Statens Havarikommisjon for Transport

SL RAP.: 8/2006

REPORT ON THE AIRCRAFT ACCIDENT AT BERGEN AIRPORT FLESLAND, NORWAY, ON 31 JANUARY 2005 INVOLVING ATR 42-320, OY-JRJ, OPERATED BY DANISH AIR TRANSPORT

This report has been translated into English and published by AIBN to facilitate access by international readers. As accurate as the translation might be, the original Norwegian text takes precedence as the report of reference.

SUBMITTED
April 2006

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REPORT ON THE AIR ACCIDENT AT BERGEN AIRPORT FLESLAND, NORWAY, ON 31 JANUARY 2005 INVOLVING ATR 42-320, OY-JRJ, OPERATED BY DANISH AIR TRANSPORT

Manufacturer and model:	Aerospatiale/Aeritalia ATR 42-320
Nationality and registration:	Danish OY-JRJ
Owner:	Danish Air Transport ApS, Kolding Airport – Vamdrup, Denmark
Operator:	As owner
Accident site:	Bergen Airport Flesland Norway (ENBR) 60° 17' 37"N, 005° 13' 05"E
Accident time:	Monday 31 January 2005, at time 1128.

All times given in this report are local times (UTC+1 hours), unless otherwise stated.

NOTIFICATION

On 31 January 2005, at time 1530, the Accident Investigation Board Norway (AIBN) was notified that Danish Air Transport flight DTR54, an aircraft of type ATR 42, had declared an emergency and returned for landing directly after take-off from Bergen Airport Flesland. The emergency landing was caused by control problems, and inspection after landing revealed that the right side elevator had partially detached and was hanging below the tail surface. AIBN sent two inspectors to Bergen who began the investigation the same evening. In accordance with international regulations (ICAO Annex 13), the AIBN forwarded a notification of the occurrence to the State of Manufacturer (France) and the State of the Operator (Denmark). The Norwegian Civil Aviation Authority was also notified. Both the accident investigation board in Denmark (HCLJ) and France (BEA) appointed “non-travelling” accredited representatives. The aircraft manufacturer ATR sent two specialists from Toulouse, France, to Bergen to assist in the technical investigation.

SUMMARY

Danish Air Transport flight DTR54, an aircraft of type ATR 42 with registration mark OY-JRJ was on a scheduled flight from Bergen Airport Flesland (ENBR) to Florø Airport (ENFL). There were 22 passengers, 1 cabin crew member and 2 pilots on board.

During take-off the pilots experienced considerable control problems related to the elevator function. They declared an emergency situation and returned for landing. The landing was accomplished without further incident 7 minutes after take-off.

After landing it was found that the control problems were caused by the right elevator hanging below the horizontal stabiliser, attached only by the inboard of the three hinges that normally connect the elevator to the stabiliser. A bolt was missing from both the centre and outer hinges. Both of the bolts and one of the nuts that normally should connect the hinge assemblies together were found. One of the bolts was found on the runway, the other inside the elevator.

Investigation indicates that the bolt belonging to the outer hinge assembly fell out during the take-off in question, while the bolt in the centre hinge assembly had fallen out at an earlier point in time, without being discovered. The report concludes that the self-locking nuts cannot have been tightened with the required torque when the elevator was fitted. This error was most probably introduced after the aircraft was repainted in 1999.

AIBN issues two safety recommendations in this report.

1 FACTUAL INFORMATION

1.1 History of the flight

1.1.1 The crew started their working day in Florø at time 0745. They flew a return trip Florø-Bergen and to Bergen again without registering any anomaly with the aircraft. The first officer was the flying pilot during these three flights. On the flight in question from Bergen, the commander (captain) was to pilot the aircraft.

1.1.2 During its time on the ground, the commander carried out the mandatory external inspection of the aircraft, without observing anything abnormal. The flight controls were routinely checked from the cockpit before take-off. Company procedure says that it is always the commander who checks that the rudder moves normally and with full deflection to each side, while the first office checks the elevators and ailerons. When the first officer carried out his check, he commented that movement of the elevator required some more force than normal, probably due to the wind. He repeated the check while waiting to be cleared for take-off.

1.1.3 Subsequently the first officer has explained in more detail what he noted when checking the elevator before take-off. The elevator moved evenly, and the stiffness was equivalent to what can be experienced when the elevator is affected by wind on the ground. The commander remembered the first officer's comments that the elevator was stiffer than normal. He has explained that he had no reason to doubt the experienced first officer's opinion that the stiffness was caused by wind. The commander made no extra check of the elevator before take-off.

1.1.4 Take-off was made from runway 35 at time 1128. Acceleration was normal, but at rotation the commander had to apply excess force on the elevator control. He has explained that at first he thought that the elevator trim was incorrect. However, immediately after lift-off it became clear that the elevator was not working as it should. Full elevator deflection was necessary to maintain normal pitch (movement around the lateral axis) of the aircraft. For a period, the first officer assisted the commander physically with the controls, and both have explained that it was extremely demanding to maintain control of the aircraft. The elevator moved now unevenly and "jerkily", fundamentally different from before take-off, according to the first officer. The commander did not attempt to engage the autopilot as he expected that it would disconnect anyway.

1.1.5 At time 1129, the crew of DTR54 declared an emergency and asked for radar vectors for runway 35. At that time, the aircraft was around 3 NM north of the airport. Its height was slightly below 2 000 ft.

1.1.6 The air traffic controller at Flesland approach confirmed reception of the emergency call, and cleared DTR54 to climb to 3 000 ft on a westerly heading. This was necessary in order to secure terrain clearance in relation to Sotra before the turn to the south. At a height of approx. 2 200 ft, the commander reported that he had visual contact with the runway, and DTR54 was then given clearance to a left downwind for landing on runway 35. The crew informed the tower that they had pitch problems and requested increased emergency readiness. The first office has explained that the control problems diminished somewhat when they levelled out and turned back towards the airport.

1.1.7 According to the report from Avinor, the duty air traffic controller in the tower observed DTR54's take-off both visually and on radar. Everything seemed to be normal. When the aircraft had climbed to approx. 1 700 ft, it was around ½ NM to the east of the centre line/standard instrument flying track, which the air traffic controller attributed to a north-westerly wind. Immediately afterwards the aircraft's course was adjusted to the west and, at the same time, the tower air traffic controller received the message that DTR54 had declared an emergency and was returning for landing. The airport emergency services were immediately scrambled and fire engines were driven into position along the runway. DTR54 landed apparently without problems at time 1135, 7 minutes after take-off. The fire trucks accompanied the aircraft to parking.

1.1.8 After landing, the commander asked the cabin crew member about how the incident had been perceived in the cabin. He was told that it had not seemed dramatic to the passengers, and the commander then merely told them that the aircraft had returned because of technical problems. The 22 passengers left the aircraft in the usual manner.

