AIRCRAFT ACCIDENT REPORT 5/92

Air Accidents Investigation Branch

Department of Transport

Report on the accident to British Aerospace ATP, G-LOGA at Edinburgh Airport, Scotland, on 5 February 1992

This investigation was carried out in accordance with
The Civil Aviation (Investigation of Air Accidents) Regulations 1989

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Department of Transport
Air Accidents Investigation Branch
Defence Research Agency
Farnborough
Hants GU14 6TD

16 September 1992

The Right Honourable John MacGregor
Secretary of State for Transport

Sir,

I have the honour to submit the report by Mr D F King, an Inspector of Air Accidents, on the circumstances of the accident to British Aerospace ATP, G-LOGA, that occurred at Edinburgh Airport, Scotland on 5 February 1992.

I have the honour to be
Sir
Your obedient servant

K P R Smart
Chief Inspector of Air Accidents

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GLOSSARY OF ABBREVIATIONS USED IN THIS REPORT

AAIB	-	Air Accidents Investigation Branch
amsl	-	above mean sea level
AFS	-	Airport Fire Service
ATC	-	Air Traffic Control
CAA	-	Civil Aviation Authority
CVR	-	Cockpit Voice Recorder
ft	-	feet
g	-	normal acceleration
hrs	-	hours
kt	-	knot(s)
lbf	-	pound force
lbf in	-	pound force inch(es)
°M	-	Degrees Magnetic
MHz	-	megahertz
PA	-	Public Address
RTF	-	Radio telephony
UFDR	-	Universal Flight Data Recorder
UTC	-	Coordinated Universal Time

Air Accidents Investigation Branch

Aircraft Accident Report No. 5/92

(EW/C92/2/1)

Registered Owner and Operator:	Loganair
Aircraft Type:	British Aerospace ATP
Nationality:	British
Registration:	G-LOGA
Place of accident:	Edinburgh Airport, Scotland
	Latitude: 55° 57' North Longitude: 003° 22' West
Date and Time:	5 February 1992 at 1730 hrs

All times in this report are Coordinated Universal Time (UTC)

Synopsis

The accident was notified to the Air Accidents Investigation Branch (AAIB) by Air Traffic Control (ATC) at Edinburgh at 1857 hrs on the day of the accident and the investigation began the following morning.

The AAIB team comprised:

Mr D F King	Investigator in Charge
Mr S R Culling	Engineering
Mr R G Matthew	Operations
Mr P F Sheppard	Flight Recorders

On landing from a visual approach to runway 31 at Edinburgh Airport the Loganair ATP, with 31 passengers and four crew aboard, immediately veered sharply to the left and ran off the side of the runway onto the grass. There were no injuries and the occupants evacuated the aircraft using the forward airstairs.

The following causal factors were identified:-

(i) The aircraft left the runway because of an undemanded nosewheel steering deflection of 15° to the left and an ineffective steering tiller.

(ii) The undemanded turn and lack of subsequent tiller response resulted from a seized nosewheel steering upper pivot joint, which led to the failure of the supporting structure of the pulley carrying the steering tiller cable to the nosewheel steering mechanism.

(iii) The nosewheel steering upper pivot joint was tight on assembly, possibly with an interference fit of the bolt in the lug and/or the fork bushes.

(iv) The pivot joint was tight on assembly because:-

A British Standard, describing the pivot joint bolt dimensions, had been transcribed incorrectly into the British Aerospace Aircraft Group Design Handbook and thence into the drawings for the nosewheel steering system.

The dimensions of the pulley lug hole were inadequately controlled during cadmium plating.

(v) The ATP pivot joint assembly process did not call for lubrication during assembly.

Five Safety Recommendations were made during the course of the investigation.

1 Factual Information

1.1 History of the flight

The crew reported for duty at 1200 hrs on the day of the accident and were scheduled for four sectors, Manchester to Belfast and return followed by Manchester to Edinburgh and return. The aircraft was not carrying any significant unserviceabilities and the flights were conducted without incident until landing at Edinburgh at 1730 hrs. The last surface wind information, which was passed to the aircraft on final approach, was 260°/16 kt and although the runway surface was wet, there was no report of precipitation or standing water and the braking action was good.

