

ACCIDENTS INVESTIGATION BRANCH
Department of Trade

Wallis WA-117 Autogyro G-AXAR
Report on the accident at
Farnborough, Hants.,
on 11 September 1970

LONDON: HER MAJESTY'S STATIONERY OFFICE
1974

List of Civil Aircraft Accident Reports issued by AIB in 1974

<i>No</i>	<i>Short title</i>	<i>Date of publication</i>
1/74	McDonnell-Douglas DC8 — 63 CF N 801 WA and Aerospatial Caravelle 6 N 00-SRG approximately 10 nautical miles southeast of Lands End VOR, March 1973	April 1974
2/74	Piper PA-30 Twin Comanche G-AXRW at Shipdham Aerodrome, Norfolk, January 1973	April 1974
3/74	Slingsby T61A G-AYUO near Wycombe Air Park, Bucks, February 1973	May 1974
4/74	Viscount 802 G-AOHI at Ben More, Perthshire, Scotland, January 1973	May 1974
5/74	Owl Racer 65-2 G-AYMS at Greenwich Reach, River Thames, London, May 1971	May 1974
6/74	British Caledonian Airways BAC 1-11 at Corfu Airport, Greece, July 1972	May 1974
7/74	Wallis WA-117 Autogyro G-AXAR at Farnborough, Hants, September 1970	January 1975
8/74	AA-1 Yankee G-AYHD at Beverley Nursery, near Uxbridge, Middlesex, April 1973	July 1974
9/74	Cessna F172H G-AYDC near Humphrey Head, Lancashire, December 1972	June 1974
10/74	Beagle A.61 Series 2 (Terrier) G-ARZT near Tonbridge, Kent, August 1973	July 1974
11/74	Beagle A.61 Series 2 (Terrier) G-ATMS near Saltby, Leicestershire, August 1973	July 1974
12/74	Piper PA-30 Twin Comanche G-ASLD at Newchurch, Isle of Wight, May 1972	August 1974
13/74	Tiger Moth G-APVT and Rollason Beta G-ATLY at Nottingham Airport, September 1973	January 1975
14/74	Cessna F172H G-AVHI in the sea 44 nm east of Wick, Scotland, December 1973	October 1974
15/74	AESL Airtourer T6/24 G-AYMF near Lands End, Cornwall, June 1972	September 1974
16/74	Piper PA 28-140 G-AVBM near Dursley, Gloucestershire, August 1973	September 1974
17/74	Avions Pierre Robin DR 360, Robin Knight G-AZOX at Biggin Hill Aerodrome, Kent, July 1973	November 1974

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18/74	Piper PA 23-250E Aztec G-AZIF near Great Sampford, Essex, January 1972	November 1974
19/74	Chipmunk DH C1 Series 22A G-ARCR at Windlesham, Surrey, September 1973	November 1974
20/74	Jodel D117 G-ZFK at Doncaster Aerodrome, April 1973	December 1974
21/74	Societe Aeronautique Normande Jodel D117 G-AVEI at Brixham, Devon, September 1973	January 1975

Department of Trade
Accidents Investigation Branch
Shell Mex House
Strand
London WC2R ODP

21 March 1974

The Rt Honourable Peter Shore MP
Secretary of State for Trade

Sir,

I have the honour to submit the report by Mr G M Kelly, an Inspector of Accidents, on the circumstances of the accident to Wallis WA-117 Autogyro G-AXAR which occurred at the Royal Aircraft Establishment Aerodrome, Farnborough, Hants on 11 September 1970.

I have the honour to be
Sir
Your obedient Servant

W H Tench
Chief Inspector of Accidents

Accidents Investigation Branch
Civil Accident Report No 7/74
(EW/C357)

Aircraft: Wallis WA-117 Autogyro G-AXAR
Engine: Rolls-Royce Continental 0-200-B
*Registered Owner
and Operator:* Airmark Ltd
Pilot: Mr J W C Judge — Killed
Place of Accident: Royal Aircraft Establishment Aerodrome,
Farnborough, Hants, 51° 17'N 00° 46'W
Date and time: 11 September 1970 at 1414 hrs
All times in this report are GMT

Summary

The aircraft was being demonstrated at the Society of British Aerospace Companies (SBAC) air show at Farnborough. After a high speed downwind run parallel to the runway the aircraft first pitched rapidly nose-up, then nose-down, and went out of control, the rotor blades striking the propeller, fin and rudder as it fell to the ground. The pilot was killed instantly.

