AIRCRAFT ACCIDENT REPORT 9/88

Air Accidents Investigation Branch

Department of Transport

Report on the accident to Aerospatiale AS 332L Super Puma G-BKZH 35 nautical miles east-north-east of Unst, Shetland Isles, on 20 May 1987

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List of Aircraft Accidents Reports issued by AAIB in 1988/89

1/88	DH 89A Dragon-Rapide G-AGTM at Duxford Airfield, Cambridge, June 1987	March 1988
2/88	Boeing Vertol BV 234 LR G-BWFC 2.5 miles east of Sumburgh, Shetland Isles, November 1986.	
3/88	Bell Model 222 G-META at Lippitts Hill, Loughton, Essex, May 1987	August 1988
4/88	Cessna F 172M 00-JEL in the sea, 3 miles east-north-east of Ryde, Isle of Wight, April 1987	August 1988
5/88	Sikorsky S-76A helicopter G-BHYB near Fulmar A Oil Platform in the North Sea, December 1987	December 1988
6/88	Hughes 369HS, G-GASB at South Heighton near Newhaven, Sussex, August 1987	November 1988
7/88	Fokker F27 Friendship G-BMAU 2nm West of East Midlands Airport, January 1987	
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Department of Transport
Air Accidents Investigation Branch
Royal Aerospace Establishment
Farnborough
Hants GU14 6TD

Date 22 December 1988

The Right Honourable Paul Channon
Secretary of State for Transport

Sir,

I have the honour to submit the report by Mr E.J.Trimble, an Inspector of Accidents, on the circumstances of the accident to an Aerospatiale AS 332 Super Puma, G-BKZH, which occurred 35 nautical miles east-north-east of Unst, Shetland Isles, on 20 May 1987.

I have the honour to be
Sir
Your obedient servant

D A COOPER
Chief Inspector of Accidents

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Air Accidents Investigation Branch

Aircraft Accident Report No 9/88
(EW/C1019)

Operator :		British International Helicopters Ltd
Aircraft:	Type:	Aerospatiale AS 332 Super Puma
	Model:	AS332L
	Nationality:	British
	Registration:	G-BKZH
Place of Accident:		North Sea, 35 nautical miles east-north-east of Unst (Baltasound) Airport, Shetland Isles.
		Latitude 60 58.5 N Longitude 000 12.8 E
Date and Time:		20 May 1987 at 1350 hrs
		All times in this report are UTC

SYNOPSIS

The accident was promptly reported to the Air Accidents Investigation Branch on 20 May 1987 and the investigation was initiated on the same day.

The AAIB team comprised Mr E.J.Trimble (Investigator in Charge), Mr R.G.Matthew (Operations), Mr C.G.Pollard (Engineering) and Mr P.F.Sheppard (Cockpit Voice Recorder).

The aircraft was about 35 nautical miles ENE of Unst, in transit between Sumburgh and the East Shetland Basin and flying in cloud, when it suddenly began to vibrate severely and pitched nose-up. The crew brought the aircraft back under control and descended until clear of the cloud, despite the loss of their main attitude references. They assessed the source of the vibration to be the tail rotor and decided to fly the aircraft in accordance with the procedures appropriate to a 'Tail Rotor Control Failure'.

The crew transmitted 'Mayday' calls on two RTF frequencies and two Search and Rescue (SAR) helicopters were vectored towards them. The crew decided that the aircraft was controllable at reduced power, and elected to go to Unst to make a 'run-on' landing. This was accomplished successfully, and the passengers and crew disembarked without any injuries.

After landing, it was seen that a large section of the trailing edge of one of the tail rotor blades was missing. Subsequent investigations revealed that the imbalance resulting from this had caused considerable structural damage to the tail pylon of the aircraft, such that the tail rotor and gearbox assembly was in imminent danger of complete detachment.

The report concludes that the direct causes of the accident were poor quality control in the local manufacture of a channel section, combined with the known susceptibility to vibration in the pylon area of the AS332, which led to a segment of steel channel separating from the tail pylon in flight and striking the tail rotor blades.

An underlying cause was the non-embodiment of a modification which introduced a 'bolt-on' inclined driveshaft fairing to replace the original hinged fairing. This modification had been made available to all operators by the manufacturer, but was not mandatory.

Seven safety recommendations are made.

1 FACTUAL INFORMATION

1.1 History of the flight

On 20 May, the Super Puma G-BKZH ('ZH') had been chartered by an oil company to carry 17 employees from Sumburgh to a semi-submersible rig, Sedneth 701. Prior to this flight, the aircraft was fully serviceable and had 3000 lbs of fuel aboard, sufficient for a land-based diversion should the necessity arise. It is the policy of the operating company to carry land, rather than offshore, diversion fuel.

Accordingly, at 1300 hrs, 'ZH' lifted-off with the 17 passengers and two crew members and climbed to 3000 feet en-route to Sedneth 701. At this height, the flight was being conducted in cloud, i.e. under instrument meteorological conditions (IMC). Under these conditions, the primary flight instrument is the attitude director indicator (ADI). There were two ADIs, one in front of each pilot, and a standby artificial horizon in the centre instrument panel.

The flight progressed normally and in continuous cloud until, at 1350 hrs, the aircraft suddenly began to vibrate severely and pitched nose-up, to an angle described by the pilots as approximately 30 degrees. Coincident with this, both ADIs indicated an aircraft attitude which both pilots considered to be incorrect. The indications on both instruments were vibrating excessively and showing a considerable degree of roll and an overall pitch-up. The standby instrument, however, showed only the pitch-up and this attitude was confirmed by reference to the other flight instruments. The handling pilot therefore elected to use the standby instrument, which he assumed to be functioning properly.

The commander immediately lowered the collective pitch lever, reducing the main rotor blade pitch angle from 15.5 degrees to 12 degrees and, consequently, the anti-torque loading on the tail rotor. At the same time, he corrected the aircraft's nose-up attitude and established a gentle rate of descent. This action was virtually instinctive and the vibration suddenly reduced to a tolerable level. It became apparent that continued flight was possible. Both pilots immediately deduced that the problem was emanating from the tail rotor and decided to respond in accordance with the procedure laid down for a 'Tail Rotor Control Failure'. The drill for this event precludes the use of the yaw pedals and requires minimal movement of the collective pitch lever.

With control of the aircraft regained the co-pilot warned the passengers, by means of the public address system, of a possible ditching. He then transmitted a 'Mayday' call on the radio telephony frequency (RTF) in use at the time, that of 'Brent Log', 123.05 MHz. He then repeated the 'Mayday' call on the 'Shetland Radar' frequency, 118.15 MHz. Both messages were acknowledged.

The crew were unaware that the intense vibration had rendered the public address system amplifier unserviceable and the passengers did not therefore receive the briefing. Despite this, due to the severity of the vibration, the passengers correctly carried out their own ditching drills by donning their lifejackets and zipping up their immersion suits, as prescribed by their compulsory survival training.