A visual approach was flown to runway 31 and a normal touchdown, at threshold speed was made on the runway centreline at the visual aiming point. When the nosewheels contacted the runway, despite the central position of the steering tiller with the Steering Master Switch ON, the the aircraft swung rapidly to the left. The commander applied full right rudder and demanded a right turn on the tiller but the aircraft continued to swing left. A yaw to the left developed and the aircraft departed the left side of the runway onto the grass. Full reverse thrust was then applied and it, together with the effect of the very boggy ground, brought the aircraft to a stop before it reached a stream at the airfield boundary. The engines were then shut down.

The No 1 stewardess, positioned in the forward cabin, told the passengers to unstrap but to remain seated and then went to the flight deck to inform the commander that there was no visible fire, smoke or disruption in the cabin. The commander ordered an evacuation using the front airstairs and the No 1 stewardess, on returning to the cabin, made an announcement to that effect on the Public Address (PA) system. She then tried to use the cabin interphone to instruct the No 2 stewardess, located at the rear of the passenger cabin, to disarm the rear door and to confirm that the evacuation was to be from the front exit only. However, she could not make contact using the intercom and was obliged to use the PA. The evacuation was conducted smoothly without incident and, as the passengers left the aircraft, the No 1 stewardess instructed them to keep clear of the propellers and to congregate upwind, well away from the aircraft.

Four vehicles of the Airport Fire Service (AFS) arrived on site within two minutes of the alert given by ATC and informed the commander that there was no fire, but suggested that there was possible damage to the landing gear and to the engines from ingestion of debris. They then helped the No 2 stewardess to escort the passengers to a safe area, where they were kept together until transport to the terminal arrived a few minutes later.

1..2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	-	-	-
Serious	-	-	-
Minor/none	4	31	

1.3 Damage to aircraft

Mud had passed through both propeller discs and had been thrown onto the fuselage and wings but, as the aircraft had yawed to the left during the ground run, the debris thrown up by the nosewheel had gone predominantly through the left hand propeller disc. Consequently, the left side of the aircraft had received more mud than the right hand side but it had not contained stones and had not caused any significant damage. Although debris had entered the left engine intake, a compressor wash sufficed to clear both engines.

The steering tiller was found to be ineffective. The pulley carrying the tiller cable to the nosewheel steering mechanism had been torn from its supporting structure and lay jammed between the nose landing gear pintle assembly and the underside of the flight deck floor (see Appendix A). The nosewheel steering upper pivot joint was found to have seized approximately 12° short of its fully closed position of 22° (see Appendix B). The resultant forces transmitted through the steering torque tube on the nosewheel leg had slightly displaced the steering control unit and had applied a steering demand of 15° to the left. The fracture surfaces of the pulley mounting flanges indicated failure by a combination of fatigue followed by overload. The direction of the overload failure indicated that the failure had occurred during the last landing gear retraction.

The nosewheel steering upper pivot joint, which comprised a bushed fork and the pulley lug, held together by a cadmium plated $^{7}/_{16}$ of an inch close tolerance shear bolt, was removed for strip and examination (see Appendix C).

1.4 Other damage

None

1.5 Personnel information

1.5.1	Commander:	Male, aged 44 years
	Licence:	Airline Transport Pilot's Licence
	Aircraft ratings:	ATP, BAe 146, BAe 125, Fokker F27
	Certificate of Test:	Base check, 15 January 1992 Line check, 24 January 1992
	Instrument Rating:	Renewed 15 January 1992
	Medical certificate:	Valid. Class I, no conditions, renewed 28 January 1992
	Flying experience:	Total: 6,125 hours On type: 35 hours 90 days: 60 hours 28 days: 24 hours Last 24 hours: 2.5 hours Current duty period: 6 hours Previous rest period: 12 hours
1.5.2	First officer:	Male, aged 35 years
	Licence:	Airline Transport Pilot's Licence
	Aircraft ratings:	ATP, BAe 146, Short 360
	Certificate of Test:	Base check, 11 December 1991 Line check, 13 December 1991
	Instrument Rating:	Renewed 11 December 1991
	Medical certificate:	Valid. Class I, no conditions, renewed 19 September 1991

