COMISIÓN DE INVESTIGACIÓN DE ACCIDENTES E INCIDENTES DE AVIACIÓN CIVIL

A-040/1999

TECHNICAL REPORT

Accident of aircraft Agusta A-109-E, registration EC-GQX, in the municipal area of Villarejo de Salvanés (Madrid), on 26th July 1999

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SUBSECRETARÍA

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WARNING

This Report is a technical document which reflects the point of view of the Air Accidents and Incidents Investigation Commission (CIAIAC) regarding the circumstances in which the event being investigated happened, with the relevant causes and consequences.

In accordance with Annex 13 to the International Civil Aviation Convention and with Royal Decree 389/1998, of 13th March, which regulates the investigation of civil aviation accidents and incidents, the investigation is of an exclusively technical nature, without having been targeted at the declaration or limits of personal or financial rights or liabilities. The investigation has been carried out without having necessarily performed legal evidence procedures and with no other basic aim than preventing future accidents. The results of the investigation do not determine or prejudge any disciplinary proceedings that, concerning the event, may be brought by the *Ley de Navegación Aérea* (Air Navigation Law).

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Abbreviations

00 ºC	Degrees centigrade
00º 00' 00"	Degrees, minutes and seconds
Ac	Altocumulus
ACC	Area Control Centre
ADF	NDB signal receiver
AIP	International Aeronautic Publications
APP	Approach Control Office
ATC	Air Transit Control
CAT I	OACI Category I
Ci	Cirrus
CTE	Captain
Cu	Cumulus
CVFR	Controlled Visual Flying Rules
CVR	Cockpit voice recorder
DH	Decision Height
DME	Distance measuring equipment
E	East
EPR	Engine pressure ratio
FAP	Final Approach point
FDR	Flight Data Recorder
ft	Feet
g	Gravity acceleration
GPWS	Ground Proximity Warning System
h	Hours
hh:mm	Time expressed in hours and minutes
hPa	Hectopascal
IAS	Indicated Air Speed
IFR	Instrumental Flying Rules
ILS	Instrument Landing System
IMC	Instrumental Meteorological Conditions
INTA	National Airspace Technology Institute
Kms	Kilometres
Kts	Knots
Kw	Kilowatts
lbs	Pounds
m	Metres
min	Minutes
MAC	Middle aerodynamics cord of the aircraft
mb	Millibars
MDA	Minimum Descent Altitude
MDH	Minimum Descent Height
METAR	Ordinary Meteorological Report
MHz	Megahertz
N	North
N/A	Not applicable
NDB	Non-Directional Radio Beacon
MN	Nautical Mile
MPa	Megapascals
P/N	Part Number
QNH	Adjustment of the pressure scale so that the altimeter marks the airport's height above sea level on takeoff and landing
RVR	Runway Visual Range
S/N	Series Number
SAS	Stability augmentation system
Sc	Stratocumulus
Shp	Shaft horse power
SVFR	Special Visual Flying Rules
UTC	Co-ordinated Universal Time
VMC	Visual Meteorological Conditions
VOR	VHF omnidirectional radio beacon
W	West

1. FACTUAL INFORMATION

1.1. History of the flight

The helicopter, which was used for medical evacuation with operations based in Las Rozas (Madrid), had flown to the operator's maintenance base, in San Vicente del Raspeig (Alicante), on 23rd July 1999, and once there had been subject to a maintenance inspection after having reached 300 flying hours during 24th and 25th July, the day on which it had been declared airworthy after the maintenance.

The helicopter took off from San Vicente del Raspeig around 4:45 h UTC on 26th July 1999, with the intention of flying to the operations base in Las Rozas. The pilot was the only person on board.

At around 6:00 h UTC (8:00 hours local time) on that day, a witness who was working in a field in Villarejo de Salvanés saw the helicopter at a high altitude, going in the direction East-West. After a few seconds he looked again and saw that the aircraft had lost considerable altitude while it was approaching where he was standing. When it was vertically above the witness, it turned 180º thus flying West to East whilst making a lot of noise and then crashed into the ground violently. There was no fire. The aircraft was destroyed and the pilot was killed due to the impact with the ground.

1.2. Injuries to persons

INJURIES	FATAL	SERIOUS	MINOR/UNINJURED
CREW	1		
PASSENGERS			
OTHER			

1.3. Damage to aircraft

The aircraft was destroyed due to crash into the ground.

1.4. Other damage

The accident occurred in a field of young olive trees and the aircraft hit one of them. There were no other damages.

1.5. Personnel information

PILOT IN COMMAND

Age / Sex:	43 years / Male.
Nationality:	Spanish.
Title:	Helicopter Commercial Pilot
Title Number:	602
Length of Service:	19-2-1988

Record of flying hours on 21-6-1999 (times rounded to hours):

Total flying hours:	3846 h
Hours over the last 12 months:	300 h
Hours in the type during last 12 months:	121 h
Hours in the last 30 days:	46 h
Hours in the last 7 days:	18 h

After the 21-6-1999, the pilot only made the flight of the day of the accident, which should have lasted for one and a quarter hours.

The pilot's flight record for the last year included the following helicopter models (times rounded to hours):

Bell 47	14 h
Bell 205	10 h
Bell 206	84 h
Bell 212	32 h
Bell 412	37 h
Agusta 109	121 h

1.6. Aircraft information

El Agusta A109E is a two-engine, four-blade helicopter with retractable landing gear. The minimum crew is one pilot, and it may carry another six occupants in its medial services version.

The EC-GQX helicopter had been registered in Spain on 27th March 1998. It was used for emergency medical services, for which purpose it had a specialised interior kit installed.

1.6.1. Airframe

Make:	Agusta
Model:	A-109-E
Manufacture no.:	11013
Year of manufacture:	1997
Registration no.:	EC-GQX
M.T.O.W.:	2850 kg
Owner:	Helicópteros del Sureste, S.A.
Operator:	Helisureste

1.6.2. Airworthiness certificate

Number:	4173
Type:	Public Passenger Transport, Public Cargo Transport, Aerial Work, Normal
Date renewed:	13/01/1999
Expiry Date:	13/01/2000

1.6.3. Maintenance record

Total Flying Hours:	302 h
Last annual inspection/300 h:	25-7-1999 (301 h)
Hours since last inspection/300 hours:	1 h 15 min

1.6.4. Engines

LEFT ENGINE:

Make:	Pratt & Whitney
Model:	PW-206-C
Power:	549 SHP
Series number:	BC0028
Total hours:	302 h
Last inspection/300 hours:	25/7/1999
Hours since last inspection/300 hours:	1 h 15 min

RIGHT ENGINE:

Make:	Pratt & Whitney
Model:	PW-206-C
Power:	549 SHP
Series number:	BC0025
Total hours:	302 h
Last inspection/ 300 hours:	25/7/1999
Hours since last inspection/300 hours:	1 h 15 min

The maintenance work listed below had previously been carried out on the helicopter (times rounded off):

22-6-98, at 101 h	100 h inspection, type A+B
19-12-98, at 197 h	100+200 h + 12 months inspection, type A+B
25-7-1999, at 301 h	100+300 h + 12 months inspection, type A+B

During the last inspection, the sleeves of the scissors assembly were found to be loose, and so it was disassembled, the sleeves were changed, the scissors assy. re-assembled and its mounting bolt assembled to the swashplate.

A test flight was then carried out on 25-7-1999, of approximately 45 minutes, with satisfactory results.

1.6.5. Main rotor elements

The rotating controls of the main rotor include (see figures in appendix E):

- Swashplate (item 40 in Figure 62-34 of the Maintenance Manual which is included in Appendix E) which transmits the control commands to the rotor blades control movements.

- Four pitch-varying links (item 20 in the aforementioned figure in Appendix E).

- Rotating scissors, which consist of two parts articulated together and joined at one end (the upper end) to the rotor head (see items 12, 13 and 14 of figure 62-20 in Appendix E) and at the other (the lower end), by a spherical bearing, to the outer ring of the swashplate. The upper part ("lever assy., half compass", P/N 109-8110-16-1) is marked in the Illustrated Parts Catalogue as item 9, Figure 1 of page 23, 62-31-00, 01/98 (see Appendix E). The lower part ("half-scissors assy.", P/N 109-0134-10-105) is marked in that figure as item 17. This set includes a spherical bearing on its lower part through which a screw passes which does not appear in the figure, but is indicated as item 20 (P/N NAS6606D28, "Bolt, close tolerance") in Figure 2 (sheet 2 of 2) 62-

31-00, Page 29, of the Illustrated Parts Catalogue A109E IPC, a copy of which can also be found in Appendix E.

Throughout this report we will specially refer to the half-scissors assy. The bolt or mounting bolt (P/N NAS6606D28) of these "half-scissors" with the swashplate is also subject to special attention throughout this report.

The swashplate (refer again to Figure 62-34, sheet 1 of 3, in Appendix E) is moved by the rotor head by means of the scissors assy. and turns around the non-rotating tilting plate which is supported on bearings. The control commands reach both plates by of three hydraulic actuators which are coupled by means of sleeves with spherical bearings to the three arms of the non-rotating plate and is transmitted to the tabs located at the base of the rotor blades to change their pitch angle, by means of the four mounting links which connect these tabs to the pins of the four arms of the swashplate.

When the three hydraulic actuators are operated to the same extent, the swashplate is displaced vertically, whatever the angle of the plate, and this changes the collective pitch. If the three actuators are operated differently, whatever the vertical position of the swashplate, its angle is changed and this changes the cyclic pitch of the blades.

1.7. Meteorological information

The general situation in the Province of Madrid between 5:00 h and 7:00 h UTC, according to the information supplied by the National Meteorological Institute was a strip of medium and high clouds with some cumulus or large cumulus which affected the area in question (Villarejo de Salvanés). The surface winds in this area were light, from 3 to 5 kt, south-easterly. Winds forecast at 1500 metros were southern from 10 to 15 kt.

The METAR of Barajas Airport on 26-7-1998, at 6:00 h UTC was:

Wind: Calm.

Visibility: 10 km or more

Cloud: 3 to 4 oktas at 4000 ft, 3 to 4 oktas at 10000 ft

Temperature: 21º C

Dew point: 13ºC

Pressure at sea level: 1014 mb

1.8. Aids to navigation

Not relevant for the investigation of this accident.

1.9. Communications

There is no record that the helicopter made any communication during the flight from San Vicente del Raspeig until it crashed into the ground in Villarejo de Salvanés.

1.10. Aerodrome information

Not relevant for the investigation of this accident.

1.11. Flight recorders.

The aircraft did not carry flight recorders. They are not mandatory for this type of aircraft.

1.12. Wreckage and impact information

The accident had occurred in the area known as "Monte de los de Madrid", municipal area of Villarejo de Salvanés (Madrid), at an altitude of km 5,500 from the M-321 motorway from Villarejo de Salvanés to Villamanrique de Tajo.

When the investigation team arrived at the place of the accident, it observed that the helicopter, which had hit a small olive tree, was 50 m from the motorway and upside down, with the landing gear retracted. In Appendix A a sketch of the wreckage trail can be seen, and in Appendix B a series of photographs have been included of the state of the wreckage as it was found.

The area was cultivated land, flat and with little vegetation.

The majority of the wreckage, including the thrown parts, was found within a circle with a radius of around 30 m.

The rotor appeared to the left of the fuselage. The rotor head had the four blades still fastened, although the trailing edges had come off and the spars were badly damaged. The red blade spar was broken. The elastomer bearing had come out of its casing. The marks on the ground and other evidence showed that the main rotor blades had crashed into the ground, had fractured and the trailing edges and other parts had been thrown in a straight line. Furthermore, a metal part of the anti-abrasion protection and the fairing of the end of a blade were found on the other side of the motorway, about 60 m from the main wreckage.

The support of the right leg of the landing gear was very damaged, whilst the left leg was affected less by the impact.

These facts indicated that the rotor had been turning during the accident. The deformation of the fuselage suggested that on impact the position of the nose was high and a tilt to the right.

The tail boom had been cut by the main rotor blades during the impact and was left 6 m behind the fuselage. The tail rotor had come loose and ended up near the cone. The two blades of the tail rotor were present and highly damaged.

The electrical battery had been thrown two metres to the right of the fuselage, with consequent damage to the nose section of the fuselage, the rest of which was not crushed.

The fuel tank had broken and some fuel had spilt. It was not possible to estimate the amount on board at the time of the accident.

1.13. Medical and pathological information

The pilot, the only occupant of the aircraft, had a number of injuries that caused his death. The main cause of the death was politraumatism. His body had remained held in by the belts within the helicopter, from which he was extracted by firemen. He had an open fracture on the distal end of his right tibia and fibia, which was in keeping with the fact that the helicopter had hit the ground tilted to the right side, and the pilot was putting his right foot down.

A chemical-toxicologist analysis was carried out and none of the toxins investigated were detected in it.

1.14. Fire

There was no fire during the accident. The fuel tank was found to be broken and fuel had spilt on the ground.

1.15. Survival aspects

Although the pilot, who was wearing a flying helmet, was held in by the seat belt, the crash happened at a high vertical speed and with the helicopter leaning towards the right (the side on which the pilot was sitting). The "livable space" of the cockpit had reduced substantially due to the crush of the right side of the fuselage and the roof of the cockpit. Both seats had twisted to the right as a result of the forces of inertia from the impact. The right seat had come out of the safety rails.

On observing the wreckage, it was concluded that the possibilities of survival on impact were few.

The witness who saw the accident went to the motorway nearby the site and got a motorist to telephone the emergency services, which arrived after a few minutes.

1.16. Tests and research

1.16.1. <u>Detailed investigation of the wreckage at a hangar.</u>

During the afternoon of the day of the accident, once a detailed in situ inspection of the wreckage had been carried out and after having concluded the field investigation phase, the wreckage of the helicopter was taken to a hangar in Alcorcón (Madrid), to carry out a more detailed inspection of the state of the helicopter's framework and systems and to establish whether some parts of it should be sent to specialised laboratories for an exhaustive examination.

This inspection began the day after the wreckage was moved, and was carried out by personnel from the Accident Investigation Commission, with assistance of the aircraft manufacturer, Agusta, of the engine manufacturer, Pratt & Whitney Canada, and of the operator.

The most important conclusions drawn from this investigation are set out below, summarised from the detailed reports prepared by those present.

1.16.1.1. Inspection of the airframe wreckage.

The wreckage was positioned in the helicopter's normal position on the ground and it could again be seen that the deformation had occurred mostly on the right side of the fuselage. The cockpit was completely crushed. The seats were leaning to the right. The cowlings were removed to allow good visibility and the framework was cut to access the flight controls.

The flight instruments and controls gave the following readings and were in the following positions:

- Right and left airspeed indicators: 0 KIAS

- Right altimeter: 2700 ft (adjustment 1014 hPa)

- Left altimeter: 2600 ft (adjustment 1014 hPa)

- Right vertical speed indicator: 450 ft/min in descent

- Left vertical speed indicator: 925 ft/min in descent

- Helipilot Panel (autopilot):	SAS 1: Off
(SAS: “stability augmentation system”)	SAS 2: Off
	COUPL.: On
	Autotrim: On
	Attitude Hold: On

- Hydraulic system control switch: BOTH

- The Attitude Director Indicators displayed a 40º tilt to the right.

- The collective landing gear controls box had come loose and on it it was seen that the Eng. Gov. was in auto and the RPM at 102.

The mast of the main rotor was leaning sharply backwards. The front mounting rods had broken in drive. The back right mounting rod was folded in two and broken. The tail rotor blade had folded in two and broken on its left side.

The transmission from the rotor to the shaft was broken.

As had been observed in the field when looking at the tail cone, the strong flapping of the blades downwards had made one of them hit the engine exhaust, the back baggage area, the horizontal tail and the control stick of the tail rotor.

The tail rotor drive shaft had broken at the front and was out of shape in other parts.

The rotor itself could be turned by hand, in spite of the damage that had been caused especially on its blades.

By looking though the peephole, the hydraulic liquid tanks seemed to be empty, and various hydraulic pipes had broken.

Experts considered that evidence showed that both the main rotor and the tail rotor were turning rapidly at the time of the crash.

1.16.1.2. Inspection of the engine wreckage.

Both engines had come out of their mounts. The air intakes were broken and out of shape, but as for the rest, with the exception of some minor damage in the Fuel Management Modules due to the crash, the engines externally did not appear to be out of shape, dented or crushed.

The airframe exhaust pipes and cowling were considerably damaged and out of shape.

The power turbine discs, with their blades, were intact in both engines and could easily be turned by hand.

The drive shafts of both engines had come free from the couplings with the main transmission. They had a few slight spiral marks which indicated that they had come into contact with adjacent parts of the structure.

The compressor of the BC0028 engine (left) could be turned by hand. In the right engine this could not be seen since the distortion of the air intake prevented its outer part from being dismantled easily. In this engine there was obviously dust and earth in the air intake. The air intake of the left engine was relatively clean.

The electronic engine controls (EEC) were visible, although they could not be taken apart since parts of the cell surrounding it were crushing it. The engine controls in the cockpit that could be seen showed the following positions:

- Engine Governor Switches: Normal

- Power levers: The left in flying position and the right slightly forward, towards maximum.

- Rotor % RPM switch: 102%

The collective landing gear switch box had separated from the lever.

After this initial inspection, it was established that in principle it was not suspected that the engines had contributed to the accident, and therefore a more detailed examination was carried out and the investigations focussed on other parts of the helicopter, in particular on the main rotor control system.

1.16.1.3. Second inspection of the airframe wreckage.

A while after the first inspection of the wreckage, again with the assistance from the manufacturer, a more detailed examination was carried out in the hangar, in order to:

- Check the type and series of fractures in the flight controls.

- Analyse how the elastomer of the red blade failed.

The manufacturer's concluded that all the fractures analysed seemed to be a result of the accident. Below, the information supplied by the experts that carried out the inspection is reproduced, almost word for word.

It was not established whether there were disconnections in the control system. In a few cases, a same component showed two different fracture sections, with different types of fracture in each section. The experts established that the fractures probably happened in quick succession with different loads. This in principle made it possible to discard vibration as a cause of the loads that caused the failures.

The elastomeric bearing (elastomer) part number (P/N) 109-0111-04-101 (LORD P/N LB4-1077-4-1), serial number LK0096, installed in the red blade was broken. The section that had failed was the top rubber layer on the inner face.

The date on which the 4 elastomers were cured was September 1996. It was established that part of the surface was not bonded properly (around 25%). There was a scratch on a small area, almost insignificant. If the part had broken prior to the crash, the two surfaces would have been joined closely together by centrifugal force and, when the blade made several movements during the accident, the scratch should have been very heavy.

The manufacturer reported that this element is a component which is “damage tolerant” with no limited life, and is replaced according to its state during inspections. The elastomer did not display signs of rubber scratches which are typical when one of these components begins to degrade. Therefore, the possibility of a progressive failure was eliminated.

The manufacturer also reported that the elastomer is continuously subject to a compression load, both on the ground (700 kg) and in flight (14000 kg). This compression load maintains the correct position of the elastomer even in the event that a layer of rubber fails. Therefore, the lack of compression may be critical for the structural integrity of the elastomer. In their opinion, that could only have come about in the final stages of the helicopter’s crash whilst the rotor was coming to a stop.

The four arms of the rotor head showed signs of having come into contact with the elastomer casing. The marks were in keeping with the movement of the blades during impact with the ground. The red arm seemed to be slightly less damaged than the others. Other evidence indicated that the red blade had been the first to hit the ground.

The fractures of the four flap limiter stops were the same, which led to the conclusion of the same series of fractures. A failure in one of these stops may only occur when the elastomer is in the correct position, and after the lower static stop fails.

In addition to thesee two examinations (flight controls and elastomer), the following was established:

- Engine operating control switches located in the ceiling panel: It was observed that the position of these switches was not the normal flying position. The switch of engine 1 was in “IDLE” and engine 2 in “OFF”. The gas levers, used only for manual control of the governor of each engine, were both in the flying position.

The roof panel was highly damaged and other switches were damaged or deformed due to the crash. Nevertheless, the OFF position may only be reached after pushing and rotating the switch, while the IDLE position simply needs to be rotated.

This position of the switch of engine 2 was the only sign of any engine malfunctioning, whilst the marks of the rotating parts indicated that the main and tail rotors were rotating rapidly during the crash. An engine failure would have required, according to the flight manual, the gas lever to be put into OFF and shut off the fuel, whilst both were found in a position consistent with a normal engine condition.

- Blade tip cap of the main rotor: the four tip caps had come off the blades but were found at the site of the accident. They were extremely damaged, as to be expected due to their impact with the ground whilst the rotor rotated. The parts detached from the blades did not indicate that they had become unbonded.

- Leading edge shield of the main rotor (blue blade): One part of this shield was found around 60 m away from the main wreckage site. This part showed a good condition of the spar bonding and the damage was a result of the impact with the ground with the rotor rotating. Therefore, the part had not become detached during flight.

- Grip lower static stop of the main rotor: The four stops had come away from the grips. They showed static failure due to a stroke against the floating ring as a result of an excessive flapping movement.

- Dampers (main rotor): The four dampers were broken on the thread rod fillet of the lug end. The failures were static due to overload, three in tensión and one, on the red blade, partly bent. The type of failure may have indicated that the first blade to hit the ground and that caused the rotor to stop suddenly was the red one.

- Lower rotating scissors bolt: It was believed that the failure in this bolt was static caused by excessive shear loads and, therefore, seemed to be a consequence of the crash.

-Transmission mounting rods: The forward rods had broken statically under tension, whilst the rear were buckling deformed, with the left one broken in bending mode. The anti-torque plate had also broken on the left side, which led to the hypothesis that the position of the helicopter on impact was with the nose up and tilted to the right.

