COMANDO DA AERONÁUTICA

CENTRO DE INVESTIGAÇÃO E PREVENÇÃO DE ACIDENTES AERONÁUTICOS

FINAL REPORT
A-546/CENIPA/2015

OCCURRENCE:	**ACCIDENT**
AIRCRAFT:	**PR-SEK**
MODEL:	**AW139**
DATE:	**19AUG2011**

NOTICE

According to the Law nº 7565, dated 19 December 1986, the Aeronautical Accident Investigation and Prevention System – SIPAER – is responsible for the planning, guidance, coordination and execution of the activities of investigation and prevention of aeronautical accidents.

The elaboration of this Final Report was conducted taking into account the contributing factors and hypotheses raised. The report is, therefore, a technical document which reflects the result obtained by SIPAER regarding the circumstances that contributed or may have contributed to triggering this occurrence.

The document does not focus on quantifying the degree of contribution of the different factors, including the individual, psychosocial or organizational variables that conditioned the human performance and interacted to create a scenario favorable to the accident.

The exclusive objective of this work is to recommend the study and the adoption of provisions of preventative nature, and the decision as to whether they should be applied belongs to the President, Director, Chief or the one corresponding to the highest level in the hierarchy of the organization to which they are being forwarded.

This Report does not resort to any proof production procedure for the determination of civil or criminal liability, and is in accordance with item 3.1, Annex 13 to the 1944 Chicago Convention, which was incorporated in the Brazilian legal system by virtue of the Decree nº 21713, dated 27 August 1946.

Thus, it is worth highlighting the importance of protecting the persons who provide information regarding an aeronautical accident. The utilization of this report for punitive purposes maculates the principle of "non-self-incrimination" derived from the "right to remain silent" sheltered by the Federal Constitution.

Consequently, the use of this report for any purpose other than that of preventing future accidents, may induce to erroneous interpretations and conclusions.

N.B.: This English version of the report has been written and published by the CENIPA with the intention of making it easier to be read by English speaking people. Taking into account the nuances of a foreign language, no matter how accurate this translation may be, readers are advised that the original Portuguese version is the work of reference.

SYNOPSIS

This is the final report of the 19 August 2011 accident with the AW139 aircraft, registration PR-SEK. The accident was classified as "*with rotor*".

After takeoff, one of the tail rotor blades separated from the aircraft, hampering control of the aircraft by the crew.

Seven seconds later, the aircraft could no longer be controlled, and crashed into the sea.

The aircraft was totally destroyed in the crash, and sank. All occupants suffered fatal injuries.

An accredited representative of the Canadian Transportation Safety Board (TSB) and another of the Italian National Flight Safety Agency (ANSV) were designated for participation in the investigation.

CONTENTS

GLOSSARY OF TECHNICAL TERMS AND ABBREVIATIONS

AACM	Macao's National Civil Aviation Agency
AAIB	Air Accidents Investigation Branch
AC	Advisory Circular
AD	Airworthiness Directive
ADELT	Automatically Deployable Emergency Locator Transmitter
AHRS	*Attitude and Heading Reference System*
ANAC	(Brazil's) National Civil Aviation Agency
ANSV	(Italy's) National Flight Safety Agency
APP	Approach/Departure Control
ATS	Air Traffic Service
BRU	Beacon Release Unit
BT	Technical Bulletin
CA	Airworthiness Certificate
CAD	Civil Aviation Department
CG	Center of Gravity
CHT	Technical Qualification Certificate
CMA	Aeronautical Medical Certificate
CMC	Central Maintenance Computer
CS	Certification Specifications
CVFDR	Cockpit Voice and Flight Data Recorder
DC	Direct Current
DCTA	Department of Science and Airspace Technology
EASA	European Aviation Safety Agency
ENAC	European Commission
FAR	Federal Aviation Regulation
GS	Ground Speed
IAS	Indicated Air Speed
IFRH	Instrument Flight Rules for Helicopters
JAR	Joint Aviation Regulations
MFD	Multi-Functional Display
NM	Nautical Miles
NR	Main Rotor Rotation
NTSB	National Transportation Safety Board
P-15	Petrobrás Oil Rig
P-65	Petrobrás Oil Rig
PA	Autopilot
PCM	Power Control Module

PLAH	Airline Transport Pilot (Helicopter category)
PN	Part number
PUMP	Hydraulic pump
RC	Tail rotor
ROV	Remotely Operated Underwater Vehicle
RP	Main Rotor
RS	Safety Recommendation
SBME	ICAO location indicator - *Macaé* Aerodrome
SERIPA	Regional Aeronautical Accident Investigation and Prevention Service
SIPAER	Aeronautical Accident Investigation and Prevention System
SIU	System Interface Unit
SN	Serial Number
SOV	Shut Off Valve
TCDS	Type Certificate Data Sheet
TGB	Tail Gear Box
TPL	Towed Pinger Locator
TRSOV	Tail Rotor Shut-Off Valve
UTC	Universal Time Coordinated
WAS	Water Activated Switch

1. FACTUAL INFORMATION.

Aircraft	**Model:** AW139 **Registration:** PR-SEK **Manufacturer:** Agusta Westland	**Operator:** *Senior Táxi Aéreo Executivo LTDA*.
Occurrence	**Date/time:** 19AUG2011 - 19:45 UTC **Location:** *Campos* Basin **Lat.** 22°42'36"S **Long.** 040°46'09"W **Municipality – State:** *Macaé* - Rio de Janeiro	**Type(s):** With rotor

1.1 History of the flight.

The aircraft was operating a passenger transport flight from the P-65 Oil Rig to SBME, as part of an offshore operation in the Campos Basin, with two crew and two passengers on board.