Flying experience:	Total:	2,400 hours
	On type:	800 hours
	Last 90 days:	134 hours
	Last 28 days:	54 hours
	Last 24 hours:	2.5 hours
	Current duty period:	6 hours
	Previous rest period:	24 hours

1.5.3 Cabin attendant No 1 — Female, aged over 21 years

ATP type check:	Renewed 12 February 1991
Safety and Emergencies check:	Renewed 13 November 1991
Fire and Wet Drill check:	Renewed 4 March 1989

1.5.4 Cabin attendant No 2 — Female, aged over 21 years

ATP type check:	Renewed 19 February 1991
Safety and Emergencies check:	Renewed 28 May 1991
Fire and Wet Drill check:	Renewed 25 February 1992

Qualified, and normally operates, as a No 1 cabin attendant.

1.6 Aircraft information

1.6.1 Leading particulars

Type:	British Aerospace ATP
Constructor's number:	2040
Date of manufacture:	7 November 1991
Certificate of registration:	G-LOGA/R2 Issued 18 November 1991
Certificate of airworthiness:	Certificate Number 041909/002 Transport Category (Passenger) Valid until 5 November 1992
Total airframe hours:	283 hours

1.6.2 Nosewheel steering system description

The pilot's steering demands are conveyed from the steering tiller by cable to a pulley located on the underside of the pilot's floor (see Appendix B). The pulley is axially connected to a pivot joint on the top of a torque tube fitted to the landing gear nose leg, which transmits the pilot's demand to the steering control unit located at the lower end of the nose leg. The pivot joint accommodates the local changes in geometry during gear retraction and extension; with the nose leg retracted the pivot joint opens to an included angle of 120°, whereas when the leg is extended the pivot joint closes to an angle of 22°.

In normal use, with the weight on the main wheels and the nosewheel steering selected, hydraulic power is available to the steering mechanism to satisfy any demand after a microswitch has detected that the nose leg has been compressed through approximately 0.5 inches.

During manufacture and flight test before aircraft delivery, the landing gear could have been cycled up to 100 times; 379 landings had been completed after delivery.

Following this accident, on 14 February 1992, British Aerospace Woodford issued a Mandatory Service Bulletin requiring a once-only inspection to ensure that the nosewheel steering upper pivot joints on other aircraft did not exhibit similar problems. One aircraft still on flight test after manufacture failed the inspection. A corroded bolt was found on another aircraft with 5,458 flying hours and 8,343 landings - the nose leg on this aircraft had been removed and refitted during scheduled maintenance after 5,919 landings on 28 March 1991.

1.7 Meteorological information

The meteorological conditions were not contibutory to this accident, except for having produced the wet and boggy grass surface which greatly assisted in the retardation of the aircraft when it left the runway.

An aftercast was provided and showed the wind at the time of the accident to have been: 250° to 280° at 16 to 22 kt. The final wind given by ATC to the flight was 260°/16 kt. There was no precipitation.

1.8 Aids to navigation

Not relevant

1.9 Communications

1.9.1 Radio telephony (RTF)

The final communications between the aircraft and Edinburgh ATC were with Approach Control (Surveillance radar) on frequency 121.2 MHz, Edinburgh Tower on 118.7 MHz and Ground Control on 121.75 MHz. The crew also kept a listening watch on the Airport Fire Service frequency of 121.6 MHz.

All RTF communications were satisfactory and those concerning the aircraft and the accident were recorded.

