Department of Trade

ACCIDENTS INVESTIGATION BRANCH

Cessna 150C G-ASHF
Report on the accident at Swanage Bay, Dorset, on 24 June 1973

LONDON
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1975

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ISBN 0 11 511425 4

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Accidents Investigation Branch
Shell Mex House
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22 May 1975

The Rt Honourable Peter Shore MP
Secretary of State for Trade

Sir,

I have the honour to submit the report by Mr R D Westlake, an Inspector of Accidents, on the circumstances of the accident to Cessna 150C G-ASHF which occurred at Swanage Bay, Dorset, on 24 June 1973.

I have the honour to be
Sir
Your obedient Servant

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Chief Inspector of Accidents

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Accidents Investigation Branch
Aircraft Accident Report No 8/75
(EW/C451)

Aircraft:	Cessna 150C G-ASHF
Engine:	Continental 0-200-A
Registered Owner:	The Royal Artillery Aero Club Limited
Operator:	Bournemouth Flying Club
Crew:	One pilot - killed
Passengers:	None
Place of Accident:	Over the sea in Swanage Bay, Dorset
Date and Time:	24 June 1973 at 1658 hrs
	All times in this report are GMT

Summary

The aircraft was on a solo local flight and while flying over the sea at about 1,500 feet it suddenly went into a near vertical spiralling dive. This terminated with the aircraft becoming inverted at which time the outer section of the left wing broke off, after which the aircraft disintegrated and fell into the sea. The pilot was killed.

The report concludes that the aircraft broke up in flight, the accident sequence being initiated by the failure of the fin front attachment. This precipitated an involuntary manoeuvre in which the aircraft was subjected to a negative 'g' loading in excess of its design ultimate limit resulting in a total in-flight structural break-up. The most probable cause of the failure of the fin front attachment was movement in the tail unit as a result of looseness and wear of the two elevator centre hinge bracket bolts and elongation of their associated holes.

1. Investigation

1.1 History of the flight

The aircraft took off at 1634 hrs from Bournemouth (Hurn) Airport for a flight in the local area. At 1641 hrs the pilot, who was the sole occupant, reported by radio that he was over Poole Harbour at an altitude of 1,500 feet above mean sea level (amsl). There were no further radio position reports from the aircraft but about 10 minutes later it was seen just south of Corfe Castle still maintaining approximately the same height and flying on a southerly heading. It then made a left hand turn and flew in the direction of Swanage, crossing the coast just south of the town.

So far as is known the aircraft's flight was normal until over Swanage Bay where, according to eye-witnesses, it suddenly started to behave in an erratic manner during which it abruptly adopted a steep nose-down attitude combined with a slowly spiralling vertical dive. After a few seconds the aircraft was inverted and apparently making a bunt manoeuvre. At about this time the left outer wing section broke off and the aircraft then rapidly disintegrated and fell into the sea in many pieces. The break up was accompanied by a loud bang but there were no reports of fire or explosion. During these manoeuvres the engine was heard to splutter and back-fire for a period after which engine noise gradually increased to a very high pitched note indicative of high rpm.

The incident happened so quickly that eye-witness reports of the sequence of the break-up of the aircraft varied greatly but on balance the evidence was that the aircraft had not been engaged in any aerobatic manoeuvres before-hand. There was evidence from some of the eye witnesses that part of the tail section of the aircraft had either been flapping or was partially detached and hanging from the structure at the moment the erratic behaviour started.

A number of rescue boats, including the local lifeboat, were on the scene within 2 minutes and recovered the body of the dead pilot from the surface of the sea. They also recovered several items of floating wreckage including the port wing tip and two seat cushions.

1.2 Injuries to persons

Injuries	*Crew*	*Passengers*	*Others*
Fatal	1	–	–
Non-Fatal	–	–	–
None	–	–	

1.3 Damage to aircraft

The aircraft was destroyed.

1.4 Other damage

None.

1.5 Crew information

The pilot, aged 28, held a valid Private Pilot's Licence obtained in March 1973. His flying training was carried out by the Bournemouth Flying Club and at the time of the accident he had completed about 90 hours flying, of which all but 2 hours had been in Cessna 150 type aircraft.