After the aircraft took off, the entire Tail Rotor assembly (including the Tail Gear Box - TGB) separated from the aircraft.

The aircraft assumed an abnormal attitude, and ended up crashing into the sea.

1.2 Injuries to persons.

Injuries	Crew	Passengers	Others
Fatal	2	2	-
Serious	-	-	-
Minor	-	-	-
None	-	-	-

1.3 Damage to the aircraft.

The aircraft was totally destroyed.

1.4 Other damage.

None.

1.5 Personnel information.

1.5.1 Crew's flight experience.

Hours Flown		
	Pilot	Copilot
Total	13,000:00	2,800:00
Total in the last 30 days	11:05	10:00
Total in the last 24 hours	05:15	00:50
In this type of aircraft	1,764:50	20:00
In this type in the last 30 days	11:05	10:00
In this type in the last 24 hours	05:15	00:50

N.B.: Data provided by *Senior Táxi Aéreo* Company.

1.5.2 Professional formation.

The captain did his Private Pilot course (helicopter category) at *Prática Táxi Aéreo Escola de Pilotos de Helicópteros Ltda*. (a flying school for prospective helicopter pilots) in 1980.

The copilot graduated from the Brazilian Air Force Academy in 1984, and earned his Private Pilot license on account of previous experience in the military.

1.5.3 Category of licenses and validity of certificates.

The copilot held an Airline Transport Pilot license (helicopter category), as well as a valid AW139 type aircraft technical qualification, in addition to being IFR-rated in helicopters.

The copilot held an Airline Transport Pilot license (helicopter category), as well a valid AW139 type aircraft technical qualification, in addition to being IFR rated in helicopters.

1.5.4 Qualification and flight experience.

The pilots had qualification and enough experience for the type of flight in question.

1.5.5 Validity of medical certificate.

The pilots held valid Aeronautical Medical Certificates (CMA).

1.6 Aircraft information.

The aircraft (SN31081) was manufactured by Agusta Westland in 2007, and registered in the non-regular public air transport service (TPX) category.

Its airworthiness certificate (CA) was valid.

The airframe, engine, and rotor logbook records were up-to-date.

The last inspection of the aircraft (50-hours type) was done on 18 August 2011 by the *Senior Taxi Aéreo* in *Macaé*, Rio de Janeiro. The aircraft flew five hours and fifteen minutes after the inspection.

The last maintenance of the aircraft (1,200-hours type) was done on 19 April 2011 by *Senior Taxi Aéreo* in Macaé, Rio de Janeiro. The aircraft flew 291 hours and 55 minutes after the maintenance.

There were no records of failure or malfunctioning related to the tail rotor blades, tail rotor assembly, and/or shutoff valves of the tail rotor hydraulic lines (Tail Rotor Shut-Off Valve - TRSOV).

The analysis of the aircraft technical records did not identify any tasks of the maintenance program that had not been complied with.

The aircraft was within the weight and balance limits specified by the manufacturer.

1.7 Meteorological information.

The prevailing weather conditions were VMC.

1.8 Aids to navigation.

Nil.

1.9 Communications.

The ATC/aircraft crew two-way communications and the communications between the crewmembers were uneventful.

1.10 Aerodrome information.

Not applicable.

1.11 Flight recorders.

The aircraft was equipped with a CVFDR (PN D51615-102, SN370020-003) manufactured by the Penny Giles company, capable of storing both voice and data.

The CVFDR was taken to the National Transportation Safety Board - NTSB (Washington-DC, USA) by CENIPA investigators for readout of the stored data.

The recordings of the flight and voice parameters were preserved and in usable condition.

The data revealed that the aircraft was making a stabilized climb, with the autopilot engaged, at a speed of 130 kt, and 60% of collective pitch.

From the data collected, it was possible to establish the exact chronology of every event recorded, from the separation of the tail rotor blade until the collision of the aircraft with the sea.

Considering the first recording of parameter variation in the CVFDR as the initial reference for the sequence of events, it is possible to describe and gather the data in accordance with four moments, as shown below:

Separation of one of the tail rotor blades;

Detachment of the TGB (with rupture of hydraulic lines);

Controlled flight; and

Failure of the TRSOV.

a) Separation of one of the tail rotor blades:

Time/Duration	Sequence of events	Recorded evidence (CVFDR)
19:48:05	Abnormal noise.	Audible noise in the pilots' cabin.
	"Moderate" lateral acceleration to the right side.	Lat Acc (AHRS) (G): variation of lateral acceleration to the right with a maximum .367G.
	Movement of pedals aiming to steer the aircraft to the left.	TAIL ROTOR PEDAL (%): Application of left pedal by the Autopilot.
19:48:05.5	Neutralization of lateral acceleration.	Lat Acc (AHRS) (G): lateral acceleration registered as 0G.

b) Detachment of the TGB (with rupture of hydraulic lines):

Time/Duration	Sequence of events	Recorded evidence (CVFDR)
19:48:05.5	Loss of TGB oil temperature signal.	TGB OIL TEMP (°C): Loss of signal.
	"High" lateral acceleration to the right.	Lat Acc (AHRS) (G): variation of lateral acceleration to the right reaching .976G (three times higher than previous mark).
19:48:05.8	Loss of hydraulic system n° 1.	PUMP1: Output pressure of the hydraulic pump of hydraulic system n° 1 below 163 bar.
19:48:06.3	Discrepancy between *Ground Speed* (GS) and IAS (*Indicated Air Speed*).	IAS recorded variation: from 130 kt to 20 kt in 1 second.
	High variation of Ground Speed.	GS recorded variation: from 130 kt to 95 kt in 1 second.
	Autopilot disengagement.	Audio in the cabin.