1.9.2 Aircraft cabin interphone

When, following the accident, the No 1 cabin attendant tried to speak to the No 2 on the cabin interphone, she was unable to do so and was obliged to use the PA system. G-LOGA was the only ATP, of the four on the operating company's fleet, which was fitted with interphone. When a handset was replaced the service last selected remained selected, whereas on the other three aircraft, the service selected on the handset in use automatically reverted to cancel when the handset was replaced. A memorandum re-emphasising this difference has since been promulgated within the operating company.

1.10 Aerodrome information

Edinburgh Airport is 135 feet above mean sea level and has three 46 metre wide asphalt runways, 07/25, 13/31 and 08/26 (day only), providing landing distances available of 2,347 metres, 1,768 metres and 799 metres respectively. On the evening when the accident occurred, although the the instrument landing runway in use was 25, runway 31 was available for visual approaches.

Runway 31 was used by the accident aircraft and, although the surface was wet, the braking action was subsequently measured and found to be 'Good'. The runway was equipped with standard 3° Visual Approach Slope Indicators.

1.11 Flight recorders

1.11.1 Cockpit voice recorder (CVR)

The aircraft was fitted with a Fairchild A100A CVR which records 4 parallel tracks of information on an endless loop of tape with a recording duration of 30 minutes. The track allocation was as follows:-

Track 1	Co-pilot's live microphone and headset audio
Track 2	Cockpit area microphone
Track 3	Passenger address
Track 4	Pilot's live microphone and headset audio

The tape was removed from the recorder for replay and it was found that only one of the tracks, track 1, contained any useful information and even this was recorded at a very low level. Tests at both AAIB and the operators servicing agents revealed that the problem was within the recording head itself. The head was worn and coated with a build-up of oxide from the tape, and this accounted for the lack of recorded information on three channels.

The CVR system contains a self test facility whereby, before flight, the crew can push a test button on the CVR controller which injects a signal into the recorder and reads it back through a monitor head. Satisfactory recording is indicated by a dial gauge on the controller, the needle of which swings momentarily into a green sector to indicate correct recording. The fault in the recording may not have been capable of being picked up when using this self test function. When the system was operated on the bench the indicator needle swung appreciably although not always into the green sector. This may have led crews to believe the recorder was functioning adequately.

1.11.2 Flight data recorder

The recording system installed was a Plessey PV1584F2, combined data acquisition and recorder unit. The system recorded a total of 34 data parameters plus 20 discrete (switch position) parameters. The replay was carried out using the AAIB facilities and good quality data was obtained.

A plot of selected parameters is shown at Appendix D.

1.11.3 Sequence of events

Information from the data recorder indicated that there was nothing abnormal about the approach. The final stages were flown at an average speed of approximately 120 kt, the autopilot having been disconnected at 3,500ft.(ref 1013.25mb). Referring to the timebase at Appendix D, at 11 seconds the aircraft began a gentle pitch up and the speed began to decay. At 22.3 seconds the aircraft touched down firmly (1.4g), on the runway, on a heading of 305°M, with a pitch attitude of 3 degrees nose up and at a speed of 103 kt. Just under 3 seconds later, at 25 seconds, the nosewheel is estimated to have contacted the runway with the speed at about 94 kt. The aircraft then immediately began a turn to the left at a rate of 6 degrees per second. Approximately 5 seconds later the accelerometer readings suggest that the aircraft left the edge of the runway on a heading of about 278°M at an indicated speed of about 64 kt. It then progressed over the relatively rough ground, which at one point caused the aircraft to pitch up to 2 degrees, before coming to rest 10 seconds later on a heading of 272°M.

The limited information from the CVR suggested that the crew believed that everything was normal until the aircraft suddenly turned left after the nosewheel was on the runway.

1.12 Wreckage and impact information

Examination of ground marks on the runway indicated that the aircraft had touched down on its main wheels, the nosewheels had then contacted the runway and spun up whilst aligned with the aircraft centreline. Very shortly after this the aircraft slewed left and departed from the runway. During this process the aircraft was yawed approximately 5° left of its track. After leaving the runway, the aircraft travelled for 145 metres across boggy ground, whilst retaining its yawed attitude, and came to rest on a heading of 268°M with the nosewheels centred. During the latter part of its ground run all the aircraft wheels penetrated the turf, reaching axle depth in places.