1.16.2. <u>Inspection of the various components in the laboratory</u>

Since, after the first examinations of the wreckage in the field and in a hangar, clear evidence could not be found of failures in any of the parts or components prior to the crash, nor of malfunctioning of any of the helicopter's systems, it was decided to select a series of parts (fittings and control levers, some of which displayed double fractures) whose fractures led to doubts as to the fracture mechanisms, and to send them to a specialised laboratory to examine them in detail and send the corresponding report on the cause of the fractures.

To this purpose, the parts chosen were sent to the "National Aerospace Technology Institute" (INTA in Spanish) for analysis. In Appendix C photographs of some of the fourteen parts sent to the INTA are included.

The laboratory of the Materials and Structures Department of the INTA analysed the parts, carried out macro and microfractographic studies of the fractures examined, and prepared the report "Study of the fractures of iron parts and control levers of the helicopter Agusta A-109E, registration number EC-GQX" (reference FS1/RPT/4310/057/INTA/00).

In this report, the following was concluded:

- All the fractures were of a ductile nature.

- The small formation of domes is characteristic of a load applied at a high velocity.

-In no case there was fracture due to fatigue, static load or rusting found, neither of a macro nor a microfractographic nature.

- In none of the fractures examined there were signs or marks that due to their appearance or their position were significant and indicative of a concentrated load on sites or areas different to normal loads on the elements that were damaged.

The report includes a detailed description of the load systems that had been basically operating on the various elements in the fracturing process. It is not deemed necessary to include these descriptions in this section since they are extensive and do not affect the general aforementioned conclusions.

The final conclusions of the report are:

- All the fractures were caused by static overload with the loads applied at a high velocity, and on all the broken elements the load was concentrated on the areas where they were joined together.

- Signs of progressive fracture were not found in the examined fractures (fatigue or corrosion under tension), nor general or local corrosion that could have weakened the mechanical resistance of the broken elements.

- There was no sign of local failure in the material of the broken parts which could have caused the beginning or development of the fractures.

- The characteristics of the fractures of the hollow coupling shafts indicated that, at the time of the helicopter's crash, the turbine and the main gear box were connected through the shafts.

As a consequence, all of the parts examined broke due to the impact of the helicopter with the ground; in other words, the primary failure that caused the accident is not to be found amongst the parts examined.

1.16.3. Study of the fracture of the lower rotating scissors bolt of the main rotor blades control system

As a result of all the aforementioned inspections and studies in the laboratory, concluding evidence had not been found of a failure or malfunction of any of the helicopter's assemblies, parts or components, and several lines of investigation were kept open until a key fact changed the course of the events.

Indeed, as indicated in section 1.17 of this report, the aircraft's manufacturer and operator informed the investigation team, on 28th August 2000, about a flaw found in the investigation of two accidents of the same helicopter model, which happened in the United Kingdom on 14th January and 17th June 2000, in which there were no fatal injuries.

In the helicopter wreckage involved in the second accident, the lower rotating scissors of the main rotor operating system were found to be assembled in the inverted position, and in the consequent re-inspection of the wreckage of the helicopter involved in the first accident the same failure was found regarding the assembly of this part.

In the two cases, it was the found that maintenance operations had been carried out on the main rotor, approximately 2 flight hours before the respective accidents occurred.

Since in the accident of the EC-GQX the same circumstances were given, a new inspection was carried out on the wreckage of this helicopter, which were still stored in a hangar in Alcorcón, and the same assembly deficiency was found.

The elements affected were taken apart and were sent to the INTA for study with the aim of determining the cause and type of fracture of the lower rotating scissors bolt of the swashplate of the main rotor blades angle control. The components sent were, apart from the bolt itself with its nut:

- the swashplate,

- the complete rotating scissors of the swashplate (fitting part to the rotor head and the two arms),

- the main rotor head with three of the four blades attached, with the four hydraulic dampers also coupled to the attaching plate of the blades,

- three of the four pitch-varying links, between the root of the blade and the swashplate,

- one of the four rotor blades, together with its link to the swashplate still coupled to the blade,

- the sub-assembly formed by the non-rotating tilting head and the hollow cylinder with a spherical bearing at one end on which this plate tilts,

- The upper sleeve of the spherical bearing, and the hardware connecting these parts.

1.16.3.1. Results of the INTA report

As a result of its work, the INTA drew up the report "Study of the fracture suffered by the lower rotating scissors bolt of the main rotor blades control system of the helicopter involved in an accident Agusta A-109-E, Registration number EC-GQX", ref. FS1/RPT/4310/005/INTA/01. In Appendix D various photographs extracted from this report have been included which illustrate the summary below.

This bolt was put to a study, and it could be seen visually that it had been received broken in two parts; one of them, the part corresponding to the thread area in which the nut was located, placed in the spherical bearing of the lower arm of the scissors with the cup washer, and the second, corresponding to the head, fitted in the swashplate.

The piece of the bolt that was received placed in the arm of the scissors, once extracted from this, showed a fracture on the body, at the point where it fitted into the swashplate, developed mostly on a more or less flat surface at a degree of around 45º in relation to the longitudinal axis of the bolt. The path of the fracture at the intersection with the cylindrical surface of the bolt generally matches the contour of this plane, except at two short sections, of approximately 45º, where it is perpendicular to the aforementioned axis.

This bolt had a protective layer which, in some areas of the column, had been partially removed due to rubbing with the inside of the spherical bearing coupling with the lower arm of the scissors.

On the part of the body immediately next to the section of the fracture running perpendicular to the longitudinal axis of the bolt, two parallel dents were observed in an arc of circumference of less than 90º, one of them coinciding with a section of the aforementioned fracture.

Furthermore, on the cup washer, which was found between the nut and the lower arm of the scissors, a dent was found produced by the pressure of the washer against the outer wall of the lower arm of the scissors. On this wall, the corresponding counter-mark was observed.

The nut appeared to have turned regarding the initial position, in relation to the bolt, since the cotter pin, used to lock the nut, had the cotters deformed and displaced regarding the logical position and deformation resulting from the locking. The upper cotter, folded over the outside of the bolt, was placed between the crest of the thread and the wall, whilst the lower cotter had strayed off the position parallel to the longitudinal axis of the bolt.

Once the cotter pin had been extracted, it could be seen that the nut could be turned with fingers in the tighting sense, approximately one and a half turns, before the first thread of the nut hit the point where the thread came out of the bolt.

The bolt material was analysed at the INTA and it was found to correspond to be a SAE 8640 still. Its contents were also analysed in hydrogen, and it was found that it had 1.9 parts per million on the surface and 0.9 parts per million in the nucleus.

The bolt had a protective cover which, after being analysed by the X-ray energy dispersion technique, was found to correspond to cadmium.

Coupons of sections of the bolt material were analysed, obtained by short transversal and longitudinal cuts to determine its metal microstructure. It was concluded that it corresponded, in this type of steel, to a tempering and anneal thermal treatment at 425ºC, approximately.

Another coupon was prepared to determine the size of the primitive austenitic grain, which after being observed under a microscope, showed the presence of a duplex grain size, which could be considered fine.

The average hardness of the bolt material was 434 HV at 30 kg, equivalent to 44 HRc y and a fracture stress of1430 MPa.

1.16.3.1.1 MACROFRACTOGRAPHIC STUDY OF THE BOLT FRACTURE

From the macrofractographic study of the surface of the fracture, it was observed that there was no general plastic macrodeformation, not even associated to the fracture. The surface of the fracture was of a soft texture on which a slight bumpy directional relief was observed, which on the surface of the fracture in area A (see figure INTA III.16 in Appendix D) was of a softer texture with a less pronounced direction than on the rest of the fracture surface.

These marks indicated development of a fracture in the diametrical direction between the aforementioned areas A and B. In area A the existence of grooves around the edge were noticed (see figure INTA III.15 in Appendix D) indicating cracks on parallel planes very close to one another.

There did not seem to be any kind of discontinuity, as far as the texture and the directional marks between these two planes of the fracture (A and B in the aforementioned figure INTA III.16) and the rest of the surface were concerned, nor discontinuities nor sharp changes in direction on the general surface of the fracture.

This macrofractographic study showed that the fracture had developed by a continuous mechanism, from the outer surface of the bolt in area A and ending near the outer wall of the bolt in area B. The absence of plastic macrodeformation indicates that the fracture process, considered from a macroscopic point of view, had been of a fragile nature.

1.16.3.1.2 MICROFRACTOGRAPHIC STUDY OF THE BOLT FRACTURE

On the plane perpendicular to the longitudinal axis of the bolt (area A of figure III.16) and located on the upper part of the diameter parallel to the main rotor shaft, it was seen through the electronic microscope magnified to 1000 X, in areas approximately 1 mm away from the outer wall of the bolt, that a micromorphology had formed by platforms of an irregular contour, marked largely by white edges, which appeared to be superimposed and showed an irregular relief that was not clear at the aforementioned magnification. At a higher magnification (5000 X), these platforms showed a complicated relief that in parts were seen as striated shapes, not very defined, with the presence of associated microcracks.

This micromorphology is typical of fractures produced by fatigue in highly resistant steels treated by tempering and anneal, such as is the case of the material of the bolt being studied.

1.16.3.1.3 STUDY OF THE SCISSORS

The overall scissors assembly was received in a state in which the position of the lower arm did not match up with the position inferred from the information received from Agusta, as can be seen by comparing it with the diagram from the manufacturer in figure INTA III.29-A in Appendix D.

In addition, in this diagram it can be seen that the retaining nut and the spherical bearing, along with the cup washer were located in the bevelled washer, whilst in the overall set of scissors received (figure INTA III.29-B) only the cup washer was between the retaining nut and the spherical bearing, and neither the bevelled washer nor the thin washer were received.

In figure INTA III.30 of Appendix D it can be seen that between the spherical bearing and the bolt fracture there is a space in which the two aforementioned washers were probably placed (bevelled and thin).

In the assembly that the helicopter was carrying, apart from the different position of the washers, the lower arm of the scissors was assembled turned at 180º in relation to its horizontal axis, compared with the position indicated by the manufacturer in figure INTA III.29-A.

On the area of the lower arm of the scissors into which the broken bolt was inserted, marks of crushing were observed which were related to the fracture process. One of these was located on the outer wall of the lower arm above the spherical bearing. This mark matched the one found on the convex face of the washer in the area in which this washer showed deformation due to flexion and in which, in turn, showed a deep dent on its concave face, which had been caused by the pressure exerted by the nut.

These marks make it possible to conclude the relative positions of the scissors and the bolt, and that in these positions the lower arm of the scissors had exerted considerable vertical loads on the threaded end of the bolt, as it was reflected by the intensity and depth of the dent mark, caused by the nut, that was present in the washer, and by the deformation suffered by the washer.

Deformations had also occurred in the spherical bearing ring housing, under the pressure exerted by the bearing itself as a consequence of the angular displacement of the lower arm, which has exceeded the normal values that can be reached in correct functioning.

1.16.3.1.4 STUDY OF THE SWASHPLATE AND PINS

The swashplate, in the shape of a four point star, can be seen in figure INTA I.2 of Appendix D. The housing pins of the links, marked as A, B, C and D in this figure, are located on the four points of the swashplate.

These links are the mechanical connections of the swashplate with the tabs on the base of the rotor blades and which act to vary their pitch (pitch angle).

In the position of pin A the fixing of the bolt connecting the scissors to the swashplate is found, marked with an arrow in figure INTA III.36. On the wall of the swashplate, the fixing area of the bolt can be seen and the fracture surface of the part housed in this fixing. On the wall, a circular ring-shaped mark was observed caused by the pressure from the thin washer, with a dent mark.

Other marks were noticed caused by the pressure from the links on the walls of the swashplate due to a delay in the rotation of the swashplate in relation to the rotation of the main rotor.

1.16.3.1.5 REPORT OF FACTS ESTABLISHED BY THE STUDIES

Of all the fractures present in the examined parts, only the fracture on the mounting bolt of the lower arm of the rotating scissors showed characteristics (progressive fracture due to fatigue) that did not match a fracture caused by the helicopter's crash into the ground and might, therefore, be the primary failure during flight which caused the accident.

The microfractographic elements present on the bolt fracture surface are typical of a fracture process due to fatigue in the type of bolt material, and make it possible to unmistakably classify the bolt fracture as a progressive fracture due to fatigue under the action of variable loads repeated a sufficient number of times.

The characteristics of the material used in the manufacture of the bolt indicate that the material is correct and shows no fault, and so there is no intrinsic factor of the material that justifies a lower performance than that expected when under any kind of mechanical load, including fatigue.

The spreading process of the fracture was rapid and continuous, culminating in a final fracture due to extremely reduced static load, but with the gradual appearance of domes (mixed with striation) before the final fracture.

The fact that there were no fatigue marks on the fracture surface coincides with that process described. This means that there had not been a break in the spreading process, but there may had been an interruption in the mechanical load during the widening phase of the crack, when the crack, which later on spreaded, could not yet be detected, and which meant a high fraction of the total number of cycles necessary for the fracture.

The basic load on the bolt had been bending, acting as a cantilever, mainly under a bending moment on the plane defined by the longitudinal axis of the bolt and the rotating axis of the swashplate (X-Y plane), although in the presence of another lower bending moment on a plane parallel to the swashplate.

Under normal conditions, the only action that exerts the scissors on the bolt is a tangential force, which receives it through the spherical bearing coupling to the lower scissors arm.

If the normal functioning conditions were altered by a change in the overall assembly position of the scissors, the lower scissors arm would exert a lever action which would reach a considerable level of load which would cause the appearance of the bending moment in the aforementioned X-Y plane.

As well as these bending moments, the initial tension caused by the tightening of the nut and the twisting caused during application of this torque may have acted on the bolt. The tightening torque value must be, according to the manufacturer's documentation, between 81 and 104 cm*kg and these values, given the bolt's diameter, do not cause high tension compared to those caused by flexion.

The dominant factor and it is enough in itself that it caused the fracture due to fatigue suffered by the bolt, was the incorrect assembly position of the lower scissors arm. The influence of this position appears to be obvious by comparing figures INTA III.29-A y III.29-B (note that in these figures the upper arm is in the same position).

The other abnormality observed (the bevelled washer was not between the cup washer and the side of the bearer) is not important regarding the effect of the inverted assembly of the lower scissors arm and moreover, if we compare figures III.29-A and III.29-B, in the case of the position of the scissors arm according to III.29-B, the position of the bevelled washer reflected in this figure is more logical and almost required by the resultant geometry.

On fracture of the bolt in which the lower rotating scissors arm is articulated, the swashplate is held back at an angle in relation to the position that it should occupy relative to the base plate of the rotor blades. As a consequence of this, the links from the swashplate to the tabs located at the base of the rotor blades tilt in the direction of rotation of the rotor, until leaning on the inner wall of the guiding pins in the swashplate of the spherical bearings of the lower end of these links, this now being how the swashplate is tightened. This tilting of the links thus causes the pitch to reduce.

Therefore, the scissors bolt fracture immediately causes a decrease in the pitch of the main rotor blades, with the consequent loss of lift, and also the serious functional alteration in the control device.

The scope of the marks and deformations seems to be excessive to have been caused only by a *dragging* action and their origin must be attributed to the action of the hydraulic actuators on the non-rotating plate-swashplate assembly on attempting to correct the loss of lift by increasing the blade pitch by the vertical movement of this assembly. This, with the tilted positions of the connecting rods, forces these even more in their support on the sides of the guiding pins of the spherical bearings of the links.

The possibility was also considered that the bolt, although already cracked by a fatigue process resulting from an anomaly detected in the assembly of the scissors, was not yet completely broken and the final fracture would have happened under the effect of the impact with the ground of the main rotor blades. It was concluded that this was not possible because:

- There was no evidence or sign found in the study of the fracture of discontinuity in the fracturing process.

- If the rotor blades, when stopped by the ground, had had a component that caused a reduced pitch in the blades but without yet breaking the bolt, the rotating scissors, which would tend to close, would exert a bending load on the bolt in the same way as happened in the fatigue process, but, on the bolt breaking, the inertia of the rotation of the swashplate, which would now be forward compared to the angular position in which it should be in relation to the base plate and the links, would tilt in the opposite direction to this, and this sudden action would have left support marks on the walls of the guiding pins of the swashplate spherical bearings, as opposed to the position of the marks actually found.

1.16.3.1.6 CONCLUSIONS FROM THE REPORT OF INTA ON THE BOLT AND THE SWASHPLATE

The study carried out on the elements of the main rotor and its mechanical control system reveals that the helicopter from which they came suffered the fracture due to fatigue of the bolt joining the swashplate to its lower rotating scissors.

This fracture initially caused a reduction in the circumferential pitch of the blades, with the consequent reduction of lift and, moreover, the loss of the correct control of the blades.

The broken bolt did not show any intrinsic flaw in the material from which it was constructed, nor fault in the thermal treatment applied or mechanical preparation.

The fatigue process suffered in the functioning of the bolt was caused by a bending moment, variable and repeated, acting on the plane defined by the longitudinal axis of the bolt and the scissors itself. This moment, which is not caused under normal functioning conditions, occurred as a consequence of a faulty assembly of the lower arm of the rotating scissors, which was installed turned at 180º in relation to its longitudinal axis, compared to its correct position.

The fractographic characteristics of the spreading of the fracture due to fatigue correspond to a continuous and rapid process. Prior to this spreading process there must have been a widening of the crack (damage to the material) which was not detectable by inspection since the crack had not yet formed; this widening needs, under the same load, a period of time equivalent to a considerable part of the total number of cycles necessary for the fracture.

1.16.4. The aircraft's flight path

The aircraft took off from San Vicente del Raspeig (Alicante) and flew in the direction of Las Rozas (Madrid). In Appendix A a reconstruction of the aircraft's flight path is shown as described by a witness, along with a sketch of the break-up of the wreckage. The most important fact regarding this final part of the flight path is that the aircraft dropped suddenly, turned 180º in relation to the initial course that it was following, and continued to descend until crashing into the ground.

1.16.5. Statemenst of witnesses

A witness who was working in the field stated that he saw the helicopter at a high altitude which was going from East to West. After a few seconds, he looked again and saw that it had lost significant altitude whilst the helicopter was getting closer to where he was standing. When it had reached a vertical position over the witness, it turned 180º thus flying from West to East, whilst making a lot of noise, and then it crashed nose down into the floor, causing a cloud of dust. He could see that it had rested on its side, the engine had stopped, and he saw that it let off smoke now and then.

He did not see flames or smoke from the helicopter while it was flying.

He then went to the motorway to see if anyone was passing by and at that moment a vehicle passed and the driver phoned for help.

1.17. Additional information

1.17.1. Similar aircraft accidents in the United Kingdom

The investigation team was informed by the aircraft manufacturer and the operator, on 28th August 2000, about a flaw found in the investigation of two helicopter accidents of the same model, maintained by the same service station, which occurred in the United Kingdom after the EC-GQX accident:

1.- Agusta A109E, G-JRSL, accident on 14 January 2000, with 2 of the 3 people on board suffering minor injuries (Reference from the "Air Accidents Investigation Branch", EW/C2000/01/01).

2.- Agusta A109E, G-TVAA, on 17 June 2000, with 2 of the 3 of the people on board suffering minor injuries (Reference from the "Air Accidents Investigation Branch", EW/C2000/6/6).

In the first accident, both pilots on board heard a sound coming from above and behind, and the helicopter almost went out of control, with total loss of electricity. It rolled to the left and there was a pitching motion upwards. The roll to the left continued, probably until reaching a vertical position (more than 90º) and the helicopter nose-dived sharply while it turned. The pilot could finally gain some control over the aircraft but, in spite of pulling the collective lever to stop the descent in the final stages of what seemed to be a landing without engines, this action had no effect and a hard crash into the ground could not be avoided. The main rotor blades, pitch-varying links and many other components of the rotor head area were broken or disconnected as a consequence of the crash. The subsequent investigation on the engine, the related fuel control and the electro-avionics system did not point out any deficiency.

A combined Annual/100 hour inspection had been carried out on this helicopter recently, and during it the rotating scissors of the swashplate had been changed. Since this change, it had only flown for 45 minutes.

While the investigation into this accident was being carried out, on 17th June 2000 the second aforementioned accident happened, in which, being 300 ft above the ground and at a speed of 60 or 80 kt, a loud noise was heard from the upper back part of the cabin and the helicopter suddenly began to fall. The helicopter made a crash landing but at a low horizontal speed. The landing gear was crushed and the lower part of the helicopter underwent serious damage, but the rotor head area remained intact, which allowed investigators to notice that the bolt of the lower rotating scissors had failed.

Afterwards, it was established that the lower scissors had been assembled back to frontwhich meant that the spherical bearing, through which the restraining bolt of the scissors passed, had restricted movement. The cup washer and the bevelled washer, mentioned in the Maintenance Manual, were not assembled.

This G-TVAA helicopter, built in 1999, had 271 flying hours, and the day before the accident, the lower rotating scissors had been changed due to the fact that excessive play in the scissors bearing had been detected. Since this change, the helicopter had flown 3 hours and 10 minutes until the accident happened.

The metallurgic examination of the bolt revealed that it had failed due to fatigue.

The verification of this fact meant that the G-JRSL helicopter wreckage was re-examined and it was found that also in this case the lower rotating scissors had been assembled back to front. The mounting bolt to the swashplate had also failed in this case, although the first visual inspection had established that the fracture had occurred as a consequence of the crash into the ground due to the fact that the fractured face formed an angle of 45º with the bolt axis. This bolt was also examined in the laboratory and it was established that its failure had been caused by fatigue. The bevelled washer was not found in its correct position.