1.1.9 When the crew left the aircraft and inspected the aircraft the cause of the control problems became immediately apparent. The right elevator had detached completely from the hinges that normally connect the elevator surface to the horizontal tail surface (the stabiliser). Only the inboard hinge next to the tail fin was still intact. The tip of the elevator was hanging 30 cm below the stabiliser.

Fig. 1 OY-JRJ's elevator seen after landing

1.1.10 Following this observation, airport personnel drove along the runway by car to check whether they could find any parts from the aircraft. They found a bolt and washer lying on the asphalt at the extreme north end of the runway, centered between the centre line and the right runway edge line. The bolt had a visible part number, NAS 6407-26, and proved to originate from OY-JRJ's elevator.

1.2 Injuries to persons

INJURIES	CREW	PASSENGERS	OTHER
FATAL			
SERIOUS			
MINOR/NONE	3	22	

1.3 Damage to aircraft

With the exception of the elevator, the aircraft suffered only insignificant damage. See chap. 1.12 for details.

1.4 Other damage

None.

1.5 Personnel information

1.5.1 Commander: Male, 38 years of age

Licence: ATPL-A (JAR-FCL). Medical certificate class 1 with limit VDL (shall wear corrective lenses and carry a spare set of spectacles) valid until 16 April 2005. Last OPC/PC performed 10 October 2004.

The commander began his commercial pilot training in the US in 1985, and has undergone education and training in Norway, Denmark and the US. He has type rating for several turboprop aircraft, and had flown as commander on ATR 42 in DAT since the autumn of 2003.

FLYING EXPERIENCE	ALL TYPES	ON TYPE
LAST 24 HOURS	3 hours	3 hours
LAST 3 DAYS	3 hours	3 hours
LAST 30 DAYS	66 hours	66 hours
LAST 90 DAYS	166 hours	166 hours
TOTAL	3 999 hours	1 582 hours

1.5.2 First Officer: Male, 26 years of age

Licence: CPL-A (JAR-FCL). Medical certificate class 1 without limits, valid until 17 August 2005 Last OPC/PC performed 17 October 2004.

The first officer received his commercial pilot's licence in Sweden. He was newly qualified when he was employed as first officer on ATR 42 at DAT in 2003.

FLYING EXPERIENCE	ALL TYPES	ON TYPE
LAST 24 HOURS	6 hours	6 hours
LAST 3 DAYS	9 hours	9 hours
LAST 30 DAYS	63 hours	63 hours
LAST 90 DAYS	140 hours	140 hours
TOTAL	1 490 hours	1 315 hours

1.6 Aircraft information

1.6.1 General

Manufacturer and model: Aerospatiale/Aeritalia ATR 42-320

Serial no.: 036

Year of manufacture: 1986

Airworthiness certificate: Standard airworthiness certificate no. 5057, issued by the Danish Civil Aviation Administration (SLV) on 12 May 1999. Expiry date 15 May 2005

Engines: 2 x Pratt & Whitney PW121 turboprop engines

Maximum take-off mass: 16 900 kg

Actual take-off mass: 15 110 kg

The permitted range for centre of gravity position for the actual take-off mass is between 15 % and 36 % MAC (Mean Aerodynamic Chord). At take-off, the centre of gravity was at 22 % MAC, in other words, virtually in the middle of the permitted range. (Trim setting 1.1 up).

Danish Air Transport acquired the aircraft in question in March 1999. At this time the aircraft had recorded 22 455 flying hours and 17 986 cycles. When the accident occurred, it had recorded 27 526 flying hours and 23 695 cycles. The aircraft had, therefore, flown 5 071 hours and 5 709 cycles for DAT before this accident.

1.6.2 The construction and function of the elevator

The movement of the aircraft around its lateral axis is controlled by two elevators, both equipped with tabs. The elevator and tabs are controlled mechanically, while the tabs are also controlled electrically for the trim function. The commander's and first officer's control columns operate the left and right elevators respectively, using rod and cable linkages. The links from the left and right systems are interconnected in a mechanism that is located between the elevators, inside the horizontal tail surface. If one of the systems jams for some reason, the connection will break when the column force exceeds a set value (525 N +/- 25 N). (Pitch uncoupling mechanism). This means that it will still be possible to control the aircraft using the other system.

The connection between the right and left systems was still intact on OY-JRJ after landing.

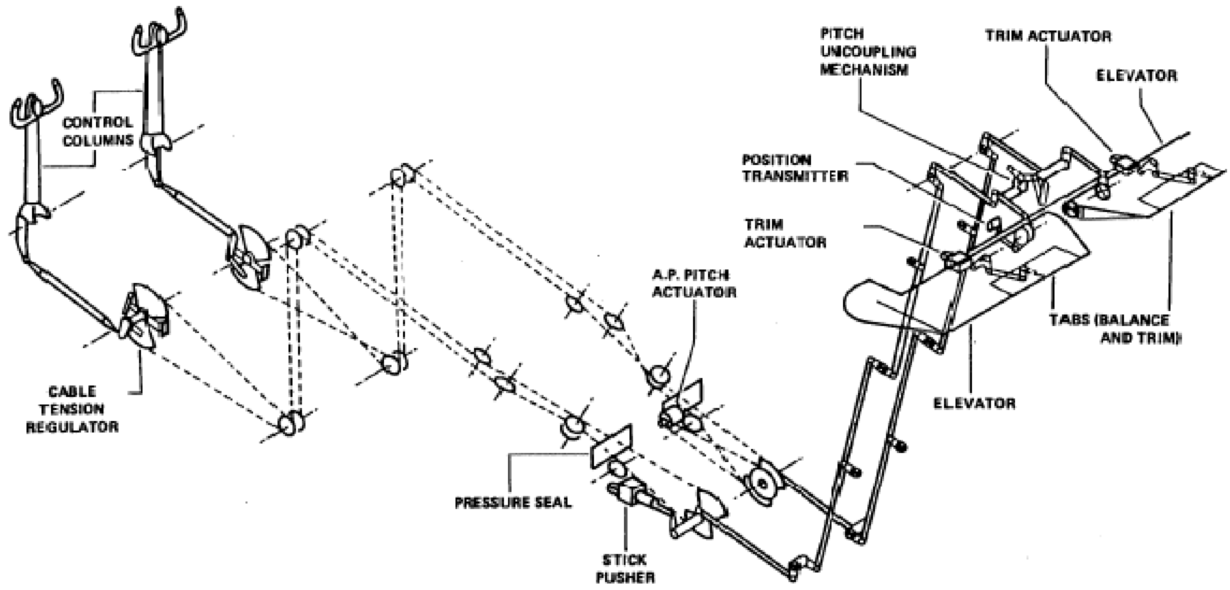

Fig. 2 Mechanical elevator controls

The three hinge assemblies that connect the elevator to the horizontal stabiliser have all been constructed in the following way (See fig. 3): A hinge lug on the stabiliser has a ball bearing fitted in its opening. A cadmium plated bolt is led through the ball bearing and the associated flange on the elevator. The bearing is a spherical ball bearing that can move a limited number of degrees in relation to the longitudinal axis of the bearing. This allows the centre of all three bearings to be adjusted linearly with respect to each other when the bolt/nut assembly is tightened. The assembly consists of a “floating bushing” and two washers, and the parts are kept in place by a self-locking nut. Tightening torque for the nut which holds everything together should, according to the installation instructions, be 3.9 – 4.5 MDAN (343 – 396 lb in).