When the aircraft was examined by the AAIB, the nosewheel steering was found to be selected ON.

1.13 Medical and pathological information

Not relevant

1.14 Fire

There was no fire.

The emergency alert was activated at 1730 hrs by ATC, who declared an 'Aircraft Accident' and the AFS together with the local emergency services responded to the call. However, at 1743 hrs, ATC downgraded the 'Aircraft Accident' to a 'Local Standby' and the incident was closed at 1811 hrs.

The AFS attended the accident site with two 'Javelin' and two 'Meteor' appliances, and the local services congregated at the appropriate Rendezvous Point. The AFS then assessed the damage to the aircraft and assisted with care of the passengers.

1.15 Survival aspects

There were no injuries and the passengers left the aircraft by the forward airstairs.

1.16 Tests and research

1.16.1 Upper Pivot Joint

The torque loading of the shear bolt through the pivot joint was measured at 46 lbf in. With the nut removed from the bolt, the seized pivot joint resisted closing forces of up to 170 lbf and end loads of up to 6,000 lbf failed to move the bolt. The pivot joint was therefore cut open to provide access to the seized surfaces.

The contacting surfaces of the bolt and the pivot joint showed evidence of interference and cadmium had been transferred between the bolt and the lug, and from the bolt to the bushes of the fork end. During episodes of small relative movements of the joint components, a build up of the cadmium plating and resultant binding had occurred.

(Additional assembly dimensional information in 1.17.4)

1.17 Additional information

1.17.1 Cabin loudhailers

On the accident aircraft a single loudhailer was provided in compliance with the Air Navigation Order (see Appendix E) and it was situated at the rear of the cabin. Although no other was required in this accident, the possible need for another, situated in the front cabin, was examined by the operating company. They are examining the feasibility of a forward cabin installation on the ATP and holding discussions with the Civil Aviation Authority (CAA) on the matter.

1.17.2 Nosewheel steering upper pivot joint

The ATP nosewheel steering upper pivot joint design is similar to the installation on the HS 748 which was designed in 1960 and, although changes have occurred in adjacent areas, the dimensions of the pulley lug, fork and bolt have remained constant.

The only significant difference between the ATP and the HS 748 pivot joint was that the HS 748 pivot joint was assembled with lubrication, whilst the ATP pivot joint was not. No torque loading of the bolt was called for on the ATP drawings.

No record of any similar occurrence has been found for the HS 748.

1.17.3 Inspection and documentation

At the time that G-LOGA (Production aircraft No 40) was produced, assembly was carried out using a Planning Process Operation Sheet which called for inspection at the end of the operation, after installation of the nose leg. The inspector was not required to oversee the assembly process, but only to check the final result. No record was kept which could identify the fitter who had carried out the assembly.

Unrelated to this accident and since the build of G-LOGA, the assembly documentation has been changed to lay greater responsibility and accountability on the fitters carrying out the assembly process.

1.17.4 Fits and tolerances

1.17.4.1 Bolts

The British Aerospace drawing for the pivot joint called up a British Standard A112-15L bolt; this was defined in the British Aerospace Aircraft Group Design Handbook as having a maximum diameter of 0.4373 inches.

The British Standard gave a maximum design diameter of 0.4373 inches, but referred to a note elsewhere in the document which stated that *" as a provision to meet possible difficulties in plating, the diameter of the plain shank after coating may be 0.0003 in greater than the maximum dimensions quoted in the table"*. Thus the actual maximum diameter of this bolt, as defined in the British Standard, was 0.4376 inches.

The following 'used' bolts were examined: The bolt from G-LOGA, bolts from two aircraft which failed the Service Bulletin and three bolts from aircraft at British Aerospace Woodford. The bolt head from G-LOGA had an impact mark on the corner of the top surface, the cause of which could not be identified. The diameter of this bolt met the British Standard, but was larger than the British Aerospace specification.