1.6 Aircraft information

The aircraft, a two-seat, single engine, high-wing monoplane, was constructed in the United States of America in April 1963 and shortly afterwards exported to the United Kingdom and placed on the British Register. At the time of the accident it had flown 5,567 hours. On 26 August 1971 just prior to the issue of its current Certificate of Airworthiness, the aircraft was given a major inspection which included, among other items, the removal and inspection of the tail assembly and renewal of the two elevator centre hinge bracket bolts. Its 2 year Certificate of Airworthiness, in the General Purpose category, was valid until 26 August 1973. It had been regularly maintained under an Approved Maintenance Schedule (ARB/GPMS/FW/1971). This Schedule requires a yearly check on the tightness of structural attachment joints. The aircraft had flown 611 hours since the last such check by the Bournemouth Flying Club 26 August 1972.

At the time of the accident the aircraft's weight is estimated to have been less than the maximum weight authorised and the centre of gravity to have been within the approved limits.

Limitations

The following limitations are taken from the Approved Flight Manual:

Never exceed speed: 157 miles per hour (mph)

Normal operating limit speed: 120 mph

Manoeuvring speed: 106 mph

Maximum speed, flaps extended 85 mph

The manoeuvring speed must not be exceeded when approaching the stall or when applying full aileron or rudder. The Flight Manual included the following note:

> 'Although the aeroplane is strong enough for steady application of full rudder control at this speed, a violently checked manoeuvre might overstress it. For example any violent yaw must not be checked with sudden application of opposite rudder'.

The Owner's Manual defines manoeuvering speed as — 'the maximum at which you can use abrupt control travel without exceeding the design load factor'. The manual also includes the following warning:

> 'In the execution of all manoeuvres avoid abrupt use of controls'. The Owners Manual quotes the following Load Factors applicable at the Maximum Design Weight of 1,500 lbs:
>
> Flight Manual Load Factor (flaps up) $+ 4.4_g$ to $- 1.76_g$
>
> Flight Manual Load Factor (flaps down) $+ 3.5_g$

It states that the design load factors are 150 per cent of the above figures and that in all cases the structure meets or exceeds design loads.

Aerobatic manoeuvres are prohibited in the aircraft; the following semi-aerobatic manoeuvres are however, permitted: chandelles, lazy eights, steep turns, stalls and spins.

1.7 Meteorological information

The weather at the time of the accident was fine with a light south westerly wind; visibility in Swanage Bay was estimated to be 2-3 miles in haze. The general conditions were not conducive to anything other than light turbulence in the vicinity of the hills south of the town.

1.8 Aids to navigation

Not applicable.

1.9 Communications

Normal radio communications were maintained with Bournemouth (Hurn) Air Traffic Control. The last message received from the aircraft was at 1641 hrs when the pilot reported leaving the Bournemouth Zone over Poole Harbour at a height of 1,500 feet.

1.10 Aerodrome and Ground facilities

Not applicable.

1.11 Flight recorders

Not required and none fitted.

1.12 Wreckage

A detailed account of the wreckage examination and a discussion on the finding is given in Appendix 1. A brief summary of the major findings only is included in this section.

1.12.1 Recovery of the wreckage

The wreckage of the aircraft fell into the sea at the entrance to Swanage Bay. Most of the major components of the structure were lying in about 60 feet of water and were scattered over an area 300 yards in diameter.

The following sections of the structure, all of which had detached in flight, were recovered by a team of divers from a local diving school:

(1) The left outer wing section which had separated just outboard of the strut.

(2) The remainder of the entire wing including the cabin roof, right door and both wing struts.

(3) The cockpit centre floor section and main undercarriage.

(4) The fin, the fuselage tail cone, the right tail plane and elevator were in separate parts but were all still attached to the cockpit centre section by various control cables.

(5) The engine and propeller together with the forward fuselage area including the nose gear, main instrument panel and right control column.

(6) Two sections of the fuselage aft of the cabin; the section of fuselage immediately forward of the tail cone was not recovered.