The report concludes that the accident resulted from a loss of control due to the effect of negative 'g' when the pilot attempted to control a nose-up pitch that occurred during a manoeuvre in which the aircraft's speed exceeded the authorised maximum.

1. Investigation

1.1 History of the flight

The aircraft had been flown during the flying display on each of the four days preceding the accident. Mr Judge had been the pilot on three of these days.

Runway 25 was in use at the time of the accident. The pilot started his display by making a short take-off on the runway adjacent to the control caravan followed by a climbing turn to the right through 180° to a height of about 200 feet above the aerodrome. The pilot then turned and started to lose height gradually until the aircraft was flying downwind at high speed roughly parallel with the edge of the runway and slightly to the north of it. At about 100 feet he initiated a gentle climb with the aircraft banked to the left. Then the aircraft suddenly pitched nose-up and then nose-down, yawing and then rolling to the right. When the aircraft was heading vertically downwards the rotor struck the propeller, fin and rudder. The aircraft then fell to the ground on a grass covered area in front of the control tower.

The crash services quickly reached the wreckage and extricated the pilot, who was found to have been killed on impact with the ground.

1.2 Injuries to persons

<i>Injuries</i>	<i>Crew</i>	<i>Passengers</i>	<i>Others</i>
Fatal	1	—	—
Non-fatal	—	—	—
None	—	—	—

1.3 Damage to aircraft

The aircraft was destroyed.

1.4 Other damage

None.

1.5 Crew information

1.5.1 *The pilot*

Mr J W C Judge, aged 48, held a valid British Commercial Pilot's Licence (Test Pilot) endorsed in Part 1 for ultra light single seat gyroplane variants

and a Private Pilot's Licence (Gyroplanes). He had been employed as a test pilot for a considerable time, first with Vickers Armstrong Aircraft and latterly with Beagle Aircraft.

His certificate of test on the Wallis WA-117 was dated 15 July 1970. At the time of the accident it is estimated that he had accumulated a total of 9,300 flying hours. Of this total 5 hours 30 minutes (22 flights) had been on the WA-117 and 14 hours 25 minutes (137 flights) on the WA-116.

His experience on the WA-116 had been gained between November 1961 and December 1963. He first flew a WA-117 G-AVJV, in March 1970.

1.6 Aircraft information

The Wallis WA-117 is a small single seat autogyro. Lift is provided by a free-turning two-bladed fixed-pitch rotor attached to an off-set gimbal teetering head. A 100 bhp piston engine drives a four-bladed fixed-pitch pusher propeller and also enables the rotor to be spun up before take-off. In flight, however, the rotor is autorotating at all times.

The aircraft is controlled by tilting the rotor disc by means of push-pull rods connecting the pilot's control column to the rotor head. Rudder pedals provide yaw control through a conventional rudder behind the propeller.

The amount of off-set in the rotor head is chosen so that the aircraft is in trim 'stick free' at an indicated airspeed (IAS) of about 60 knots. The amount of thrust available determines whether this speed is maintained in level flight, climb or descent. To extend this capability down to speeds of about 20 knots a variable spring bias is fitted to apply a backward (ie nose-up) tension on the control column. Trim in roll to counteract engine torque is also provided. The spring tensions are adjusted by a pair of levers below the instrument panel immediately forward of the base of the control column; their setting is maintained by friction alone. Nose-up trim is increased by moving both levers rearwards, and roll trim is adjusted by moving them differentially. No provision is made for forward bias of the control column at speeds higher than 60 knots. Any increase of speed beyond this value calls for a progressively increasing push force to maintain level flight.