The five other 'used' bolts were checked for excessive diameter and all were satisfactory. None of these 'used' bolt heads showed signs of damage. Concentricity checks were carried out on all of these bolts, and they were found to be satisfactory.

Six new bolts were examined and two were found to be below the British Standard requirement for minimum diameter, however, none of the others exceeded the maximum allowable diameter.

1.17.4.2 Fork fitting

The fork fitting incorporated aluminium-bronze bushes which were reamed to between 0.4375 and 0.4385 inches after installation in the fork. The bushes were cadmium plated, but the drawing specified that the cadmium plating should not enter the bore of the bush. The dimensions of the bushes on the fork fitting from the accident aircraft could not be established, as they had been damaged in service and then slit to facilitate the removal of the seized bolt.

1.17.4.3 Lug fitting

The pulley lug hole dimensions could not be established for the same reasons as those for the fork bushes, but the drawing showed that the hole was sized at between 0.4385 and 0.4375 inches before plating. No size was specified for the hole after it had been plated and, although the cadmium process was expected to produce a nominal plating thickness of 0.0003 inches (0.0006 inches on a diameter), it tended to deposit more material towards the edges of the hole. This tendency was observed in four unused pulley lugs, in which the holes were measured at both ends and at their centres, and the worst hole had an end diameter 0.0017 inches less than its central diameter.

The table shows the difference, in units of 0.0001 inches, between the three measurements taken on each of the four lugs, and the maximum bolt diameter of 0.4376 inches allowed under the British Standard. A positive sign indicates an interference fit.

Top	Centre	Bottom
+8	-1	+8
+8	+1	+6
+17	0	+7
+7	-1	+1

The holes were also contaminated with paint and it was common practice on the assembly line to ream the hole to remove the paint. This process could also have removed some of the cadmium protection and reduced the diameter difference along the length of the bore. Additionally, the paint on the flat sides of the lug often hindered assembly into the fork fitting, and this paint also was commonly removed.

There was no evidence that these assembly problems had been brought to the attention of the design office with a view to achieving a permanent solution.
It was noted that the revised assembly documentation, introduced since the build of G-LOGA, encouraged the assembly fitters to report difficulties encountered during build.

1.17.5 British Standards

The British Standard 2A112 dated 1961 included the 0.0003 inches dimension as an addition to the figures entitled 'maximum design dimensions', and successive editions of this standard have retained this format. However, other standards defining cadmium plated aerospace bolts, such as A211, do not contain a similar addition but provide the absolute maximum dimension in the table.

The origin of this discrepancy in formats is not known, however the British Standard Institute have said that they would accept a recommendation on formats from the British aerospace industry.

1.18 New investigation techniques

None

2 Analysis

2.1 Conduct of the flight

The accidental outcome of the landing at Edinburgh was in no way caused or influenced by the manner in which the operating crew handled the flight. All cockpit checks and drills had been carried out, the approach was performed within the normal parameters of angle and speed and the flare produced a normal landing at the visual aiming point and on the runway centreline.

In the existing wind conditions, it is reasonable that the commander should initially consider the deviation from the runway centreline to be only momentary and probably caused by weathercocking in a sudden gust of wind. As such, it would easily be rectified by his application of right rudder. In fact, he attempted to correct the rapid swing to the left using full right rudder and the tiller, unaware that the tiller was ineffective. With hindsight knowledge of the real cause, it is known that the immediate de-selection of the Steering Master Switch would have removed the offset signal to the nosewheel and allowed it to caster into an in-line position. Acting as he was, without the benefit of this knowledge, the commander's actions were totally logical.

Apart from the mis-selection of an interphone switch which did not effect the outcome, the entire emergency situation was handled by all company and emergency services personnel in a professional manner. However, in an emergency under different circumstances the ability of the cabin crew to communicate by interphone could be significant. This operator has issued a memorandum re-emphasising the operating differences for the two systems. However, standardisation across the fleet would be a far more certain way of ensuring good communications during the response to an emergency situation.