It was established that in the information in the maintenance manual "...the representation of the lower scissors had not been drawn with enough detail to assist a mechanic in identifying the correct position. One clue to an incorrect installation would be that the flange on the hinger bush would have to be at the opposite end to that shown in order to engage with the machined shoulder on the side of the link". The manual did not contain enough written information on the correct position of the scissors. In fact, there was an error in the instructions, since the bevelled washer was quoted as item 29 when in the diagram it seemed to be 25.

The AAIB issued 3 safety recommendations regarding the 14-7-2000

These circumstances led to the re-examination of the wreckage of the EC-GQX helicopter involved in the accident in Spain. It was found that the lower scissors had been assembled back to front and so the whole assembly was sent to the INTA for its study, as indicated in section 1.16.3 of this report.

1.17.2. <u>Contact with the Air Accident Investigation Branch (AAIB) in the United Kingdom</u>

After having evidence of the similar accidents that occurred in the United Kingdom, the first contact was made from the investigation team of the CIAIAC with that of the AAIB, and the available data on the three accidents were shared.

A final meeting was held between the investigators of the CIAIAC and the AAIB at the INTA (Torrejón de Ardoz, Madrid) in order to comment on the definitive results of the laboratory studies. The conclusion reached was that in the three cases a fracture due to oligocyclic fatigue of the bolt connecting the lower rotating scissors to the swashplate of the main rotor had been caused, due to incorrect assembly of the scissors.

1.17.3. <u>Action taken by the manufacturer and the Design Authority</u>

On 19th June 2000, that is, two days after the second of the accidents that happened in the United Kingdom as mentioned in section 1.17.1, the manufacturer issued the Information Letter 109-2000-005, which informed the operators about the accident and advised a preventive inspection in order to check the correct installation of the lower rotating scissors. The Information Letter 109-2000-006 was subsequently issued, which included a diagram detailing the correct installation of the components.

The manufacturer also issued the Temporary Revision 62-1 (24th July 2000) to the Maintenance Manual A109EMM, the assembly procedures of the lower scissors link adding the following warning:

"WARNING: THE LOWER LINK (43) IS ASYMMETRIC; IF INSTALLED IN THE INVERTED POSITION DAMAGE TO HELICOPTER MAY OCCUR. VERIFY THE CORRECT POSITION OF LINK -AS STATED IN THE FOLLOWING STEPS"

The Temporary Revision 4 to the Illustrated Parts Catalogue IPC was also issued which *"provides information about the scissors installation on the rotary controls"*.

On 24th July 2000, the "Ente Nazionale per l'Aviazione Civile" in Italy issued the "Prescrizione di Aeronavigabilitá" 2000-371, with the classification of "urgent-immediate application", applied to the Agusta A109E helicopters up to series number 11082, the date of effectivity being 26th July 2000, in which it was required that before the following flight, Part I of the Technical Bulletin of Agusta 109EP-12 was fulfilled, de 24-7-2000, and that before 50 flying hours Part II of this Report was fulfilled.

The AAIB considered that these actions responded to the three recommendations made.

In Appendix E a copy of the installation diagram that appeared in the Maintenance Manual, in Revision 2 (4-2-2000), the diagram modified by the temporary 62-31, and the illustration of the Temporary Revision no. 4 to the Illustrated Parts Catalogue can be seen.

1.17.4. Information on the maintenance carried out by the operator

The operator had a long experience in the maintenance of various types of helicopters, and had operated the Agusta A109A and A109B for years. Nevertheless, the aircraft EC-GQX was the first A109E aircraft in his fleet and had been registered on 27th March 1998, having accumulated around 302 flying hours with this model until the accident occurred on 26-7-1999.

The information collected indicates that during the maintenance carried out on 24th and 25th July 1999, the operator's maintenance staff carried out the first dismantling and assembly of the rotating scissors on this aircraft model.

The maintenance manual, in its Revision 2, and section 62-31-13, indicates that the installation procedure involves the following:

"...(2) Install a washer AN960C616L on the lower link mounting bolt located on the swashplate outer ring.

(3) Connect lower link (30, fig. 62-34) to the mounting bolt and install bevelled washer (29) P/N 109-0134-01-101 and washer (28) P/N 109-0130-49-1 and nut (27). Torque the nut to 8-10.2 Nm and install the cotter pin".

The reference to item 29 seems to be wrong, since the bevelled washer should be item 25 of the diagram (see figure 62-34 sheet 2 of 3 "Rotating Controls" in Appendix E).

In the aircraft Agusta A109A, already maintained by the operator, the lower scissors link is also an asymmetric part that may not be assembled either in a position or rotated 180º around its longitudinal axis in relation to that position. However, it has a different configuration with respect to that of the A109E (see Figure 2 of Section 65-13-00 of the A109A Maintenance Manual which is reproduced in Appendix E). The mounting bolt of the lower scissors in this case is a NAS1306-24D, BOLT, SHEAR.

1.17.5. <u>Certification Requirements to avoid the incorrect assembly of parts of the flight control systems</u>

The "Federal Aviation Regulations" FAR 27 airworthiness requirements applied to normal category helicopters, in paragraph 27.671 b), state:

"Each element of each flight control system must be designed, or distinctively and permanently marked, to minimise the probability of any incorrect assembly that could result in the malfunction of the system"

The Advisory Circular of the Federal Aviation Administration AC 27-1B "Certification of Normal Category Rotorcraft" provides on page D-31 guides and additional information on compliance with this paragraph FAR 27.671 b), as follows:

"To meet the requirement that incorrect assembly be prevented, the preferred method is providing design features which make incorrect assembly impossible. Typical design features which can be used are different lug thicknesses, different member lengths, or significantly different configurations for each system component. In the event that incorrect assembly is physically possible (because of other considerations), the rule may be met by the use of permanent, obvious, and simple markings. Permanent (durable) decals or stencils may be used".

2. ANALYSIS

2.1. Development of the flight

The considerations made in the previous chapter, and the similarity of circumstances with the accidents mentioned in 1.17, make it possible to establish that the sequence of events was the following:

- A programmed maintenance of 300 flying hours was carried out (of 100 hours + 300 hours + 12 months type A+B) on the aircraft, which included a dismantling and subsequent assembly of the rotating scissors of the swashplate. The operator's maintenance staff, who carried out this operation for the first time on this type of aircraft, perhaps influenced by the experience of having previously worked on A109A aircraft, in which the half-scissors assy is of a different design , did not notice that the assembly had to leave the convex part of the arm of the lower scissors facing outwards, instead of towards the swashplate (see figure INTA III.29 in Appendix D) as was eventually done.

In this position, the arm of the lower scissors was forced towards the washers and the bolt nut.

It is highly likely that the maintenance staff also made a mistake in placing the bevelled washer between the spherical bearing and the swashplate, instead of between the nut and the bearing.

- After a test flight of 45 minutes with satisfactory results, the helicopter was approved for return to service.

- The following day, on 26-7-1999, the helicopter took off towards Las Rozas. During the flight, bending moments that were not planned in the design of the aircraft acted on two different planes on the mounting bolt of the lower scissors. The moment acting on the plane formed by the bolt axis and the rotation axis of the swashplate was of considerable magnitude. These moments acted for around one and a quarter flying hours, apart from the test flight on the previous day, which lasted for about 45 minutes.

- The application of these loads, not planned in the aircraft's design, finally caused the failure due to fatigue as described in detail in section 1.16.3. The spreading process of the damage must have continued up to the fracture. As is discussed in that section, the possibility that only a partial failure of the bolt during flight had been caused and that it had finally broken during the crash into the ground is discarded.

- Although it is impossible to determine the exact moment, in other words, the aircraft's position, in which the failure was caused, from the witness' statements, in the sense that he saw the helicopter going from East to West and "it was going at a great height", the conclusion could be drawn that the aircraft was flying at around 2000 ft altitude and around 300 m from the witness' position when the failure happened. It is highly likely, taking into consideration usual practise and the position in which the switches were found in the cockpit, that the autopilot was connected and therefore, the pilot was not touching the flight controls.

- Once the bolt was broken, the immediate effect on the aircraft would be, as stated several times in section 1.16.3.1.5, an immediate loss of lift (due to the effect of the reduction in the blades pitch). In the accidents that occurred in the United Kingdom, the pilots said that they heard a noise coming from the upper back part of the cockpit and immediately there was a sudden loss of lift and the aircraft's controllability was reduced.

Therefore, the bolt fracture in the EC-GQX, when it was about 300-400 metres away from the place where the wreckage was finally found, and it was at an altitude of 2000 ft, there must have been sudden effects on the helicopter's controllability and lift, as the witness described, stating that “after a few seconds, I looked again and the helicopter had lost considerable height”, although he could not specify the amount of that loss of height.

Nevertheless, it is important to point out that, just as happened in the accidents in the United Kingdom, the aircraft did not sink immediately, but it continued to fly, although somewhat out of control, for a distance that, going from the witness' statements, could be estimated at around 300 metres horizontally, whilst it continued to lose height rapidly. During that stage, when the pilot probably tried to recover control while he tried to discover the origin of the malfunction that affected the aircraft, it turned 180º on its horizontal path, until reaching the point when it crashed into the ground. The two accidents in the United Kingdom allowed the occupants to survive, who only suffered minor injuries, although the main difference with the accident that occurred in Spain is that in the former, the landing gear was down, which absorbed part of the loads caused during impact.

The accident of the G-JRSL occurred when the aircraft was at an altitude of 1700 ft and 148 KIAS. Although the helicopter did a sharp dive and rolled more than 90º to the left, the application of the cyclical control to the right and backwards could have stabilised the helicopter to a certain extent. Pulling on the collective gear lever to stop the descent in the final stage of the crash landing had no effect and the helicopter crashed violently into the ground and turned on its right side.

The accident of the G-TVAA occurred when the aircraft was at 300 ft and between 60-80 kt during a landing approach. There was a sharp descent and roll to the right. The pilot lowered the landing gear and sent a “MAYDAY" call by radio. Just before crashing into the ground, he put the engine power levers into the OFF position in an attempt to minimise the damages from the crash. During the 10 seconds that the descent lasted, the pilot carried out from memory the majority of the steps from the checklist of the procedure "Double engine failure". The landing gear was crushed and the helicopter was thrown forward, although it did not overturn and it finally stopped in an upright position.

In the EC-GQX, in which the initial altitude and speed when the bolt failure occurred may have been similar to those of the G-JRSL, the engine controls were found as follows:

- Power levers: The left in flying position and the right slightly forwards, towards maximum.

- Engine control system switches located in the ceiling panel: It was observed that the position of these switches was not the normal flying position. The switch of engine 1 was in IDLE and engine 2 in OFF. The gas levers, used only for manual control of the governor of each engine, were both in the flying position.

The ceiling panel was highly damaged due to the crash. However, the OFF position may only be reached after pressing and rotating the switch, whilst the IDLE position only needs a simple rotation. An engine failure would have required, according to the flight manual, putting the gas lever in OFF and cutting the fuel switch. Both the lever and the fuel switches were in the normal flying position.

- Both switches of the Stability Augmentation System (SAS) were OFF. This fact could be due to the power off after the crash, since the two switches are in fact electromagnetically retained.

The helicopter crashed into the ground with the landing gear retracted.

All of these facts indicate that, after the first moments of confusion produced by the effects of the bolt fracture on the helicopter's lift and stability, the pilot disconnected the automatic pilot and focussed on trying to recover control of the aircraft and reduce its descent rate. Initially, he probably suspected failure of one or both engines, but he did not carry out the corresponding procedure from the flight manual, since the levers and the fuel switches were in the flying position.

Although the possibility that the levers were moved during recovery of the pilot's body cannot be discarded, it seems more difficult that the same happened with the fuel switches. The only switch from the power management system that it is almost certain was operated by the pilot before the accident is the one of the right engine power management system, located in the roof, since it needs two different movements to place it in the OFF position.

The pilot, during those moments, probably did not have time to issue an emergency MAYDAY call, nor even to lower the landing gear, whilst he was busy with the primary task of recovering control of the helicopter. The medical examinations indicate that the pilot could have been firmly acting the right pedal at the time of the crash.

In spite of his extensive flying experience, evidence points to the fact that he had no chance to recover control, and he crashed into the ground at a high descent speed. Although the horizontal speed was relatively low, the crash with around 40º of roll to the right and the landing gear retracted were fatal regarding chances of survival, since, unlike the accidents in the United Kingdom in which the crash happened in a relatively balanced position as far as roll was concerned, added to the fact that the landing gear was down, and so it could absorb the loads from impact, in the case of the EC-GQX, the space of the right side of the cockpit was reduced to levels that made survival after the crash improbable.

2.2. Maintenance and design documentation of the half-scissors assembly

As stated in Section 1.17, the maintenance documentation which provided by figure 62-34 of the A109E-MM Maintenance Manual, including Revision 2 on 4-2-2000 (after the accident occurred), was ambiguous regarding the assembly instructions of the half-scissors assy, since the diagram's perspective did not clearly show towards which side it had to be assembled. Being a spherical bearing, physically it could have been assembled in both positions, as happened with the equivalent part of the A109A helicopters previously maintained by the operator. Neither were there written instructions on how to carry out this assembly.

The Maintenance Manual did include the correct assembly in the diagram of figure 62-38, section 62-31-04 “Swashplate Friction Adjustment” (see Appendix E), but this figure, being part of another maintenance task, was not in the half-scissors assy section.

Moreover, as it happens, the arrangement of the washers on both sides of the spherical bearing were correctly drawn in figure 62-34, but the bevelled washer was indicated as item 25, while in the text, when the installation procedure of the rotating scissors was described in writhing, it was mentioned as item 29. This could have led the maintenance staff to think that there was an error in the diagram, which, along with the fact that when assembling the lower scissors in the inverted position it was more logical to place the bevelled washer between the bearing and the swashplate, it probably meant that the washers were assembled as in figure INTA III.29B in Appendix D. Nevertheless, neither the bevelled washer nor the thin washer were found amongst the wreckage, and so it can not be definitively concluded whether they were installed or not when the part was assembled.

Once the assembly had been completed, the functional or flight tests carried out after maintenance did not manage to detect any problem of malfunctioning of the helicopter since, as has been seen, the destructive effect of the incorrect assembly is shown to be in the form of fracture due to fatigue after several hours of flying in those conditions.

Experience has shown that two maintenance centres (one in the United Kingdom and one in Spain) with different maintenance staff, experience and culture, incorrectly assembled a part in the same way from the same helicopter maintenance documentation. Maintenance´s staff previous experience on A109 models could have led to assembly misunderstandings.

The manufacturer quickly reacted after finding out about the G-TVAA accident and modified this documentation, making the correct assembly of the part clearer.

Assessing compliance with the provisions of the FAR 27.671 when it comes to minimising, through design or distinctive marks, the probability of incorrect assembly that could lead to malfunctioning of the flight controls system, is a complicated exercise. If the recommendations of the aforementioned Advisory Circular 27-1B are applied, the markings of the part, in the event that its incorrect assembly is physically possible as in the first case, must be "obvious and simple", as well as permanent. On one face of the part the part number is recorded, which in itself is not an obvious or simple marking in order to determine the way in which to assemble the part, unless it is used together with maintenance documentation which clearly explains its meaning.

Experience shows that, in spite of the provisions of FAR/JAR 23, 25, 27 and 29 in paragraphs 671, aeroplane and helicopter accidents continue to occur due to the incorrect assembly of flight control system parts after maintenance or manufacture.

2.3. Corrective actions and safety recommendations

As has been explained in sections 1.16.1.5 and 1.17.1, the investigation team was informed on 29th August 2000 about the second accident that occurred in the United Kingdom and the possibility that the scissors had been incorrectly assembled. By that time, and after the safety recommendations issued by the AAIB, the first safety measures had already been taken by the manufacturer and the Airworthiness Authorities.

In subsequent meetings with the manufacturer, the measures taken to avoid reocurrence of the circumstances that led to this accident being repeated were assessed.

2.4. Visual inspection of the mounting bolt

During the two detailed inspections of the wreckage, which were carried out in a hangar in Alcorcón, and in which the representatives of the engine and aircraft manufacturers participated (in the first inspection) and the aircraft manufacturer (in the second) the fracture noticed in the lower scissors mounting bolt (on first impression of a fragile nature) was considered to be due to an overload during the crash into the ground, that is, subsequent to the accident.

This fact also occurred during the inspection of the wreckages of the G-JRSL in the United Kingdom. In both cases, the rotor head and annexed elements had suffered considerable damages and multiple fractures, which, together with the complete lack of clearly visible fatigue marks and the presence of a continued fracture face mostly at an inclination of 45º in the case of the EC-GQX, led to the aforementioned conclusion.

As has been seen in section 1.16.3, only the microscopic analysis of the fracture, carried out by specialised staff, could detect that the cause of the fracture had been due to fatigue.

The circumstances surrounding the second accident in the United Kingdom, in which the rotor was hardly damaged, made it possible to see quickly that the lower scissors were loose and led to the ultimate establishment of the cause of the accidents.

3. CONCLUSIONS

3.1. Findings

The pilot had a valid licence and was qualified for the flight.

The aircraft had a current Certificate of Airworthiness.

On 25th July 1999 a 300 hours maintenance inspection had been completed, carried out on the aircraft on the basis of the operator's maintenance.

During this inspection, the part P/N 109-0134-10-105, half-scissors assembly had been dismantled and assembled.

The assembly of this part was done incorrectly, turning it 180º in relation to its longitudinal axis, compared to the correct position according to the aircraft's design and type.

The instructions for the assembly of the half-scissors assy, provided by the maintenance manual in section 62-31 “Rotating Controls”, edition of 1st July 1999, did not make it possible to determine clearly the correct position in which the part should have been assembled.

The bevelled washer and thin washer, mentioned in the manufacturer's documentation, were not assembled in their correct position.

This incorrect assembly of the half-scissors assy. caused bending moments, not considered during the design, on the mounting bolt of the half-scissors assy., “Bolt, close tolerance” P/N NAS6606D28, which finally broke due to fatigue after approximately two hours of flying time.

3.2. Causes

The most probable cause of the accident is considered to be the incorrect assembly of the half-scissors assembly during programmed maintenance tasks, as a consequence of the incomplete information supplied by the relevant section of the aircraft's maintenance manual.

In accordance with the requirements and recommendations of Annex 13 of ICAO, Ninth Edition, Chapter 6, paragraph 6.3, the comments to this final report submitted by Agusta, as type certificate holder of the aircraft, are included in Appendix F.

4. SAFETY RECOMMENDATIONS

The actions taken by the aircraft manufacturer (Agusta) and by the Airworthiness Authority of the State of Design (ENAC-Italia), described in section 1.17, adequately meet the safety recommendations that could have been relevant as a consequence of this accident.

5. APPENDICES

Appendix A

Sketch of the break-up of the wreckage and the aircraft's final path.

Appendix B

Photographs of the aircraft wreckage.

Appendix C

Some of the parts initially sent to the INTA for their detailed study.

Appendix D

Photographs of the detailed study of the fracture of the half-scissors assy. mounting bolt.

Appendix E

Copy of the aircraft's maintenance documentation.

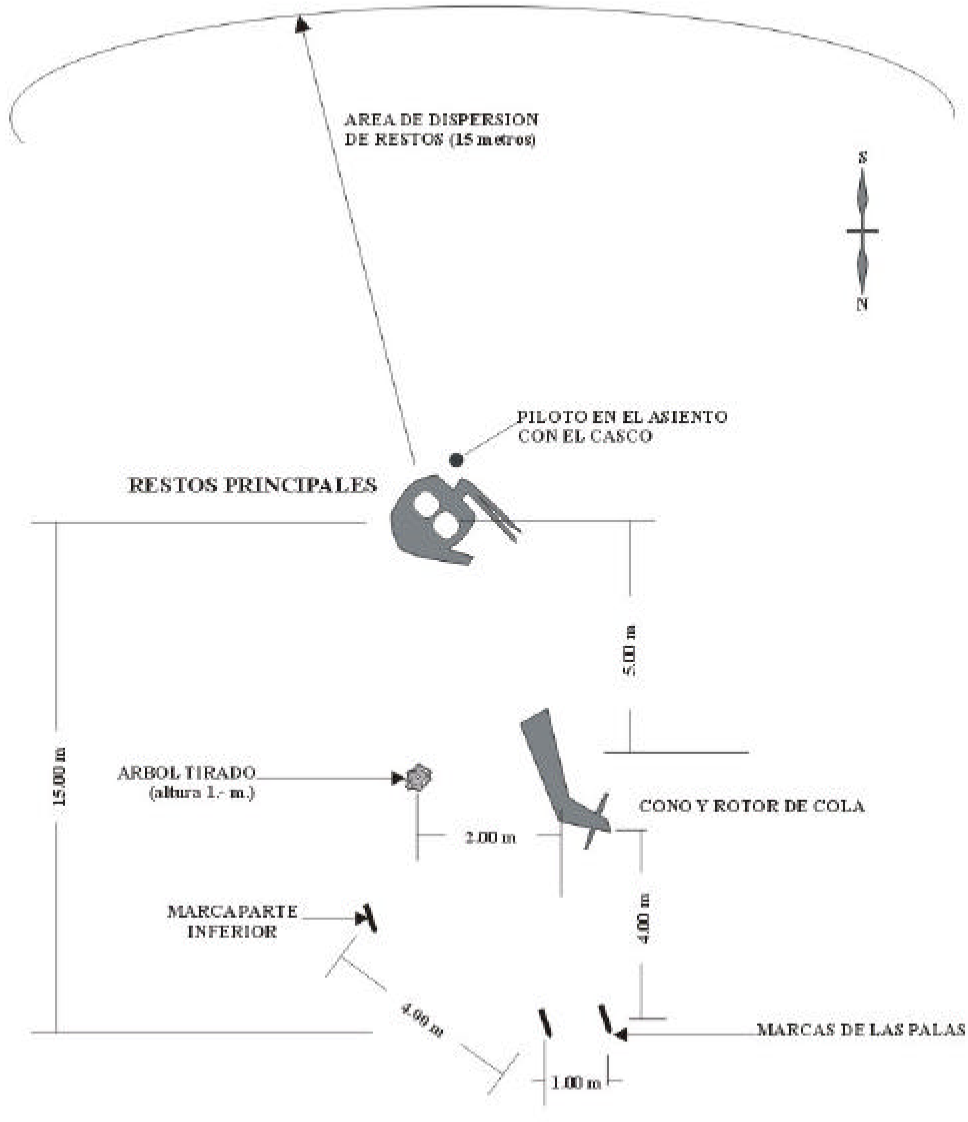
Appendix F

Agusta's comments to the final report.