As soon as the crew realised that there was a reasonable chance of remaining airborne, they turned the aircraft towards the nearest land, the island of Unst some 35 nm distant.

Shetland Radar alerted the Search and Rescue (SAR) services and Unst airport. As a result an SAR equipped Bell 212, G-BALZ, took off from Unst and was vectored towards 'ZH'. The SAR dedicated Coastguard Sikorsky S61 helicopter G-BDOC, which was already airborne on exercise in the Thistle Field some 80 nm from Unst, was also vectored towards 'ZH'.

Meanwhile as 'ZH' continued towards Unst, with the aid of headings from Shetland Radar, the co-pilot briefed the passengers by means of hand signals and provided the commander with the requested checklists. The sea state in the area was 3-3.5 metre waves with a period of 6-7 seconds, and a wind of 330°/30 kt.

At about 1355 hrs, 'ZH' broke out of the cloudbase, was levelled at 800 feet and continued towards Unst at this height. At 1408 hrs, the crew of the Bell 212 made visual contact with 'ZH' and escorted it for the remaining 7 or 8 nm.

At 1410 hrs, 'ZH' transferred to the Unst frequency, 130.35 MHz, and received clearance to make a straight-in approach to runway 30. This approach had been chosen by the commander as the most direct and was ideally suited to the 'run-on' landing needed in the case of tail rotor control failure. The checklist for this condition states that the wind should be on the right on the final approach; the aircraft should be flown at an indicated air speed (IAS) of 50-60 kt. using a main rotor collective pitch of 9-11°, maximum 12.5°; and with a descent rate of 500 feet/minute.

The wind at Unst was 330°/20-28 kt. The commander carried out a safe landing without use of the yaw pedals and at the 12° of collective pitch already set. Once on the ground, directional control was maintained by use of the nose wheel steering lock and, when necessary, differential brakes. When the aircraft had been shut down, the occupants disembarked normally.

During the course of the emergency, the Air Traffic Control Officer (ATCO) at Unst had alerted the telephone exchange (PBX) and the Airport Fire Service (AFS) to the fact that there was a "Mayday" aircraft inbound. They consequently came to "Local Standby" status, which did not involve calling out the local emergency services. The ATC controller, however, believed that this warning had constituted a "Full Emergency", which would have included the local emergency services. (See para 1.9)

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	-	-	-
Serious	-	-	-
Minor/none	2	17	

1.3 Damage to aircraft

Two tail rotor blades had suffered leading edge damage and one of these had a large section of its trailing edge missing.

The tail pylon was almost severed just below the tail rotor gearbox mountings.

The standby artificial horizon and the public address amplifier had been rendered inoperative by severe vibration.

1.4 Other damage

Nil

1.5 Personnel information

1.5.1 Commander:	Male, aged 39 years
Licence:	Airline Transport Pilot's Licence (Helicopter) issued 20 October 1980, valid for 10 years.
Aircraft ratings:	AS332L Super Puma, valid Wessex 60, Sikorsky 58 ET and 61N.
Instrument rating:	Valid until 10 April 1988

Medical certificate:	Valid until 18 August 1987.
Flying experience	Total hours: 6000 hours Total hours (helicopters): 5500 hours Total hours on type: 400 hours Total hours in last 90 days 92 hours Total hours in last 28 days 35 hours Total hours in last 24 hours 3.05 hours
Previous rest period:	18 hours

1.5.2 *Co-pilot:* Male, aged 43 years

Licence:	Airline Transport Pilot's Licence (Helicopter). Issued 23 June 1980, valid for 10 years.
Aircraft ratings:	AS332L Super Puma, valid. Westland S55, Bell 206, Sikorsky S61N.
Instrument rating:	Valid until 13 March 1988.
Medical Certificate:	Valid until 30 June 1987.
Flying experience:	Total hours: 7900 hours Total hours (helicopters): 7690 hours Total hours on type: 1500 hours Total hours in last 90 days 197 hours Total hours in last 28 days 60 hours Total hours in last 24 hours: 8.30 hours
Previous rest period:	17 hours

1.6. Aircraft information

1.6.1 General data

Aircraft type:-	AS332L (Super Puma)
Manufacturer:-	Aerospatiale
Date of manufacture:-	1984
Constructors No:-	2107

Registered owner:-	British International Helicopters Ltd
Certificate of Registration:-	G-BKZH/R1
Certificate of Airworthiness:-	11613-1, Transport Category (Passenger) Valid until 18 March 1988
Certificate of Maintenance - Review:	Valid until 11 September 1987
Total airframe hours:-	4497 hrs
Last maintenance check:-	'A' check and 25 hour check at 4492 hrs, on 19 May 1987.
Weight and Balance	Within limits at all times during flight

1.6.2 *Tail pylon and inclined drive shaft (IDS) fairing. (see Appendix 1)*

The tail pylon of the AS332 is a conventional metal monocoque box structure forming the central part of an aerofoil section, with a hinged drive shaft fairing acting as a non-structural leading edge, and a secondary box section forming a bluff trailing edge. The tail rotor gearbox (TRGB) is attached to a locally reinforced area of the front diaphragm spar of the main box (referred to as the inclined face) by three bolts, two of which are on the right (rotor) side and one on the left. At the time of the accident, the IDS fairing was hinged on the left side, for maintenance access, and held closed by two over-centre latches on the other side. The latching edge of the fairing closed onto a rubber strip which was held in a series of four segments of channel section, each about 8 inches long, which were riveted to the inclined face. (see Appendix 2a) The latches were adjustable in length to set the correct closing pressure between the fairing and the rubber strip. A modification had been incorporated to assist the latching edge of the fairing to locate correctly in the channels and to prevent it from vibrating laterally. This consisted of a tapered spigot, attached to the fairing, which engaged in a rubber bush mounted in a fitting riveted to the inclined face just inboard of the lower latch. An optional modification, which reinforced the fairing with two ribs at the lower latch position, was also available and 'ZH' was the only aircraft in this operator's fleet which had this modification incorporated.

The tail rotor is positioned on the right side of the pylon and rotates in an anticlockwise direction when viewed from that side. The blade tips pass about 4½ inches forward of the lower end of the locating channel on the inclined face. The mean plane of the tail rotor disc lies about 11 inches clear of the right side of the pylon and the 'flapping' range of the tail rotor blades allows the tip clearance to vary from 3 to 19 inches.

1.6.3 *Maintenance history of tail rotor pylon during the preceding 6 months.*

During the 6 months preceding the accident, the aircraft had flown about 700 hours. The technical log showed that there had been a number of maintenance actions carried out on the pylon, related to the attachments of the IDS fairing and vibration of the tail rotor. Over this period there had been 11 replacement latches fitted, 9 of which were lower latches.

Of these latch replacements, 4 (3 lower and 1 upper) had been effected in the last 55 flying hours. During this time, the bracket which held the spigot on the IDS fairing was also found to be cracked and was replaced by a locally manufactured (temporary) bracket whilst the correct spare part was being awaited. This temporary bracket had not been riveted to the fairing reinforcing ribs but was bolted to the skin of the IDS fairing, as it would normally have been on an unreinforced fairing.