As a result of this accident, the operator has examined a need for more than one loudhailer to be installed on an aircraft the size of an ATP to increase availability to the cabin staff in a variety of emergency situations. Currently the Air Navigation Order requires "*... If the aircraft may ... carry more than 19 and less than 100 passengers, one portable battery-powered megaphone ...*" (see Appendix E). The ATP may carry up to 72 passengers.

It is recommended that the CAA review the requirements of the Air Navigation Order, Schedule 4, Scale Y2 to increase the number of megaphones required.

2.2 The nosewheel steering upper pivot joint

After removal of the joint and an initial visual inspection an attempt was made to quantify just how tight it had become and efforts to move the seized pivot joint were halted at a closing force of 170 lbf. The pivot joint would therefore have been able to transmit sufficient loads to the structure, during gear extension and retraction, to account for the fatigue and final overload failure of the pulley supports.

The seizure of the joint resulted from progressive tightening of an already tight pin joint, possibly with an interference fit of the bolt in the lug and/or the fork bushes, on assembly. The contacting surfaces of the bolt and the pivot joint showed that cadmium had been transferred between the bolt and the lug, and from the bolt to the bushes of the fork end. A build up of the cadmium plating and the resultant binding, during episodes of small relative movement of the joint components, led to final seizure.

The joint was tight because:-

British Aerospace Aircraft Group Design Handbook incorrectly defined the maximum diameter of British Standard A112 bolts.

The British Aerospace drawing of the pivot joint did not take account of the additional 0.0003 inches on the diameter of the bolt, allowed by the British Standard for plating difficulties.

The drawing of the pulley lug did not specify a hole dimension to be achieved after cadmium plating and did not take account of the difficulties in achieving a uniform cadmium plating thickness throughout the length of the hole.

Unlike the assembly process for the pivot joint on the HS 748, the ATP assembly process did not call for lubrication during assembly.

The combination of the largest bolt within the British Standard with the smallest hole seen could result in an interference fit of 0.0017 inches. Similarly, the fork bushes could have a minimum bore size of $^{7}/_{16}$ of an inch and an interference fit of 0.0001 inches. It is unlikely that the four lugs examined contained the minimum sized hole possible, indeed assuming that their sizes conformed to a Normal Distribution, approximately 5% of all lugs would have holes equal or smaller in diameter to the smallest of the four holes measured.

The potential for a tight joint on assembly has existed since the introduction of the HS 748, however, no records of seizure were found on the HS 748, most probably because the use of lubrication during the assembly prevented progressive tightening of the joint.

It is recommended that British Aerospace:-

> Review the accuracy of their Design Handbook standards and manufacturing drawings for cadmium plated fasteners against the appropriate British Standards.
>
> Introduce checks on the after plating dimensions of the hole in the pulley lug.
>
> Review their assembly procedures for the ATP nosewheel steering upper pivot joint, and other similar pin joints on the ATP aircraft, with a view to including lubrication.

2.3 The British Standard

A disparity in formats existed between A112, which specified the bolt fitted to the ATP nosewheel steering upper pivot joint, and other British Standards describing cadmium plated aerospace bolts. Whilst A112 contained all the necessary information, it was fragmented and its presentation contained a latent deficiency which emerged thirty years after its publication to contribute to this accident.

It is recommended that the British Standards Institute obtain a consensus from the British aerospace industry on the format of the information to be used in British Standards describing cadmium plated bolts for aircraft, and that the appropriate British Standards be brought into line with that format.

3 Conclusions

(a) Findings

(i) The crew were properly licensed, rested and medically fit to conduct the flight.

(ii) The flight was conducted without incident until after the landing at Edinburgh.

(iii) When the nosewheels contacted the runway after a normal touchdown the aircraft swung rapidly to the left and rolled off the side of the runway onto the grass.