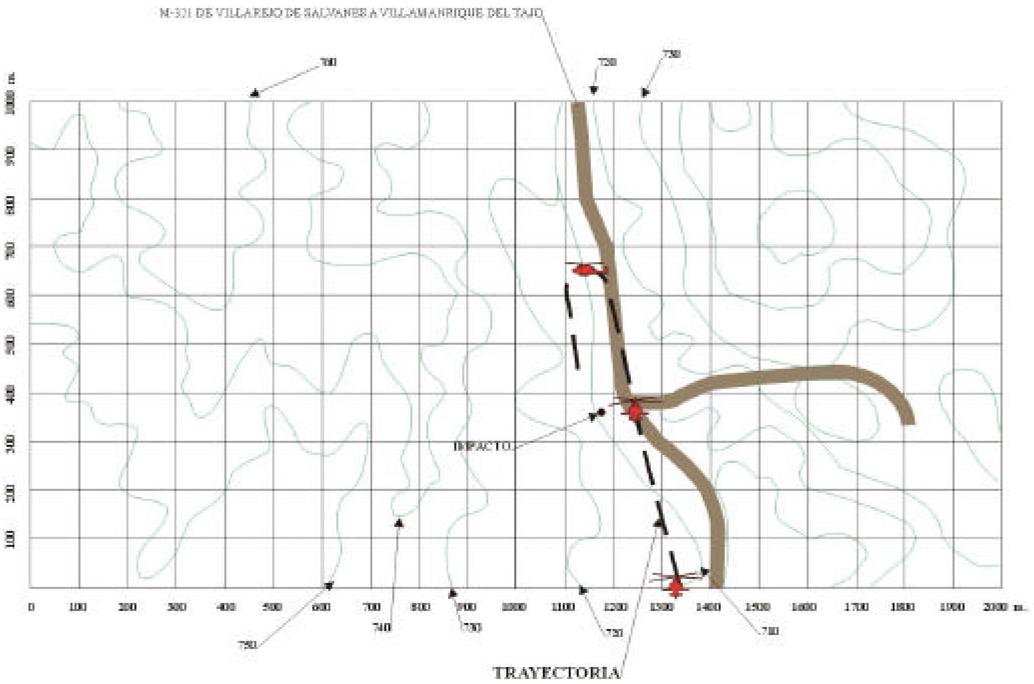
APPENDIX A

SKETCH OF THE BREAK-UP OF THE WRECKAGE AND THE AIRCRAFT'S FINAL PATH

CROQUIS DE DISPERSION DE RESTOS



A-40/99 EC-GQX
VILLAREJO DE SALVANES
ESCALA 1:100



APPENDIX B

PHOTOGRAPHS OF THE AIRCRAFT WRECKAGE

Photo 1.- General view. The helicopter entered from the top right area of the photograph, turned 180º and carried on descending until crashing into the ground

Photo 2.- Nose view. Landing gear retracted.

Photo 3.- Lateral view of the wreckage.

Photo 4.- Left lateral view.

Photo 5.- Blade leading edge shield (blue blade) located 60 m away from the wreckage.

Photo 6.- Tail boom.

Photo 7.- Detail of the position of the power levers and engine switches on the ceiling panel. Right hand switch is in the “OFF” position.

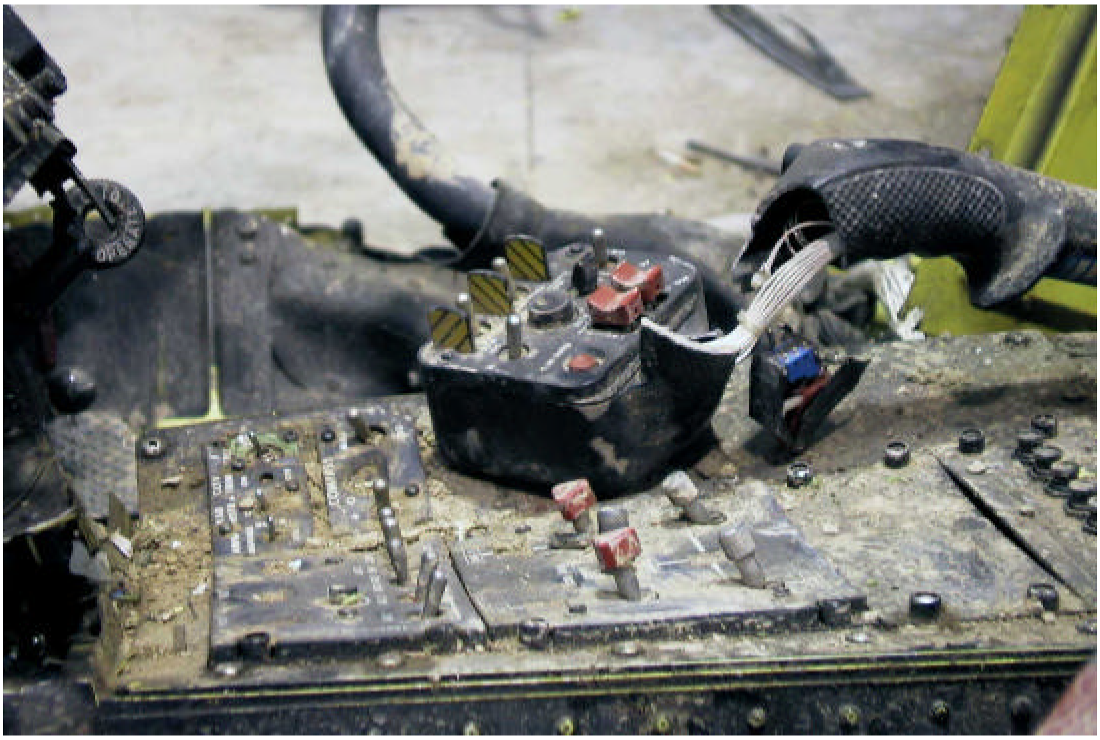


Photo 8.- Switches on the collective lever grip switch box.

APPENDIX C

SOME OF THE PARTS INITIALLY SENT TO THE INTA FOR THEIR DETAILED STUDY

Fig 1.- *Elementos cuya configuración parece indicar que corresponden a varillas tubulares de mando*

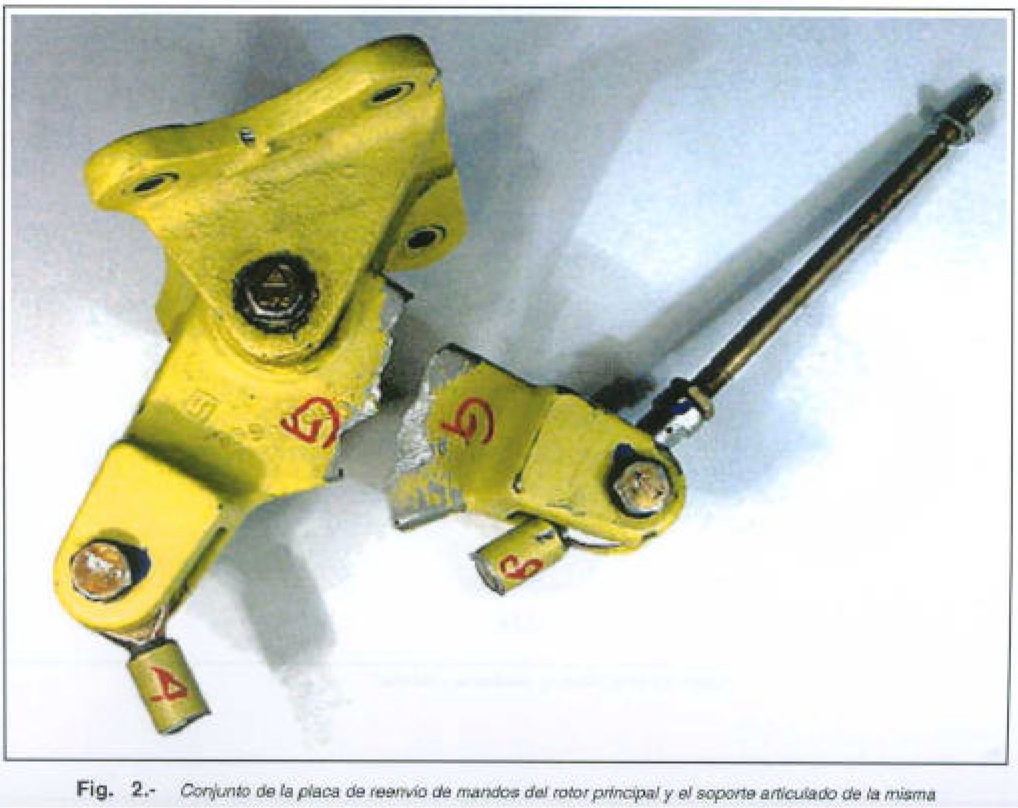


Fig. 2.- *Conjunto de la placa de reenvío de mandos del rotor principal y el soporte articulado de la misma*

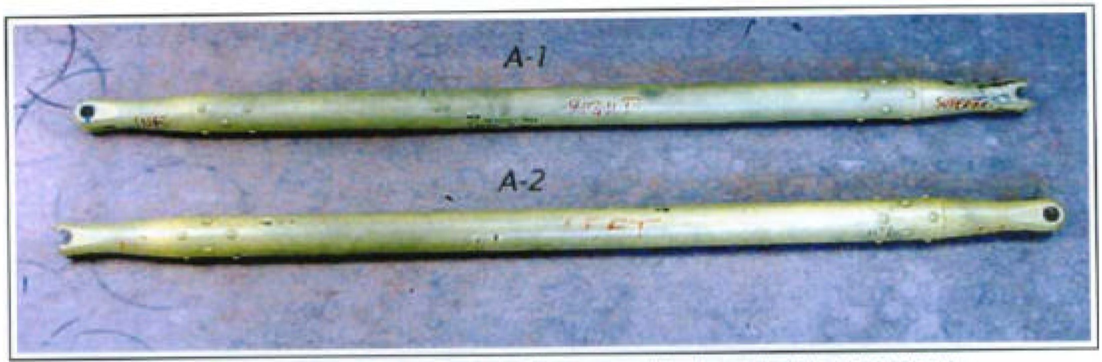


Fig. 3.- *Tornapuntas estructurales de tubo hueco con orejetas de acoplamiento en los extremos*

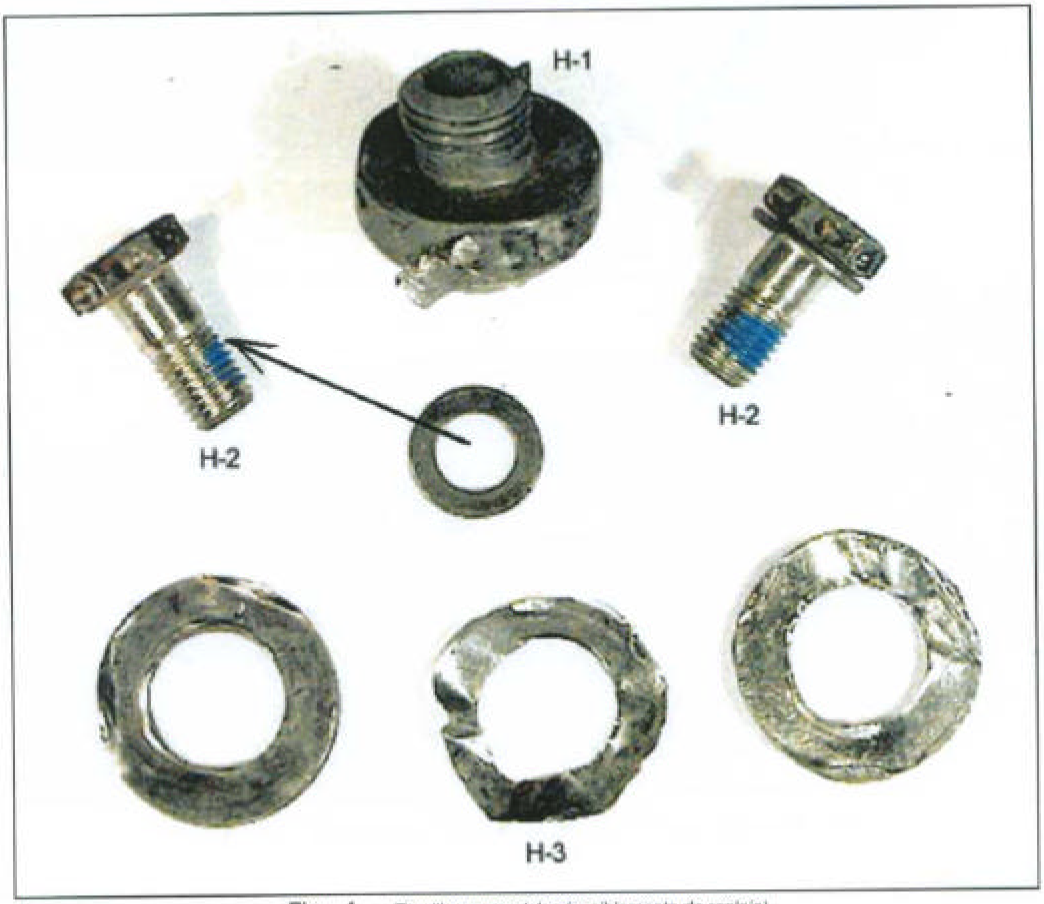


Fig. 4.- *Tornillos y arandelas (posiblemente de reglaje)*

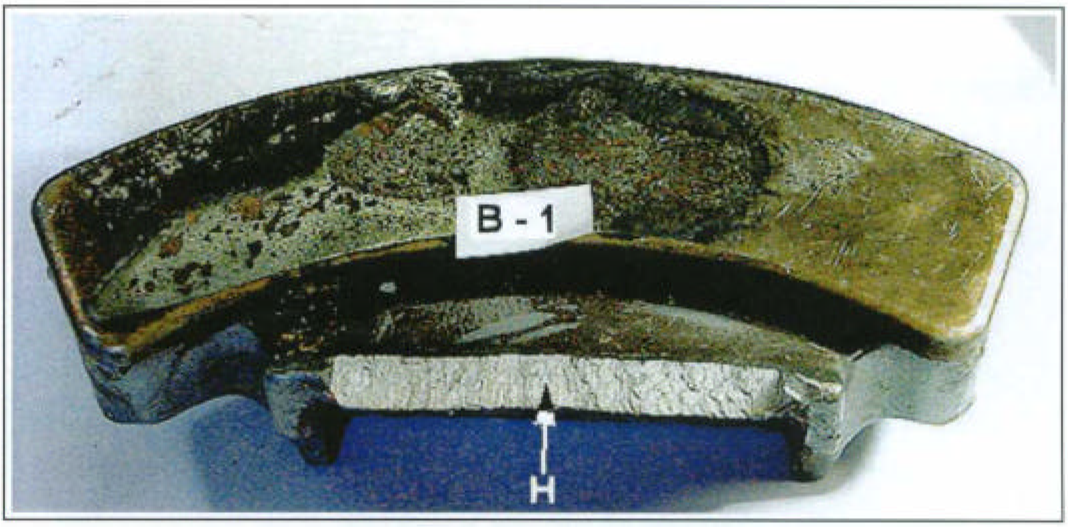


Fig. 5.- *Tope de posición límite de las palas con rotor parado (rotor principal)*

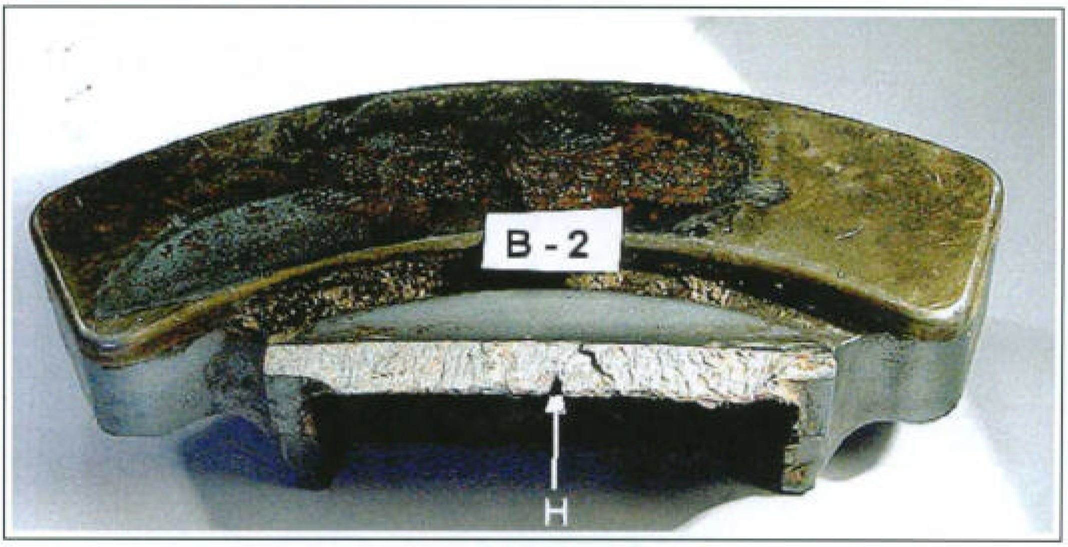


Fig. 6.- *Tope de posición límite de las palas con rotor parado (rotor principal)*

Fig. 13.- *Fragmentos, dos procedentes de las orejetas de los tornapuntas (Fig. 3) y el tercero, no identificado*

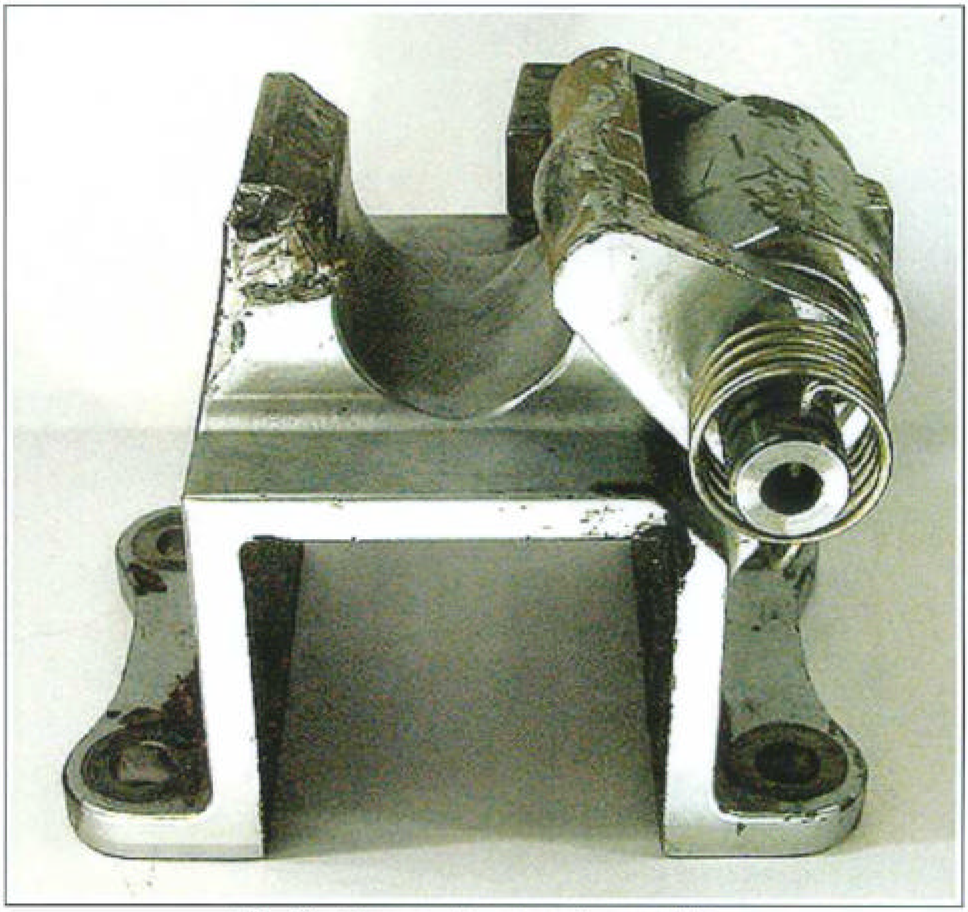


Fig. 14.- *Pieza con muelle y contrapeso de una pala del rotor*

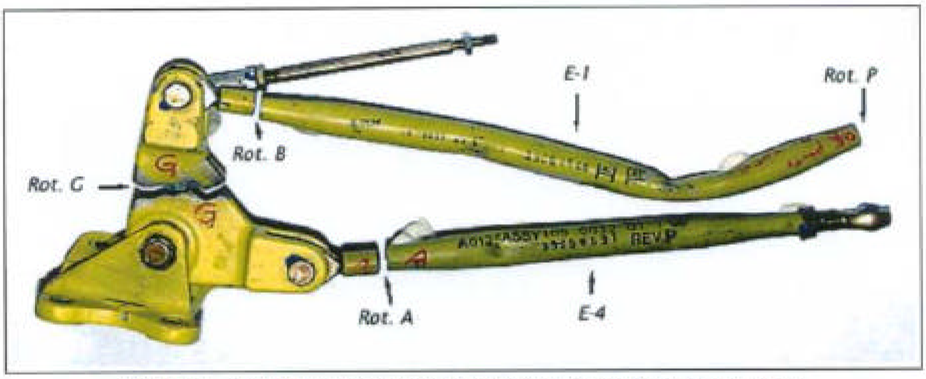


Fig. 15.- *Conjunto de reenvío de mandos y varillas tubulares de mando del rotor principal*

