ACCIDENTS INVESTIGATION BRANCH
Department of Trade and Industry

Helicopter Bell 47D1 G–ASJW
Report on the accident 1 mile northwest of Saxilby, Lincolnshire on 19 July 1971

LONDON: HER MAJESTY'S STATIONERY OFFICE
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Department of Trade and Industry
Accidents Investigation Branch
Shell Mex House
Strand
London WC2R 0DP

20 June 1973

The Rt Honourable Peter Walker MBE MP
Secretary of State for Trade and Industry

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 Helicopter Bell 47D1 G–ASJW which occurred 1 mile northwest of Saxilby, Lincolnshire on 19 July 1971.

I have the honour to be
Sir
Your obedient Servant

V A M Hunt
Chief Inspector of Accidents

Accidents Investigation Branch
Civil Aircraft Accident Report No 10/73
(EW/C 389)

Aircraft:	Helicopter Bell 47D1 G–ASJW
Engine:	Franklin 6V4–200–C33
Owners:	Airlift Ltd
Operators:	Autair Helicopter Services Ltd
Pilot:	J Zwozny – Killed
Passengers:	Nil
Place of Accident:	1 mile northwest of Saxilby, Lincolnshire
Date and Time:	19 July 1971 at about 1608 hrs
	All times in this report are GMT

Summary

The helicopter crashed in a barley field during a test flight about twelve minutes after taking-off from a field on the outskirts of Saxilby village. After making several low level spraying runs over two fields in the vicinity of the village, it made a sharp left hand turn and lost height until it was very close to the ground. Then it zoomed vertically, went out of control, dived into the ground and caught fire. The pilot was killed.

1. Investigation

1.1 History of the flight

The helicopter had been grounded by the pilot on 17 July 1971 because of an apparent defect in the lateral control system. The licensed engineer responsible for its maintenance in the field decided that the lateral control disc was unserviceable and on 19 July 1971 replaced the defective unit with one that he believed to be serviceable. Then, he said, he re-rigged the lateral controls and completed a daily inspection.

The helicopter was re-fuelled in preparation for a test flight and water ballast put in the spray tanks.

A relief pilot arrived during the afternoon of 19 July and carried out a duplicate inspection of the work done to the lateral control system, and an acceptance inspection. Shortly afterwards he entered the control cabin, started up the engine and, according to the engineer, checked the full range of movement on the cyclic control before lifting the helicopter into the hover. In the hover he exercised the cyclic control again by smart movements of the stick, then landed and, with the engine still running, called to the engineer to ease the friction on the lateral control disc. This the engineer did by fractionally slackening the disc clamp bolt. Then the pilot hovered the helicopter and again exercised the lateral control. Then he nodded his head, gave a 'thumbs up' sign to the engineer, and lifted the helicopter over a car and a hedge and flew north. The time was about 1556 hrs. Witnesses about a mile north of Saxilby village saw the helicopter at this time manoeuvring for several minutes about 40 feet above the ground apparently testing the spraying equipment. Finally, during a spray run at about 20 feet, the helicopter turned sharply left through more than 360°, losing height in the first half of the turn and climbing through the remaining 180°. It then rapidly lost height until it was very close to the ground when it zoomed steeply up to a height of some 40 to 50 feet with the fuselage vertical or slightly over vertical. At this point the engine noise was heard to cease and the helicopter rolled over to the left and dived to the ground. A witness described the manoeuvre as being similar to a stall turn on a fixed wing aircraft.

1.2 Injuries to persons

Injuries	*Crew*	*Passengers*	*Other*
Fatal	1	—	—
Non-fatal	—	—	—
None	—	—	—

1.3 Damage to aircraft

Destroyed.

1.4 Other damage

Slight damage to a barley crop.

1.5 Pilot information

Mr J Zwozny, aged 29 at the time of the accident, learned to fly helicopters in the Royal Navy. He left the service as a lieutenant in January 1966 with an 'above average' assessment and took up civilian employment as helicopter pilot in Australia and Africa. He returned to the United Kingdom in January 1971 and flew for Autair in a free-lance capacity until the day of the accident.