The minimum clearances between the rotor blades, the propeller tips, and the fin/rudder were measured on another WA-117 aircraft with the rotor head in the fully aft (nose-up) position. The following figures were obtained:

	Propeller Clearance	Fin/Rudder Clearance
Teeter stops engaged	17 cm	34 cm
Teeter stops disengaged	8 cm	16 cm

The teeter stops, which limit teetering during spin-up, are centrifugally operated and automatically withdraw (disengage) at approximately 200 rotor rev/min. The rotor is normally only tilted fully aft for the later stages of the 'spin up' and during the initial stages of the take-off run. The film of the take-off for the accident flight showed that there was adequate clearance between the rotor and the structure.

Considerable experience of this type of autogyro has been gained over a period of years on the WA-116, which is structurally similar to the WA-117. The WA-116 has a less powerful and lighter engine driving a two-bladed propeller. Both types are fitted with essentially the same rotor head and blades. The disc area is some 320 ft², but since the WA-117 is heavier than the WA-116 its disc loading is higher (2.47 lb/ft² and 1.42 lb/ft² respectively). The WA-116 had been issued with a Special Category Certificate of Airworthiness (C of A); the WA-117 was operating on a Permit to Fly.

WA-117 G-AXAR was built in March 1970. A seat lap strap was provided for the pilot and instruments to enable him to determine airspeed, height and engine speed. A preliminary calibration of the pitot-static system was made in August 1970 and among other things the airspeed indicator (ASI) was found to be under-reading by 10 knots at an IAS of 65 knots. Extrapolation of the relevant curves showed a tendency for the error to increase rapidly with increased IAS. On 3 September 1970 G-AXAR was issued with a Permit to Fly valid for ten days, specifically to cover flying at the SBAC display. The Permit included a maximum speed restriction of 65 knots.

When Mr Judge flew G-AVJV in March 1970 he achieved a speed of 110 knots IAS without untoward incident, during the course of his second flight. At that time there was no maximum IAS specified in the Permit to Fly.

The fuel used was a 1:5 mixture of 100/130 octane and 80 octane aviation petrol. At the time of the accident G-AXAR had flown a total of seven hours since manufacture.

1.7 Meteorological information

The following special weather observation was made immediately after the accident at 1415 hrs:

Surface wind:	220° at 14 knots (varying in direction in gusts between 180° and 260°).
Visibility:	Over 5 nm.
Cloud:	3/8 at 2,700 feet. 5/8 at 22,000 feet.
Present weather:	Nil.
Air Temperature:	17° C.
QNH:	1005.5.

QFE: 997.

Condition of light: Daylight.

1.8 Aids to navigation

Not applicable.

1.9 Communications

There was no communication with the aircraft after the pilot's acknowledgement of take-off clearance.

1.10 Aerodrome and ground facilities

Not relevant.

1.11 Flight recorder

Not fitted and not required to be fitted.

1.12 Wreckage

Examination of the wreckage revealed that both rotor blades had struck the fin, rudder and propeller. The fin and rudder registered seven rotor strikes. All of them were straight, indicating that there was little or no bending of the outer portion of the rotor blades.

The rotor blades had been intact until portions of their wooden box structure were torn away after contact with the propeller. There was very little damage to the rotor head. The fore and aft stops showed only minor damage, mainly confined to a single impact mark on the rear stop. The teeter stops showed marks of having been struck at both 'engaged' and 'disengaged' positions. The stop retaining bolts had sheared, and the stops had become detached. There were indications that this occurred when the stops were 'disengaged', that is when the rotor speed was in excess of 200 rev/min.

The aircraft had first struck the ground in a steep nose-down attitude. It then rolled to the right, bounced, and came to rest on the engine.

Damage to the spin-up wheel and head showed that the rotor head had tilted sideways beyond the normal control range, which was consistent with the mast having broken away from the fuselage structure at ground impact.

It was concluded that all damage, except that sustained by the rotor blades, propeller, fin and rudder, was caused by ground impact.

1.13 Medical and pathological information

There was no evidence of significant disease or toxic condition that could have contributed to the accident.

1.14 Fire

There was no fire.