(7) The left tailplane, the left elevator, the rudder, the left cabin door, the pilot's blind flying panel with the left control column; these items were all found separately.

1.12.2 Examination of the wreckage

From the detailed examination and related analysis given in Appendix 1 the following significant points have emerged:

(a) Both the wings and both the tailplanes exhibited symmetrical down load creases. The left outer wing had detached in a downwards direction.

(b) The left tailplane attachment had broken in a downwards direction and the right one in an upwards direction.

(c) The fin front attachment, a single bolt securing the base of the fin through the nose rib, had failed to the right and rearwards due to overload tearing and shear of the nose rib. The bolt was tight and had not failed; there was no evidence of any external impact force on the fin.

(d) The engine mounting had failed in an upwards direction.

(e) The two bolts which hold the elevator centre hinge bracket on to the fin rear spar had failed in overload shear, the left one in a downwards direction and the right one upwards. Both these bolts and their associated holes in the bracket showed evidence of looseness and wear; only the shank ends of the two bolts were recovered. There was also evidence that the fin rear spar had been in contact with the vertical lever of the elevator bell crank.

(f) The flap lever was found in a position which corresponded to the 20° flap selection and there was evidence to confirm that this was its position when the main break-up occurred. Although the flaps themselves were seen to be fully down when recovered from the sea, examination revealed that they had been driven to this position during the break-up.

(g) There was no pre-crash mechanical defect or failure in the engine and no evidence of defective materials was found in the structure.

1.13 Medical and Pathological information

A full post mortem and toxicological analysis was performed on the pilot and death was attributed to multiple injuries received in the accident. Although the post mortem revealed that he had coronary artery disease the circumstances of the accident indicate that this was not a significant factor and nothing was found to suggest any medical reason for the accident.

1.14 Fire

There was no fire.

1.15 Survival aspects

The accident was not survivable.

1.16 Tests and research

The wing structure of the Cessna 150C is designed to an ultimate strength of 6.6 'g' positive and 2.6 'g' negative at a maximum permitted weight of 1,500 lbs. This complies with the United States Federal Airworthiness and United Kingdom Airworthiness design requirements. The left wing had failed because it had been subjected to over-stressing in down-load (negative 'g') beyond the design ultimate strength. Such an excessive negative loading could be achieved in a bunt manoeuvre at a speed of about 100 mph.

Laboratory tests upon a specimen of material from the failed wing showed that it was up to specified strength and there were no defects or signs of fatigue.

The two bolts which secure the tailplane and fin were examined metallurgically and it was determined that the bolts had failed due to overload shear. Hardness tests showed both bolts were up to specified strength.

2. Analysis and Conclusions

2.1 Analysis

The evidence from eye-witnesses, from the wreckage examination and from the post mortem carried out on the pilot, was all consistent with the aircraft having disintegrated before it hit the sea. There was no evidence from witnesses nor from examination of the wreckage to indicate in-flight explosion nor was there any evidence of defective material which would have led to the in-flight break-up. It is not considered that the pilot could have consciously or deliberately overstressed the aircraft since consideration of all the eye-witness evidence indicated that the aircraft had not been engaged in aerobatic manoeuvres either at the time of the sudden entry into the steep dive which led to the break-up, nor in any observed period prior to it.

The wreckage examination revealed a sequence of failure which had begun with a displacement of the fin to the right causing its front attachment to fail. The fin then folded over to the right and moved aft in such a way that its rear spar fouled the vertical lever arm of the elevator bellcrank, and imposed a down movement on the elevators, pitching the aircraft involuntarily and progressively nose down into a left hand spiral dive. The combination of the rising airspeed and the increasing bunt manoeuvre created air loads of sufficient force to exceed the design negative load strength of the structure resulting in downwards bending of both wings and tailplanes relative to the fuselage. Eventually the left outer wing separated just outboard of the wing strut and the aircraft made a rapid rolling inverted gyration. Total disintegration of the rest of the structure followed immediately.