In order to identify the cause of the increase in unscheduled maintenance in this area, the operator had conducted a series of checks. Accordingly, in the 40 flying hours preceding the accident, they had checked the balance of the tail rotor twice, the alignment of the TRGB to the intermediate gearbox (IGB) and performed an internal inspection of the pylon structure and the joint between the tail boom and pylon. They also replaced the upper and lower channel segments into which the latching edge of the IDS fairing located, because they were found to have severely worn flanges.

1.6.4 *Replacement channel sections*

The operator had found that the outboard edge of the latching side of the IDS fairing had chafed against the outboard flange of the locating channel causing severe abrasion to both components. To alleviate this the operator, under its approved design authority, had designed a channel section with deeper flanges to effect better lateral containment of the latching edge of the IDS fairing. This design called for the channel to be made from 16 swg light alloy similar to the original manufacturers specification.

During routine maintenance, a supervisor decided that the upper and lower segments of channel on 'ZH' needed replacing. As replacement parts were not immediately available he consulted the Senior Technical Engineer who, after inspecting the worn parts, suggested verbally that replacements should be manufactured locally to the same dimensions and from the UK equivalent of the original material. The Senior Technical Engineer also indicated that a Design Deviation Authority (DDA) would be issued to cover this work. This information was passed to the night supervisor who was in charge of the repair.

The operator did not have the right equipment to bend the light alloy specified without cracking it, and so the supervisor had the section made from 16 swg stainless steel. He believed that, as the parts were non-structural, he had the necessary authority to fabricate channel sections from a different material, inspect them and have them fitted to an aircraft. The operator's design department was not consulted on this but have since stated that, had they known of the change to steel, they would have had no fundamental objection. They did, however, feel that they would have suggested that thinner gauge material was used.

Samples of the channel section examined after the accident showed them to be poorly formed, with rounded base sections (see appendix 2b). The upper and lower segments of channel on 'ZH' were replaced on 15 May 1987 at 4480 aircraft flying hours, 17 hours before the incident.

1.6.5 *Airframe vibration in AS332L*

All three operators of the AS332 in the United Kingdom believe that this helicopter type is inherently more susceptible to the effects of vibration than the other single rotor types in common use, even though quantitative measurement does not reveal the existence of significantly higher actual vibration levels. This opinion is based on the frequency with which latches, fasteners and fittings, particularly those related to openable panels, fairings and doors, need to be replaced. The tail boom/pylon zone appears to be the most seriously affected in comparison with other types operated.

As a result of reports from operators, the manufacturer had issued a series of service bulletins, each addressing a single problem. In general, these bulletins detailed the ways in which improvements might be made, but left the operator with the option of continuing to accept a high maintenance burden if they did not wish to incorporate any proposed modification. The manufacturer had not issued any general advice emphasising the need for rigorous maintenance associated with the attachment and servicing of secondary structure and fasteners.

In particular, one of these bulletins related to the introduction of a 'bolt-on' IDS fairing, to replace the original hinged fairing. This modification (AMS 332A07-22-328 Issued 5 March 1986) arose as a direct result of an accident to an AS332L in 1983 (Ref: Aircraft Accident Report 4/84). This modification was not made mandatory by either the Direction Generale de l'Aviation Civile of France (DGAC, the primary certificating Authority) or the Civil Aviation Authority for UK registered aircraft. The CAA perceived this modification as being relevant to reducing the maintenance workload rather than improving the safety of the aircraft. The CAA has stated that, at the time of the accident to 'ZH', it was under assessment to see whether it would introduce other hazards to flight safety. Notwithstanding this, it had been deemed satisfactory for embodiment into UK registered aircraft, and another operator was modifying their entire fleet to this standard.

The only modification in the tail boom/pylon zone which has been made mandatory (AMS 332A07-22-320) relates to the securing of the IDS fairing hinge pin (the cause of the accident in 1983) which is applicable to aircraft to which the 'bolt-on' fairing has not been fitted.

1.7 Meteorological information

1.7.1 Actual weather and sea state

The weather at Unst was reported by Unst ATC as:
"330/18-28 kt 8 km occ light rain 3 oktas 1000 feet.
The sea state has been reported by the Meteorological Office as:
Waves 3-3.5 metres high of period 6-7 seconds with an overall wind of NNW/25-30 kt.

1.8 Aids to navigation

The navigation aid used to direct the crew towards Unst was the associated non-directional beacon, in addition to the radar service provided by Shetland Radar.

1.9 Communications

Radio telephony (RTF) communications throughout this event were satisfactory and were recorded by both Air Traffic Control (ATC) and by the cockpit voice recorder.

The communications between the Unst ATCO, the PBX and the AFS were not satisfactory.

The ATCO is provided with a plastic covered board on which he logs the various pieces of information as they are relayed to him. The purpose of this board is to ensure that he is in possession of all the relevant details of an emergency, thus providing a checklist for him, and enabling him to pass the required information to other agencies.

There is a similar board in the PBX, upon which the details passed by the ATCO are similarly recorded. If these details have been categorised by the ATCO as a 'Full Emergency', the PBX operator then relays them to the local emergency services, who make the appropriate preparations.

The first information which is recorded on both boards is the emergency status. There are several options, but only two were relevant to this event:

'Full Emergency' and 'Local Standby'.

The ATCO wrote neither of these status categories on his board but, instead, wrote the word 'Mayday'. This is not one of the available options but is an RTF codeword for use by aircraft in distress. Consequently, when the ATCO telephoned details of the emergency to the PBX, he used this, rather than the laid down wording. This was taken, by the PBX operator, to mean 'Local Standby' and consequently the local emergency services were not alerted.

The ATCO also used this word when alerting the AFS, who went to 'Local Standby' readiness. However, the AFS have subsequently stated that, when the emergency was over and they were writing up their report, they were still unsure of the designated status of the emergency. Nevertheless, no-one in the AFS sought clarification from the ATCO until that time.

1.10 Aerodrome information

Unst airport has a single runway, 30/12, 640 m long by 28 m wide, with a tarmac surface. There is one navigation aid, a 'non-directional beacon' (NDB), operating on 258 KHz. The aerodrome has Fire and Rescue coverage to Category IV (two foam tenders).

1.11 Flight recorders

1.11.1 Cockpit Voice Recorder (CVR)

The aircraft was fitted with a Fairchild A100 four track CVR. This used plastic based tape as a recording medium, and was of the endless loop type with a recording duration of 30 minutes.

The allocation of the four tracks was as follows:

TRACK 1	Captains microphone and headset signals
TRACK 2	Cockpit Area microphone
TRACK 3	Main Rotor speed
TRACK 4	Co-pilot's microphone and headset signals

A satisfactory replay of the CVR was obtained and there were no apparent defects in the equipment. A record of the audible events from shortly before the accident until the aircraft landed was obtained. At the time of the occurrence, frequencies associated with the tail rotor speed became significantly increased in amplitude, indicating a problem in that area.