1.15 Survival aspects

The accident was not survivable. However the provision of a shoulder harness would appear to be desirable.

1.16 Tests and research

The accident to G-AXAR was the fourth fatal accident to a light gyroplane to have occurred during the 18 months from 9 March 1969 and there appeared to be some similarity between three of them. Unlike the earlier accidents the one at Farnborough was the subject of some high quality cine film of the sequence of events.

The Helicopter Flight Group of the Royal Aircraft Establishment (RAE) were asked to assist in the investigation and to make two studies. First, a detailed analysis of two high quality TV films to provide information on the flight path and second, an appraisal of the stability and control characteristics of the Wallis WA-117 autogyro. The results are set out in *Royal Aircraft Establishment Technical Memorandum Aero 146* and are summarised at Appendix 1.

2. Analysis and Conclusions

2.1 Analysis

2.1.1 *The final manoeuvre and its causes*

From the pattern of his previous displays at Farnborough in the WA-117 earlier in the week it may be inferred that Mr Judge intended to execute a fast run downwind followed by a gentle climbing turn to the left before reversing direction to align the aircraft with the runway for a slow run into wind. The evidence of eyewitnesses and an analysis of the film records indicate that, apart from the high speed attained, the flight appeared to be following this pattern in the normal way until about 7 seconds before impact when the rate of nose-up pitch suddenly increased and there was, according to some eyewitnesses, a slight pitching oscillation. Then, 6.28 seconds before impact, the control column appears to have moved progressively forward. In the absence of any mechanical or aerodynamic explanation it must be assumed that this movement was made by the pilot.

In the flight tests carried out by G-AVJV the aircraft showed no hazardous characteristics at air speeds between 26 and 78 knots and appeared manoeuvrable and easy to fly. At higher speeds, however, the aircraft became increasingly sensitive to longitudinal control movements — a characteristic shared by many helicopters. G-AXAR just before the accident was flying at some 92 knots equivalent airspeed (EAS), that is about 73 knots IAS and at that speed a relatively small relaxation of the push force required to maintain level flight such as to allow the control column to move aft one inch, could account for the last steep portion of the climb. To recover, the aircraft could have been flown out of this manoeuvre by increasing the bank angle and executing a 'wing over' to maintain positive 'g'. In the event the pilot moved the control column rapidly forward. This would have been a correct response in a fixed wing aircraft and was possibly the instinctive reaction of a fixed wing pilot with limited gyroplane experience. In this context it is worth noting that the pilot was an extremely experienced light aeroplane test pilot, but had not flown a rotary wing aircraft during the 6½ years previous to 1970 and that his experience on the WA-117 amounted to 22 short flights totalling 5 hours 30 minutes spread over six months. This gap in his recent experience may be related to the evidence of spectators that during his previous demonstrations at Farnborough he consistently made what might be described as a 'staircase' approach followed by a fairly firm touchdown.

Once full forward control had been applied and sustained for approximately one second the aircraft inevitably followed the flight path that terminated in the accident. When the aircraft was pitching rapidly nose-down the pilot would be expected to try to counteract the motion as soon as the aircraft appeared to him to have recovered from the steep nose-up attitude which had caused him to move the control column forward in the first place. Some 4.76 seconds before impact the rotor head did, in fact, tilt fully back indicating that the pilot had moved the control column fully aft. However,

the rotor rev/min had by this time started to fall, negative 'g' having unloaded the rotor, and as a result of the consequent reduction in control effectiveness the aircraft did not respond, continuing to pitch nose-down until it reached the vertical and the rotor blades came into contact with the aircraft structure.

It was the pilot's practice towards the end of the high speed downwind run to retrim the aircraft for the ensuing low speed run, thereby significantly increasing the push force required on the control column to maintain level flight. The design of the trim levers was such that at some stage in the retrimming exercise it was necessary to change hands on the control column. It is possible that this habit led to the initial pitch up, and thence to the precipitate forward movement of the stick that brought about the loss of control, however it was not possible to establish if the pilot used this technique on the accident flight.