There was no evidence of any external in-flight impact which could have produced the initial side load on the fin and, as previously noted, there was no eye-witness evidence of any violent yawing manoeuvres which could have caused it. There was however clear evidence of long term wear and eventual shearing of the two bolts which attach the elevator centre hinge bracket to the rear spar of the fin and serve also to maintain the fixed relationship between the fin and the rear spar of the tail-plane. There is no way of establishing when these bolts finally sheared and it may possibly have occurred before the accident flight.

Certainly the wear on the bolts and the elongation of the related holes in the assembly are indicative of long term looseness at this attachment point and therefore also indicative of a consequential loss of rigidity of the tail assembly. Although it is not possible to predict what effect this loss of rigidity would have had it is reasonable to consider that such prolonged looseness could well have progressively weakened the fin front attachment. Eventually even the normally acceptable turbulent air flow over the tail such as would result from setting the flaps to 20^{o} may have sufficed to induce a degree of flutter or vibration which, in turn, was enough to cause the failure of the front attachment of the fin.

Whatever the exact sequence of events which resulted finally in the failure of the front attachment of the fin there can be little doubt that the primary cause was the previous looseness of the attachment bolts securing the elevator centre hinge bracket to the fin rear spar. The nature of the wear is indicative of left deflection of the tip of the fin and/or upwards deflection of the left tail plane and downwards deflection of the right tail plane. Although there is no evidence to relate this to any particular incident it is a pattern of loading which could be expected to occur as a result of spinning manoeuvres made to the left. It is understandable that inexperienced pilots may be somewhat coarse in the use of rudder control during the recovery phase and it is also easy to approach the aircraft's design manoeuvring speed of 106 mph during the recovery dive.

The integrity of the empennage in this type of aircraft is directly dependent on the preservation of the tightness of the two attachment bolts of the fin rear spar to elevator rear spar assembly. The problems of preserving bolt torque loadings in light alloy sandwich types of construction such as was used in that assembly are noted in Appendix 1. Although this type of sandwich construction is used successfully in many positions on aircraft, when used in a critical position such as this tail assembly it would appear to merit a greater frequency of inspection than might apply to more static and less critical positions. Nevertheless the Maintenance Schedule ARB/GPMS/FW/1971 applicable to this aircraft required only an annual inspection without regard to flying hours or the type and frequency of manoeuvres involving significant yaw to which the aircraft might be subjected.

On 24 July 1973, when the failure of these bolts came to light, the Civil Aviation Authority was alerted and they circularised all UK operators of Cessna 150A, B &C series aircraft; subsequent series of Cessna 150 aircraft were not involved since a different form of construction was employed. The circular called for a mandatory inspection for wear and looseness in the bolts, and for elongation of the related holes.

2.2 Conclusions

(a) *Findings*

(i) The pilot held a valid Private Pilot's Licence.

(ii) The documentation of the aircraft was in order and it had been maintained to the appropriate maintenance schedule.

(iii) The aircraft was on a local flight and in normal cruising flight when it started to behave erratically.

(iv) The aircraft was seen to enter a spiral dive abruptly and become inverted, after which it broke up and fell into the sea.

(v) There was no evidence of in-flight fire or explosion.

(vi) There was no evidence of defective material in the aircraft.

(vii) The pilot was killed in the accident; there was no evidence of any medical factor which had contributed to the accident.

(viii) Failure of the front attachment of the fin caused the fin to fold rearwards and to the right. The fin rear spar then fouled the elevator bell-crank and applied down elevator causing the aircraft to make a bunt type of manoeuvre.

(ix) Both wings and tail planes were overstressed in down-load during the bunt manoeuvre and the aircraft broke-up as a result of this loading.

(x) There was evidence of long term wear on the two elevator centre hinge bracket bolts and their associated holes; the two bolts had sheared.

(xi) Looseness in the tail plane/fin assembly probably weakened the fin front attachment leading to eventual failure.