(iv) The aircraft left the runway because a failure in the nosewheel steering system produced a steering demand of 15° to the left and rendered the tiller ineffective.

(v) The nosewheel steering failed because the supporting structure for the pulley carrying the steering tiller cable to the nosewheel steering mechanism had failed as a result of fatigue followed by overload.

(vi) The nosewheel steering upper pivot joint was seized and had transmitted sufficient loads to the pulley supporting structure during gear extension and retraction to cause its failure.

(vii) The pivot joint had seized because a process of binding, as a result of build up and transfer of the cadium plating in an unlubricated environment, had led to the progressive tightening of an already tight pin joint.

(viii) The British Aerospace Aircraft Group Design Handbook incorrectly defined the maximum diameter of British Standard A112 bolts.

(ix) The British Aerospace drawing of the pivot joint did not take account of the additional 0.0003 inches on the diameter of the bolt, which was allowed by the British Standard for plating difficulties.

(x) The British Aerospace drawing of the pulley lug did not specify a hole dimension to be achieved after cadmium plating

and did not take account of the difficulties in achieving a uniform cadmium plating thickness throughout the length of the hole.

(xi) Unlike the assembly process for the pivot joint on the HS 748, the ATP assembly process did not call for lubrication during assembly.

(xii) A disparity in formats existed between British Standard A112, which specified the bolt fitted to the ATP upper nosewheel steering pivot joint, and other British Standards describing cadmium plated aerospace bolts.

(xiii) The No 1 stewardess could not use the cabin interphone system to brief the No 2 stewardess on the evacuation because the handset in the aft cabin was not selected to interphone.

(xiv) The interphone system on G-LOGA differed from that installed on the operators other ATP aircraft in that the station service selection did not automatically revert to interphone whenever the handset was restowed.

(xv) The aircraft, in accordance with the Air Navigation Order, was equipped with a single loudhailer situated in the aft cabin.

(b) **Causal factors:-**

(i) The aircraft left the runway because of an undemanded nosewheel steering deflection of 15° to the left and an ineffective tiller.

(ii) The undemanded turn and lack of subsequent tiller response resulted from a seized nosewheel steering upper pivot joint, which led to the failure of the supporting structure of the pulley carrying the steering tiller cable to the nosewheel steering mechanism.

(iii) The nosewheel steering upper pivot joint was tight on assembly, possibly with an interference fit of the bolt in the lug and/or the fork bushes.

(iv) The pivot joint was tight on assembly because:-

A British Standard, describing the pivot joint bolt dimensions, had been transcribed incorrectly into the British Aerospace Aircraft Group Design Handbook and thence into the drawings for the nosewheel steering system.

The dimensions of the pulley lug hole were inadequately controlled during cadmium plating.

(v) The ATP pivot joint assembly process did not call for lubrication during assembly.

4 Safety Recommendations

4.1 It is recommended that British Aerospace review the accuracy of their Design Handbook standards and manufacturing drawings for cadmium plated fasteners against the appropriate British Standards (Recommendation No 92-72).

4.2 It is recommended that British Aerospace introduce checks on the 'after plating' dimensions of the hole in the pulley lug (Recommendation No 92-73).

4.3 It is recommended that British Aerospace review their assembly procedures for the ATP nosewheel steering upper pivot joint, and other similar pin joints on the ATP aircraft, with a view to including lubrication (Recommendation No 92-74).

4.4 It is recommended that the British Standards Institute obtain a consensus from the British aerospace industry on the format of the information to be used in British Standards describing cadmium plated bolts for aircraft, and that the appropriate British Standards be brought into line with that format (Recommendation No 92-75).

4.5 It is recommended that the CAA review the requirements of the Air Navigation Order, Schedule 4, Scale Y2 to increase the number of megaphones required (Recommendation No 92-76).

D F KING
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The Civil Aviation Authority's response to these Safety Recommendations is contained in CAA Follow-up on Accident Reports (FACTAR) No. 5/92, to be published coincident with this report.