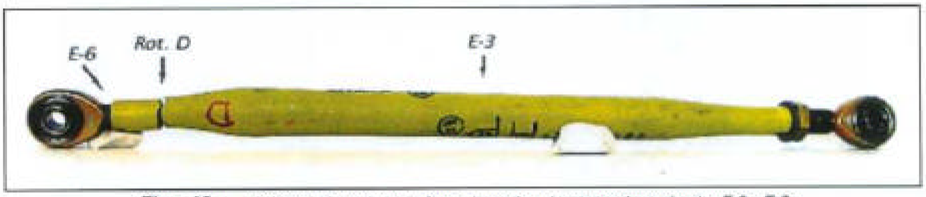


Fig. 16.- *Varilla tubular de mando formado por los elementos denominados **E-3** y **E-6***

Fig. 17.- *Fragmento **E-8** acoplado en el tornapuntas **A-1** del que procedía*

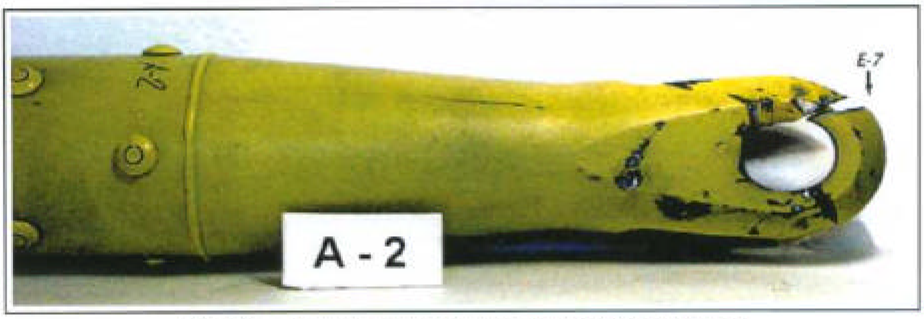


Fig. 18.- *Fragmento **E-7** acoplado en el tornapuntas **A-2** del que procedía*

APPENDIX D

PHOTOGRAPHS OF THE DETAILED STUDY OF THE FRACTURE OF THE HALF-SCISSORS ASSY MOUNTING BOLT

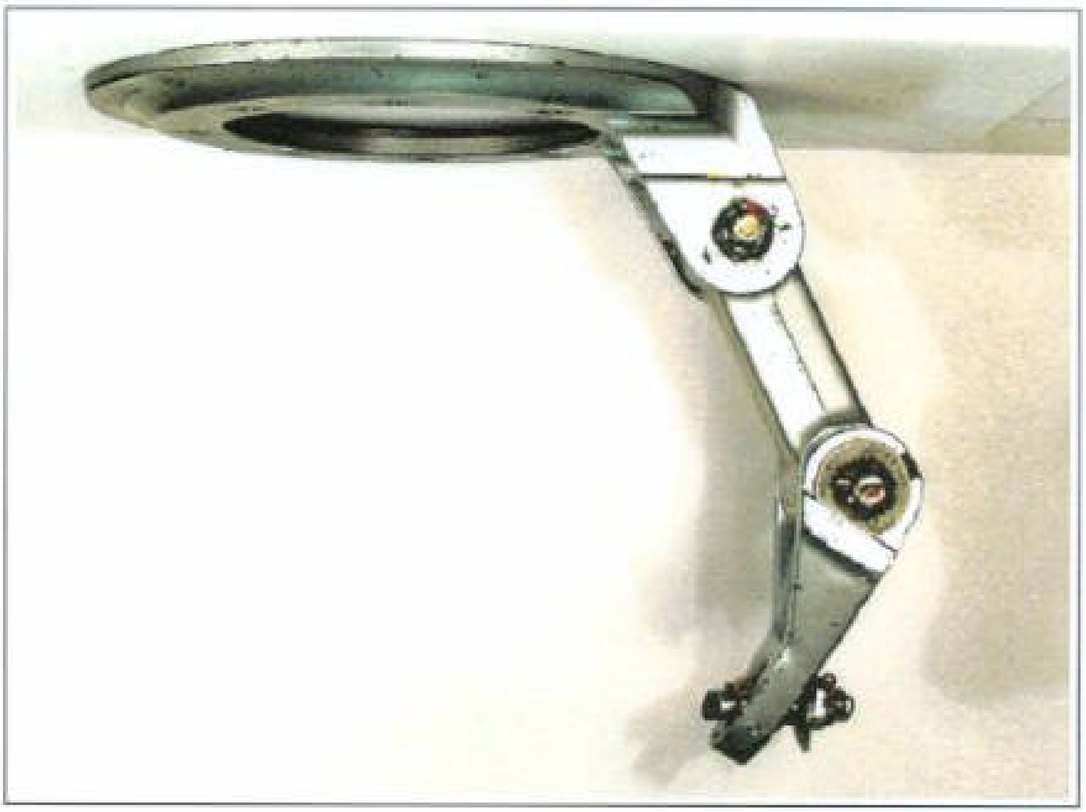
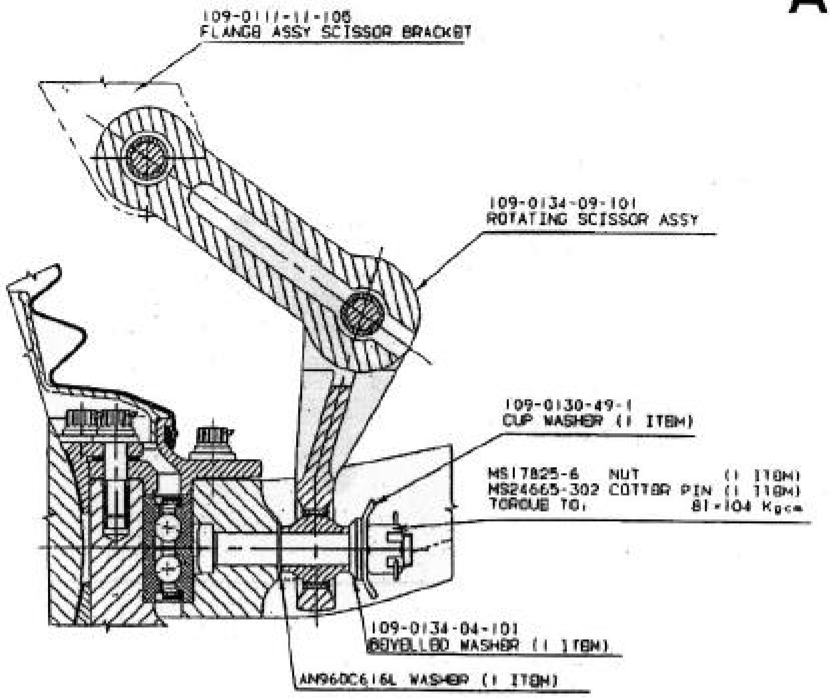


Fig. I.1.- *Tijera completa recibida*

Fig. I.2.- *Vista del plato giratorio desde la cabeza del rotor principal*

Rotating Scissors - Section

A



B

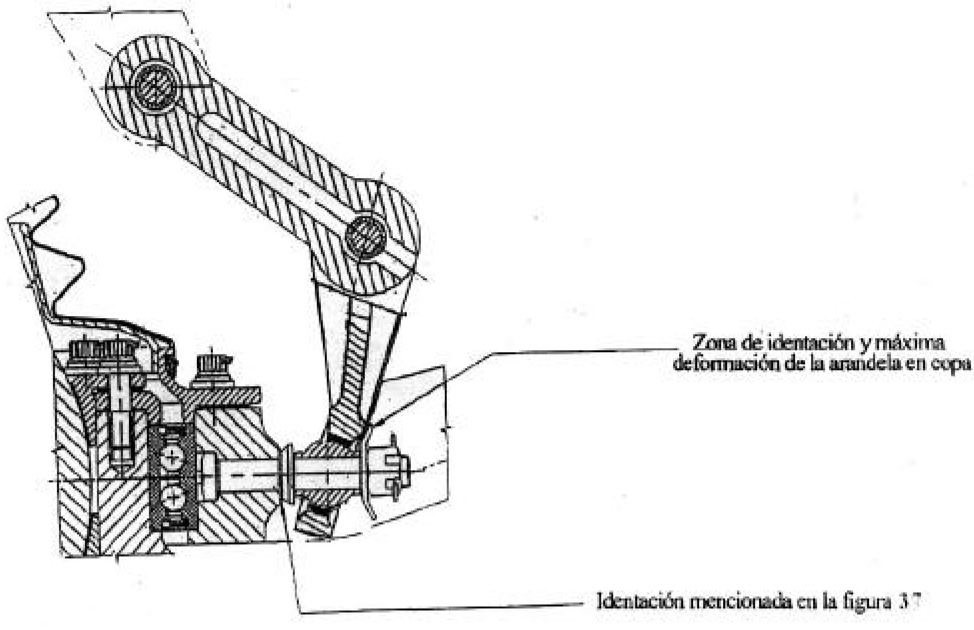


Fig. III.12.- *Conjunto tuerca-bulón en el brazo de la tijera*

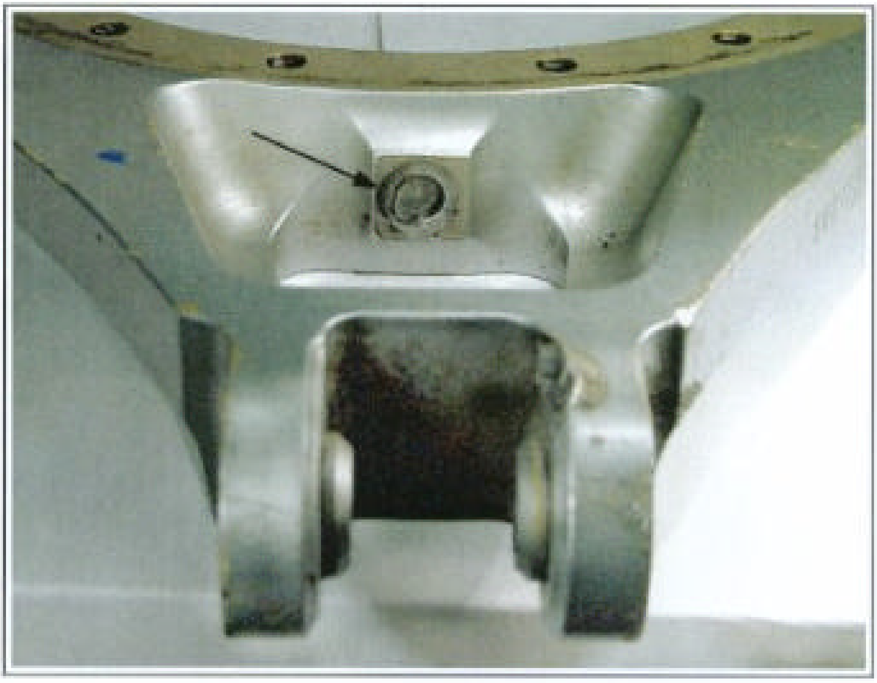


Fig. III.36.- *Zona de empotramiento del bulón en el plato*

Fig. III.30.- *Espacio entre la rotula y la rotura del bulón en el que probablemente estuvieran colocadas las arandelas*

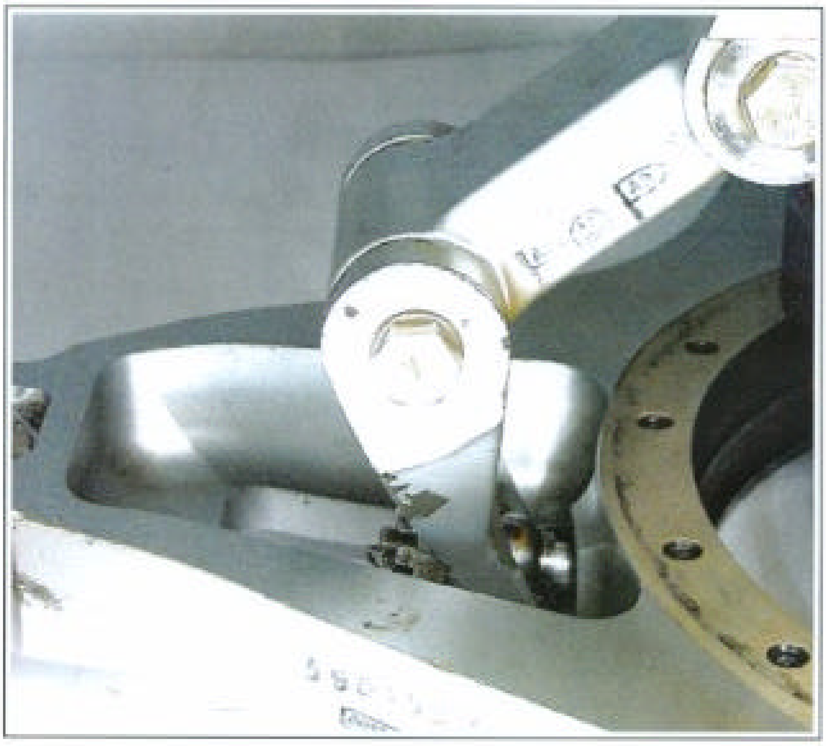


Fig. III.31.- *Disposición relativa entre tijera y plato giratorio en las condiciones de montaje*

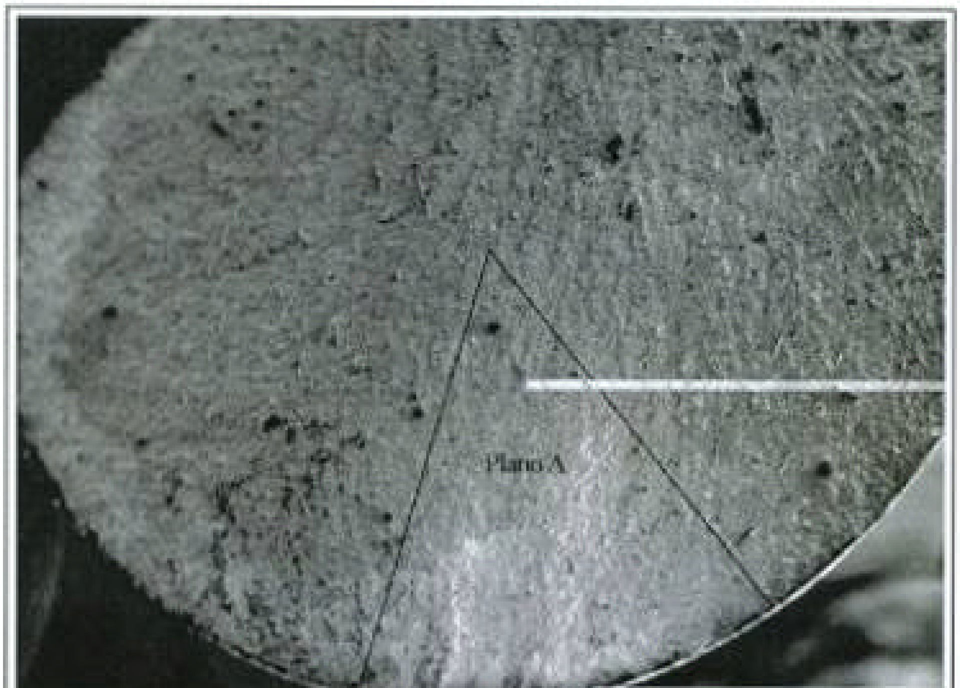
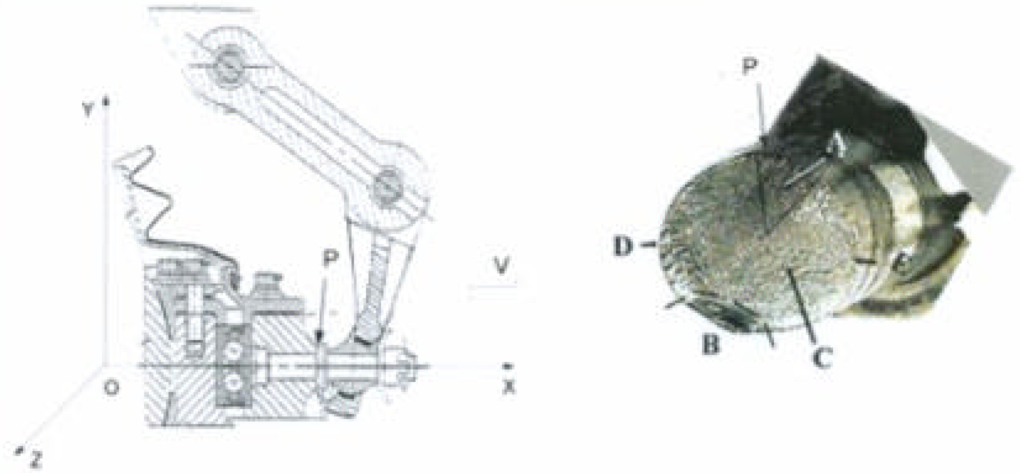


Fig. III.16.- *Detalle de la zona A de la superficie de fractura*



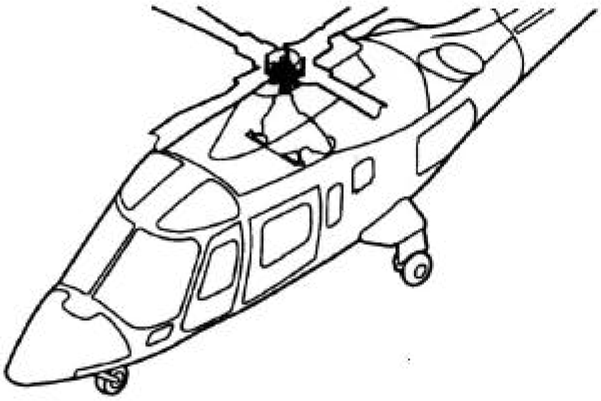
a) Sección por un plano que contiene los ejes X, del bulón, e Y, del plato giratorio.

b) Vista por V del la superficie de fractura del bulón en el trozo que contiene la tuerca.

Fig. III.15.- *Situación del bulón roto y superficie de fractura del bulón*

APPENDIX E

COPY OF THE AIRCRAFT'S MAINTENANCE DOCUMENTATION



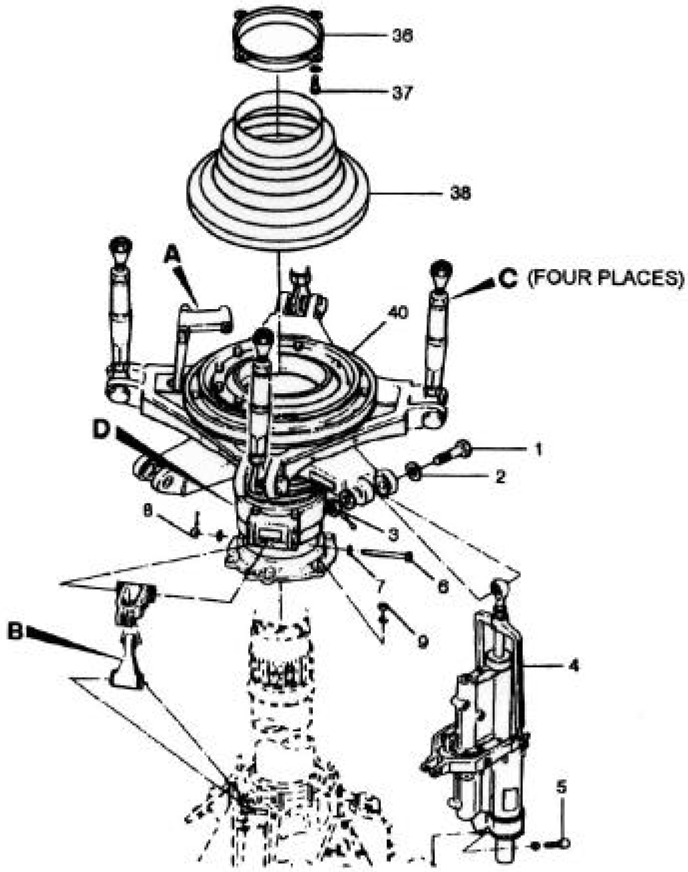
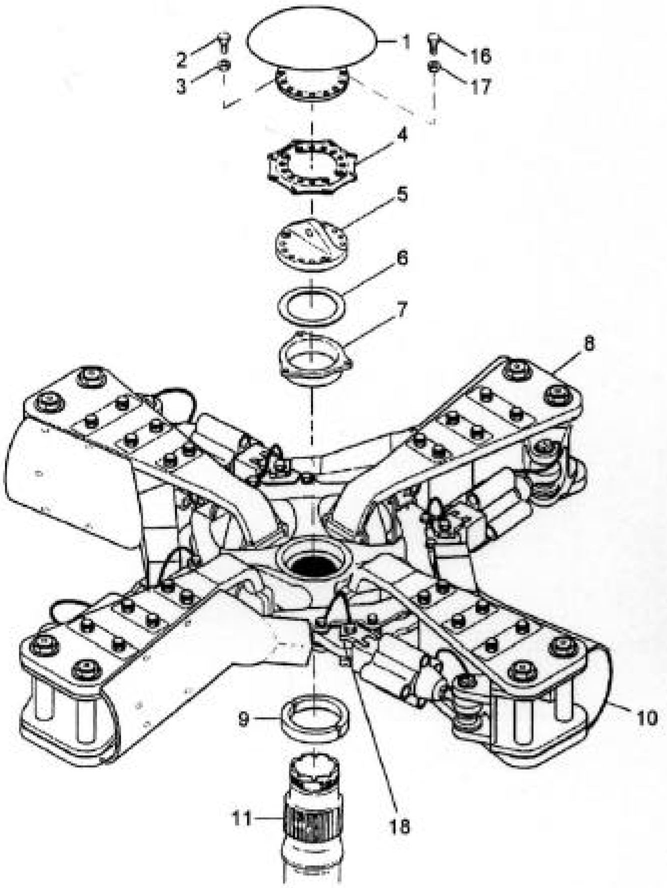