In 1985, ATR 42 was certified according to the aviation regulations governing air transport (JAR 25/FAR 25), and is constructed to be capable of continued safe flight and landing if, for example, an individual mechanical error should occur in the flight controls. Each element of each flight control system should be designed, or distinctively and permanently marked, to minimize the probability of incorrect assembly that could result in the malfunctioning of the system. (JAR 25/FAR 25 Section 25.671).

Self-locking nuts without separate locks can be used for bolts that do not rotate, under certain conditions. (JAR 25/FAR 25 Section 25.607).

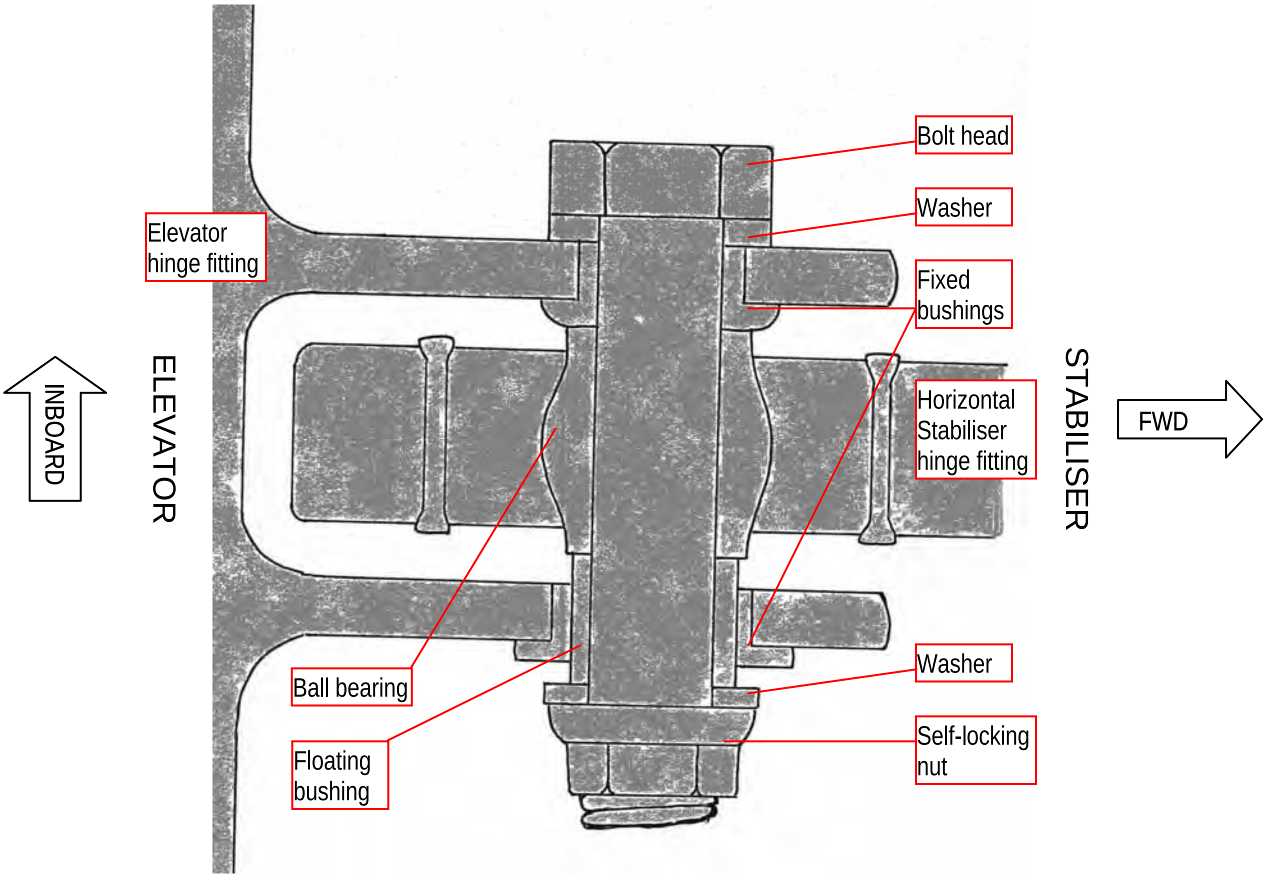

Fig. 3 Simplified sketch of elevator hinge assembly

1.6.3 Technical investigations

Visual inspection was made and photographs taken before the elevator was dismantled. There was a bolt missing from both the centre and outer hinges. The condition of the inboard was normal; the nut was tightened, washers and bushings were in place and the bolt was not bent. There was no sign of deformation of the stabiliser.

Fig. 4a The right tail surface from the side

Fig. 4b Outboard hinge point

Fig. 4c Centre hinge point

The bracket into which the bearings are fitted is equipped with grease nipples. Grease is applied to the bearing through a nipple and drillings in the bracket and tracks/holes in the outer bearing race. The bolt hole in the bearing for the centre hinge point was full of grease. There were some almost vertical abrasions on the side of the centre fixing lug. The bolt holes on the centre and outboard bearings showed traces of surface corrosion.

The bolt hole on the inboard bearing was shiny and showed no trace of corrosion. All of the three bearings were well lubricated and rotated freely.

In addition to the bolt and washer that were found on the runway, a bolt and washer were found lying loose in the elevator, in the leading edge box at the centre hinge location. The bolts and washers are assumed to originate from the outboard and centre hinge points. A nut and washer that are assumed to have originated from the outboard hinge were found in the space between the outboard hinge point and the end plate, at the rear of the stabiliser.

Fig. 5a Outboard hinge bolt

The bolt and washer that were found on the runway. The surface treatment (cadmium plating) was partially eroded.

Fig. 5b Centre hinge bolt

The bolt that was found in the elevator. All surface treatment was eroded, and the surface was polluted by congealed grease. This pollution increased the diameter to such an extent that the loose washer that was found by the bolt could not be fitted onto it.

Fig. 5c Inboard hinge bolt

The bolt from the inboard hinge point after dismantling. The surface treatment was intact.