c) Controlled flight:

Time/Duration	Sequence of events	Recorded evidence (CVFDR)
19:48:06.3	Cyclic control input forward and to the left.	Recording of the cyclic forward movement along longitudinal axis and movement to the left along lateral axis.
From 19:48:06.3 to 19:48:08.3	Aircraft roll-to-the-left.	Recording of roll-to-the-left up to 120°
	Collective control input for minimum pitch and then for approximately 75%.	Recording of collective movement from 60% to 0% and then to 75%.
From 19:48:08.3 to 19:48:12.8	Cyclic control input for aircraft stabilization in autorotation.	Recording of cyclic movements consistent with aircraft attitude recovery.
	Collective control input.	Recording of collective movements close to minimum pitch.
	Decrease in the variation of heading.	Recording of heading variation of approximately 20° per second.
	Copilot calls APP-*Macaé* to declare emergency.	Recording of copilot's voice while declaring emergency.

d) Failure of TRSOV:

Time/Duration	Sequence of events	Recorded evidence (CVFDR)
From 19:48:12.8 to 19:48:33.8	Loss of hydraulic system number 2.	PUMP2 and PUMP4: Output pressure in the hydraulic pumps below 163 bar.
	Cyclic control inputs incongruent with aircraft movements.	Recording of cyclic movements varying with high amplitude in random directions.
	Collective control inputs incongruent with aircraft movements.	Recording of low amplitude/high frequency collective movements.
	Total loss of aircraft control.	Recording of extensive aircraft attitude variations.
	Copilot informs APP-*Macaé* about loss of hydraulic systems.	Recording of copilot's voice while informing type of emergency.

In the graphs below, it's possible to see the four distinct moments presented in the CVFDR data:

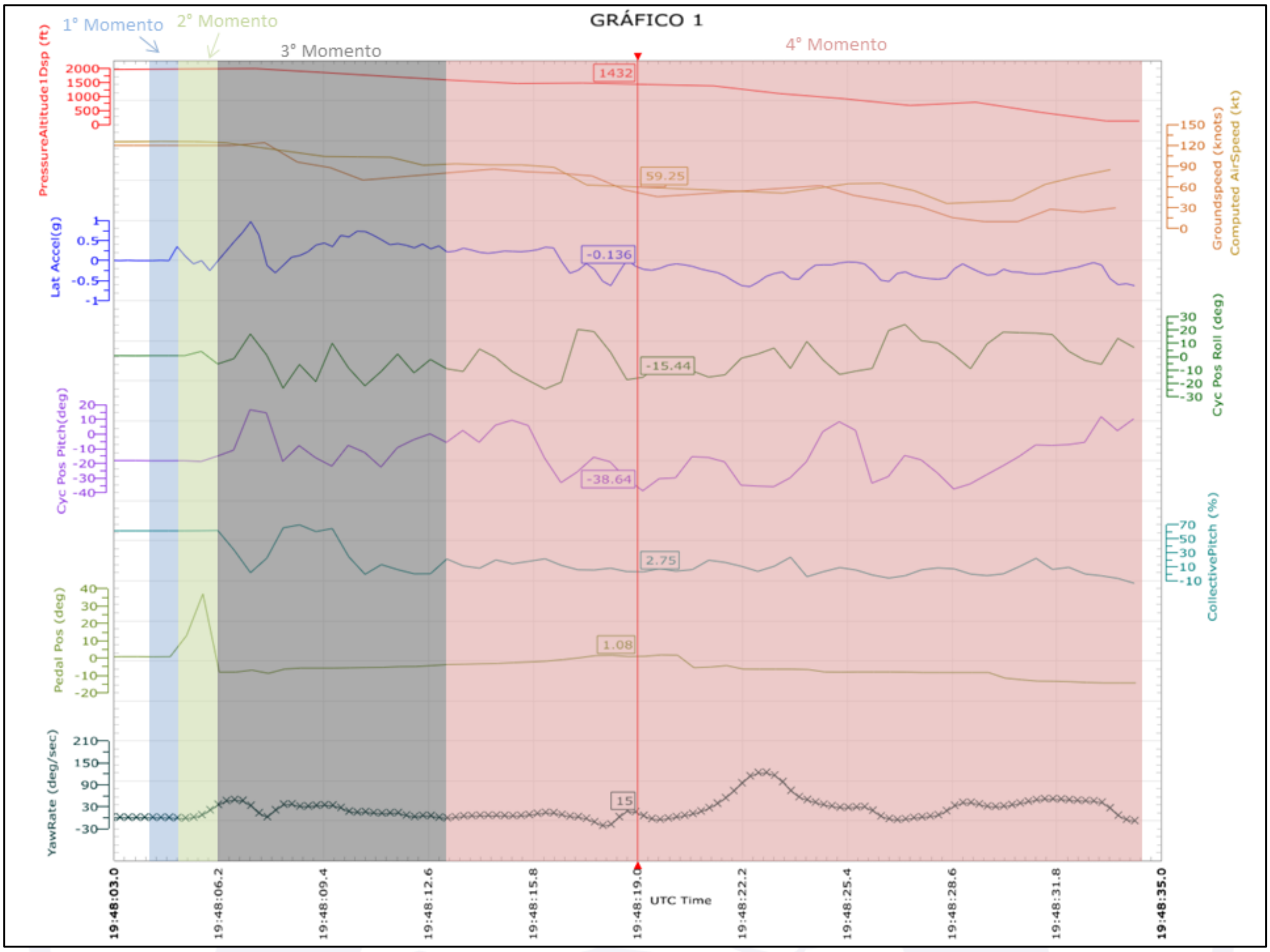

Figure 1 - Flight parameters and position of controls as recorded in the CVFDR.