He held a current Airline Transport Pilot's Licence (Helicopters) endorsed for Hiller 360 series UH12, Bell 47 and Bell 206A helicopters, and had completed over 3,500 hours helicopter flying, 132 hours of which were on Bell 47 aircraft. Of this total 22 hours were flown during June/July 1971.

He passed his most recent medical examination on 11 July 1971. There was nothing significant in his medical history, and the post mortem examination revealed no evidence of any medical condition that could have had a bearing on the cause of the accident.

1.6 Aircraft information

The aircraft was constructed in 1957 by the Bell Aircraft Corporation, Fort Worth, Texas, and was first registered in the United States of America. It was exported to the United Kingdom in 1963 with an export certificate of airworthiness dated 6 June of that year, issued by the Federal Aviation Administration in London. The aircraft was then registered in the UK as G–ASJW in the name of World Wide Helicopters (UK) Ltd, and the export certificate of airworthiness was validated in the Transport Category (Passenger) with effect from 5 July 1963. On 8 September 1964 the aircraft was re-registered in the name of Airlift Ltd and one year later the certificate of validation was replaced by a UK certificate of airworthiness. This certificate was last renewed on 5 March 1971 and was valid for one year.

The aircraft had been leased to Autair Helicopter Services Ltd since April 1971, and maintained by them under an approved maintenance schedule. A certificate of maintenance was issued on 13 July 1971 valid for 31 days or 50 flying hours. Since that date the aircraft had flown 16 hours.

The records show that the aircraft had flown a total of 9,510 hours and the engine had run for a total of 670 hours since its last complete overhaul.

Prior to the accident flight the aircraft had been re-fuelled with 91 octane fuel to a tank capacity of 19 US gallons. The weight of the aircraft at the commencement of the flight on which the accident occurred was less than the authorised maximum and the centre of gravity was within the authorised range and 0.6 inches forward of the aft limit.

1.7 Meteorological information

Witnesses at the scene of the accident said that the weather was fine and the wind was light and westerly. An aftercast (1600 hrs) for the area 7 miles west of Lincoln was prepared by the Meteorological Office:

Surface wind	Light and variable
Visibility	10 kilometres
Weather	Nil
Cloud	1/8-3/8 3,000 feet; 7/8 base 5,000 feet
Temperature	Plus 18° C
Dewpoint	Plus 10° C

1.8 Aids to navigation

Not applicable.

1.9 Communications

No communication equipment in the aircraft.

1.10 Aerodrome and ground facilities

Not applicable.

1.11 Flight recorders

Not required and none fitted.

1.12 Wreckage

Examination at the scene of the accident showed that the aircraft had struck hard ground in a field of standing barley on a heading of 099° magnetic. It had caused a minimum of disturbance to the barley. Characteristics of the wreckage and ground impact marks indicated that the aircraft had nose-dived into the field at an angle of about 45°. It had then bounced sideways, to the right, which suggested a degree of right slip before impact. The wreckage finally settled in a near level attitude. The forward part of the aircraft's structure was completely wrecked but the rear part, including the tail girder and tail rotor, remained almost intact.

The main rotor blades had struck the ground heavily causing the outer sections of the blades to disintegrate and pieces to be thrown about 100 feet. The general characteristics of the damage to the blades suggested that the main rotor had been under considerable power at impact. The tail rotor blades were found at maximum pitch angle, the tail rotor cable having been released from its drum when the fuselage distorted.

An intensive ground fire, caused by fuel spilled over the engine when inertia loads ruptured the fuel tank on impact, consumed parts of the crew compartment, and melted much of the light alloy structure and parts of the controls. There was no evidence of fire having occurred before impact.

Both lapstraps were fastened and their attachments secure but the pilot's lapstrap had been cut to release him.

Further examination of the wreckage revealed no evidence of any pre-crash failure or malfunction of the engine; the indications were that it was running normally at the time of the impact.

Examination of the main and tail rotor assemblies, including the bearings and their transmission drives, revealed no evidence of pre-crash mechanical failure or malfunction. A blade of the tail rotor had been deflected, indicating that the tail rotor was under power at the time of impact.

The lateral cyclic control disc however was found to have been wrongly installed, with the grease nipples facing aft instead of forward. There was no other evidence of fault or failure in the control system.