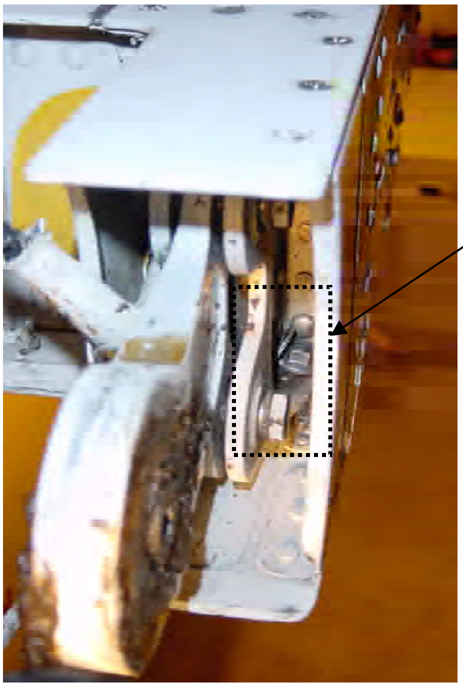

Fig. 6a Outboard hinge point right stabiliser

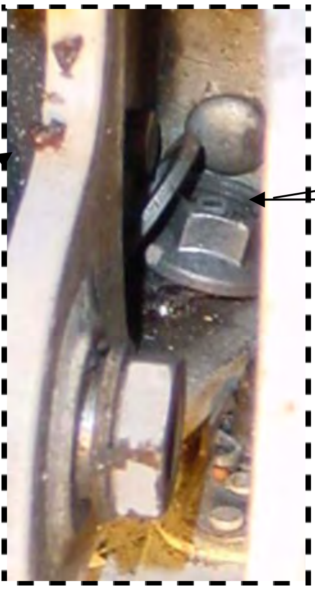

Fig. 6b Washer and nut

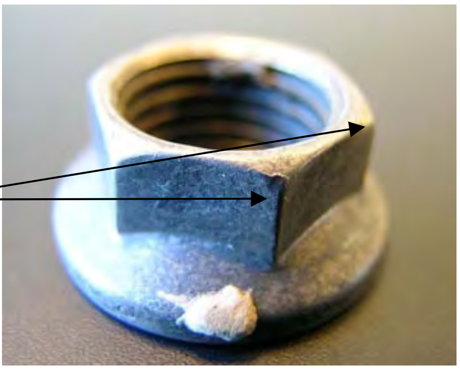

Fig. 6c
Nut with tool marks and torque seal

In connection with investigation of this accident, the self-locking nut from the outboard hinge screwed onto the bolt from the outboard hinge using finger force, and tightened with a tool until two threads of the bolt were visible on the "outside" of the nut. The torque that was necessary to turn the nut further was measured at 33 lb in. This is the torque that is necessary to break the self-lock on the nut in the condition that it was in when it was found (uncleaned and not lubricated). In comparison, the self-locking nut from the inboard hinge was installed on the same bolt (outboard hinge bolt). The equivalent measure torque was 50 lb in.

1.6.4 Maintenance on elevator

Before DAT acquired the aircraft in 1999, C-check was carried out at LAB, Dinard in France. Following the work carried out at Dinard, the airplane was sent to Air Littoral Industries (ALI), Montpellier, France to be painted. For this painting work, the elevators were removed and then re-installed and checked. (The company name LAB no longer exists, but is now part of TAT Industries. The company ALI later went out of business).

The manufacturer's documentation for installation of elevators is included as Appendix 2 to this report. The manufacturer's procedure states nothing as to whether the installation shall be specially inspected after completion, before the covers are replaced.

Between 1999-2001 maintenance was carried out by the Dutch company Schreiner. In 2001, the Danish JAR 145 company Air Service assumed responsibility for maintenance. The maintenance documentation for these periods was reviewed as part of the AIBN's technical investigation following the accident. Neither the documentation from Schreiner or from Air Service contained information that could indicate that the elevator has been removed. Nor has any special maintenance work been carried out in connection with the hinges, as a result of damage, etc.

The routine maintenance that is carried out in the relevant location consists of lubrication and visual inspection. The table below shows a summarised list of relevant requirements and history for OY-JRJ.

Maintenance task	Interval	Latest carried out on OY-JRJ
Lubrication of bearings	Each “4A-check”, i.e. every 2 000th flying hour	30. November 2004
General Visual Inspection (GVI) of Horizontal Stabiliser (External Surface)	Each “C-check”, i.e. every 4 000th flying hour	3. February 2004
Detailed Visual Inspection (DVI) of the Elevators Fittings	Every 8th calendar year	5. February 2003

The bearings must be lubricated at each “4A-check”, i.e. for every 2 000th flying hour. The grease nipples can be reached without removing the covers that hide the hinges, meaning that nuts and bolts will not be visible when this job is being carried out.

At each "C-check", i.e. for every 4 000th flying hour, the "General Visual Inspection (GVI) of Horizontal Stabiliser (External Surface)", is carried out, including "Spar Box, Leading Edge, Elevator and Tab". ATR has calculated a time consumption of 12 minutes for the performance of this task. The manufacturer's general description of what is meant by a general visual inspection (*Maintenance Planning Document, MPD Glossary),* states the following:

> *GVI: "A visual check of an installation or structure for obvious unsatisfactory conditions/ discrepancies. This inspection may require the use of access equipment (platforms, work stands, etc.), removal of fillets, fairing access panels/doors, etc, and the use of such inspection aids as a flash light, mirrors."*

It is assumed that the person carrying out the inspection possesses sufficient knowledge of the aircraft's construction and systems, and a detailed list of what has to be inspected is normally not provided. Critical points are specified in certain cases (ref. MPD Zonal Program, Introduction). No critical points, that had to be checked, were specified for "GVI of Horizontal Stabiliser".

Every 8th year (8YE) "Detailed Visual Inspection (DVI) of the Elevators Fittings" shall be carried out. In order to carry out this inspection, it is specified that the covers that hide the hinges must be removed. The introduction to the job description states that the inspection is primarily for cracks and corrosion. It also states:

1. *Carefully clean the surface to be inspected (use authorized products only).*
2. *Perform the detailed visual inspection of the fittings connecting elevators to horizontal stabilizer.*

NOTE: Pay particular attention to fittings lugs.

3. *If damage is found contact the manufacturer. (Elevator fittings are restricted area items).*

No special attention to bolts/nuts/bearings in the hinges is specified. ATR has calculated a time consumption of 50 minutes for the performance of this task.

The aforementioned "DVI of Elevator Fittings" was carried out on OY-JRJ and signed off in connection with the 8-year inspection carried out by Air Service in February 2003. According to the note on the work order the inspection took 1 ½ hours. The AIBN interviewed the technician who carried out the job. He explained that he could not remember the actual inspection, but was of the opinion that it would not be possible to avoid noticing if a nut and/or a bolt was missing from a hinge.