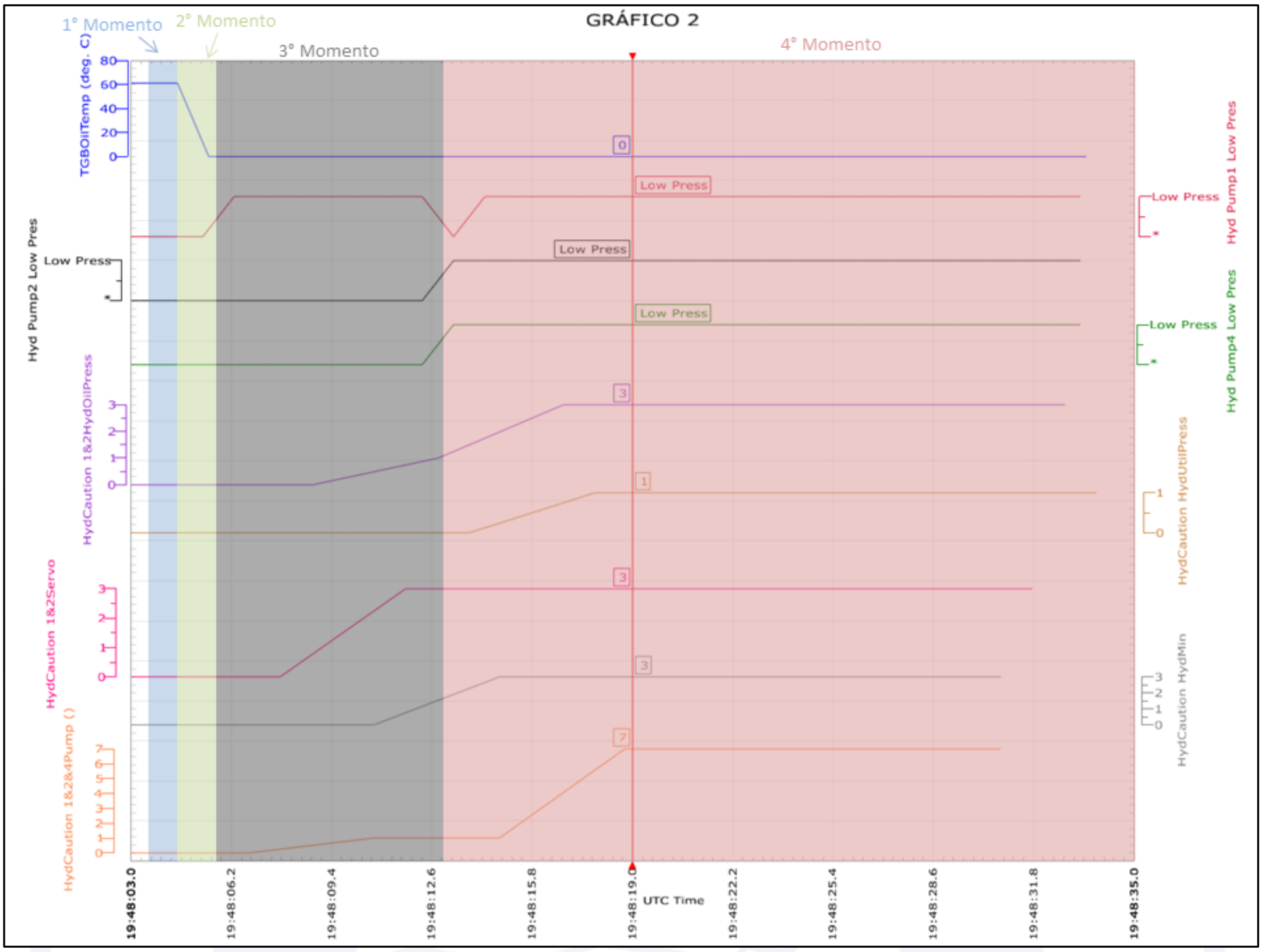

Figure 2 - Hydraulic parameters recorded in the CVFDR.

1.12 Wreckage and impact information.

The accident occurred outside of aerodrome area, and the aircraft crashed into the sea without any previous impact.

The wreckage distribution was linear, as can be seen in Figure 3. One of the tail rotor blades and the remainder of the tail rotor assembly detached from the aircraft at two distinct moments before the impact, and were found separated from the fuselage and main rotor.

The descent trajectory until the impact with the sea was pronouncedly vertical (approximately 80°), at a rate of descent of, at least, 8,000 ft/min. The attitude of the aircraft at the moment of impact was in accordance with an 80-degree roll-angle to the right and a 15-degree pitch-down angle.

The marks of impact on the fuselage had characteristics compatible with high speed and large angle.

The aircraft was found at the bottom of the sea at a depth of 100 meters, at a distance of 58 nautical miles from *Macaé* aerodrome and at a distance of two kilometers from the point where the secondary radar contact was lost, roughly along the projection of the flight path detected by the APP-Macaé radar.