1.11.2 *Flight Data Recorder (FDR)*

There was no requirement to carry a Flight Data Recorder nor was one fitted.

In the absence of a Flight Data Recorder, a successful investigation would have been seriously impaired had the tail rotor gearbox detached in flight, during the recovery at 800 feet amsl, and the aircraft suffered an uncontrolled impact with the sea.

1.12 Examination of the aircraft

1.12.1 *Initial examination*

Examination of the tail rotor blades showed that about 45% of the trailing edge section of one blade, at about mid span, was missing. Both this blade and the one preceding it (in order of rotation) had evidence of having been struck on their leading edges just outboard of blade mid span. The preceding blade had suffered a double strike (see Appendix 3). The appearance of the strike marks was consistent with them having been made by a segment of the IDS fairing landing channel.

Initial examination of the aircraft revealed no obvious signs of damage anywhere except on the rear pylon (see Appendix 4). The right side skin of the pylon was cracked across its full chord from the lower TRGB attachment point, the crack running at right angles to the inclined face of the pylon. At the point where the side crack met the inclined face, the folded edge flange of the face had cracked on the same line as the skin. Where the skin crack met the trailing edge of the pylon, the trailing edge face had buckled across its width and cracked from both edges towards the centre. Only the centre third (about 1½ inches) remained intact. The left side skin forward of this crack had buckled slightly.

The inclined face of the pylon had cracked along its right edge fold line for about 2 inches either side of the crack in the right side skin and face edge flange. At the lower end, this crack had turned inboard and progressed across 70% of the width of the inclined face below the lower right side TRGB attachment. At its upper end the crack on the inclined face had also turned inboard and run under the gearbox. The reinforcing plate at the left side gearbox attachment point on the inclined face had cracked both above and below its bolt hole and had been distorted upwards.

The lowest segment of the IDS fairing landing channel was missing. The tails of all the attaching rivets had remained in their holes and the rivet failures had occurred some depth below the inclined face. It was observed that the inclined face had a slight convex curvature in the area from which the channel sector had separated. The bore of the rubber bush into which the fairing spigot engaged had worn oval, the wear having occurred on the outboard side. (See Appendix 2a)

Examination of the latch fittings showed that the clamping surface of the lower one had evidence of 'hammering' and there was considerable slackness of its articulating joints. The amount of 'clamp-down', to which the IDS fairing was subject, was measured and it was found that the lower end was latched 0.1 inch less tightly than the upper end.

As a result of the pilots' report that they had experienced failure of the PA system and toppling of the main attitude director indicators, these items were tested using both aircraft internal and external ground electrical supplies. The PA system was found to be inoperable with no side tone. Examination of the amplifier showed that its mounting tray had been damaged and there was evidence of the anti-vibration mounts having overtravelled. There was also some distortion of the amplifier casing. The main attitude indicators were observed to run although they did not 'erect'. The standby attitude indicator did not operate. These items were removed for further investigation.

1.12.2 *Detailed examination of pylon*

1.12.2.1 *Channel attachment rivet failures*

The tails of all the attachment rivets had remained in the holes in the inclined face of the pylon. Examination of the fracture faces of the rivets, which had attached the channel segment to the inclined face, showed that they had all failed as a result of fatigue. The orientation of the fatigue progression was lateral in all cases with about half of them initiating on the outboard side, the remainder from the inboard. Checks revealed that the rivet material was an aluminium/copper alloy with a strength of about 60 ksi. This compared almost exactly with properties of the rivets from the joint between the TRGB mounting reinforcement and the rib which had been fitted from initial manufacture.

1.12.2.2 *Pylon structure*

The pylon structure and the joint between the pylon and tail boom were examined to determine whether there had been any pre-existing looseness in the structure which might have led to increased vibration levels in the rear of the aircraft. The examination was effected first by visual inspection through windows cut into the left side skin of the main pylon structural box and subsequently by dismantling the tail boom/pylon joint and removing the left pylon main box skin.

Visual inspection revealed that a considerable number of the rivets which had attached the lower TRGB mounting reinforcement to the rib had failed. There was also a crack in the rear spar of the main box, running from near the intersection of the crack in the right skin and the spar, which had progressed almost completely across the spar from the right side. It was also noted that the stringers on the right side skin had fractured where the main skin crack had crossed them. There was also a crack which ran under the stabiliser forward attachment fitting, curving towards the left side above and below the fitting.

After dismantling the boom/pylon joint and removing the pylon left skin, no evidence was seen of either relative movement between any of the components or looseness or failure of rivets, except in the immediate locality of the TRGB mountings. In this area , however, it could be seen that there had been some relative movement between components. There was a considerable amount of fretting debris in this area particularly from the rivets which attached the tail rotor gearbox fairing mounting strip. It was also noted that the reinforcing channel under the inclined face at the forward stabiliser attachment had cracked through completely.

Metallurgical examination of the pylon revealed that most of the failures in the skins, stiffeners and spar diaphragms had occurred due to rapid tearing under cyclic loading. There was one area of fatigue cracking around the left TRGB attachment point, and another in the inclined face and channel stiffener at the stabiliser forward attachment. No evidence was found to suggest that any of these failures had been in existence for a significant period of time. Many of the fracture surfaces had been damaged as a result of relative movement of the mating faces and it was not possible to determine the failure origins clearly.

The rivets which had attached the TRGB mounting reinforcement to the internal rib had all failed in shear except one, which had failed in bending tension. There was evidence, from the large amount of fretting debris, that considerable relative shear movement had occurred between the reinforcement and the rib over some period of time during the recovery to Unst.

1.12.3 Detailed examination of tail rotor

1.12.3.1 Tail rotor blades (see Appendix 3)

Only the 'white' and 'black' position tail rotor blades appeared to have suffered any damage. These were adjacent blades in passing order with the 'white' blade leading.

The 'white' blade had suffered two strikes on its leading edge, one 14 inches inboard of the tip and the other 16½ inches inboard. The shape of the indentations formed by both strikes was consistent with their having been made by the flanges of the IDS fairing landing channel. The more inboard of the strikes had ocurred squarely on the leading edge, the flanges of the channel having bitten deeply into the leading edge. The other strike had occurred entirely on the convex (suction) face of the leading edge anti-erosion strip.

The 'black' blade had suffered a single strike 15 inches inboard of the tip. The appearance of this strike was consistent with it having been made by the base of the channel, and with the channel having wrapped around the leading edge. There was evidence of contact all round the anti-erosion strip, with severe crushing at the rear edge of the blade spar on the suction side. Where this crushing had occurred, the trailing edge section had been sufficiently damaged for a large section to become detached from the spar and separate from the blade.

