ACCIDENTS INVESTIGATION BRANCH
Department of Trade and Industry

Hiller 360 Series UH-12E G-ASIH
Report on the accident at Shinnel Head, Thornhill, Dumfriesshire on 11 March 1971

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13/71	Piper Cherokee PA 28-180 G–AVYN, near Pateley Bridge, September 1969	September 1971
14/71	Hiller 360 UH–12E G–ASIH at Thornhill, Dumfriesshire.	September 1971

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Department of Trade and Industry
Accidents Investigation Branch
Shell Mex House
Strand
London WC2

27 July 1971

The Rt. Honourable John Davies MBE MP
Secretary of State for Trade and Industry

Sir,

I have the honour to submit the report by Mr G M Kelly on the circumstances of the accident to Hiller 360 Series UH–12E G–ASIH which occurred at Shinnel Head, Thornhill, Dumfriesshire on 11 March 1971.

I have the honour to be

Sir,

Your obedient Servant,

V A M Hunt
Chief Inspector of Accidents

Accidents Investigation Branch

Civil Accident Report No EW/C373/01

Aircraft:	Hiller 360 Series UH–12E G–ASIH
Engine:	One Lycoming VO–540–B2D
Registered Owner and Operator:	Management Aviation Limited, Bourn, Cambridgeshire.
Crew:	Captain Norman Moffat McLeod - Injured
Passengers:	None
Place of Accident:	Shinnel Head, Thornhill, Dumfriesshire
Date and Time:	11 March 1971 at approximately 1445 hrs.
	All times in this report are GMT

Summary

The aircraft was engaged on fertiliser spreading operations over a grass covered hillside. Whilst flying at about 40 feet and 35 knots it pitched sharply nose-up to a near vertical attitude, went out of control and crashed, injuring the pilot. The report concludes that the accident was due to a loss of control caused by the longitudinal cyclic control push rod becoming detached from the wobble plate because the retaining bolt fell out after its securing nut had come off.

1. Investigation

1.1 History of the flight

Since 4 March the aircraft and pilot had been engaged on forestry operations in Dumfriesshire, spreading fertiliser dust from an underslung hopper over grass-covered hillsides.

On the morning of 11 March the aircraft was flown to a new operating site at Shinnel Head. Later that morning operations started on the southerly slope of a 1,500 foot high ridge which lay northwest to southeast. Two flights of 1.05 hours each, involving a total of 51 spreading runs, were made without incident. At about 1425 hrs the helicopter took off on its final flight. Weather conditions were satisfactory and similar to those on the previous flights, and eight spreading runs were carried out without difficulty or incident. On the ninth the flight pattern was as before. The helicopter hovered at a landing site in the valley while 5½ cwt of fertiliser was loaded into the hopper. The pilot then carried out a right hand climbing turn to position for a spreading run along the line and near the top of the ridge. The run was made at an IAS of 35 knots on a heading of about 120°T, the line being indicated to the pilot by two forestry workers who acted as markers, one at the point where spreading was to commence and the other about 400 yards further on. When the hopper had been emptied the pilot started a climbing turn to starboard.

The bank angle was 15 to 20°, the IAS 35 knots and the aircraft at 40 to 50 feet (hopper about 25 feet above the ground) when it suddenly pitched nose-up and the pilot heard a "clatter and bang". He applied full forward cyclic control without effect; the aircraft reached a very steep nose-up attitude out of control, before crashing on the hillside in a nearly vertical dive.

1.2 Injuries to persons

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

1.3 Damage to aircraft

Destroyed.

1.4 Other damage

There was no other damage.

1.5 Crew information

Captain Norman McLeod, age 27, held a valid commercial pilot's licence (helicopters and gyroplanes) issued in December 1970. He joined Management Aviation Ltd in January 1971 and underwent conversion training to the Hiller 360 Series UH–12E, followed by training in forestry operations. At the time of the accident Captain McLeod had flown 1,060 hours of which about 1,000 were on helicopters. He had flown the Hiller 12E for a total of 28.25 hours. During the 28 days before the accident Captain McLeod had flown 22 hours, all on the Hiller 12E.