The tail-rotor TGB was found .3 nautical miles short of where the fuselage was located, still with three blades attached to the assembly, in addition to the root of the blade that had detached.

Figure 3 - Last radar contact of the aircraft in relation to the positions where the Q1018 blade, tail rotor assembly, and aircraft wreckage were located.

The blade that detached was found at a distance of .12 nautical miles (230 meters) short of the TGB location and, approximately, .42 nautical miles (800 meters) short of the fuselage position, as shown in Figure 4.

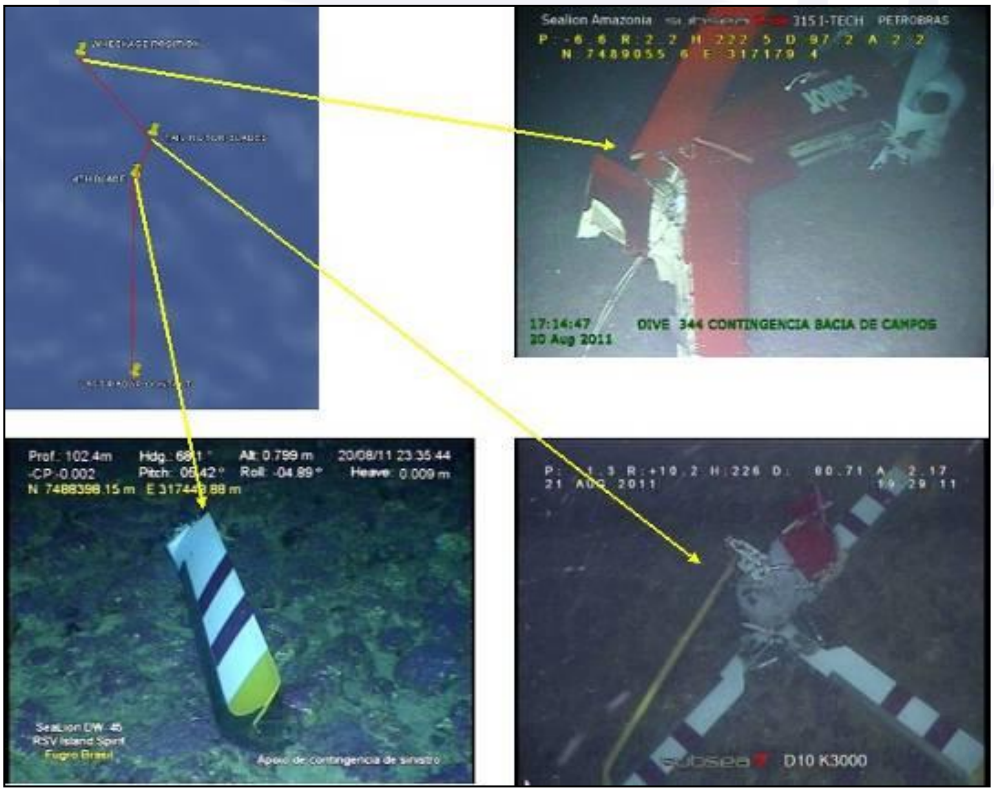

Figure 4 - Wreckage distribution in relation to position and distances.

The lines of the hydraulic systems numbers 1 and 2 were found ruptured at the point of attachment to the TGB. The level of destruction of the aircraft made it impossible to identify the positions of the switches, controls and circuit breakers in the pilot’s cabin.

1.13 Medical and pathological information.

1.13.1 Medical aspects.

The bodies of the four occupants sank with the aircraft, and were rescued by divers. The autopsy exams revealed that the occupants perished at the moment of impact with the sea water.

1.13.2 Ergonomic information.

Nil.

1.13.3 Psychological aspects.

Not investigated.

1.14 Fire.

No signs of either inflight or post-impact fire.

1.15 Survival aspects.

The initial search was made by means of helicopters and ships that were in the vicinity of the crash-site and debris were being sighted on the surface of the water.

The helicopters took turns flying over the debris for over two hours. Then, a Brazilian Navy aircraft made a night-time visual search for survivors, making use of search-lights. Ten supporting vessels remained the whole night searching for survivors, and collecting debris found floating on the surface.

After the likely area of the accident was defined, the search for wreckage at the bottom of the sea was immediately initiated.

The aircraft CVFDR was equipped with an underwater locator beacon, the purpose of which is to facilitate location by means of emission of acoustic waves. As a counterpart, it was necessary for the ships involved to possess a type of SONAR equipment called Towed Pinger Locator (TPL), which, as a matter of fact, was not present in the Brazilian Navy and Petrobras ships engaged in the search.

The helicopter emergency floats and the Automatically Deployable Emergency Locator Transmitter (ADELT) were not activated either by the crew or otherwise.

A Petrobras-owned remotely operated underwater vehicle (ROV) was utilized for the search, and located the aircraft wreckage the next day after the accident.

1.16 Tests and research.

Tail-rotor blade

AW139 helicopters typically have four-blade tail-rotors.

The PN 3G6410A00131 (SN Q1018) tail-rotor blade, which separated in flight, was manufactured in June 2008 and installed by Agusta in the aircraft (SN31156) in September 2008.

In January 2010, the blade (after 589 hours and 55 minutes of accumulated operation) was removed from the aircraft by the HNZ PTY LTD Company on account of the presence of corrosion in the PITCH HORN.