1.12.3.2 *Tail rotor spindle bearing*

Examination of the pitch change mechanism of the tail rotor revealed that there was some roughness in the bearings of the 'blue' blade. After disconnection of the feathering link the roughness was found to emanate from the feathering spindle bearings. The flapping hinge was observed to operate smoothly. On dismantling the spindle bearing pack, it was found that the retaining torque of both the inner and outer races was slightly below specification, but was still sufficient to maintain clamping. Examination of the five bearings in the stack showed that the four which absorb the centrifugal loads were in good condition and all the roughness was associated with the single opposed bearing. Although, before dismantling, the bearing pack had exhibited considerable intermittent 'binding', after dismantling and cleaning, the defective bearing was found to be only slightly worn and just outside acceptance limits.

1.12.4 *Public address (PA) amplifier*

Investigation of the amplifier showed that it had been subjected to severe shock loading resulting in the mechanical failure of some of the wiring. This in turn had led to electrical damage to some components, rendering the amplifier unserviceable.

1.12.5 *Attitude indicators*

The three attitude indicators were taken to the manufacturers and subjected to standard acceptance tests. Both main indicators were found to function. The commander's instrument met the acceptance standard. The co-pilot's instrument functioned but did not meet one of the realignment time requirements. The standby horizon, however, did not function. Investigation revealed that it had suffered failure of the power transistors in the internal power supply unit. On fitting a slave power supply section, it was demonstrated that the gyro unit still operated but it was not possible to perform an acceptance test in this configuration.

1.13 Medical and pathological information

The aircraft commander, the co-pilot and the ATCO carried valid medical certificates and were medically fit to carry out their duties.

1.14 Fire

There was no fire. However, the AFS were alerted by the ATCO at 1353 hrs to the effect that there was a 'Mayday aircraft coming to us' and subsequently that it had 'severe airframe vibration'. The AFS responded by coming to 'Local Standby' status. This required the crews to dress in their protective clothing and position the two fire vehicles on the forecourt of the fire station.

In the event of a 'Full Emergency', all the local emergency services have to be alerted by the PBX. The local fire brigade then attend to augment the AFS.

1.15 Survival aspects

1.15.1 Search and rescue

The SAR equipped S61 of HM Coastguard (G-BDOC) and the similarly equipped Bell 212 from Unst (G-BALZ) were vectored towards ZH. A Britten-Norman Islander (G-BFCX), on ambulance duty with 2 nurses on board, was on the ground at Whalsay island, and remained there on stand-by until the Super Puma had landed safely.

The S61 was already en-route from Thistle rig to Sumburgh, on an SAR exercise, when it was diverted towards the Super Puma as soon as the Mayday was called, at 1350 hrs. It made contact with the distress aircraft at 1408 hrs. The Bell 212 at Unst, on a '20 minute Stand-by', was also called at 1350 hrs and was airborne at 1359 hrs, making contact almost immediately. Both aircraft remained in the vicinity until 'ZH' landed safely at 1413 hrs.

1.15.2 *Crew-Passenger Communications*

As previously mentioned, the amplifier of the PA system failed as a result of the severity of the vibration resulting from the tail rotor damage. This failure prevented some of the emergency instructions from being passed by the crew to the passengers.

In the event, the crew used such hand and light signals as they were able to devise and the passengers responded in accordance with their training instruction. This had included the Survival Course at the Robert Gordon Institute of Technology.

1.16 Tests and research

None.

1.17 Additional information

1.17.1 *Flotation tests*

In 1980, Aerospatiale conducted a series of tank tests, using scale models, in order to substantiate the Super Puma emergency flotation gear. These were carried out at the Lille Fluid Mechanics Institute, and the relevant results were as quoted below:

"A. Scale-model test of stability afloat

The tank tests were conducted using a 1:30 scale model, with wave heights from 4.5 to 10.2 metres and wave lengths from 60 to 120 metres. The H/L ratio (wave height/length) varied from 1/16 to 1/11. For some tests a wind of about 100 km per hour was simulated.

The tests were conducted at the following aircraft weights (with the corresponding CG positions and inertia characteristics):

4160 kg
8000 kg forward cg
8000 kg aft cg

At 8000 kg the waterline is closest to the cabin floor, but at lighter weights the lateral tossing of the helicopter in the swell is more pronounced.

Of all the configurations tested (swell, aircraft weight, with or without 100 km/h wind, side doors open or closed), the most critical appears to be with the nose heading 90° to the swell. Nevertheless, stability was satisfactory in all the tests.

With no wind, the aircraft tends to head in a direction of 90° to the swell. When there is a wind, no matter what swell, the helicopter tends to head +25° away from the direction of the wind.

Test with one punctured compartment in the nose float, or one of the side floats, showed satisfactory stability in sea conditions up to force 6.

B. Scale-model tests of sea landing

The sea landing tests were conducted with a 1:8 scale model, at an aircraft weight of 8 tons in the following conditions:

Vx = 15.5 m/s, Vz = 2 m/s: -	-on calm surface - heading into swell - at ±45° to swell
Vx = 27.8 m/s, Vz = 2 m/s	-on calm surface
Vx = 0. Vz = m/s *(sic)*	-on calm surface, and with rotor lift of 0 - 5000 daN and 8000 daN.

There was no configuration in the sea landing tests in which the aircraft's stability appeared critical, either longitudinally or laterally.

The wave characteristics for the swell tests were:

Height =	2.4 m	
Length =	30 m	i.e. H/L = 1/12.5

All these tests were conducted without wind, since this parameter appeared to have no significant effect on sea landings.

Note:- Vx=Forward velocity, Vz=Vertical velocity. "

1.17 2 *Vibration related problems on AS332 type*

In the past, a considerable number of vibration induced problems, many related to the security of non-structural fittings and fasteners, have been experienced by all three UK operators of this type. Whilst most of these can be assessed as falling into the 'nuisance' category, some have resulted in distinct hazards to flight safety. In particular, the loss of an IDS fairing hinge pin in flight, due to vibration, combined with the intentional removal of the fairing folding stay, resulted in the total loss of an aircraft in July 1983 (ref:- Aircraft Accident Report 4/84). The survival of the 18 occupants on this occasion was entirely fortuitous.

All operators have stated that they have consistently brought vibration related problems to the attention of both the Civil Aviation Authority and the manufacturer.

1.17.3 *Reliability of ADIs*

Another UK operator who had two different Aerospatiale types fitted with basically similar ADIs noticed that the unscheduled removal rate of these instruments, due to pilot reported unservicability, was nearly 4 times higher on the AS332L than on the AS365N. As a result of this observation, this operator commissioned an 'in flight' study of the vibration levels at all frequencies on several locations of the instrument panel of the AS332. Following this, a modification was made to the instrument panel mountings which reduced the critical vibration modes and has resulted in greatly improved ADI longevity.

1.18 New investigation techniques

None

2 Analysis

2.1 General

The Search and Rescue co-ordination worked well and quickly provided as much support as was available. This is a reflection of the efficient manner in which the ATCOs at 'Shetland Radar' handled the situation, and also the rapid response by the SAR and other volunteer crews.