1.6.5 Responsibility for double inspection after maintenance work on critical systems

Current certification requirements for maintenance organisations, EASA PART 145 Section 145.A.65 "Safety and quality policy, maintenance procedure and quality system" subparagraph (b) states the following:

> *"(b) The organisation shall establish procedures agreed by the competent authority taking into account human factors and human performance to ensure good maintenance practices and compliance with this Part ..."*
>
> …

"3. With regard to aircraft line and base maintenance, the organisation shall establish procedures to minimise the risk of multiple errors and capture errors on critical systems, …"

In addition, the following is also stated in the associated "Acceptable Means of Compliance", AMC 145.A.65 (b)(3):

"2. Procedures should be established to detect and rectify maintenance errors that could, as minimum, result in a failure, malfunction, or defect endangering the safe operation of the aircraft if not performed properly. The procedure should identify the method for capturing errors, and the maintenance tasks or processes concerned. In order to determine the work items to be considered, the following maintenance tasks should primarily be reviewed to assess their impact on safety:

- *Installation, rigging and adjustments of flight controls,*
- *Installation of aircraft engines, propellers and rotors,*
- *Overhaul, calibration or rigging of components such as engines, propellers, transmissions and gearboxes, but additional information should also be processed, such as:*
- *Previous experiences of maintenance errors, depending on the consequence of the failure,*
- *Information arising from the 'occurrence reporting system' required by 145.A.60,*
- *Member State requirements for error capturing, if applicable."*

The Norwegian and the Danish CAA have not implemented additional national requirements for error capturing.

The EASA regulations Part M, which concern the responsibility of aircraft operators, state the following about the requirements for continual airworthiness:

"M.A.201 Responsibilities (a) The owner is responsible for the continuing airworthiness of an aircraft and shall ensure that no flight takes place unless:

1. the aircraft is maintained in an airworthy condition, and;
----
4. the maintenance of the aircraft is performed in accordance with the approved maintenance programme as specified in M.A.302.

The associated AMC M.A.201 (h), *Responsibilities,* states the following:

"3. The requirement means that the operator is responsible for determining what maintenance is required, when it has to be performed and by whom and to what standard, in order to ensure the continued airworthiness of the aircraft being operated."

1.7 Meteorological information

METAR ENBR 1050UTC: 32011KT 280V360 9999 VCSH FEW012 BKN050 02/M00 Q1013=

1.8 Aids to navigation

Not relevant.

1.9 Communications

No irregularities.

1.10 Aerodrome information

The elevation of Bergen Airport Flesland (ENBR) is 165 ft (approx. 50 m. above sea level). Its position is 60° 17' 37"N, 005° 13' 05"E. Take-off distance available (TODA) for runway 35 is 2 555 m.

1.11 Flight recorders

1.11.1 Both the flight data recorder and the cockpit voice recorder were removed and downloaded at the Aircraft Accident Investigation Branch UK (AAIB UK).

1.11.2 The flight data recorder was of type DFDR Fairchild model F800. The elevator position is registered four times per second using a position transmitter. The data on the flight data recorder was of good quality. It confirmed that the elevator was checked twice; once at the same time as the rudder in connection with the “normal” rudder check, and an extra check 20 seconds later, which was equivalent to approx. 20 seconds before take-off. The maximum elevator deflection during the rudder check was normal; 16° (down) and -26° (up).

1.11.3 Data from the last take-off was compared with an earlier take-off. Elevator deflections varied somewhat more after lift-off on the accident flight than previously. Around 20 seconds after lift-off in the relevant take-off, as the aircraft passed around 800 ft climbing, especially frequent variations of elevator position were registered that lasted a couple of seconds. The maximum value was -6°. Only insignificant pitch deviations were registered at the same time. During the continuing climb, manoeuvring, level off and descent no elevator deflections were registered that exceeded ±5°, with the exception of the landing flare (-9 °). Invalid data was registered in some periods of a few seconds.

1.11.4 The Cockpit Voice Recorder, CVR, was type Fairchild model A100A. The recording lasts 30 minutes. The recordings from the relevant flight were recorded over, because the power to the recorder was not turned off immediately after landing. At the time of the accident, the operator had not implemented a procedure to preserve the recorded data according to the regulations.

1.11.5 It is, unfortunately, not unusual for CVR recordings to be inadvertently recorded over. This is one of the reasons for the requirement for recording length being increased from 30 minutes to 2 hours for new aircraft. (JAR OPS 1.700).

1.11.6 AIBN has previously made a recommendation that the Civil Aviation Authority Norway should consider whether the Norwegian regulations governing preservation of recordings after an occurrence are in line with ICAO Annex 6, and whether they function as intended. (Rep. 40/2003). In its follow-up to this recommendation, the Civil Aviation Authority Norway (CAA-N) responded that this is an international problem, and for that reason it chose to write to JAA, with the recommendation that JAR-OPS be amended so that operators are required to have written routines for how CVR data is protected following an aviation accident or incident. According to CAA-N, this recommendation was discussed in JAA and closed without any action in February 2005.

1.11.7 The international standard in ICAO Annex 6 pt. 11.6, *Flight recorder records (includes both flight data and cockpit voice recorder),* clarifies the official requirement in this matter:

> *"An operator shall ensure, to the extent possible, in the event the aeroplane becomes involved in an accident or incident, the preservation of all related flight recorder records and, if necessary, the associated flight recorders, and their retention in safe custody pending their disposition as determined in accordance with Annex 13".*

In the pan-European JAR OPS 1, the requirement is linked to protection of cockpit voice recorder data noted in pt. 1.160 (a), *Preservation of recordings:*

> *"(1) Following an accident, the operator of an aeroplane on which a flight recorder is carried shall, to the extent possible, preserve the original recorded data pertaining to that accident, as retained by the recorder for a period of 60 days unless otherwise directed by the investigating authority.*
> *(2) Unless prior permission has been granted by the Authority, following an incident that is subject to mandatory reporting, the operator of an aeroplane on which a flight recorder is carried shall, to the extent possible, preserve the original recorded data pertaining to that incident, as retained by the recorder for a period of 60 days unless otherwise directed by the investigating authority."*

1.11.8 Appendix 1 to JAR OPS 1.1045, Operations Manual – Structure and Contents, pt. 11 is entitled *"Handling, notifying and reporting occurrences"*. It does not specify that the operator must have a routine to ensure adherence to the requirement in pt. 1.160 (a). According to AMC OPS 1.1045 the intention of this appendix is as follows:

> *"Appendix 1 to JAR-OPS 1.1045 prescribes in detail the operational policies, instructions, procedures and other information to be contained in the Operations Manual in order that operations personnel can satisfactorily perform their duties."*

1.12 Wreckage and impact information

Description of wreckage and impact information is not relevant to this accident. The reason for this event being classified as an aircraft accident and not as an incident is the damage to the right elevator and ensuing control problems. Some of the criteria in the current definition of an aviation accident are as follows:

> *"Accident […] as long as […] the aircraft sustains damage or structural failure which adversely affects the structural strength, performance or flight*

characteristics of the aircraft, and would normally require major repair or replacement of the affected component."