1.6 Aircraft information

G–ASIH (manufacturer's serial number 2192) was made by the Hiller Aircraft Corporation in 1962 and was registered in the name of Management Aviation Ltd, Bourn, Cambridgeshire in December 1963.

At the time of the accident the aircraft was equipped with an underslung hopper installation for fertiliser spreading operations. The aircraft's all-up weight (hopper loaded) at the start of its final flight was about 3,025 lb and at the time of the accident twenty minutes later (hopper empty) was about 2,340 lb. The aircraft's weight and centre of gravity were within permissible limits throughout the flight.

A certificate of airworthiness in the transport category (passenger) had been issued for G–ASIH and it was valid at the time of the accident. The maintenance records showed that the aircraft had been maintained in accordance with an approved schedule and that there were no outstanding items in the technical log. A certificate of maintenance issued on 22 February 1971 on the completion of a Check IV was also valid at the time of the accident. The aircraft had flown a total of 2,496 hours, 35 of which had been flown between the completion of the Check IV and the accident on 11 March. During this period a Check A and a pre-flight inspection had been certified in the technical log on each of the 14 days on which the aircraft flew. From 22 February to the morning of 4 March the aircraft was at Bourn aerodrome and the Check As were all certified by an aircraft engineer. On 4 March the aircraft was flown to Dumfriesshire by Captain McLeod and it was engaged on forestry operations there until the accident. Captain McLeod was accompanied by an aircraft engineer. From 5 to 11 March inclusive every Check A as well as the pre-flight inspection, was certified in the technical log by Captain McLeod. However, both he and the engineer stated that most of the Check As, including the one on 11 March, had been done by the engineer. The Check A specifically calls for the rod ends, attachment bolts, and nuts of the visible push rods between the fire wall and the wobble plate to be inspected for security of attachment and locking. No defect was noticed at any time.

1.7 Meteorological information

There was 4/8 stratus at 2,000 feet, with cloud above. Visibility was good and there was no precipitation. The wind was about 315°, 15 to 20 knots, with only minor turbulence in the operating areas.

1.8 Aids to navigation

Not relevant.

1.9 Communications

Not relevant.

1.10 Aerodrome and ground facilities

Not relevant.

1.11 Flight recorder

None was required nor fitted.

1.12 Examination of the wreckage

The wreckage was situated on a grass covered hill side at about 1,400 feet. Its distribution and the damage substained indicated that the helicopter had struck the ground in a steep nose-down attitude and had then fallen onto its starboard side. The aircraft was severely damaged and was beyond repair but no part of the fuel system had ruptured.

The longitudinal cyclic control upper push rod was found apart from the rest of the wreckage. This rod connects the upper bellcrank to the wobble plate. The rod's upper eye end was undamaged, as were the corresponding mating lugs on the wobble plate. The lower end of the rod was partly fractured and bent at right angles near the threaded eye end, to which was still attached a part of the bellcrank. The rod bore abrasions which had apparently been caused by its having bent over and rubbed against an adjacent wire braid armoured oil pipe. The ¼ inch diameter x 28 ANF x 1.9 inch steel bolt which normally secures the upper eye end of the rod to the wobble plate was found about 125 yards to the north of the main wreckage. This bolt is normally fitted with a plain washer and an all-steel flanged self-locking (or "stiff") nut, but neither of these was recovered.

The wreckage examination revealed no other pre-crash damage or aircraft unserviceability.

1.13 Fire

There was no aircraft fire. However, the pilot had a box of matches of the non-safety type in a trouser pocket and these caught alight on impact, burning his left thigh.

1.14 Survival aspects

When the aircraft had come to rest the pilot, who was lying on his right side, tried unsuccessfully to release his safety harness. This harness consisted of two shoulder straps looped around two lap-straps, the latter being secured by a lifting buckle. The pilot found that the lap-strap had been rolled upwards through 180°, apparently by a pull force on the shoulder straps, and the buckle was held so tightly against his body that he was unable to operate it. The two forestry workers who had been marking the spreading area quickly arrived and released the pilot.