Analysis of the CVR and ATC recordings showed that the crew of G-BKZH performed a commendably professional operation in recovery to a safe landing at Unst. Control of the aircraft with severely restricted use of main rotor-blade pitch and tail rotor yaw is difficult, particularly in the landing phase, and this the crew successfully accomplished with considerable skill.

2.2 Structural failure

2.2.1 Sequence of failure and implications

The sudden onset of the severe vibration in flight was consistent with a single initiating event giving rise to a significant imbalance of a rotating component. The instantaneous loss of a considerable portion of the trailing edge of one of the tail rotor blades would have produced such an imbalance.

The accident originated with the detachment of a section of steel channel, from an otherwise undamaged zone of the pylon, which was then struck by two tail rotor blades as it fell away from the aircraft. The damage caused by the contact between the section of channel and one of the tail rotor blades was sufficient to cause the separation of part of its trailing edge, thus creating the imbalance.

Examination of the fractures and fastener failures on the upper part of the pylon showed that all failures had been in existence for only a relatively short time. The absence of any evidence of long-standing structural degradation indicated that there had been no reduction of the inherent stiffness of the structure which would have led to increased sensitivity of the pylon to vibration.

The locations and directions of the failures in the upper pylon structure were entirely consistent with the anticipated effects of the alternating loads induced by a serious imbalance of the tail rotor.

The cracks in the pylon right skin and inclined face close to the lower TRGB mounts stemmed directly from the reactive loads in the mounts. The failures in the inclined face and reinforcing channel, at the forward stabiliser attachment, resulted from induced oscillations of the stabiliser.

The condition of the pylon structure after the aircraft had landed was such that the upper part of the pylon, containing all the TRGB attachments, could easily be deflected in the direction of tail rotor thrust (to the left) by hand and had negligible residual strength. It was clear that, even with the technique used by the pilot which required minimal tail rotor thrust, the structure could not have sustained flight loads for much longer. Had the upper part of the pylon separated, a total loss of control very similar to that experienced by another AS332, G-TIGD at Aberdeen in 1983 (Ref:- Aircraft Accident Report 4/84) could have occurred.

In the accident to G-TIGD, ten of the sixteen passengers on board were seriously injured when the helicopter crashed on runway 17 after a loss of control occurred at some 50 feet agl. Control was lost as a result of in-flight detachment of the tail rotor assembly, together with the tail rotor gearbox and upper pylon structure, due to excessive rotor imbalance forces following damage to the tail rotor blades. This damage had occurred due to contact between the blades and the IDS fairing after in-flight detachment of the fairing hinge-pin allowed the fairing to open towards the tail rotor without the restraint of the folding stay, which had been removed .

2.2.2 *Damage to tail rotor*

After the attachment rivets of the landing channel had failed it would have been able to escape from below the latching edge of the IDS fairing and fall free. This would have been made easier by both the rounded form of the channel base and the relatively slack latching of the lower end of the fairing. The tail rotor disc lies only 11 inches outboard of the edge of the IDS fairing, with the tips of the blades passing 4½ inches forward of the lower end of the channel. Thus the position of the strikes on the tail rotor blades was consistent with the channel having emerged laterally from under the fairing edge, and fallen aft and downwards into the rotor disc. The orientation of the strike marks on the blades showed that the channel entered the disc laterally, and suggested that it had swung outwards from under the fairing edge, lower end first. Since the pylon lies on the suction side of the tail rotor disc, the airstream would have tended to draw the channel into the disc. The blades pass forwards and upwards past the lower end of the IDS fairing, so although contact of the channel on the suction face of a blade would have tended to throw the channel towards the pylon, it would also have tended to throw it upwards above the fairing. This could account for the fact that there was no evidence of the channel having contacted the pylon or fairing sides.

When the steel channel section struck the 'black' blade leading edge, the associated inertial forces were sufficient to detach a large section of the trailing edge. The amount of trailing edge thus removed has been calculated to have caused a 300 Kg mechanical imbalance of the rotor, in addition to the thrust imbalance caused by the attendant loss of aerodynamic efficiency of the blade. These imbalances would have led immediately to a high level of airframe vibration, which is consistent with the pilots' reports.

2.2.3 *Secondary effects of airframe vibration*

The most significant secondary effect of the vibration was the immediate loss of the main attitude references, as reported by the crew. Post accident examination of these instruments showed that they had not been damaged permanently, suggesting that the frequency and severity of the vibration had caused them to topple because it was outside the instrument design limits. The standby horizon, which was mounted in a part of the instrument panel which had different vibration characteristics, had not apparently toppled, but was however subsequently found to have suffered component failures. Studies conducted by another UK operator have shown that, under some flight conditions, the vibration levels experienced by the main ADIs approached the instrument specification limits. Thus any increase in vibration would be likely to exceed those limits and cause the instruments to malfunction.

The failure of the PA amplifier was clearly the result of the assembly having been subjected to such violent vibrations that the anti-shock mountings were unable to restrain it sufficiently to prevent damage. In this particular case, the PA failure did not result in any hazard to the passengers, nor is it known how soon after the onset of the vibration that the system became disabled.

It is clearly unsatisfactory that the main attitude reference instruments and the PA system can fail under the kind of critical conditions in which they may be essential for the continued control of the aircraft and for the crew to brief the passengers quickly.

2.2.4 *Separation of the lower IDS fairing edge locating channel*

The lower segment of the landing channel which became detached was not recovered, so its base shape can only be inferred from that of the upper channel segment which was formed and fitted to the aircraft at the same time. The base of this segment was significantly convex, as was the inclined face outboard of the rivet line where the lower segment was attached. Thus, when fitted, the channel would not have been firmly seated across its full width on the inclined face, but would have been in contact with the face only along the rivet line. As a result, any downward or lateral forces imposed on either edge of the channel would have tended to rock it sideways, inducing tensile loads in the attaching rivets by a 'levering' action. It should be noted that, since the face of the inclined face was not flat, this levering action would still have been possible in one direction even if the channel section had had a flat base.

The failure of the attaching rivets in fatigue due to tension and lateral bending indicated that this levering action had occurred. The severe wear of the outer edge of the IDS fairing, where it had been in contact with the outer flanges of all segments of landing channel, showed clearly that there had been considerable vertical and lateral relative movement between the fairing and channel over a long period. This relative movement would have been increased, if the tension in the latches had been insufficient, and by the wear in the spigot block rubber bush.

The presence of the tails of all the failed attachment rivets in their holes in the inclined face suggested that they had been installed with satisfactory hole filling characteristics, at least in the lower part of the joint.

2.2.5 *Replacement of the channel sections*

The operator was aware of the chafing which was occurring on the outboard side of the closing edge of the IDS fairing. As a result, their design department had drafted a scheme for a replacement channel section with a deeper flange specifically to counteract the movements of the IDS fairing edge induced by the high inherent vibration levels in the pylon area. They believed that the better lateral containment that this modified channel section would give would reduce the wear on both the fairing edge and the channel flange. As a natural corollary to this, the attachment of the channel to the pylon should also have to be resistant to vibration induced movement. This would require that the channel section was seated firmly on the inclined face in order to resist vertical and lateral forces imposed on it by the IDS fairing edge. The existence of such forces was clearly shown by the wear which was occurring on the channel flange and fairing edge in service.