(b) *Cause*

The accident was caused by the failure of the fin front attachment which allowed the fin to move to the right and rearwards so that the fin rear spar fouled the elevator bellcrank thus applying progressively increasing down elevator. The negative air loads produced during the resulting bunt manoeuvre, exceeded the design ultimate strength of the aircraft and it broke up. The most probable cause of the failure of the fin front attachment was long term loss of rigidity in the tail assembly resulting from looseness of the attachment bolts holding the elevator centre hinge bracket to the fin rear spar.

R D Westlake
Inspector of Accidents

Accidents Investigation Branch
Department of Trade

May 1975

APPENDIX 1

Wreckage Examination

The general mode of break-up is illustrated in Fig. 1.

The area of failure of the left outer wing showed distortion of the main spar and surrounding structure which was indicative of a severe tip-downwards displacement prior to detachment (see Fig. 2). Down-load buckling and associated cracking was present at the same station on the right main wing spar (rib 102) as shown in Fig. 3. Metallurgical checks carried out on the main spar material adjacent to the area of failure confirmed the strength of the material to be satisfactory. There was no evidence of fatigue and the failures were due to overstressing. The cockpit flap sector lever was found in the third detent ie the 20° setting.

Both tail-planes and elevators also exhibited marked down-load creasing. The tail-planes had, however, ultimately detached in a right tail-plane upwards, left tail-plane downwards manner, as indicated by deflection of their forward attachment bolts, and also by a particular damage impression on the tail cone lower platform. Some arc-like scrapes were present on the right tail-plane upper surface.

Both elevator outer hinges showed evidence of over-rotation in a downwards sense. The bell-crank assembly had distorted such that the angle between the left attachment arms had increased and that between the right arms decreased.

The vertical lever of the bell-crank assembly, had also detached from the right attachment arms at the welded junction due to relative bending through some 40°.

The fin had become detached to the right and rearwards due to the overload failure of the nose rib. As it finally became detached it twisted the elevator centre hinge bracket from the tail-plane rear spar due to excessive aft deflection (see Fig. 4). Bending failure of the fin rear spar occurred below the rudder bell-crank due to this right/aft deflection. There was no evidence of any external in-flight impact on the fin.

As a result of the rearwards bending of the fin the elevator bell-crank had fouled the upper and lower cable guide slots and was also distorted into an 'S' shape due to interaction with the rear spar.

Both elevator centre hinge bolts (AN 4-5A type) had sheared flush with the aft face of the fin rear spar (see Fig. 6). The port bolt had failed downwards and the starboard bolt upwards. The sheared head portions of these bolts were not recovered and the remaining sections of both showed evidence of wear consistent with the ovality found in both holes in the elevator centre hinge bracket. This ovality is shown in Fig. 4 and associated Talyrond measurements are reproduced in Fig. 5.

The rudder bell-crank was still attached to the fin rear spar, and had been bowed in a downwards direction at either side. The rudder had detached from the fin due to shearing of the upper hinge and detachment of the bell-crank due to tension failure of the associated retaining rivets. Distinctive arclike scrapes were present on the starboard side of the rudder.

The tail cone, which had separated from the fuselage displayed marked torsional creasing resulting from displacement of the sternframe base to port. The port rudder cable slot was also badly torn at its forward end. The remainder of the fuselage had broken up extensively.

The port seat belt attachments exhibited distortion consistent with excessive loading of this belt in an upwards/forwards direction.

No evidence of pre-crash defect or failure was found during examination of the engine.

ANALYSIS

The evidence on both wings and tail-planes was indicative of excessive symmetrical down-load beyond the design ultimate strength.

The possible causes of such a wing failure may be listed as follows:

(a) Loss of complete tail section in flight, causing sharp pitch-down or bunt manoeuvre due to removal of normal down-load moment, aggravated by resultant forward C G shift.

(b) Loss of tail-plane(s) in flight, with consequencies as in (a).

(c) Gross and sustained down-deflection of elevators either by direct input by the pilot or due to some mechanical failure.

With regard to possibility (a), the tail cone had indeed separated from the remainder of the fuselage. However, the distinctive torsional distortion displayed by the tail cone indicated that the latter must have been rigidly attached to the fuselage to resist the associated force. Loss of the complete tail section could not then have been the initial malfunction.