When the lateral cyclic control disc was removed it was noted that both the pivot bolt and the input link attachment bolt were ¼ inch diameter. The latter should have been of 3/16 inch diameter. The bushes in the disc were both of 0.342 inch external diameter drilled to accommodate the ¼ inch bolts and the holes in the links had been enlarged to suit the oversize bolt.

Examination of the control disc showed it to be complete and wire locked. An 'X' was etched on the steel ring at the base of the push/pull rod but no corresponding 'V' lapping marks were discernible on the bronze disc. On separating the disc plates it was seen there were no shims between them, indicating that the unit was nearing the end of its life. The bevelled edges of the disc plates, which mate with lands on the steel ring, were indented where the lands had driven into them on impact but there was no evidence of fretting or seizure. A Tallyrond check of the bevelled surface showed that the disc was distorted about 0.010 inch; this was attributed to crash impact. No conclusions could be drawn about the pre-crash effectiveness of the friction element of the unit.

Examination of the lateral cyclic control disc removed prior to the fatal flight showed that both the holes in the disc were of the larger diameter. That is to say, this unit had also been altered to accommodate an oversize input link attachment bolt and did not conform to the original design. This control disc had first been fitted to G–ASJW in June 1971, then removed for servicing and refitted at the beginning of July 1971. It has not been possible to determine when the unit was altered but it seems likely that it had been done on one of these occasions. This alteration was not authorised.

1.13 Fire

An intense ground fire almost immediately after impact followed the bursting of the fuel tank above and behind the pilot.

The fire brigade in Saxilby village were informed at 1610 hrs and their appliance was on the scene by 1618 hrs. Using a single hose jet from the water tender supply tank they had the fire under control at 1629 hrs.

1.14 Survival aspects

The accident was not survivable. The pilot's lap strap remained intact, and his protective helmet certainly preserved his skull from damage. Certain localised injuries from flailing would have been prevented by shoulder harness but it is doubtful that such harness would in this case have affected the outcome. The bulkhead behind the seat had been forced forward, severely reducing the space between its forward face and the control column. The final compression of the pilot's body over the controls would not have been influenced by shoulder harness and if such compression had not itself caused traumatic rupture of the heart, death would have resulted from traumatic asphyxia or burning.

1.15 Tests and research

1.15.1 *The cyclic control disc described* (see Appendix)

The work carried out on the aircraft immediately before the accident concerned the lateral cyclic control disc unit. This unit and a similar but not identical unit in the pitch control system are sometimes called 'irreversibles'. They serve in the push/pull control system and incorporate a friction device to damp out any undesirable forces fed back from the main rotor to the cyclic control column.

The upper end of the push/pull rod terminates in an adjustable eye-end connection to the swashplate horn. The lower end of the push/pull rod, which accommodates the friction device, consists of a steel ring of triangular cross-section. Within the ring a pair of bronze discs, each having a bevelled edge, are bolted together, the bevelled edges forming matching working faces with those of the ring.

These faces are lapped to give uniform friction in the normal operating range. This range is usually denoted by an 'X' on the ring and two 'V' marks on the discs. In order to permit the friction to be adjusted the steel ring is split and provided with a clamp bolt. The discs normally have shims between them which can be progressively removed to take up wear.

A pivot hole in the discs near their periphery has a steel bush of 0.342 inch outside diameter and the unit is mounted to bracket on the main transmission casing by a ¼ inch diameter steel bolt. When so mounted rotation of the discs about the pivot and within the ring imparts reciprocating movement to the push/pull rod.

In the case of the lateral control unit, input to the discs from the control circuit is imparted by a pair of light alloy links. These are normally coupled to the discs by a bolt of $^{3}/_{16}$ inch diameter through a second hole with a bush 0.313 inch outside diameter, near the periphery of the discs. It will be noted that the design, which intentionally makes provision for bolts and bushes of different sizes, normally renders it impossible to assemble the unit to the aircraft other than in the correct manner.