Closer investigation revealed that, in addition to the visible damage to the leading edge fairings, there was damage to the main beam. There were also traces of three lightning strikes. This meant that the elevator had to undergo comprehensive repair before being reintroduced to operations.

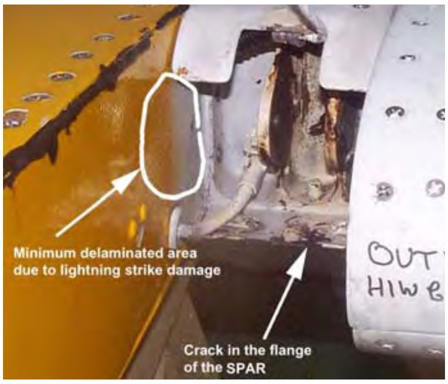

Fig. 7a The damage to the main beam flange at the outboard hinge

Fig. 7b The damage to the main beam flange at the centre hinge

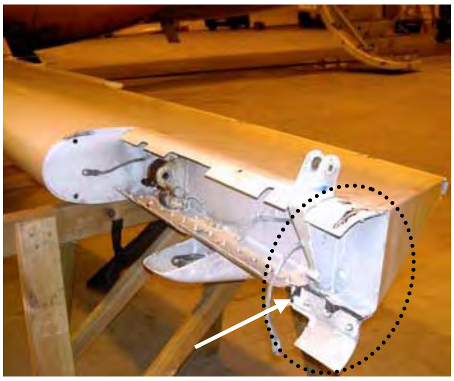

Fig. 7c Damage to the elevator's leading edge fairings close to the tail fin

1.13 Medical and pathological information

Not relevant.

1.14 Fire

No fire occurred.

1.15 Survival aspects

Not relevant.

1.16 Tests and research

None.

1.17 Organisational and management information

The company Danish Air Transport was established in 1989. The company holds a licence for commercial transport of passengers, mail and/or freight. Air Operator Certificate (AOC) No DK 043 was issued by the Danish Civil Aviation Administration (SLV) on 1 July 2000. At the time of the accident, the company operated 4 aircraft of type ATR42, 2 aircraft of type ATR72, 2 x BE1900 and 1 x BE90.

Danish Air Transport has operated the routes Bergen – Florø and Florø – Oslo since 1 April 2003.

At the time of the accident, DAT was in the process of establishing its own Part-145 maintenance facility.

1.18 Additional information

None.

1.19 Useful or effective investigation techniques

This investigation has not used methods that qualify for special discussion.

2 ANALYSIS

2.1 Introduction

In this investigation, the AIBN has examined the maintenance documentation for the aircraft as far back as 1999, without finding anything that could indicate that the bolts in question had been unscrewed during this period. Therefore, it is assumed that the problem was introduced in connection with the repaint and refitting of the elevator in 1999. More detailed discussion of the findings that support this theory can be found in pt. 2.4. Ideally speaking, both the circumstances around the actual installation of the elevator and the organisational conditions at the relevant maintenance organisation should be investigated to find the underlying root causes. In this case, such use of resources was considered not to be appropriate. Both the time perspective and the fact that the companies involved no longer exist, accounted heavily in this assessment.

2.2 Flight operational matters

2.2.1 The AIBN thinks it probable that the outboard hinge bolt was about to fall out when the first officer felt that the elevator was moving abnormally during the pre-flight check. Correct elevator function is a condition for safe flight, and in the light of hindsight it easy to see that the commander should have been more careful and investigated whether he could register any anomaly with the elevator when the first officer commented that it required more force to move it than normally.

2.2.2 The literature on human factors teaches us that our expectations can influence us in such a way that we unconsciously sift incoming information and only register what we want to see, not what actually is happening (confirmation bias). The crew check the elevator before each flight, several times each day, and anomalies occur very rarely. When wind conditions are not calm, the elevator surfaces are exposed to the power of the wind when they are moved while the aircraft is on the ground, and the “control feeling” will vary. It is the opinion of the AIBN that expectation can explain why the first officer attempted to find a natural explanation for what he experienced, and why the commander did not carry out an extra check. Neither of them had any reason to expect that there should be a sudden serious defect on an aircraft they had just flown without any problems.

2.2.3 It is the opinion of the AIBN that the crew of OY-JRJ exhibited good judgement when they declared an emergency and requested increased emergency readiness as soon as the serious problems occurred. Based on the available information, it seems that air traffic control and airport management handled the emergency situation well.

2.3 Technical findings and performed maintenance work

2.3.1 In the opinion of AIBN, the damage to the leading edge fairings and the flange on the main beam resulted from abnormal movement when the hinges became loose. The lightning strike marks that were discovered subsequent to the event are assumed to be of an earlier date, and had no effect on this occurrence.

2.3.2 In the opinion of the AIBN, the self-locking nuts on the centre and outboard hinges cannot have been tightened with the required torque, as they are not exposed to forces that could cause them to loosen. (No rotational forces). The maintenance documentation shows that the bolts/nuts have not been touched since 1999. This indicates that the installation carried out in France in 1999 was not according to specification. It is most probable that the two nuts were only applied/tightened finger tight, without this being discovered.

2.3.3 It seems reasonable to assume that the mandatory error capturing method has not been carried out, or was unsatisfactorily performed. One common method in practice is an independent double inspection with separate signing off of completion in the company's maintenance documentation. Further underlying factors can, however, not be excluded. Investigation has not been made as to whether the workshop had established, and received official aviation authority approval of, systems and methods for error capturing in critical systems, and whether the maintenance documentation showed clearly that the installation should be inspected before panels were reinstalled.

2.3.4 The following findings indicate that the nuts on the centre and outboard bolts have been loose for a long time:

- Wear on the surface treatment of both bolts indicates that they have rotated and wandered sideways in the hole
- Corrosion in the centre and outboard boltholes indicates that there has been a loose connection, so that there could be moisture ingress into the hole

2.3.5 The following findings indicate that the centre hinge bolt fell out earlier than the outboard bolt:

- Presence of grease in the centre bolt hole indicates that lubrication has taken place while the bolt was missing
- Accumulation of pollution had increased the diameter of the bolt to such an extent that the associated washer could not be affixed
- Vertical abrasions on the centre fixed bushings indicate that the centre part of the elevator spar has not been supported and has moved up and down when the elevator moved/was under load.