This channel design had not been fully approved at the time that the maintenance shift supervisor decided that the upper and lower segments of the channel on ZH needed to be replaced. Consequently it was agreed between the design and maintenance staff that replacement channel sements, of similar material and of the same section as the originals, would be locally manufactured.

At this point there appears to have been a failure of the operator's quality control system. A situation seems to have arisen in which the licensed supervising engineer believed that his qualifications empowered him to authorise the manufacture, inspection, fitment and certification of small non-structural parts, even though this power is specifically denied by CAA Airworthiness Notice No 3.

Although Airworthiness Notice No 3 denies a licensed engineer the authority to certify manufactured parts it does not clarify the manner in which certification should be effected. This is embedded in British Civil Airworthiness Requirements.-.Section A Ch 8-2 which, in effect, states that components can be manufactured without reference to a design authority provided that they comply exactly with the Primary Design Authority's (manufacturer's) drawing. Any deviation from this drawing requires design approval from a competent and approved design authority, for which purpose the operator's design authority was, in this case, sufficient.

Although the initial approach to replace the channel had been through the Senior Technical Engineer, the supervisor who arranged for the manufacture, inspection and fitting of the replacement channel sections wrongly believed himself empowered to alter the material specification and determine the acceptable quality standard, without further reference to the operators design authority who were responsible for laying down the quality standards required.

In this particular case it would seem that low quality standards were applied on the grounds that the parts were non-structural and the potential effects of poor mating of surfaces in a vibration-susceptible environment were insufficiently appreciated. The change of material to steel would not have had any effect on the primary function of the channel (to contain the rubber landing strip). However, the threefold increase in stiffness, resulting from this change, may have significantly increased the loading on the attachment rivets due to the 'levering action'.

2.2.6 *Appreciation of the effects of vibration.*

As has been stated, at para. 1.6.5, the operator was of the opinion that this helicopter type was more susceptible to the effects of vibration than the other single rotor types in common use.

As a result, the operator's staff were well aware that the high maintenance requirements in the tail boom/pylon area were mainly due to vibration. It is, therefore, a matter of concern that they did not excercise greater caution in the control of the fitting of the modified channel segments, particularly since the reason that new parts were needed was obviously attributable to vibration-induced wear.

It is also a matter of concern that the CAA had not considered the modification which introduced the bolted on IDS fairing to constitute an improvement to safety, but merely considered it as an optional means of reducing maintenance work. The operator had considered the fitment of the modified 'bolt-on' IDS fairing, when faced with evidence of severe wear of the hinged type fairing, and had purchased a modification kit to be incorporated on this aircraft at its 4800 hr major check.

2.2.7 *Airworthiness implications*

The accident to the AS332 G-TIGD at Aberdeen in 1983 highlighted the vulnerability of the IDS fairing zone to vibration-induced failure, with ensuing damage to the tail rotor. It also brought into focus the potential for the inherent susceptibility to vibration to prejudice the security of fasteners in the tail area of this type. A modified IDS fairing which was attached by bolts (see 1.6.5.) was made available by the manufacturer after that accident, but was not made mandatory. Had this modification been made mandatory, and been fitted to this aircraft, this potentially fatal accident would not have ocurred.

The CAA had been conducting a review of the security of access panel fasteners at the time of the accident to TIGD and this is apparently still in progress, some 5 years later. The CAA have stated that this review 'has since progressed into a continuous and continuing process and findings from this process have been implimented across the helicopter fleet in general'. Since the tail rotors of helicopters are prone to damage as a result of separation of small parts from airframes, it is considered that this review should result in the earliest mandatory incorporation of all modifications which improve their security.

It has been CAA policy that the primary certificating authority (in this case the Direction Generale de l'Aviation Civile of France) is responsible for designating modifications as mandatory. As the authority charged with safety regulation for U.K. operations, it is considered that the CAA should be prepared to act unilaterally to declare modifications mandatory if it is evident that such action would safeguard the airworthiness of the UK fleet.

2.3 Crew reaction to the failure

The sudden onset of severe vibration caused the commander instinctively to reduce power by lowering the collective pitch lever. He also moved the cyclic stick aft to reduce speed. Furthermore, with the 'Height Hold' engaged, the autopilot may have caused the aircraft to pitch-up in an attempt to maintain the selected height, as cyclic pitch is its sole control in this mode. Whilst this response may be demonstrated on a Super Puma, there remains the possibility of a transient pitch input to the autopilot, caused by the sudden vibration affecting the vertical gyro. The relative proportion (if any) of the latter input would be difficult to quantify and is, essentially, not significant in the context of this accident.

The commander quickly regained control of the aircraft. He and the co-pilot deduced, correctly, that the source of the problem was tail rotor related. Their decision to carry out the 'Tail Rotor Control Failure' drill probably saved the aircraft from failure and detachment of the tail rotor/gearbox support structure.

As power was reduced, the vibration decreased to a more tolerable level, and the commander realised that continued control of the aircraft was possible. This had a considerable influence on his decision concerning the advisability of ditching. Nevertheless the crew continued to consider the possibility of ditching in the event of failing to reach dry land.

The wind and sea-state appear to have been within the tested parameters for flotation, but the sea state was outside that demonstrated, by scale models, for a water landing. The crew believed that it was probable that the helicopter would roll inverted during ditching, with consequent severe egress problems for the passengers, due to the ensuing disorientation. Furthermore, they were aware that the Super Puma cabin doors cannot be jettisoned when the aircraft is inverted. Although the normal mode of opening the doors by sliding is theoretically available when the aircraft is inverted, experience from other ditching accidents has shown that the ensuing disorientation of occupants who find themselves inverted and submerged, escalates the difficulty of performing even the most simple of tasks.

Whilst the vibration was progressively cracking and weakening the tail pylon structure, the commander was unaware of the increasingly critical nature of this damage. Thus, having considered that a ditching might not be successful and that the aircraft was still controllable, his decision to fly to dry land may be understood, in the light of the information that was then available to the crew. However, if the TRGB had detached in-flight as in the case of TIGD, the consequences of an ensuing loss of control and impact with the sea from a cruising height of 800 feet could have been catastrophic.

The commander elected to recover at 800 feet since he was concerned that possible air turbulence at lower heights, particularly in the lee of Unst in the prevailing wind conditions, would have necessitated more frequent rudder and collective control corrections which he was anxious to avoid. Since very little of the pylon structure supporting the TRGB remained intact, this decision is likely to have reduced the rate of deterioration of this stucture, allowing it to survive long enough to complete the flight to Unst.

In different circumstances, however, if immediate ditching is considered inadvisable, flight at a lower height may offer a better chance of accomplishing a successful ditching should there subsequently occur a sudden degradation in, or loss of, control.