Although the aircraft's cockpit was severely damaged the pilot escaped severe injury. This is attributed to the following factors:

(a) He was wearing a tightly fastened full harness and it remained secure in the crash.

(b) He was wearing a protective helmet.

(c) The cockpit structure, although extensively crushed, fortunately deformed in such a way that it did not impact his body severely.

(d) The aircraft did not catch fire.

1.15 Tests and research

The bolt which became detached from the longitudinal cyclic control was examined. The amount of wear on the leading threads was normal. However, the amount of wear on the crests of the last two turns of thread and the appearance of the worn surface suggested that at some time during its service a washer had vibrated against it. Tests were also carried out on five similar nut/bolt assemblies from the aircraft. Four of these came from the upper bellcranks and the fifth from the wobble plate lateral cyclic push rod connection. The initial torque required to slacken these nuts was measured. After disassembly the nuts were replaced on their respective bolts and measurements were then made of the torque required to unscrew each nut. Table 1 details the results of these tests. The figures given in Column 2 were those obtained when first slackening the nuts from their assembled condition in the control unit. The figures in Columns 3 and 4 are the torque values required to overcome the locking friction of each nut or its bolt once the axial load had been removed.

Table 1

Bolt (1)	Torque Required to Slacken Nut (lb/inch) (2)	Torque Require to Unscrew Unit (lb/inch) (3)	
		Max (3)	Min (4)
A	29	2	¼
B	30	2¾	½
C	32	2½	1½
D	36	4	2½
E	25	2	1½

SBAC Performance Specification TS2 for all-metal self-locking nuts (unified threads) prescribes a criterion for testing batches of new nuts of the same type. This is that the maximum locking torque without axial load should not exceed 30lb/inch on first assembly, and that the minimum torque on the 15th removal should not be less than 3.5lb/inch. Such tests were made on two new nuts and bolts. They consisted of screwing and unscrewing each nut/bolt combination fifteen times, and produced the results given in Table 2.

Table 2

	Max. Torque Obtain – lb/inch			
	At First Application		At 15th Application	
Bolt (1)	Assembly (2)	Removal (3)	Assembly (4)	Removal (5)
X	25	15	4½	5¼
Y	Over 30	Over 30	4¼	4½

Comparison of all the eight bolts examined showed that the effective diameter of the worn turns of thread was closely similar. However, the effective diameter of the clenched part of the five nuts removed from the bolts in the control system was generally larger than found on the two new nuts after fifteen applications, and it was considered that the difference in size would account for the difference in the unscrewing torque values obtained.

Tests carried out with a nut of this type (measurements: 5/16 inch across the flats and 7/32 inch in height) established that the maximum torque which a man could apply with the fingers was about one lb/inch.

1.16 Other information

From the operator's maintenance and stores record and the aircraft log books it was established that the detached bolt had been fitted new in May 1969 and had been removed and refitted at least seven and possibly nine times since, the final occasion being during the Check IV which was completed on 22 February 1971. The full history of the associated nut could not be ascertained but it was established that it had been removed from the bolt and refitted to it during the Check IV and, according to the records and evidence, had not been disturbed since. The aircraft engineer who carried out this work stated that the nut was an all-steel flanged type stiff nut and that a plain steel washer was used in re-assembly. He recalled checking the locking friction by turning the nut onto the bolt using his fingers until the locking friction was felt and then establishing that it was not possible to turn the nut any further in this manner. The nut was then tightened using a pair of ring spanners, no specific torque being applied as this is not called for by the aircraft maintenance manual. After the control system had been fully assembled and rigged the normal duplicate inspection was completed and certified.

The recommended maintenance practice for ascertaining that stiff nuts are fit for re-use in British civil aircraft is laid down by the Air Registration Board in *Civil Aircraft Inspection Procedures*, leaflet BL.5/1 which states:

> "8. STIFFNUTS . . . . . if nuts are to be re-used, their general condition should be checked, and they should be tested by screwing the nut onto a bolt by hand. The locking characteristics are considered unsatisfactory when the nut can be turned on to the mating thread of a new bolt by hand."