1.15.2 *The procurement of the replacement lateral control disc unit*

When the engineer working on G–ASJW requested a replacement lateral control unit from the company's main base at Luton on 17 July 1971 he was told that an engineer had gone to get one from Luxembourg, where another helicopter of the same type was operating. The engineer in charge at Luxembourg gave the visiting engineer a pair of control units, one of each type. These had been removed from helicopter G–ASOL 'due to excessive wear', the pilot having complained of feed-back in the fore and aft cyclic control. The pilot had asked for the lateral control unit to be changed at the same time to restore the controls to their optimum condition. This lateral control unit was the one that was eventually fitted to G–ASJW before the accident and was one of three supplied by Ogden Aero-Equipment Corporation, Sun Valley, California, USA. It had been fitted to G–ASOL on 23 August 1970 and by the time it came to be removed on 19 June 1971 it had completed 70 hours 25 minutes flying.

The engineer in charge at Luxembourg later stated he had examined both units. The fore and aft unit he had found slack but the lateral cyclic control unit had seemed 'OK'. No labels indicating their serviceability had been attached to them; as far as he could remember one had been marked 'unserviceable' with masking tape. The absence of any record of subsequent rectification or satisfactory checking rendered the units technically unserviceable but not necessarily defective.

Both units arrived at Luton on 19 July 1971 and after being cleared by customs were passed to Autair's works manager. The lateral control unit was without a label or serial number. The works manager, who was an experienced engineer but not in possession of an inspection authority or aircraft licence, examined it and assessed its condition as good. He then carried out a friction pull-off check, which he considered satisfactory, before he dispatched the unit to the engineer working on G–ASJW in the field. This engineer received it the same day (19 July). The unit was wire locked, the bushes were in place and it was fitted with grease nipples, but the documentation was incomplete. He therefore telephoned Luton to ask for the serial number and airworthiness approval reference. He was given the serial number and, erroneously, a 'Goods Received' reference and these he accepted in good faith as confirming serviceability of the unit. Before installing it he checked it by carrying out a friction pull-off, clamping the disc in a vice and rotating the arm 30° in each direction. He said the 'V' lapping marks that indicate the range of movement over which this check should be made had been painted over.

1.15.3 *The fitting of the lateral cyclic control unit*

The engineer working on G–ASJW subsequently described how he fitted the replacement lateral control unit. He began by offering up the unit to the pivot bracket and inserting the ¼ inch bolt, but when he came to attach the parallel links he found that the ¼ inch bolt he had taken out of the previous unit would not go into the bush, although it fitted the holes in the links. He thereupon removed the unit from the aircraft and reamed out the hole to take the larger size bush to suit the ¼ inch bolt.

He said he thought his action appropriate 'on this occasion . . . I have come across this situation before where the bushes and bolts were the same sizes'.

Having now made it possible for the unit to be installed the wrong way round the engineer proceeded to fit it incorrectly. This meant that at some time the discs must have rotated, or been turned through about 120° so that the wrong holes were aligned with the bracket and parallel links. The engineer said he did not do it, and did not have equipment in the field to do so. He said 'I referred to the maker's manual in regard to the pull-off check and rigging, but not closely enough as regards the detail of ensuring that the grease nipples should face forward'.

After fitting the unit incorrectly he carried out a rigging check of the lateral controls. The aircraft was resting on soft ground and he did not think it practicable to place the aircraft in the rigging position. Instead he checked the lateral level and found it was 2° down to the right, and he set the cyclic control column 2° to the right of the vertical to compensate. The specified inclinometer reading for the swashplate, with the aircraft level in the rigging position and the cyclic control column vertical is ½° down to the left. So, taking into account the aircraft's 2° tilt, he adjusted the rod eye end to give an inclinometer reading of 1½° down to the right.

The engineer finally checked the full range of travel of the controls and although he could not remember the actual figures he was sure they were within the required limits. He then signed the worksheet for the first part of the duplicate inspection, expecting the second part to be signed for by the pilot before he himself signed the certificate of compliance. He said he did not see the pilot actually check the rigging, but he did see him carry out a duplicate inspection of the controls, including the acceptance check, and inspect the technical log and worksheet.

1.15.4 *Rigging check with an incorrectly installed lateral cyclic control disc*

To assess the effect of fitting the lateral cyclic control disc incorrectly, rigging checks were carried out on a similar type of helicopter to G–ASJW.