In July 2010, the blade was repaired at the premises of the Agusta maintenance base, being later sold to *SENIOR TAXI AEREO*, which later installed it (August 2010) in the PR-SEL aircraft (SN31084), from which it was removed in April 2011 (with 1,280 hours and 30 minutes of operation) to accommodate a maintenance sector's convenience.

In the same month, the blade was installed in the SN31081 aircraft (PR-SEK), where it stayed until the date of the accident, with a total 1,572 hours and 35 minutes of operation.

In May 2011, there was compliance with the AD 2011-0081, which introduced the 600-hours periodical inspection for the tail-rotor blades by virtue of the Technical Bulletin BT 139-251 on account of a dynamic unbalance event involving an AW139 helicopter. The service was watched by Agusta technicians.

On the occasion, cracks were found in the blades SN Q1004 and Q1005, which were removed from service and sent to AGUSTA for analysis. No discrepancies were found in the blade SN Q1018.

The aircraft flew 254 hours and 40 minutes after compliance with the AD 2011-0081.

In accordance with the certification requisites for tail-rotor blades, Section 29.547 (AC 29-02C), the component must keep integrity under normal operating conditions until the time designated for overhaul, inspection, or life limit.

The exams and tests of the fractured blade confirmed the presence of defects during the process of manufacture. Porosity, blank areas, and delamination in the structure of the blade gave rise to cracks, which propagated to the point of breakage.

Hydraulic system

The main hydraulic system of the aircraft is divided into two independent systems (hydraulic system n° 1 and hydraulic system n° 2).

The hydraulic system n° 1 has the following basic components: *Power Control Module* 1 (PCM1), mechanic hydraulic pump (PUMP1) and hydraulic lines.

The PCM1 is composed of reservoir, distributing block, and attachment support. It provides filtered hydraulic fluid to the hydraulic system n° 1, and monitors the system pressure and temperature, in addition to monitoring the variation of the hydraulic fluid volume in the reservoir.

The diaphragm-type hydraulic reservoir has a total volume of 4.1 liters.

A spring exerts force on the diaphragm by means of a piston rod for supplying the inlet pressure of the PUMP1. This spring also maintains the diaphragm in the correct position during the operation.

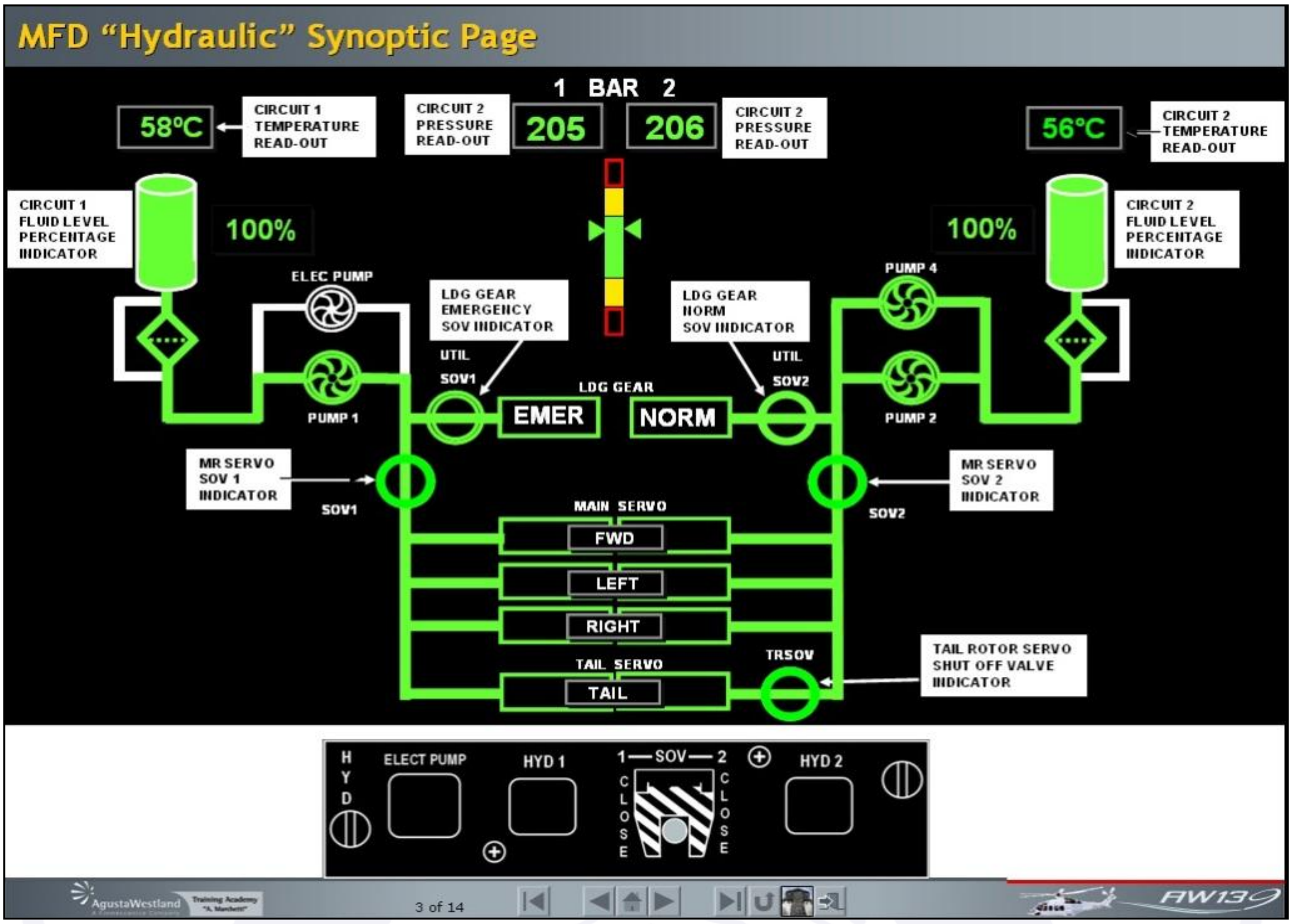

Figure 5 - Synoptic presentation of the AW139 hydraulic system.

