

6. The processes involved in approving the stunt, and in approving the pilot to carry out the stunt, were ineffectively controlled and poorly documented by the Civil Aviation Authority.

7. The pilot did not carry out this particular flight under the conditions specified by the Civil Aviation Authority.

8. The aircraft was not fitted with the required fine-pitch propeller.

9. The incorrect propeller installation was not detected during an airworthiness survey of the aircraft.

10. The fuel needle installed in the carburettor was of an obsolete configuration and a modification, to increase the fuel needle to housing clearance to preclude jamming, had not been carried out.

11. The fuel needle and housing showed evidence of particulate contamination which would have increased the probability of the needle jamming.

12. The manufacturer introduced the modification in 1957 for incorporation at the next overhaul. The Australian regulatory authority did not list the modification for mandatory incorporation.

13. The engine lost power suddenly, possibly because of a jammed fuel needle valve.

14. The loss of power occurred shortly after takeoff while the aircraft was climbing at slow speed in a nose-high, high-drag configuration.

15. The aircraft's speed rapidly decayed to a point where control was lost.

16. The video recording showed that, following loss of power, the nose of the aircraft was not effectively lowered, and the controls were in a pro-spin configuration (i.e. left rudder and right aileron applied).

17. When control was lost there was insufficient height to effect a recovery before the aircraft impacted the ground.

3.2 Significant factors

The following factors were considered relevant to the development of the accident.

1. The performance of the Tiger Moth was such that the aircraft was probably inappropriate for carrying out wing-walking stunts.

2. The flight was not carried out in accordance with the conditions for wing-walking prescribed by the Civil Aviation Authority.

3. The aircraft suffered a power loss while in the climb.

4. Immediate, appropriate control inputs were not applied and control was consequently lost at a height insufficient to effect a recovery.

4. SAFETY ACTION

4.1 Recommendations

As a result of this investigation the Bureau, on 14 June 1994, issued Interim Recommendation IR940146, which stated:

The Bureau of Air Safety Investigation recommends that the Civil Aviation Authority review all approvals granted for high drag installations fitted to aircraft to ensure that the particular aircraft has been proven to have a satisfactory performance. This should meet, as a minimum, the manufacturer's climb speed, and take regard of common emergency conditions that could arise.

The Civil Aviation Safety Authority response, dated 30 August 1995, stated:

The Authority does not maintain a central register of approvals issued for high drag installations. However, the number of such approvals is small and most are issued for reasons unrelated to high drag or low performance. I am therefore confident that the problem highlighted by this accident is confined to "wing walking" situations.

The Authority formally accepts your recommendation, and will review any further applications for "wing walking" flights to take account of the performance parameters outlined in the recommendation.

4.2 Safety advisory notices

As a result of the investigation into this occurrence, The Bureau of Air Safety Investigation issues the following Safety Advisory Notice.

SAN960062

The Bureau of Air Safety Investigation suggests that the Civil Aviation Safety Authority advise all owners of Gipsy Major-powered aircraft to expedite the incorporation of Gipsy Major modification G1136.