1.15.4.1 Effect on the rigging of fitting the control disc incorrectly

The helicopter was placed in rigging position with the unit correctly fitted and rigged. Swashplate angles were noted with the cyclic stick neutral (vertical) and in 5° stages each side of neutral up to the port and starboard stops. The unit was then disconnected and, without any other adjustments, it was wrongly re-fitted with the grease nipples facing aft. To do this it was necessary, because the link hole became the pivot hole, to replace the bushes in the unit with specially made bushes of appropriate size and to rotate the discs through about 120° before the bolts could be inserted. Swashplate angles were again taken for the same stick positions. Consideration of the results, making due allowance for the difference in lengths of the adjustable push/pull rods in this aircraft and the one involved in the accident, shows that

the effect on the rigging of the incorrectly fitted controls would have been to displace the cyclic stick up to 4° to port, with the swashplate at the neutral setting. With the cyclic stick on the lateral stops the effect would be to reduce swashplate travel to port by up to 1° and increase it to starboard by up to 3°.

1.15.4.2 Control forces

Since fitting the unit back to front causes the link hole to become the pivot hole and since the link hole is nearer to the disc periphery the lever arm to the swashplate is lengthened without any change of input leverage. This is equivalent to a change of approximately 20 per cent in gearing. More force would be required to move the cyclic controls, and any feed-back forces would have a greater effect on the cyclic stick.

1.15.4.3 Frictional qualities

An additional effect on the control characteristics may have resulted from the rotation of the discs. A displacement of 120° from the normal operating arc, within which the unit is normally lapped and adjusted, could very well change its frictional qualities. Such a change may make the unit less effective as a damper or alternatively tend to create stiffness in the controls particularly at the limits of control travel. In this context it was noted that on first trying the controls in the air the pilot had requested that the clamp bolt on the unit be slackened to reduce the degree of friction.

1.15.4.4 Rigging adjustments

It was found to be impracticable during these rigging checks to rig the controls correctly by adjusting the eye-end of the lateral control disc push/pull rod, there being insufficient adjustment available to shorten the rod to the necessary length.

2. Analysis and Conclusions

2.1 Analysis

The evidence concerning this accident high-lighted three main points for consideration:

(a) The state of serviceability of the replacement lateral cyclic control unit.

(b) The incorrect installation of the unit.

(c) The effect of the incorrect installation of the unit.

(a) *The state of the lateral cyclic control unit*

The lateral cyclic control unit was technically unserviceable, since the necessary documentation certifying that it was serviceable was absent. The unit was inspected and subjected to two pull-off friction checks by experienced engineers who considered it to be satisfactory. However, the absence of 'V' lapping marks – which had been omitted during manufacture and whose absence had evoked no action at the time of the initial receipt – to indicate the range of movement over which the pull-off check should be made throws some doubt on the validity of these checks. In any case because of the rotation of the discs that had enabled the unit to be fitted back to front the lapped faces would no longer match. This and the subsequent slackening of the clamp bolt (at the pilot's instigation), make it impossible to give any useful opinion as to the efficacy of the unit as a damper.

The link bolt hole and bush of the unit and the attachment to the parallel links had been altered to take a ¼ inch diameter bolt similar to the pivot bolt, as had the unit that it replaced. The aircraft log book did not contain any entry to indicate why, when or by whom these assemblies had been altered. Although this alteration would not affect the operation of a correctly installed unit, it removed one of the safeguards against fitting the unit back to front. The unknown state of serviceability of the unit, the absence of proper documentation and the unauthorised alterations without record or explanation point to a departure by the operating company from proper maintenance procedures.

(b) *The incorrect installation of the unit*

The unit was designed to have pivot and control input bolts and bushes of different sizes in order to prevent it being fitted to the aircraft the wrong way round.

The unit to be replaced had been altered in that the bush and bolt connecting the parallel links to the discs had been replaced with the larger diameter pivot type bush and bolt. This had necessitated reaming out the appropriate holes in the discs and connecting links. With the link holes and the pivot hole in the airframe and their respective bolts the same size the standard unit could not be properly secured either way round. Thus if the discs had already been rotated through 120° there would be no obvious indications that this was so, as there would have been with the right size bolts and holes. Such a situation could well have encouraged the engineer to continue with the task of fitting the unit the wrong way round. In fact he reamed out the only odd-sized hole in the assembly.