Figure 6 shows the composition of the PCM hydraulic reservoir in detail.

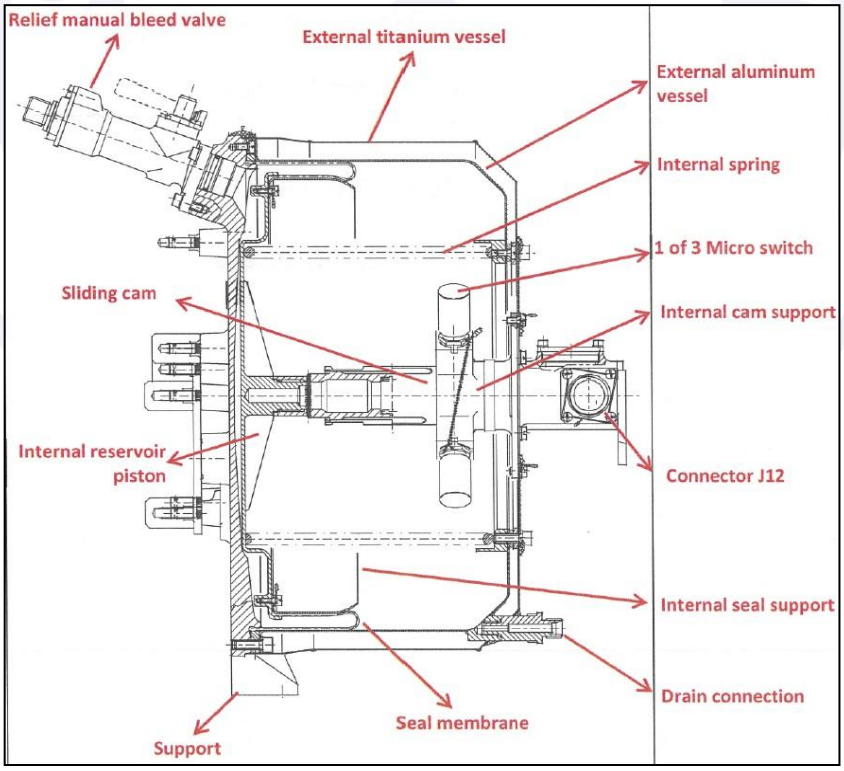

Figure 6 - PCM hydraulic reservoir set.

Three level micro-switches of a pole (*double-throw* type) are installed in the reservoir. The micro-switches are put in action by means of a shaft with grooves which moves with the diaphragm as the fluid volume varies in the reservoir.

The *micro-switches* are triggered when the hydraulic fluid level reaches 1.3dm^3, .9dm^3 and .7dm^3, corresponding to 50%, 28% and 22% of the usable fluid quantity.

The signal released through the activation of the micro-switches starts a process of alerts sent to the pilots and maintenance, which appear in the *Multi-Functional Display* (MFD), and are recorded in the CFVDR and in the Central Maintenance Computer (CMC).

The hydraulic system n° 2 consists of the PCM2 (identical to the PCM1), two mechanical hydraulic pumps (PUMP2 and PUMP 4), and a *Tail Rotor Shut-Off Valve* (TRSOV) on the pressure line for tail-rotor control.

The TRSOV is electrically activated by means of the electromechanical control of the PCM2 when the 50% and 28% micro-switches (installed in series in the electric circuit) close.

The TRSOV has three paths (inlet, outlet and return), as well as two positions (open and closed). It is basically composed of an aluminum body, a sphere valve, and a solenoid valve (called pilot valve), as illustrated in Figure 7.