Figure 62-34. (Sheet 1 of 3) Rotating Controls



1. Cover
2. Bolt
3. Nut
4. Lockplate
5. Locknut
6. Ring
7. Conic ring
8. Rotor head
9. Split ring
10. Fairing
11. Mast
12. Scissor support flange
13. Bolt
14. Link
15. Bellows
16. Bolt
17. Washer
18. Fitting

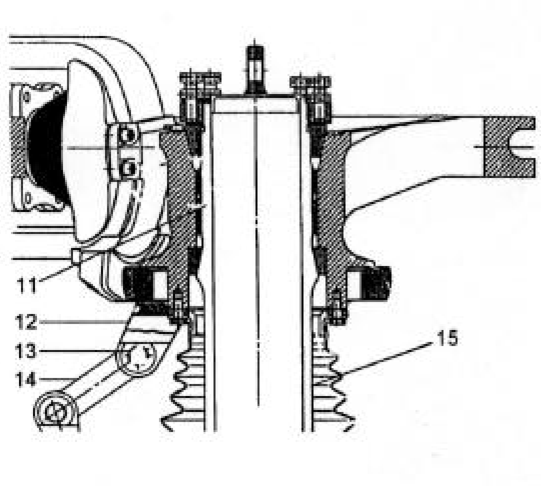


Figure 62-20. Main Rotor Head Installation

A8HD400B

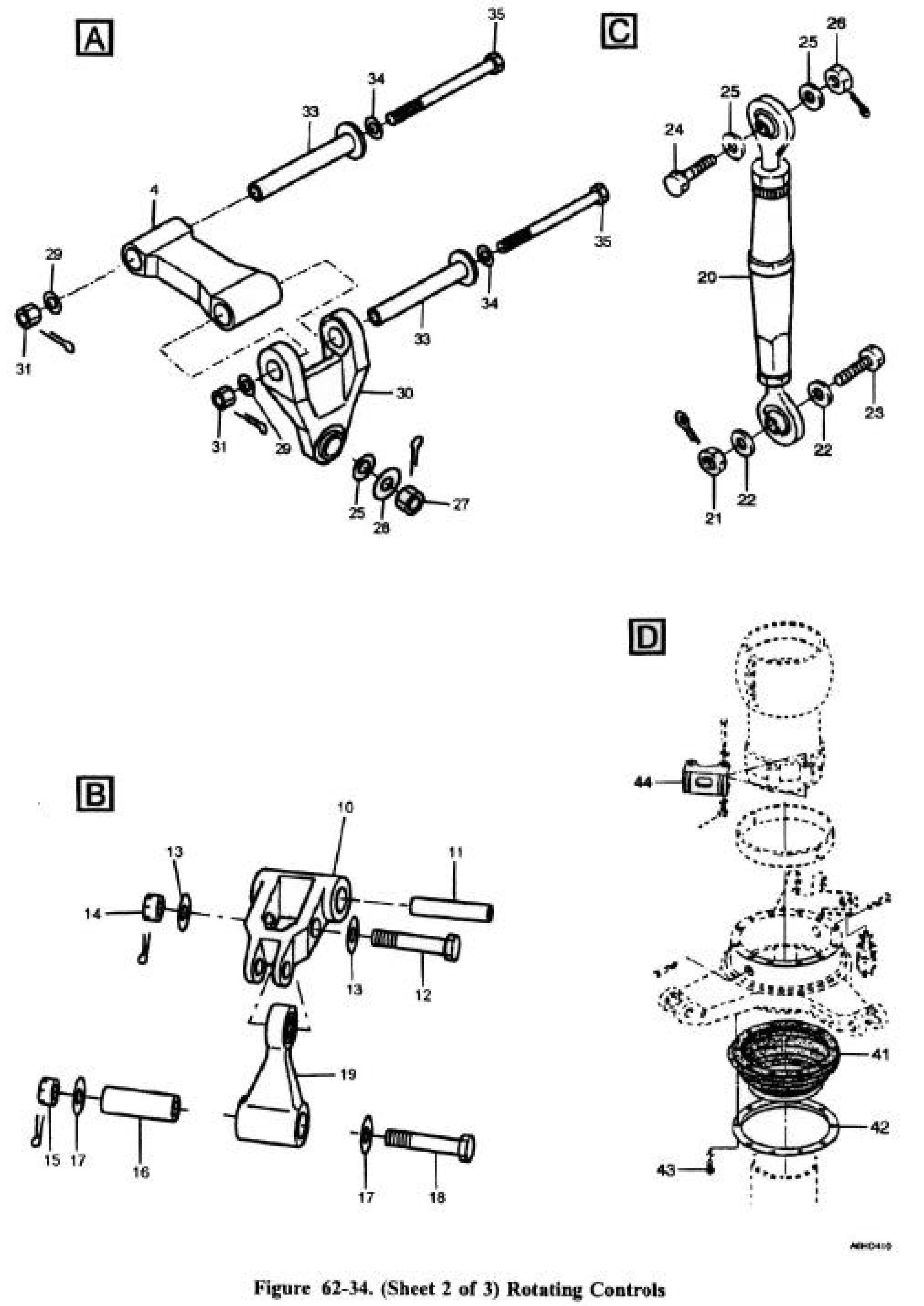


Figure 62-34. (Sheet 2 of 3) Rotating Controls

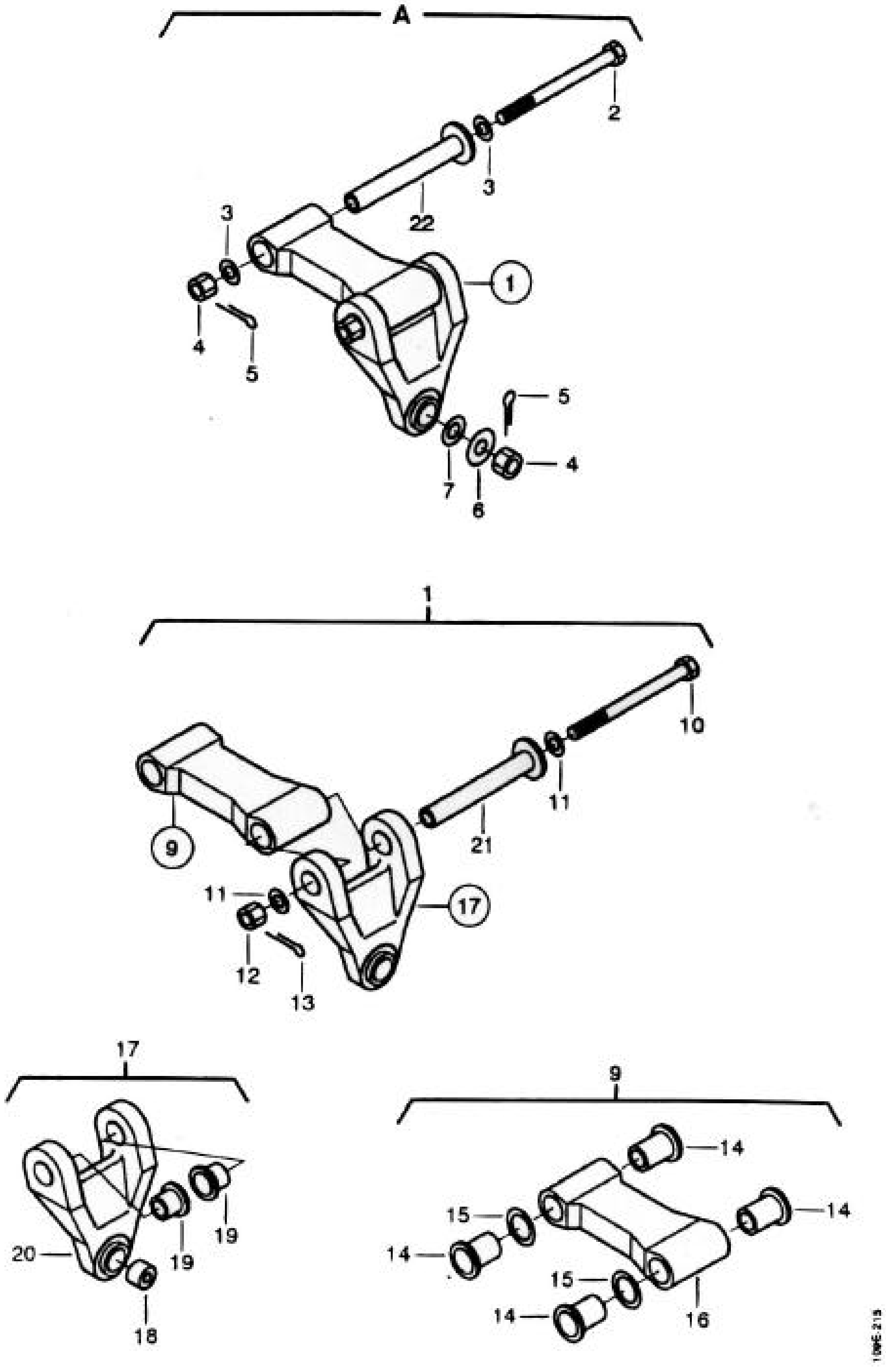


FIG. 1 (SHEET 2 OF 3). ROTARY CONTROL INSTL, MAIN ROTOR

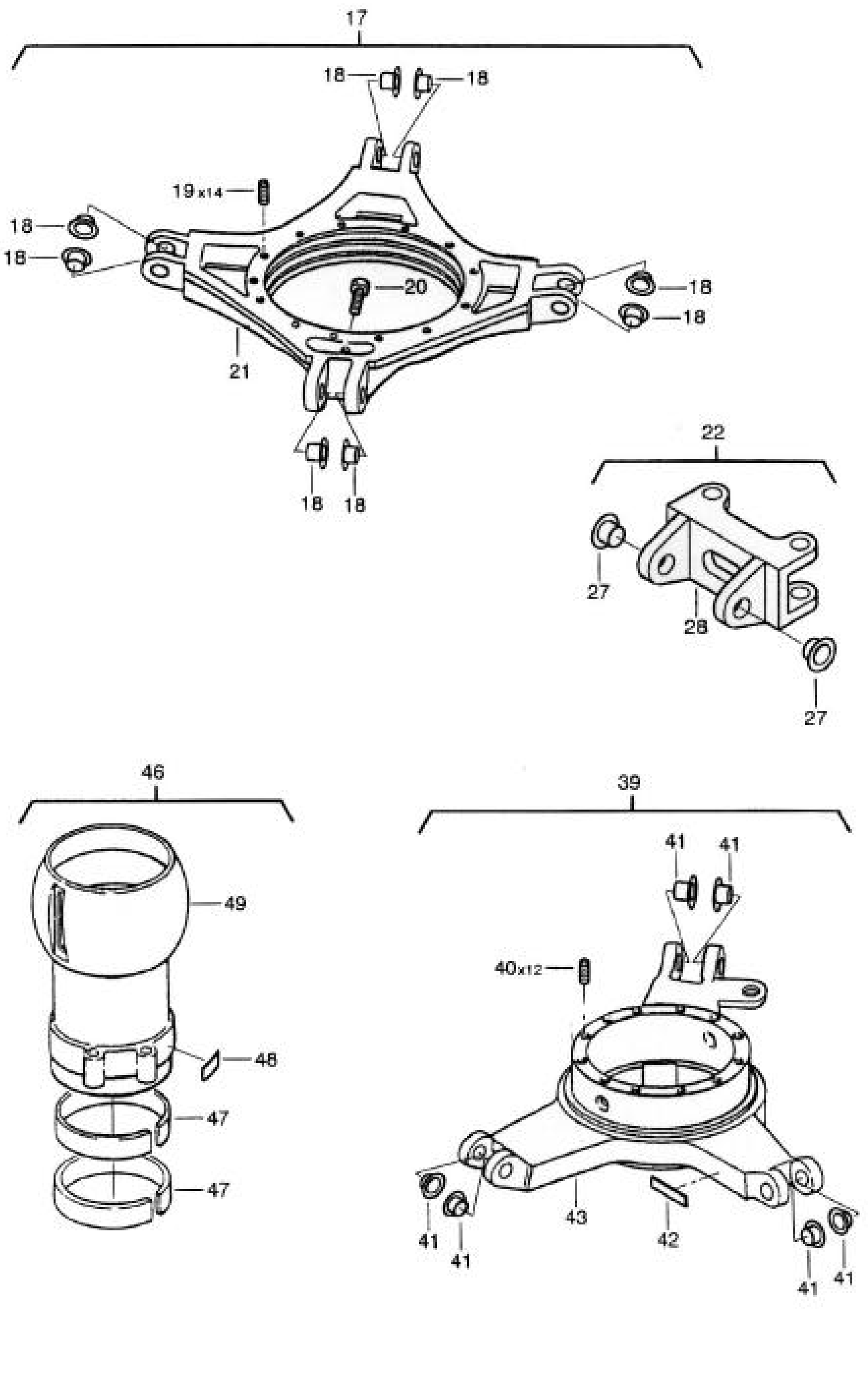


FIG. 2 (SHEET 2 OF 2). SWASHPLATE ASSY

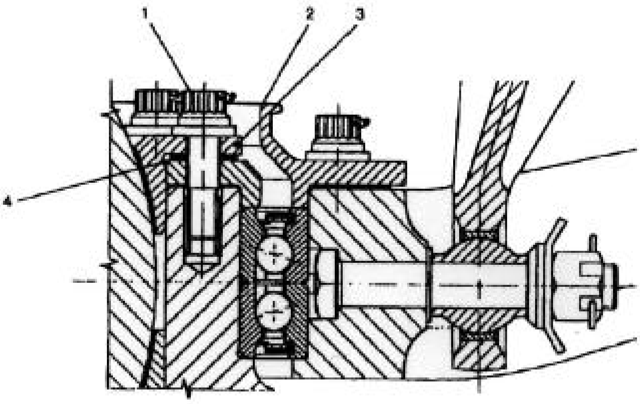
(4) Check the swashplate friction as indicated in step B above.

(5) Lockwire the attaching hardware (1) when the swashplate friction has been adjusted as required.

(6) Position the bellows (38, fig 62-34) around retaining ring (39) and safety wire (LCM NO 74)

D. Follow-On Maintenance Required:

— If previously removed, install the main rotor head (para 62-21-12)



1. Attaching screw
2. Bellows retaining ring
3. Upper ring
4. Shim

Figure 62-38. Swashplate Friction Adjustment

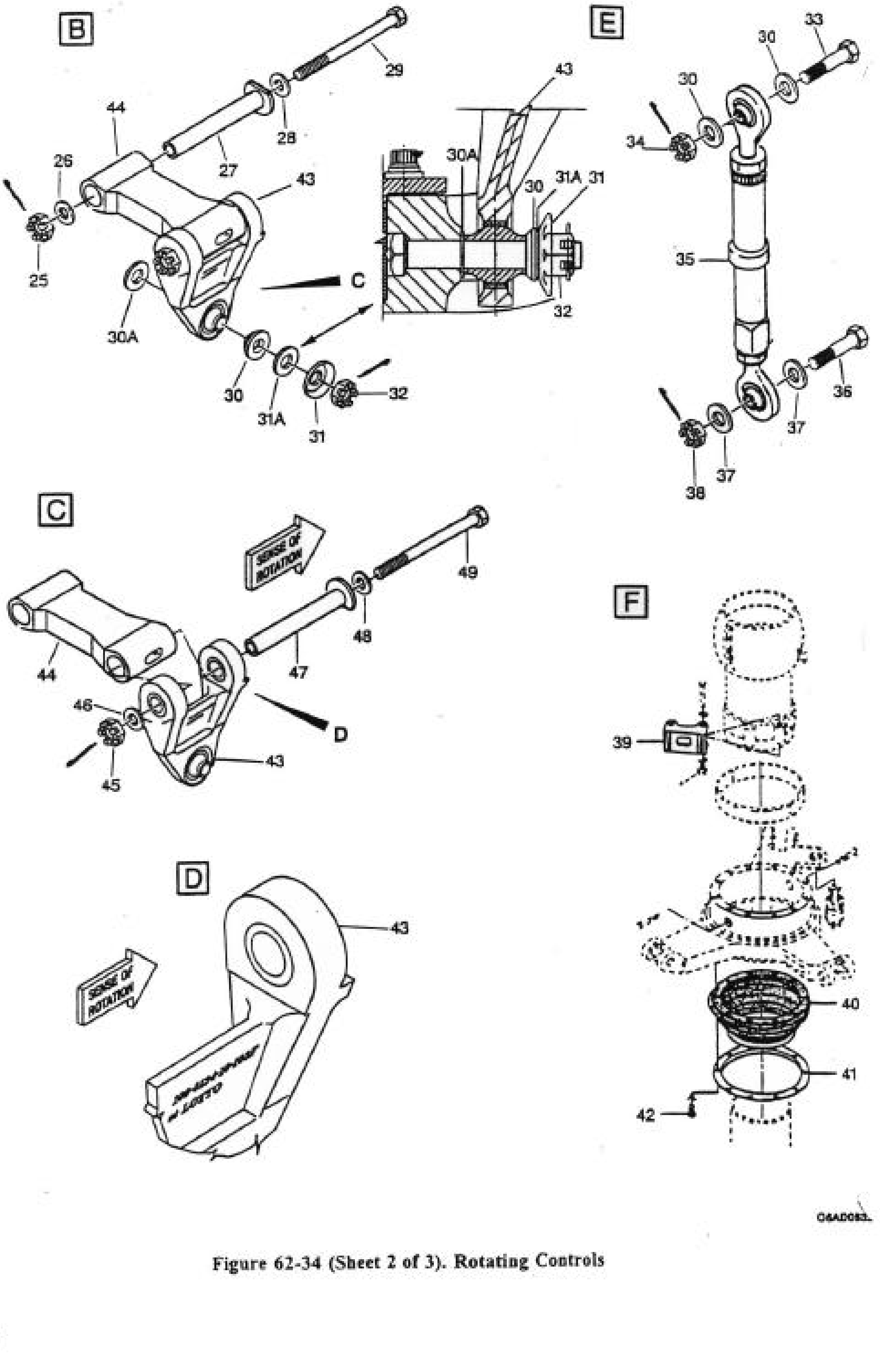


Figure 62-34 (Sheet 2 of 3). Rotating Controls

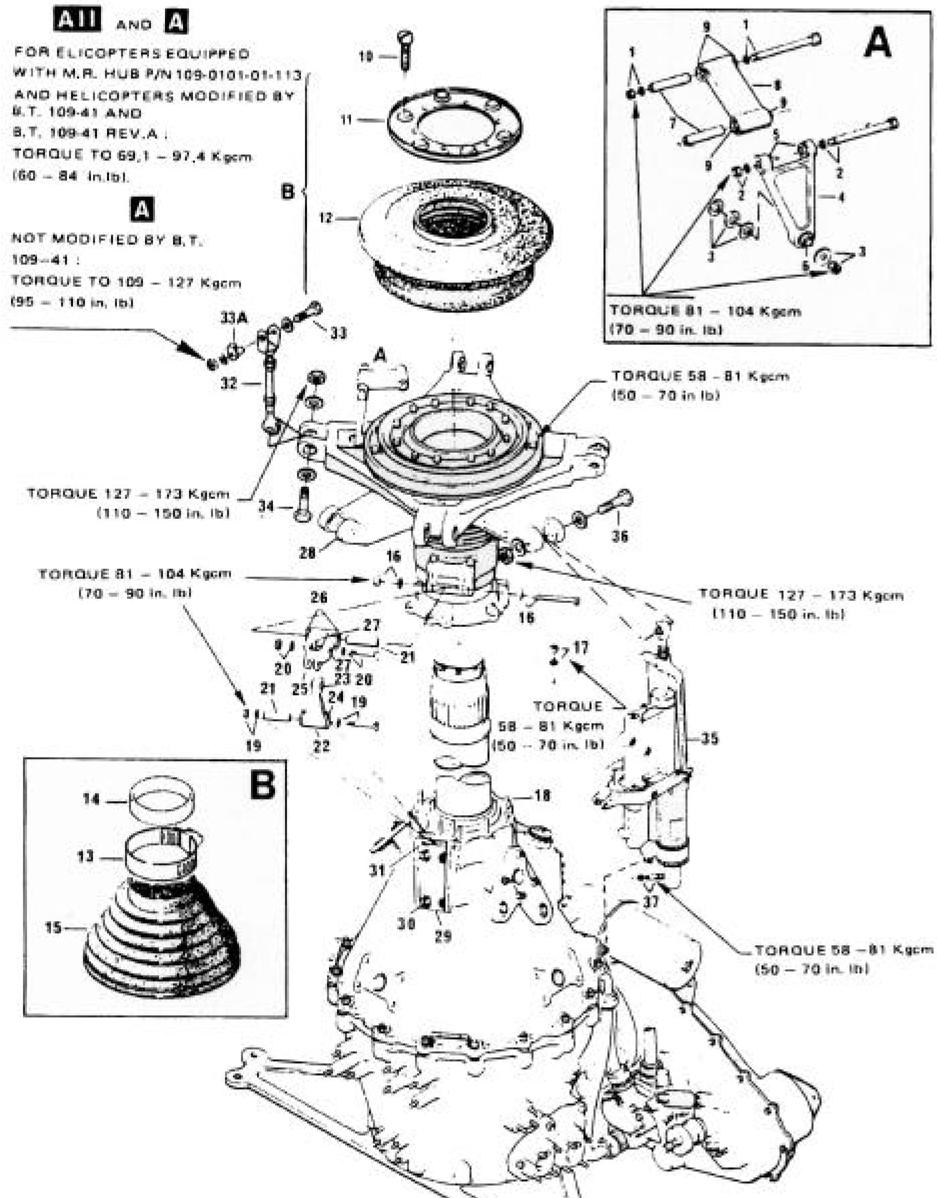


Figure 1 (sheet 1 of 2). Main rotor controls.