2.3.6 The nut that was found by the outboard hinge was not worn. The self-locking force, which is equivalent to 33 lb, would in the opinion of AIBN have been sufficient to keep the assembly in place if the nut had been tightened in accordance with the specifications.

2.3.7 Later inspections did not reveal that the elevator had been incorrectly installed. In the opinion of AIBN, it is not reasonable to expect that the error should have been discovered during lubrication and General Visual Inspection (GVI), as this work can be carried out without removing the panels that hide the hinges. During a detailed visual inspection, "DVI of Elevator Fittings", it should, however, be expected that a technician would discover the loose/missing nuts and bolts in these hinge assemblies.

2.3.8 The technician who carried out the detailed visual inspection of OY-JRJ in February 2003 did not discover any anomalies. AIBN considers that it is not possible to determine with any certainty the condition of these hinge assemblies at the time of this inspection. The grease in the centre bolt hole may have been applied during the lubrication that took place in November 2004 or earlier. Nor can any of the other findings place an exact time on exactly when the centre bolt fell out. It cannot be excluded that the bolts were in place in the bearings, with the nuts loosely fitted, when the DVI was performed.

2.3.9 Expectation (confirmation bias) may also be an element here, as the technician was primarily looking for cracks and corrosion, and did not expect there to lack bolts and/or nuts in the hinge assemblies. This is part of the dilemma, with respect to how specifically and detailed the description of an inspection should be. It is important that personnel who perform an inspection both gain a general overview and focus on special details.

2.4 Responsibility for double inspection after maintenance work on critical systems

2.4.1 EASA Part 145-approved maintenance organisations are obliged to have procedures that identify safety-critical tasks or processes that require special methods for capturing and rectifying maintenance errors before the aircraft returns to operations. Also, the operator is responsible for determining what maintenance is required, and to what standard to ensure the continued airworthiness of the aircraft. The manufacturer is not obliged to contribute in identifying and indicating what is critical/what requires double inspection. (Ref. pt. 1.6.5).

2.4.2 AIBN is of the opinion that the current division of responsibility may have the effect that no assessment is taking place regarding which tasks are to be considered critical and therefore should undergo double inspection. The following text is from a Scandinavian Part 145 maintenance organisation's MOE EASA PART 145 Part 2, Maintenance Procedures:

> *"2.25 PROCEDURES TO DETECT AND RECTIFY MAINTENANCE ERRORS*
>
> *[Name of Part 145 organisation] will where manufacturer, TC holder etc. require it, perform double control of the work specified in the maintenance data. …"*

2.4.3 The text shows that the maintenance organisation uses manufacturer (and others) specifications as basis for double inspection requirement. In today's market, where operators to a larger extent than before buy maintenance services from different organisations, the possibility for continuous transfer of experience between operator and workshop is reduced. Maintenance documents provided by the manufacturer are used regardless of where services are purchased. In the opinion of AIBN, it should therefore be considered whether the manufacturer should be obliged to identify which tasks, as a minimum, should be regarded as safety critical, and to specify certain measures that shall apply.

2.5 Discussion of the need for safety measures to be taken

2.5.1 In this case, an error was introduced onto an aircraft during maintenance work on a safety-critical system. The error was not discovered during the double inspection immediately following installation, later maintenance work, various inspections, checks or pre-flight check of elevator function. Several safety barriers seem to have failed in turn, so that one single error was allowed to develop into a serious situation involving control problems during flight. Such circumstantial factors as position of the centre of gravity, weather conditions and the fact that the aircraft did not receive consequential damage when the elevator detached, all contributed to it being possible for the crew to handle the situation and carry out a controlled landing.

2.5.2 AIBN has considered whether the knowledge gained from this investigation should result in safety recommendations that would prevent recurrence. Design, construction, maintenance and operational procedures could; basically, all form relevant areas for improvement.

2.5.3 In the opinion of AIBN, the accident has not revealed construction weaknesses that clearly question the certification of the aircraft in regard to JAR/FAR Part 25. Integral redundancy in the elevator system seems to have fulfilled the fail safe criterion. Use of self-locking nuts for the relevant purpose is common and tried and tested.

2.5.4 Special procedures are required when maintenance work is performed on safety critical systems, and responsibility for double inspection is discussed in pt. 2.4 above. In the opinion of AIBN, the current division of responsibilities regarding identifying which tasks are critical and requires double inspection should be reconsidered by the authorities. A safety recommendation is made on this subject.

2.5.5 AIBN has considered if the current inspection program should be amended to include inspection of the bolts/nuts in the elevator hinge assemblies. However, nothing indicates that a self locking nut on these bolts will come loose when correctly tightened. Any error on the installation has to be captured before the aircraft returns to service. Therefore, no recommendation regarding inspection with purpose to capture such errors at a later stage is made.

2.5.6 A recommendation to change the procedure in which the first officer checks the elevator and stabiliser was considered, but decided against. Both of the pilots are basically qualified to assess elevator functions, and division of labour should be that which provides best flow. The opinion of AIBN is that pilots should note this incident and learn from others' experience. This illustrates the importance of taking abnormal responses when checking elevator functions seriously, and involving other crew members when in doubt.

3 CONCLUSIONS

3.1 Findings

a) The right elevator was probably installed on the stabiliser without the self-locking nuts on the centre and outboard hinge bolts being tightened to the correct torque following a major service and repaint of the aircraft in 1999. This has allowed the nuts over time to loosen from the bolts.

b) The mandatory double inspection (error capturing method) following installation of the right elevator was not performed, or was performed unsatisfactorily.

c) The elevator hinges will normally only be visible during a Detailed Visual Inspection of the Elevators Fittings (DVI), which is performed every 8th year. The DVI does not specify special attention to the bolts/nuts/bearings in the hinges.

d) Detailed Visual Inspection of the Elevators Fittings (DVI) was performed in February 2003 without discovering the incorrect assembly.

e) The bolt in the centre hinge assembly had, at an earlier point in time, probably several months before the accident, fallen out of the hinge and into a space in the elevator.

f) The first officer registered that movement of the elevator required some more force than normal before take-off, but concluded that was probably because of wind.

g) The bolt in the outboard hinge assembly fell out during take-off, so that the elevator was only attached to the stabiliser by the inboard hinge assembly during the flight in question.

h) The outer part of the elevator was hanging below the stabiliser, which made it difficult to maintain control of the aircraft.

i) The aircraft returned and landed 7 minutes after take-off without further incident.

j) Power was not disconnected from the cockpit voice recorder, which had a capacity of 30 minutes, after landing, and recordings from the period in question were recorded over.