2.1.2 *Stability and control*

The tests carried out during the course of the investigation on G-AVJV indicated that, provided the WA-117 was flown within the limits set out in the Permit to Fly (ie below 65 knots IAS) and under positive 'g' loading it exhibited no dangerous characteristics and was safe and pleasant to fly. Principally because of the unstable pitching moment provided by the cockpit nacelle, the theoretical stability analysis of the aircraft, without tailplane, showed a marked instability 'stick fixed' as speed increased. This instability was not so noticeable in practice below 65 knots because of a contribution from the aircraft's markedly stable 'stick free' characteristics in which forces present at the control column tended to move the pilot's hand in the correcting direction. A likely further beneficial influence was the forward (chordwise) C of G of the rotor blade near the tip, which, since the blades are flexible in torsion, may have produced a stabilising effect on the motion of the aircraft. This effect was not included in the theoretical analysis.

Some quantitative improvement in 'stick fixed' stability resulted when the aircraft was fitted with an experimental tailplane, but no qualitative improvement was apparent to the pilot. This difference may have been due to interference with the airflow over the tailplane from the fuselage and landing gear and to increased sensitivity to atmospheric turbulence.

Because the manoeuvre is dangerous in a gyroplane and because the theory is only applicable to small excursions from the 'in trim' condition, neither the flight tests nor the theoretical work included a high speed bunt. To investigate a manoeuvre of this sort the theoretical work would need to be considerably extended, ideally to include rotor aeroelastic effects, and feed back from a pilot in a suitable flight simulator.

2.1.3 *Design and workmanship*

The standard of design and workmanship in the WA-117 was of a high order. Detailed examination of the aircraft showed that it compared favourably with other designs in the light gyroplane field.

2.1.4 *Airworthiness*

The tests and analysis carried out in the course of the investigation indicated that the terms of the Permit to Fly were realistic in the light of knowledge available at the time; if the limitations specified had been adhered to the aircraft would have been safe to fly. However, in view of the known sensitivity of the light gyroplane to sustained 'g' values of less than unity it might have been prudent to have specifically prohibited such manoeuvres in the Permit to Fly.

The large negative position error of 10 knots or more on G-AXAR no doubt contributed to the pilot's apparent lack of appreciation of his excess airspeed.

2.1.5 *Training*

The light gyroplane has certain handling characteristics, not found in either fixed wing aircraft or helicopters, that can only be adequately demonstrated in flight. There appears to be no system of training specifically for gyroplane pilots, who must necessarily discover these characteristics for themselves. The absence of such a system of training could well have an adverse effect on the safety in operation of these aircraft, particularly when flown by private pilots with a low total level of air experience.

2.1.6 *Air displays*

Three of the four fatal accidents to gyroplanes occurred when the aircraft were either appearing in an air display or being demonstrated to potential buyers. The quite natural human desire to give of one's best when performing in the public eye may well have been a factor leading to inadvertent erosion of safety margins.

2.2 *Conclusions*

(a) *Findings*

- (i) The aircraft had a current Permit to Fly and had been properly maintained.
- (ii) The pilot was properly licensed.
- (iii) There was no evidence of any medical condition that could have had a bearing on the accident.
- (iv) There was no evidence of pre-crash failure or mechanical malfunction of the aircraft.
- (v) The aircraft was allowed to exceed the maximum speed authorised in the Permit to Fly, and flown at a speed requiring increased forward pressure on the control column to maintain level flight.
- (vi) While flying in this condition the aircraft pitched nose-up and during the recovery from this attitude a significant amount of negative 'g' was induced.
- (vii) The aircraft went out of control into a vertical nose-down attitude and the rotor blades struck portions of the aircraft structure.

- (viii) Stability and control analysis and tests indicate that the aircraft is safe to operate within the permitted flight envelope.
- (ix) There was no evidence of basic rotor blade instability.

(b) *Cause*

The accident resulted from a loss of control due to the effect of negative 'g' when the pilot attempted to control a nose-up pitch which occurred during a manoeuvre when the aircraft was flying at a speed in excess of the authorised maximum.

G M Kelly
Inspector of Accidents

Accidents Investigation Branch
Department of Trade

March 1974