APPENDIX F

COMMENTS OF AGUSTA TO THE FINAL REPORT PREPARED BY THE CIAIAC

In accordance with Annex 13 of ICAO, a draft of the final report was forwarded to Agusta, as Holder of the Type Design of the aircraft.

Agusta answered with several comments to the text, some of which were accepted and included in the final report by the CIAIAC.

The final version of the Agusta comments, submitted with their letter 2003/3.011, is included in this Appendix F.

APPENDIX F

Agusta considerations on the final draft accident report n° A-040/1999.

- Agusta finds that the most probable cause of the accident is the incorrect assembly of the Main Rotor rotating scissor assy performed during programmed maintenance task.
  The wrong installation (lower scissor link in reverse position) induced anomalous loads (bending moment) on the lower scissor connecting bolt to the swashplate causing a premature fatigue failure.
  On the contrary Agusta refuses to agree with the contributory fact indicated as the incomplete information supplied by the relevant section of the maintenance manual.
  The following reasons clarify the Agusta point of view.

- The maintenance activity is usually performed by trained personnel on the base of the information contained in the pertinent manuals. The Manuals include the removal/installation, adjustment/test, inspection/check and repair instruction as applicable.
  The Maintenance Manual section 62-31 refer to the rotating controls including:
  rotating scissor description at par. 62-31-3 with relative fig. 62-27.
  (Here below are reported the pertinent paragraph and figure)

62-31-3. ROTATING SCISSORS AND NON ROTATING SCISSORS
(Fig 62-27)

A. The rotating scissors (30 and 32) consist of two hinged links attached at one end to the main rotor hub flange bracket (12, fig 62-18) and to the other end to the swashplate outer ring.
The rotating scissors drive the swashplate outer ring and allow the outer ring to tilt and move vertically in response to the cyclic and collective commands.

B. The non rotating scissors consists of two hinged links (10 and 19, fig. 62-23) attached at the lower end to the transmission upper case fitting and at the upper end to the swashplate pivot sleeve.

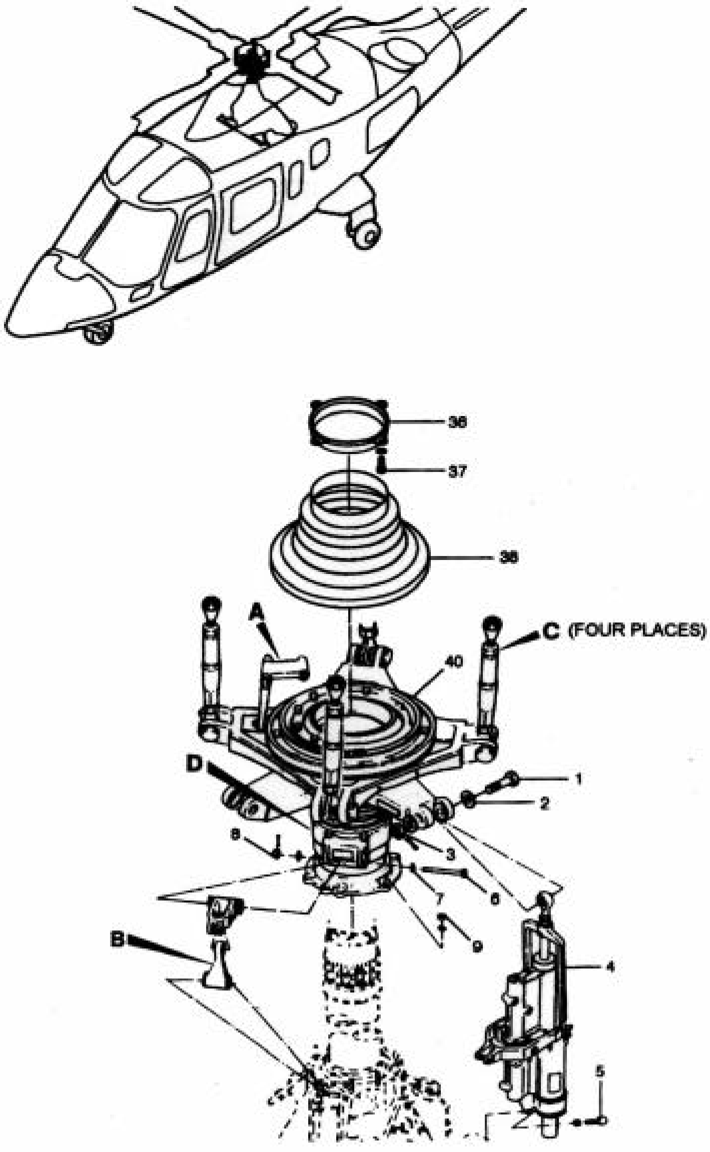


Figure 62-27. (Sheet 1 of 3) Rotating Controls

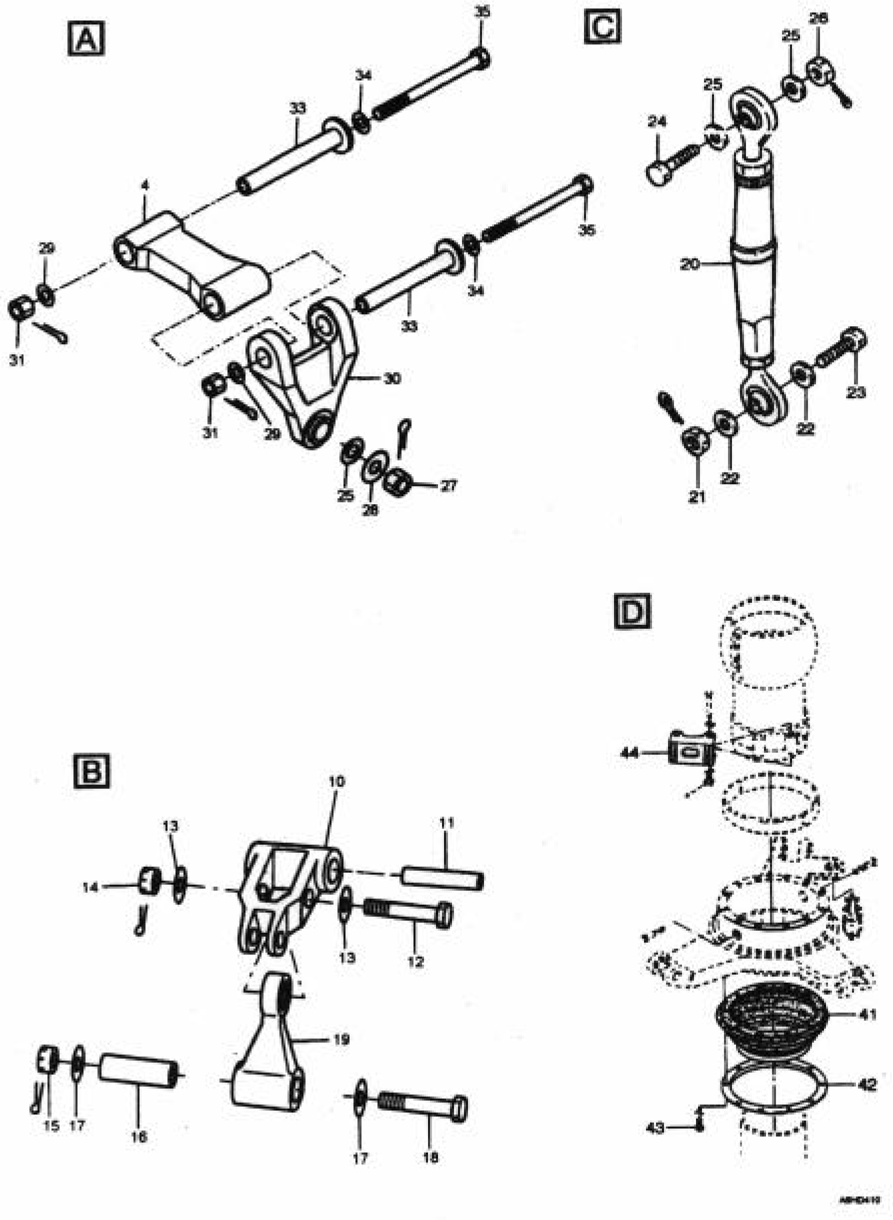
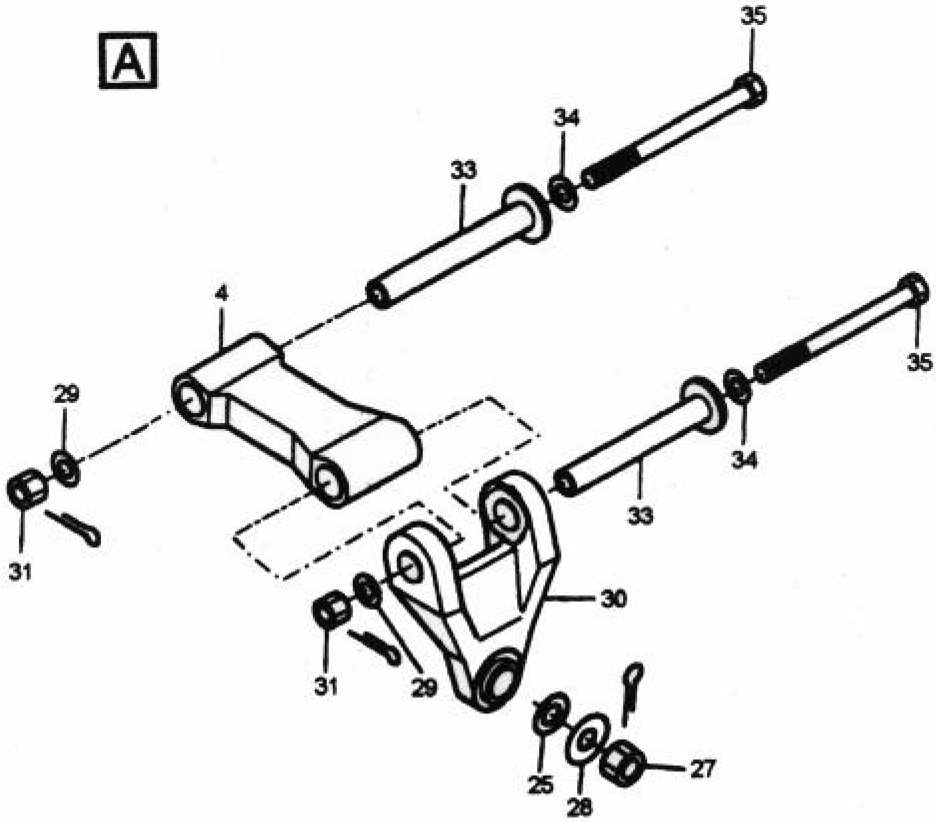


Figure 62-27. (Sheet 2 of 3) Rotating Controls

1. Bolt
2. Washer
3. Nut
4. Servoactuator
5. Bolt
6. Bolt
7. Washer
8. Nut
9. Nut
10. Upper link, non rotating scissors
11. Sleeve
12. Bolt
13. Washer
14. Nut
15. Nut
16. Sleeve
17. Washer
18. Bolt
19. Lower link, non rotating scissors
20. Pitch change link
21. Nit
22. Washer
23. Bolt
24. Bolt
25. Washer
26. Nut
27. Nut
28. Washer
29. Washer
30. Lower link, rotating scissors
31. Nut
32. Upper link, rotating scissors
33. Sleeve
34. Washer
35. Bolt
36. Ring
37. Bolt
38. Bellows
39. Reserved
40. Swashplate and support
41. Lower bellows
42. Ring
43. Screw
44. Fitting

Figure 62-27. (Sheet 3 of 3) Rotating Controls

- The fig. 62-27, detail A, is clear and self explanatory for a correct installation of the parts. It is certainly expected that the maintenance personnel is asked to check the manual and the related figures before to performed the requested maintenance activity.

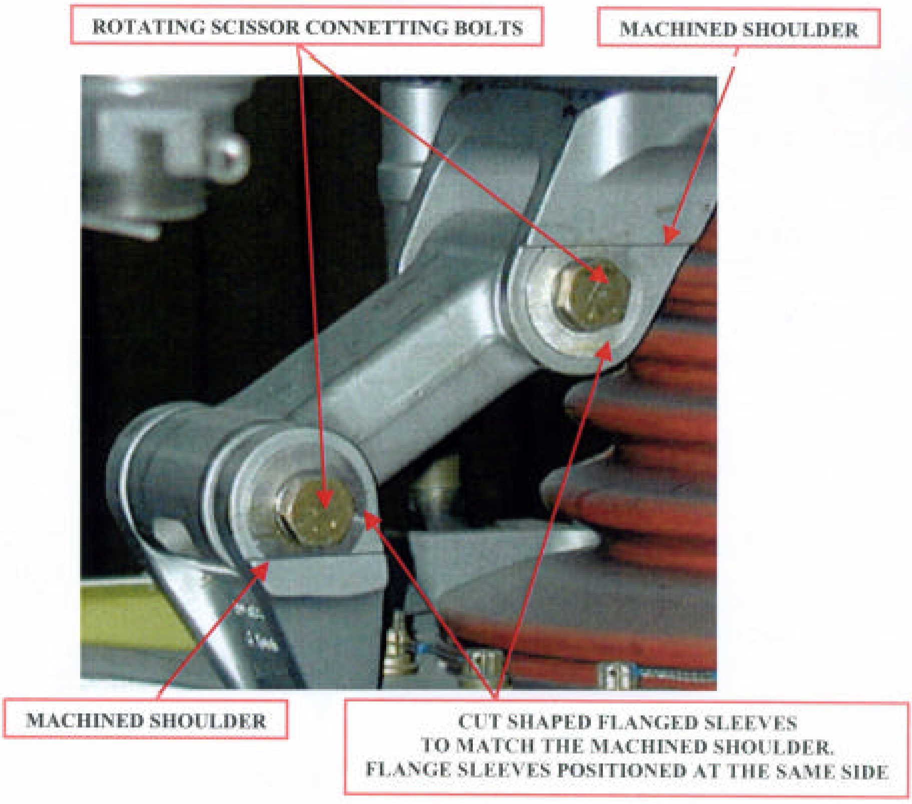


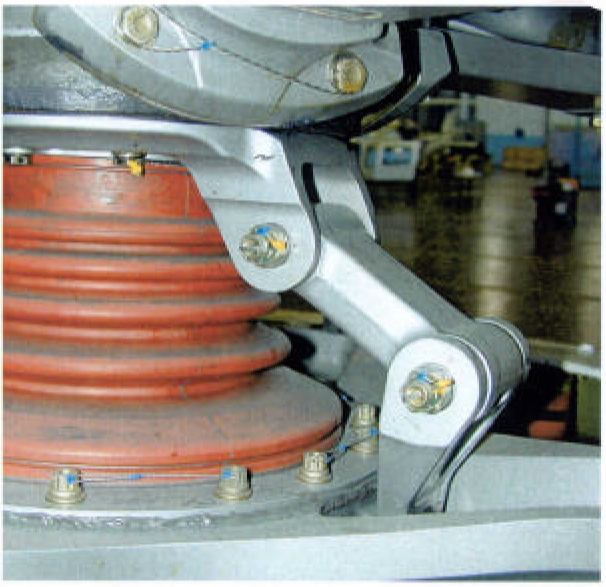
The installation figure in Maintenance Manual, if properly followed, is sufficient to preclude a wrong installation. In fact the figure showed the rotating scissor connecting bolts and the flanged sleeves on the same side so to be engaged on the machined shoulder of the link.

The maintenance manual relevant information in place at the time of accident, (issued 1st July 1999), if strictly followed, should have precluded the wrong installation (back to front) of the lower scissor link on the basis of the right positioning of the flanged sleeves and bolts.

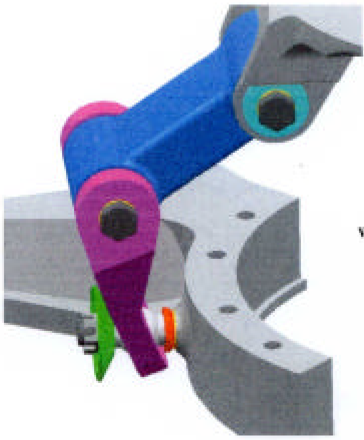
Agusta cannot therefore agree with the conclusion of the investigation performed by the Spanish Commission that assumes as contributory fact for the wrong installation the incomplete information supplied by the relevant section of the aircraft maintenance manual.

The following photos are reported for a better understanding of the previous considerations.


ROTATING SCISSOR CONNETTING BOLTS
MACHINED SHOULDER
MACHINED SHOULDER
CUT SHAPED FLANGED SLEEVES
TO MATCH THE MACHINED SHOULDER.
FLANGE SLEEVES POSITIONED AT THE SAME SIDE

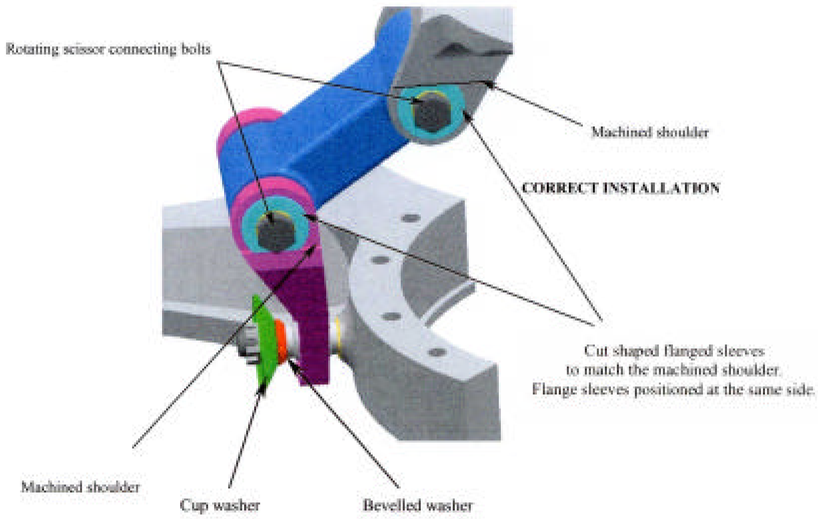


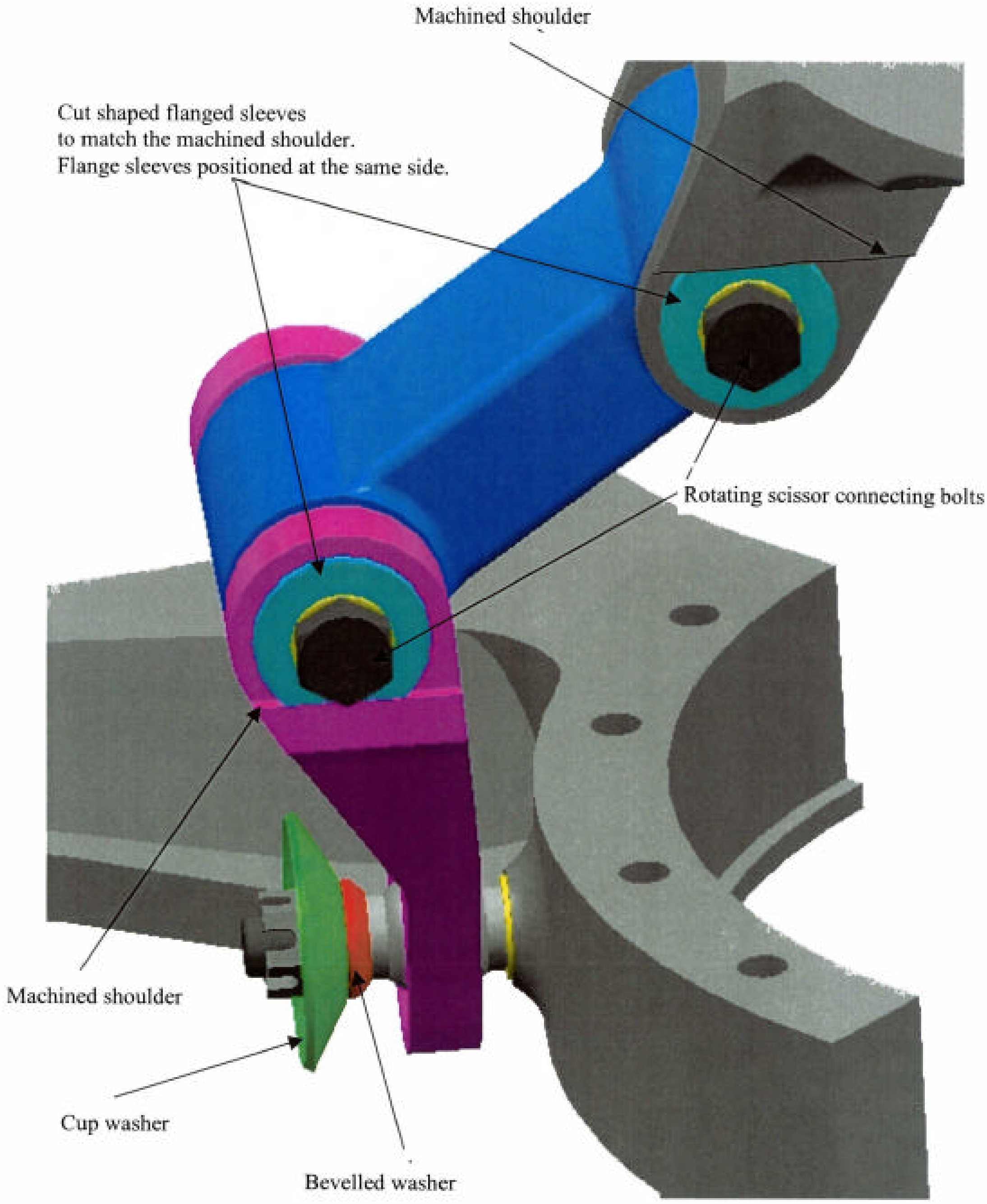
- The reverse installation of the lower scissor link (back to front) needs a consequently wrong positioning of the flanged sleeve. The installation that can be realized is clearly not consistent with the indication of the figure 62-27 A.
The following three dimension figures clearly show as appear a correct installation in respect to the wrong one. It is evident that a correct positioning of the two flanged sleeves preclude an incorrect installation of the scissors.