2. Analysis and Conclusions

2.1 Analysis

The evidence of the pilot and the two eye witnesses together established that the aircraft was flying at a safe speed, height and attitude in satisfactory weather conditions when it pitched sharply nose-up and, despite the cyclic stick being put fully forward, reached a near vertical attitude before crashing out of control. The wreckage examination revealed that the longitudinal cyclic control push rod had become disconnected in flight from the wobble plate due to the loss of the securing bolt. Such a disconnection would cause a complete loss of longitudinal control, the initial result of which would be a sharp nose-up pitch, and this was the cause of the accident.

The bolt was recovered and was found to be fully serviceable. However, the wear on the crests of the back two turns, and their appearance, suggested that at some time a washer had vibrated against the bolt. This could only have occurred if the nut was not fully tight. As there was no evidence that the subject nut had at any previous time been other than fully tight it seems likely that the wear had occurred since the last Check IV. This implies that the nut had loosened even though the evidence indicates it had been checked, assembled and subsequently inspected in accordance with the relevant instructions. Even if it was assumed, for the purposes of argument, that the nut was not fully tightened during assembly the localised wear due to the washer shows that the nut was fully engaged on the bolt. The nut could thus only have come off if its unscrewing torque was inadequate, but since it was not recovered no direct conclusion can be drawn as to the cause of this inadequacy, eg whether the nut was unduly worn, had split or had stripped.

However, the tests on the five similar nut/bolt combinations taken from the aircraft control system established that their unscrewing torque was less than that of the two new combinations after fifteen applications, and was also below the minimum torque value specified for such tests in SBAC Specification TS 2. The tests also showed that whereas the effective diameter of the worn turns of thread of all of the eight bolts examined was closely the same, the effective diameter of the clenched part of the five stiff nuts removed from the aircraft was larger than on the two new nuts after fifteen applications by an amount which would account for the difference in unscrewing torque values obtained. If it is assumed that originally the clenching of all seven nuts was similar it would suggest that the difference in internal size was caused by one or more factors due to use, eg a far greater number of applications, a much

higher rate of wear due to increased abrasiveness, or by the nuts having taken a permanent set. If these results are considered alongside the maximum torque figure of about one lb/inch which a man can exert with the fingers on a nut of this type it seems possible that a nut having unsatisfactory locking characteristics could be fitted in good faith by engineers complying completely with the laid down procedures. This might well have been the case in this accident.

In consequence it would be prudent to review the practice of employing stiff nuts as the sole means of locking bolts at critical points in aircraft systems, and also to consider whether the instructions which permit stiff nuts to be re-used and which lay down the method of assessing their locking characteristics should be revised.

2.2 Conclusions

(a) Findings

(i) The aircraft documents were in order.

(ii) The aircraft had been maintained in accordance with an approved maintenance schedule, and it was properly loaded for the flight.

(iii) The pilot was properly licensed and adequately experienced to conduct the flight.

(iv) The longitudinal cyclic control push rod became detached from the wobble plate in flight causing the aircraft to go out of control and crash.

(v) The push rod became detached because the bolt securing it to the wobble plate fell out after the all-steel stiff nut securing it had come off.

(vi) The reason why the nut came off could not be positively determined but it is possible that it became unscrewed due to lack of adequate locking qualities.

(vii) It would, therefore, be prudent to review the practice of employing stiff nuts as the sole means of locking bolts at critical points in aircraft systems, and also to consider whether the instructions which permit stiff nuts to be re-used and which lay down the method of assessing their locking friction should be revised.

(b) *Cause*

The accident was due to a loss of control caused by the longitudinal cyclic control push rod becoming detached from the wobble plate because the retaining bolt fell out after its securing nut had come off.

G M Kelly
Inspector of Accidents

Accidents Investigation Branch
Department of Trade and Industry
July 1971

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