Since both tail-planes exhibited marked down-load creasing, it follows that up to the time when this down-load occurred the tail-plane structure was intact. Loss of tail-plane(s) as postulated in (b) cannot therefore have been the original malfunction.

With regard to possibility (c), both elevator, outer hinges showed evidence of over-rotation in a downwards sense. In addition, there had been fouling between the elevator bell-crank vertical lever and the rear spar of the fin, in the full elevator down position.

The manner of failure of the fin front attachment was consistent with over-stressing due to excessive tip-deflection to the right. The torsional damage of the fin and tail cone was consistent with the fin pivoting to the right about its rear spar. This angular displacement is consistent also with the measured distortion to the elevator bell-crank arms. In addition, the radii of the scrapes on the right side of the rudder were found to correspond with certain features of the right elevator inboard edge.

The fin, pivoting rearwards, caused almost immediate displacement of the elevator bell-crank in a full down-elevator sense. This resulted in a self-accelerating process in that initial down-deflection would increase air speed, generating higher drag loads on the fin, producing more aft movement of the fin and consequently more down elevator.

This evidence of mechanical fouling and failure makes it unnecessary to consider the possibility that pilot input had contributed to the sustained elevator deflection. Moreover, even if pilot input were postulated, analysis of the resultant break-up sequence would not explain the damage to and direction in which the fin failed. The possibility of pilot input may therefore be completely discounted.

With the increasing down deflection of the elevators, the aircraft would have been subject to an ever-increasing angle of dive with progressive yaw to the left. This would have culminated in an involuntary bunt manoeuvre causing the left wing to fail in down-load, and overstressing the right wing. On failure of the left wing under these severe down-load conditions, the aircraft would have had a tendency towards an immediate rapid roll to the right which would explain the manner of detachment of both tail-planes due to an inertia/air loading effect on the already weakened structure. In addition, the engine mountings deflection is consistent with the effects of such a bunt manoeuvre.

The only pre-existing defect found associated with the fin mountings was in the elevator centre hinge bracket assembly. The bracket is attached to the rear spar of the tail-plane by eight rivets and, in addition to carrying the elevator centre hinge, provides the only fixed relationship between the rear spar of the tail-plane and the fin rear spar by means of two bolts. Both these retaining bolts had clearly been loose for some time and had generated wear and ovality of both bolts and holes. The pattern of wear was consistent with the direction of failure in shear of both bolts and indicated a predominance of one type of loading (Fig. 6). The direction of this loading was consistent with excessive left deflection of the fin or/and excessive upwards deflection of the left tail-plane and downwards deflection of the right tail-plane.

There was no evidence to suggest that such deflections could have occurred during the break-up sequence, and consequently it would appear likely that these two bolts had failed prior to the fin detachment sequence. It is therefore probable that over-stressing of one or both bolts, which were already clearly in a loosened and worn condition, had occurred at some time prior to this accident.

The junction of the rear spars of the tail-plane and fin, together with the elevator centre hinge bracket, involves bolting through a multiple layer light alloy sandwich and at this point in the aircraft structure the preservation of the initial torque loadings of the bolts is vital to the integrity of the empennage structure. However, particularly in manoeuvres involving significant amounts of yaw, very considerable shear loads are applied to individual layers of the assembly and these can result in elongation of the bolt holes, leading to looseness and ultimate failure as in this accident.

The problems associated with maintaining bolt torque settings in this type of sandwich construction are well known and an ARB Airworthiness Notice (No. 12, 20 July 1972) drew attention to them and to the need to ensure the maintenance of the initial torque loadings.

Although this type of assembly is used successfully in many positions in aircraft construction its suitability for use in such a critical position, where it is subject to loads of the type involved here, must be conditioned by an appropriate frequency of inspection if the torque settings are to be preserved. It is relevant to note that G-ASHF had flown some 611 hours since the last required check for tightness of the assembly as per Maintenance Schedule ARB/GPMS/FW/1971.

Produced in England by Her Majesty's Stationery Office, Reprographic Centre, Basildon

R 23782/R92 K6 6/75 C