The wind at Unst airfield was ideal, in both strength and direction, for a straight-in run-on landing on runway 30. The commander stated that the emergency landing was greatly facilitated by practice carried out in the 6-axis simulator on which the BIH crews do their recurrent training. The landing was skillfully carried out without further incident. This was fortunate, since the AFS were on only 'Local Stand-by' status and the civil emergency services had not been alerted.

2.4 ATC at Unst

The decisions regarding SAR response were made whilst the aircraft was under the control of Shetland Radar. However, the Unst controller's initiative in picking up the 'Mayday' call on the Shetland radar frequency, and in contacting the local SAR helicopter and the aircraft's parent company, are to be commended.

It is unfortunate that, in the heat of the moment, the controller did not follow the laid down instructions covering such an emergency. He did not sound the Crash Alarm and did not call for the assistance of another controller. In addition, and as discussed, he did not use the correct phraseology when alerting the AFS and PBX operator. In the event, none of these omissions had any effect upon this accident. However, had the landing not been successful, the consequent lack of additional fire fighting and rescue support could have been a major factor in survivability.

In the first case, the controller decided that, as he had already alerted the Chief Fire Officer by personal radio, and the duty Watch Officer by direct line, there was no purpose to be served by pressing the Crash Alarm.

In the second, the situation gave him plenty of time to carry-out the required actions and he therefore considered that another controller was not necessary. It is likely however that, had he sounded the crash alarm, the other controller on the station at the time would have heard it and automatically gone to the ATC tower. Furthermore, it is possible that he might have recognised the lack of understanding between the participants and taken action to improve the emergency response available.

Regarding the phraseology used, it is infrequent that a 'Mayday' is declared, and the event is likely to generate some tension in an ATCO. The first square on the plastic board, provided for use during an emergency, should have been filled in with either the words 'Full Emergency' or 'Local Standby'. It is believed that by writing the word 'Mayday' in this square, the controller caused himself to use that word, instead of the correct phraseology, when alerting both the AFS and PBX.

2.5 The AFS

The ATC controller's decision not to sound the Crash Alarm may have contributed to the misunderstanding of the emergency status by the AFS. However, even when the Watch Log was later completed, no-one within the AFS appears to have known what the status was. It is therefore difficult to understand why no-one made any request for clarification of that status during the considerable time interval between the alert and the aircraft landing. Had they done so, they would have noticed, and presumably rectified, the absence of the civil emergency services back-up.

2.6 The PBX

The PBX operator stated that the plastic board was immediately annotated with the words 'Local Standby', which had been assumed to be the meaning of the word Mayday, used by the ATCO. In accordance with the PBX Emergency Orders there was therefore no reason to alert the local Emergency Services unless subsequently instructed to do so by the ATCO. Contradictory evidence, however, makes it impossible to say whether these written words were the original inscription, or had been added later as a result of conversation with the ATCO.

2.7 Responsibilities of the Airport Authority

The evident lack of understanding between the ATCO, the AFS and the PBX clearly stemmed from the incorrect phraseology used by the ATCO. However, it might reasonably be expected that the other two sections would have provided greater support to the ATCO.

The use of non-standard phraseology, coupled with the failure on the part of either of the other two sections to query it, suggests a general lack of familiarity with Emergency Procedures.

3 CONCLUSIONS

(a) Findings

(i) The crew and the ATCO were properly licensed and medically fit to carry out their duties.

(ii) The crew handled all aspects of this serious emergency with exemplary professionalism and skill, considering the information available to them.

(iii) The emergency service provided by the SAR organisation and the Shetland Radar controllers was both prompt and appropriate to the circumstances.

(iv) The ATCO at Unst airport failed to follow the Emergency Procedures for the airport. However, in the event, this did not influence the outcome of events.

(v) Although the word 'Mayday' was not fully understood by either the AFS or the PBX, neither requested clarification from the ATCO.

(vi) The local Emergency Services were not alerted to the accident. However, in the event, they were not required.

(vii) The breakdown of communications between the various sections responsible to the Airport Authority suggested a general lack of familiarity with the Emergency Procedure.

(viii) A modification introducing a bolt-on IDS fairing, to replace the original hinged fairing, was available from the manufacturer before this accident but had not been made mandatory.

(ix) The operator had purchased kits to incorporate this modification at the next major inspection period.

(x) The aircraft had been maintained in accordance with the appropriate schedule and was properly certificated, with the exception of the work related to the replacement channel sections .

(xi) The lower segment of the IDS fairing landing channel became detached in flight and collided with the tail rotor.

(xii) A substantial portion of the trailing edge of one tail rotor blade became detached as a result of this collision.

(xiii) The imbalance caused by this detachment generated excessively high loads in the pylon structure which almost caused total failure of the pylon structure immediately below the tail rotor gearbox attachment.

(xiv) From the knowledge gained in the investigation, it was evident that the TRGB was near to complete detachment when the aircraft landed. Had the TRGB separated in-flight, this could have caused a potentially fatal loss of control had it occurred during the recovery to Unst.

(xv) The recently fitted segment of channel which became detached was locally fabricated by the operator, from steel instead of the specified light alloy, and was poorly formed.

(xvi) Although the operator appreciated the possibility that the inherent susceptibility of this type of aircraft to vibration in the pylon could exploit weaknesses in the attachment of components in this zone, they did not excercise adequate quality control of the components that they manufactured.

(b) Causes

The direct causes of the accident were poor quality control in the local manufacture of a channel section, combined with the known susceptibility to vibration in the pylon area of the AS332, which led to a segment of steel channel separating from the tail pylon in flight and striking the tail rotor blades.

An underlying cause was the non-embodiment of a modification which introduced a 'bolt-on' IDS fairing to replace the original hinged fairing. This modification had been made available to all operators by the manufacturer, but was not mandatory.

4 Safety recommendations

4.1 Operators should be reminded of the need for the highest standards of repair and maintenance in zones of high vibration, particularly in those places where parts which become detached might cause serious secondary damage.

4.2 The CAA and French Airworthiness Authorities, together with the manufacturer, should urgently implement action to secure, effectively, all components associated with the attachment and locking of access panels and fairings on the AS332 and generally similar types.

4.3 The CAA should be more prepared to act unilaterally to declare modifications mandatory if it is evident that such action will safeguard the airworthiness of the UK fleet.

4.4 The lack of a facility to jettison the cabin doors on an AS332 in an inverted position should be reviewed.

4.5 The evident susceptibility of the attitude director indicators and the PA system amplifier to the high vibration levels resulting from tail rotor damage should be reviewed by the CAA and French Airworthiness Authorities, together with the manufacturer, since malfunctions of these components have the potential to compound an already critical in-flight situation.

4.6 The Civil Aviation Authority should clarify the requirements for the certification of locally manufactured components.

4.7 The Civil Aviation Authority should require that helicopters be equipped with flight data recorders in accordance with current ICAO standards and recommended practices.

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Inspector of Accidents

Air Accidents Investigation Branch
Department of Transport
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