The holes in the links having already been enlarged the only remaining safeguard against fitting the unit incorrectly was to ensure that the grease nipples on the unit faced forwards as prescribed in the maintenance manuals. Inspection would also show that the holes now serving as link bolt hole and pivot bolt hole were not at the correct distances from the centre of the disc but this point is not made in the manual.

In the event the guidance in the manual that the grease nipples were not facing forward was missed and the fact that the unit was installed back to front went unnoticed.

The engineer said that he then made rigging checks and obtained figures within the required tolerance. But post-crash rigging checks on another helicopter of the same type as G–ASJW suggest that with the lateral cyclic control unit fitted the wrong way round this is unlikely to have been so.

If, however, the engineer, in setting the angle of the cyclic control stick to compensate for the aircraft's 2° of tilt, had set it 2° to port instead of 2° to starboard the actual displacement would then have been 4° to port, which corresponds neatly to the neutral swashplate angle of ½° down to port. Checks of full travel of the controls would then have given a full deflection of the swashplate to port which would have been legitimately within limits, and too great a deflection to starboard by approximately 1°. The observation of two out of the required three results within limits and the third only a little outside, and that giving an excess as opposed to a limitation of travel, may have prompted acceptance.

The installation of the unit called for a duplicate inspection of the completed work. British Civil Airworthiness Requirements (BCARs) state that where only a minor adjustment is made away from base a duplicate inspection may be completed by a pilot licensed for the type of aircraft concerned. The change of a lateral control disc is not a minor adjustment, and the duplicate inspection of its installation falls within the province and responsibility of a qualified engineer.

(c) *The effect of the wrong installation of the unit*

Although the incorrect installation of the lateral cyclic control disc resulted in a change in gearing between cyclic control and the rotor head and a displacement of the neutral datum it did not change the sense of the controls.

The change of gearing would have made the cyclic controls harder to move, and it was probably this that made the pilot ask for the friction disc clamp bolt to be slackened. Easier operation of the controls would thus have been gained at the expense of less dampening of any feed-back that might occur.

Fitting the lateral cyclic control disc assembly back to front necessitated rotating the disc within the ring through about 120°, taking it out of the range over which its friction is normally tested. Since the disc was not inscribed with lapping marks the precise range over which the unit had been lapped is not known. Thus although it can be said that the friction characteristics of the control disc would have been altered, particularly at the extreme range of control travel, it was not possible to determine by how much or in what sense.

The available evidence thus falls short of establishing that fitting the lateral cyclic control disc back to front and slackening the clamp bolt caused the pilot to lose control. In the event he flew the aircraft and tested the spraying equipment for some 12 minutes without any apparent difficulty. However it is within the bounds of possibility that during a steep turn or similar manoeuvre near the ground an unexpectedly strong feed-back, or a sudden increase in friction at the extreme ends of the range of control movement threw the pilot off balance and put him in a position from which he was unable to recover before the aircraft struck the ground.

2.2 Conclusions

(a) *Findings*

(i) The pilot was experienced and properly licensed.

(ii) The aircraft was correctly loaded.

(iii) The documentation of the aircraft was not in order. There was no record to show that the replacement lateral control unit was serviceable, and no signature to confirm that it had been properly installed and inspected.

(iv) Unauthorised alterations to the aircraft's lateral cyclic controls removed an important safeguard against fitting the unit incorrectly.

(v) In these respects the operating company had departed from proper maintenance procedures.

(vi) The engineer installing the lateral cyclic control unit did not make proper reference to the maintenance manual and as a result the unit was installed back to front.

(vii) The effect on the controls of the wrongly fitted unit may have disconcerted the pilot at a critical stage of flight near the ground.

(viii) The evidence was insufficient to establish that the incorrect installation of the unit was a direct cause of the accident.

(b) *Cause*

The accident resulted from loss of control by the pilot at a height too low to effect recovery, possibly as the result of the effect on the controls of an incorrectly fitted lateral cyclic control disc.

G M Kelly
Inspector of Accidents

Accidents Investigation Branch
Department of Trade and Industry
June 1973

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