3.2 Significant investigation results

The control problems experienced by the crew during take-off and the rest of the flight began when the outboard of the three hinge bolts that attach the right elevator to the stabiliser loosened and fell out. As the centre bolt had fallen out at an earlier point in time without being discovered, the elevator was hanging in place only attached by the inboard hinge.

The self-locking nuts that should hold the centre and outboard hinge bolts in place cannot have been tightened with the required torque.

4 SAFETY RECOMMENDATIONS

Incorrect installation of the nuts on the hinge bolts on the elevator was not discovered. The manufacturer’s maintenance documentation does not specify that installation of elevators must be double checked. The maintenance organisation has responsibility for identifying which maintenance tasks and processes are critical to safety and require special measures for discovering and correcting any errors found. At the same time, the operator is responsible for specifying what maintenance work should be carried out, and to what standard it should be carried out, when it purchases maintenance services from a maintenance organisation. In the opinion of the AIBN this division of responsibility may lead to the systematic assessment and specification of which tasks should be double checked not taking place. For this reason, the AIBN recommends that

JAA/EASA consider whether the regulations should be amended in order that systems that are critical to safety are double checked following maintenance work. Special consideration should be made as to whether the manufacturer should be given a responsibility on this matter. (AIBN recommendation 12/2006).

The cockpit voice recording from the occurrence was recorded over, because the duration of the recording was only 30 minutes, and the power supply to the recorder was not disconnected after landing. The AIBN has noted that several operators lack procedures to ensure that registered data is retained, and recommend that JAA/EASA consider whether the regulations (Appendix 1 JAR OPS 1.1045 pt. 11) should specify that procedures must be drawn up for preservation of data from flight and cockpit voice recorders and included in operation manuals, so that the JAR OPS 1.160 requirements are better adhered to. (AIBN recommendation 13/2006).

5 APPENDICES

Appendix 1: Abbreviations

Appendix 2: ATR Job Instruction Card Elevator Removal and Installation

ACCIDENT INVESTIGATION BOARD NORWAY

Lillestrøm, 10 April 2006

ABBREVIATIONS

AAIB UK	Aircraft Accident Investigation Branch (UK)
AIBN	Accident Investigation Board Norway
AOC	Air Operator Certificate
BEA	Bureau Enquêtes-Accidents (French Accident Investigation Board)
CVR	Cockpit Voice Recorder
DAT	Danish Air Transport
DVI	Detailed Visual Inspection
EASA	European Aviation Safety Agency
FAA	Federal Aviation Administration
FAR	Federal Aviation Requirements
FDR	Flight Data Recorder
ft	Foot, feet
GVI	General Visual Inspection
HCLJ	Accident Investigation Board (Denmark)
hPa	Hectopascal
ICAO	International Civil Aviation Organization
JAR	Joint Aviation Requirements
kt	Knot/knots
MAC	Mean Aerodynamic Chord
METAR	Meteorological Aerodrome Report
MPD	Maintenance Planning Document
NM	Nautical mile, equivalent to 1 852 m
OPC/PC	(Operators) Proficiency Check
QNH	Altimeter adjusted so that height above sea level is shown when the aircraft is on the ground
RWY	Runway
SLV	Statens Luftfartsvæsen (Danish CAA)
SHT	The Accident Investigation Board Norway
TODA	Take-off Distance Available
UTC	Co-ordinated Universal Time

Job Instruction Card Elevator Removal and Installation

…

003 INSTALLATION

REF. FIG. : 552000-RAI-00102
REF. FIG. : 552000-RAI-00110
CAUTION: BEFORE INSTALLING THE NEW ELEVATOR, IT IS MANDATORY TO VERIFY THAT THE IDENTIFICATION PLATE LOCATED AT THE AFT PART OF NEW ELEVATOR SPECIFIES: ATR 42.
WARNING: INSTALLATION OF INCORRECT ELEVATOR (E.G. ATR 72 ELEVATOR) COULD HAZARD THE A/C.
NOTE: THE FOLLOWING PROCEDURE IS IDENTICAL FOR BOTH SIDES (L OR R).

1. ELEVATOR INSTALLATION (DETAIL B):
   A.LIFT UP THE ELEVATOR.

NOTE: THE ELEVATOR WEIGHS APPROXIMATELY 70.5 KG (155 LBS). USE CARE WHEN HANDLING TO PREVENT DAMAGE TO ELEVATOR AND ADJACENT A/C STRUCTURE.
NOTE : INSTALL BOLTS IN POSITIONS RECORDED ON REMOVAL.

   B.PLACE THE ELEVATOR ON THE HORIZONTAL STABILIZER CORRECTLY.
   C.INSTALL BUSH (9).
   D.INSTALL BOLT (7) WITH WASHER (8) BELOW HEAD.
   E.INSTALL WASHER (11) AND NUT (10).
   F.TIGHTEN NUT AT 3.9 TO 4.5 MDAN (343 TO 396 LBF.IN).
   G.INSTALL BONDING LEADS.
2. POSITION TRANSMITTER LINK INSTALLATION (SECTION D-D ONLY L SIDE):
   A.PLACE SLEEVE (5) BETWEEN LINK (1) AND FITTING HOLE.
   B.INSERT BOLT (4) WITH WASHER (6) BELOW HEAD.
   C.INSTALL NUT (3).
   D.TIGHTEN NUT AT 0.2 TO 0.5 MDAN (18 TO 44 LBF.IN) AND SAFETY WITH COTTER PIN (2).
3. CONTROL LINK INSTALLATION (DETAIL C):
   A.PLACE THE LINK (17) CORRECTLY.
   B.INSTALL BOLT (12) WITH WASHER (13) BELOW HEAD.
   C.INSTALL WASHER (16) AND NUT (15).
   D.TIGHTEN NUT AT 0.3 TO 0.8 MDAN (26.5 TO 70.5 LBF.IN) AND SAFETY WITH COTTER PIN (14).
   E.AT EACH ELEVATOR REMOVAL/INSTALLATION (INSPECTION,REPAIR AND SO ON) AND FOR THE INSTALLATION OF THE NEW ONE,TAKE CARE THE FOLLOWING NOTE: THE MAX ALLOWED AXIAL GAP ON THE ELEVATOR HINGE IS 0,7MM

004 CLOSE UP

REF. FIG. : 552000-RAI-00100

1. REMOVE SAFETY CLIP AND TAG AND CLOSE THE FOLLOWING CIRCUIT BREAKERS:
   - 32DM
   - 63DM
2. CONNECT ELECTRICAL CONNECTORS 5059VCA AND 5060VCA.
3. INSTALL ACCESS PANELS 333CT, 333DT, 333ET, 343CT, 343DT, 343ET.
4. MAKE CERTAIN THAT WORKING AREA IS CLEAN AND CLEAR OF TOOLS AND MISCELLANEOUS ITEMS OF EQUIPMENT.