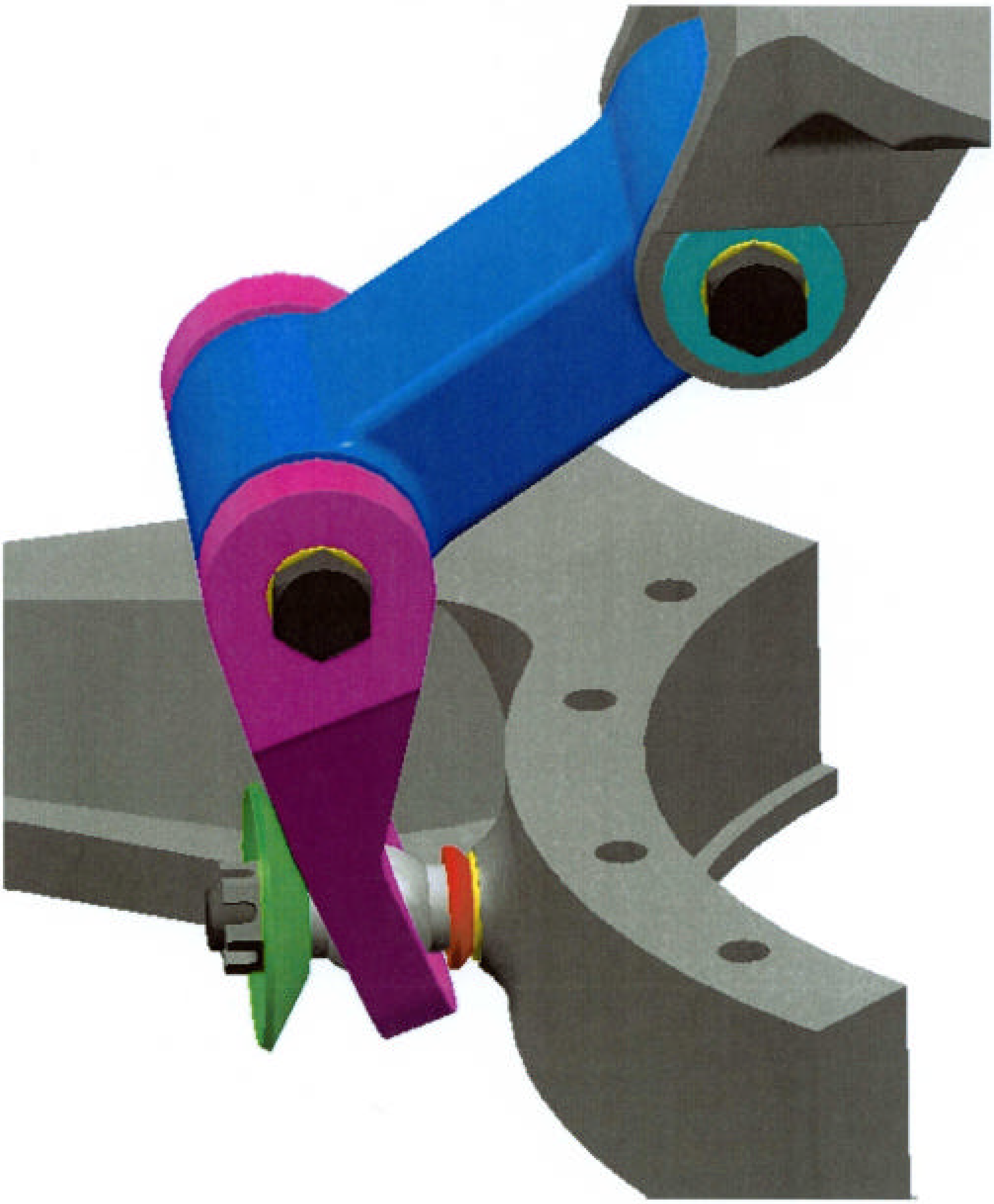
WRONG INSTALLATION

The operator installing the lower link in the reverse position (back to front) have consequently assembled also the flanged sleeve in the opposite direction.
So doing it was realized an installation clearly not consistent with the indication of the figure 62-27 A.

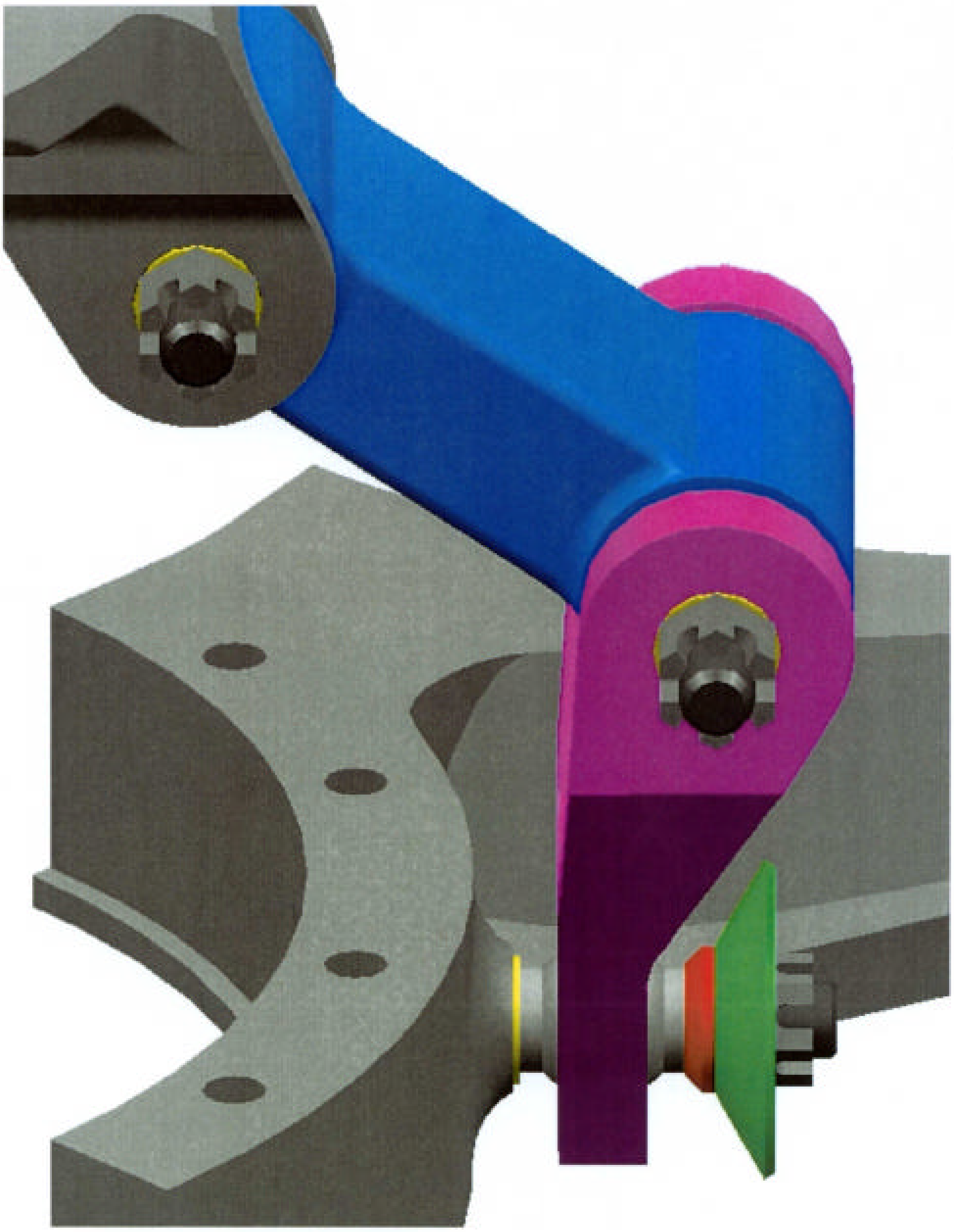




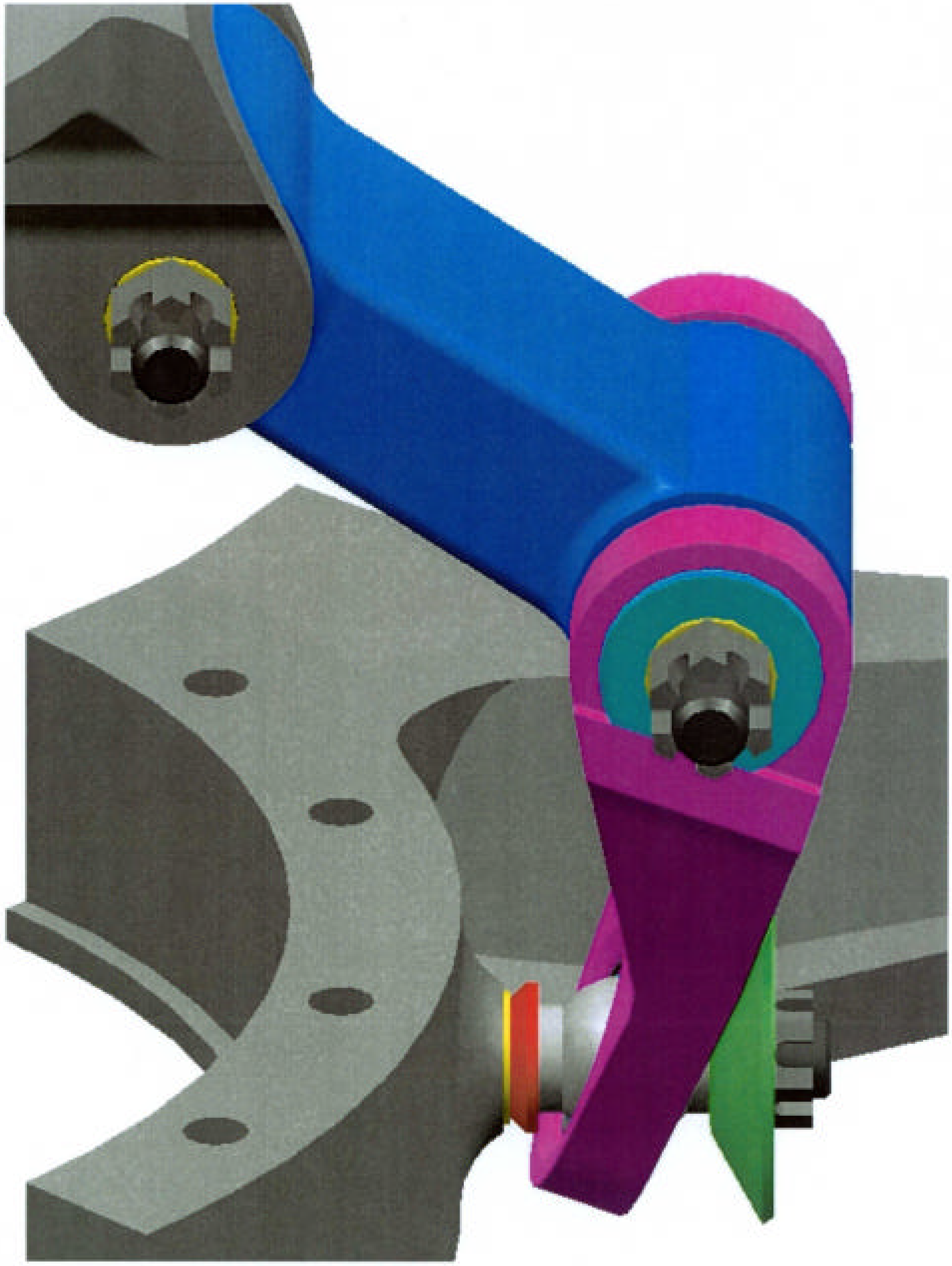
CORRECT INSTALLATION



WRONG INSTALLATION



CORRECT INSTALLATION



WRONG INSTALLATION

The explanatory figures are introduced in Manuals for specific purpose to avoid a mistakable instruction presentation. Furthermore in case of doubts and for requested clarification, Agusta supports the customers and the service stations with the 24 hours service desk that can help for technical-maintenance consultation.

This service has to be utilized for avoiding personal, perhaps logic, but wrong interpretation of the technical instructions as requested from unanimously recognized aeronautical rules.

- Agusta, on the basis of the formal Authority request, subsequently improved the instructions contained in the Maintenance Manual in section 62-31 but considers still suitable for a right installation the information in place at that time.
  On the basis that the figure consultation is the key point for a correct installation also the implemented manual instruction could not be considered adequate if not properly taken in consideration.

Furthermore the Agusta considerations were arranged in points to replay the statement presented at the different paragraph of the accident report.

The comments are quoted with reference to the paragraph number and the accident report text statement is reported between the quotation mark in italics followed by the Agusta consideration.

1. **Par. 1.16.3.1**

   "...... The nut appeared to have turned regarding the initial position, in relation to the bolt, since the cotter pin, used to lock the nut, had the cotters deformed and displaced regarding the logical position and deformation resulting from the locking. The upper cotter, folded over the outside of the bolt, was placed between the crest of the thread and the wall, whilst the lower cotter had strayed off the position parallel to the longitudinal axis of the bolt. ......"

   It is AGUSTA view that:

   From the photos presented in appendix D, it is evident that one end of the cotter pin (lug end) is not deformed and properly in position proved also by the paint mark still present. This observation can exclude a nut rotation from its initial position (installation).

2. **Par. 1.16.3.1**

   "...... Once the cotter pin had been extracted, it could be seen that the nut could be turned with fingers in the tightening sense, approximately one and a half turns, before the first thread of the nut hit the point where the thread came out of the bolt. ......"

   AGUSTA considers that:

   The possibility of the nut to be rotated by finger indicates a not correct installation performed using a wore nut. The tightening procedure asks to verify, before to the nut re-use, the torque value of the self locking bolt (nut) in accordance with par 20-10-5 of Maintenance Manual.
   A nut with a correct self locking torque value do not allow a rotation by finger.
   However considering the possibility of the nut to rotate one and a half turn before reaching the thread end, it is confirmed the capability of the parts installed to be correctly torqued realising a proper thread bound.

3. **Par. 1.16.3.1.5**

   "...... The other abnormality observed (the bevelled washer was not between the cup washer and the side of the bearer) is not important regarding the effect of the inverted assembly of the lower scissor arm and moreover, if we compare figures III.29-A and III.29-B, in the case of the position of the bevelled washer reflected in this figure is more logical and almost required by the resultant geometry. ......"

   AGUSTA finds questionable the assertion of "the wrong bevelled washer positioning as more logical and almost required by the geometry with the lower scissor inverted" as the assembling of the part is a matter of design and certainly any logic involved should be strictly related to the manufacturers design (see three dimension figures).

4. **Par. 1.17.1**

"...... It was established that in the information in the maintenance manual "...the representation of the lower scissors had not been drawn with enough detail to assist a mechanic in identifying the correct position. One clue to an incorrect installation would be that the flange on the hinger bush would have to be at the opposite end to that shown in order to engage with the machined shoulder on the side of the link...". The manual did not contain enough written information on the correct position of the scissors. In fact, there was an error in the instructions, since the bevelled washer was quoted as item 29 when in the diagram it seemed to be 25. ......"

AGUSTA position differs from the Spanish report due to the following considerations:

The installation figure in Maintenance Manual, whether properly followed, is sufficient to preclude a wrong installation. In fact the figure showed the rotating scissor connecting bolts and the flanged sleeves on the same side so to be engaged on the machined shoulder of the link. The washer identification P/N misprint noted in the fig. 62-27 (sheet 2 of 3) "A" is negligible due to installation instructions reported at par. 62-31-14 of the Maintenance Manual. The instruction reported the correct washer stack up to be performed although the bevelled washer contained a clerical P/N misprint (109-0134-01-101 instead of 109-0134-04-101 and the identification number 29 instead of 25).
The Agusta evaluation proved in any case that the control limitation and the following failure were due only to the wrong scissor installation while the wrong bevelled washer positioning was demonstrated to be not influent both for the static and the fatigue strength of the assembly.

5. **Par. 2.2**

"As stated in Section 1.17, the maintenance documentation which provided by figure 62-34 of the A109E-MM Maintenance Manual, including Revision 2 on 4-2-2000 (after the accident occurred), was ambiguous regarding the assembly instructions of the half-scissors assy, since the diagram's perspective did not clearly show towards which side it had to be assembled. Being a spherical bearing, physically it could have been assembled in both positions. Neither were there written instructions on how to carry out this assembly.
The Maintenance Manual did include the correct assembly in the diagram of figure 62-38, section 62-31-04 "Swashplate Friction Adjustment" (see Appendix E), but this figure, being part of another maintenance task, was not in the half-scissor assy section".

Agusta would point out the fact that:

The installation figure in Maintenance Manual, if properly followed, is sufficient to preclude a wrong installation. In fact the figure showed the rotating scissor connecting bolts and the flanged sleeves on the same side so to be engaged on the machined shoulder of the link. Furthermore Maintenance's staff previous experience on A109 models could have led to assembly misunderstandings, unless manufacture's Maintenance Manual is properly followed, considering that the A109E scissors have a different configuration.
In fact on previous A109 models, the P/N in relief of the lower scissor was positioned in the back side, while on A109E is in front side.
The helicopters maintenance requires operator's staff adequate knowledge of the maintenance manual as a whole due to the interrelation of all parts involved in the proper assembly of A109E.

6. **Par. 2.2**

"...... Moreover, as it happens, the arrangement of the washer on both sides of the spherical bearing were correctly drawn in figure 62-34, but the bevelled washer was indicated as item 25, while in the text, when the installation procedure of the rotating scissors was described in writing, it was mentioned as item 29. This could have led the maintenance staff to think that there was an error in the diagram, which, along with the fact that when assembling the lower scissors in the inverted position it was more logical to place the bevelled washer between the bearing and the swashplate, it probably meant that the washers were assembled as in figure INTA III.29 in Appendix D. ......"

AGUSTA considers that:

The washer clerical P/N misprint noted in the fig. 62-27 (sheet 2 of 3) "A" is negligible due to installation instructions reported at par. 62-31-14 of the Maintenance Manual.
The instruction reported the correct washer stack up to be performed although the bevelled washer contained a clerical P/N misprint (109-0134-01-101 instead of 109-0134-04-101 and the identification number 29 instead of 25).

The Agusta evaluation proved in any case that the control limitation and the following failure were due only to the wrong scissor installation while the wrong bevelled washer positioning was demonstrated to be not influent both for the static and the fatigue strength of the assembly.

7. **Par. 2.2**

"...... Nevertheless, neither the bevelled washer nor the thin washer were found amongst the wreckage, and so it can not be definitively concluded whether they were installed or not when the part was assembled. ......"

AGUSTA wants to point out the following:

The two washers certainly were positioned between the scissor and the swash plate considering the existing gap between the bolt failure section and the ball bearing shoulder as proved by the wreckage.
Only the mutual incontestable position of the two washers cannot be defined, although from the signs on the bolt shank, the most probable position sequence was: swashplate body - thin washer - bevelled washer – lower scissor.
The presence of the two washers in any case proved by the fact that differently the stack up could not be realised with the nut in the found position and with the requested torque applied.

8. **Par. 3.1**

"...... The instructions for the assembly of the half-scissors assy, provided by the maintenance manual in section 62-31 "Rotating Controls", edition of 1st July 1999, did not make it possible to determine clearly the correct position in which the part should have been assembled. ......"

It is AGUSTA opinion that:

Although the Maintenance Manual in section 62-31 have been improved on the base of the formal Authorities request, Agusta considers still suitable for a right installation the information contained in the quoted issue of 1st July 1999. Furthermore it is expected that if a trained maintenance person is asked to perform the installation following the Maintenance Manual indication, the assembly shall be realised correctly.
This concept is indirectly proved by the other aircraft in service at the time of the accident.

9. Par. 3.2

"The most probable cause of the accident is considered to be the incorrect assembly of the half-scissors assembly during programmed maintenance tasks, as a consequence of the incomplete information supplied by the relevant section of the aircraft's maintenance manual."

AGUSTA agrees with the statement "The most probable cause of the accident is considered to be the incorrect assembly of the half-scissors assembly during programmed maintenance tasks", but considers that the **proximate cause** should be clearly separated from the possible **contributory facts** as follows:

Cause

The most probable cause of the accident is considered to be the incorrect assembly of the half-scissors assembly during programmed maintenance task.

Contributory facts

i. **Operator's Maintenance staff unchecked A109E assembly procedure, specifically with reference to the installation figure N° 62-27 A.**

ii. **Operator's Maintenance staff lack of adequate familiarization with the maintenance manual as a whole.**

iii. **Operator's Maintenance staff failure to request technical advices from manufacturer as unanimously recognized as a good aeronautical practice.**