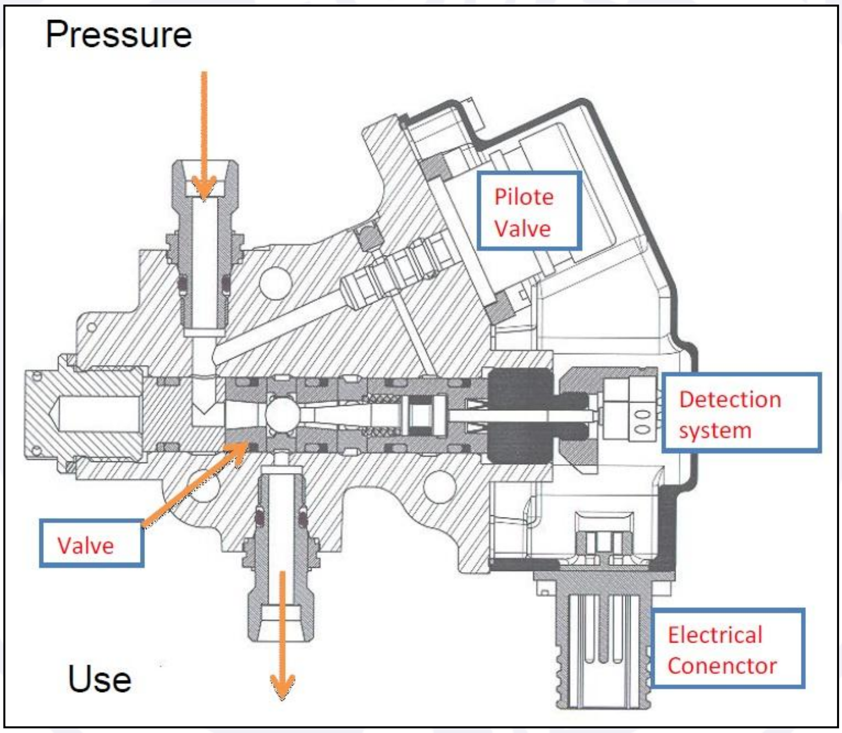

Figure 7 - Illustration of the TRSOV.

The electric activation of the pilot valve (Figure 8) by the level switches 28% and 22% of the PCM2, activates the sphere valve by pressure differential, blocking the flow of hydraulic fluid for the pressure line of the tail-rotor actuator.

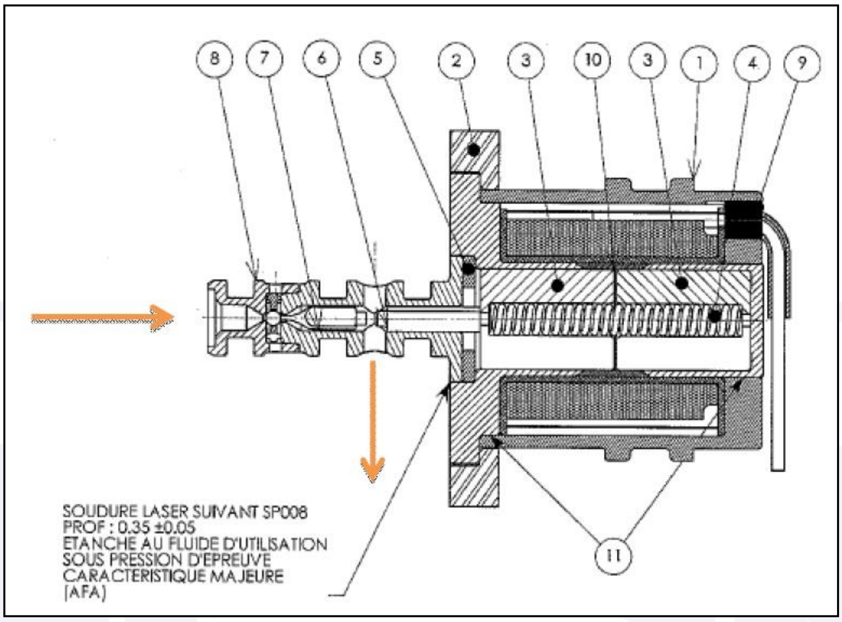

Figure 8 - *Pilot valve* in detail.

Figures 9 and 10 show the operation of the TRSOV with the *pilot valve* not energized and energized, respectively.

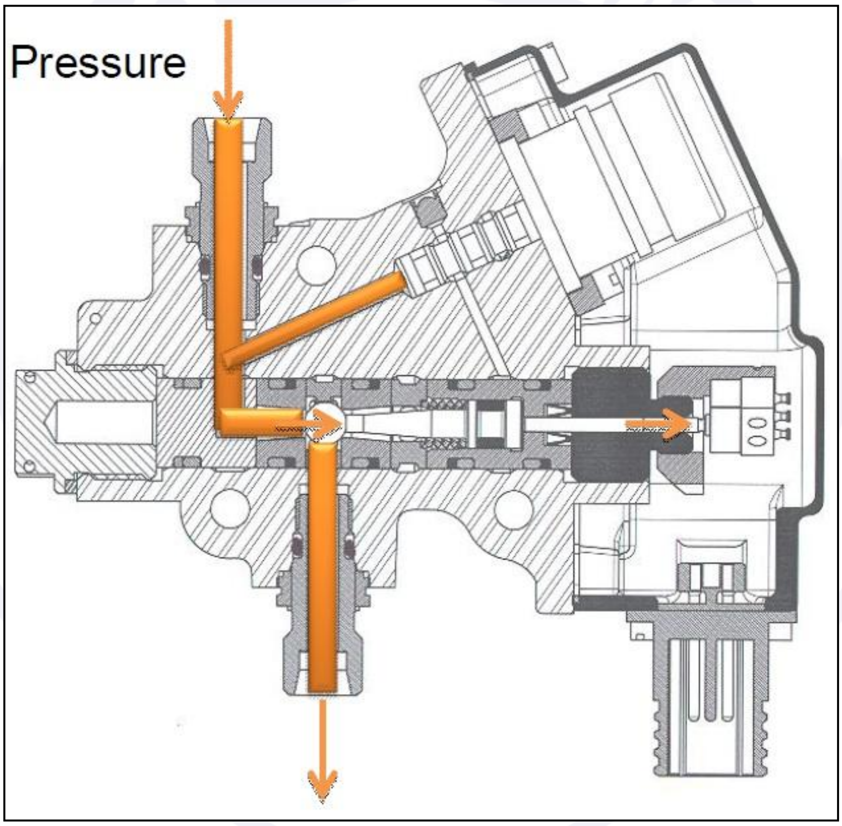

Figure 9 - TRSOV open, with the *pilot valve* not energized.

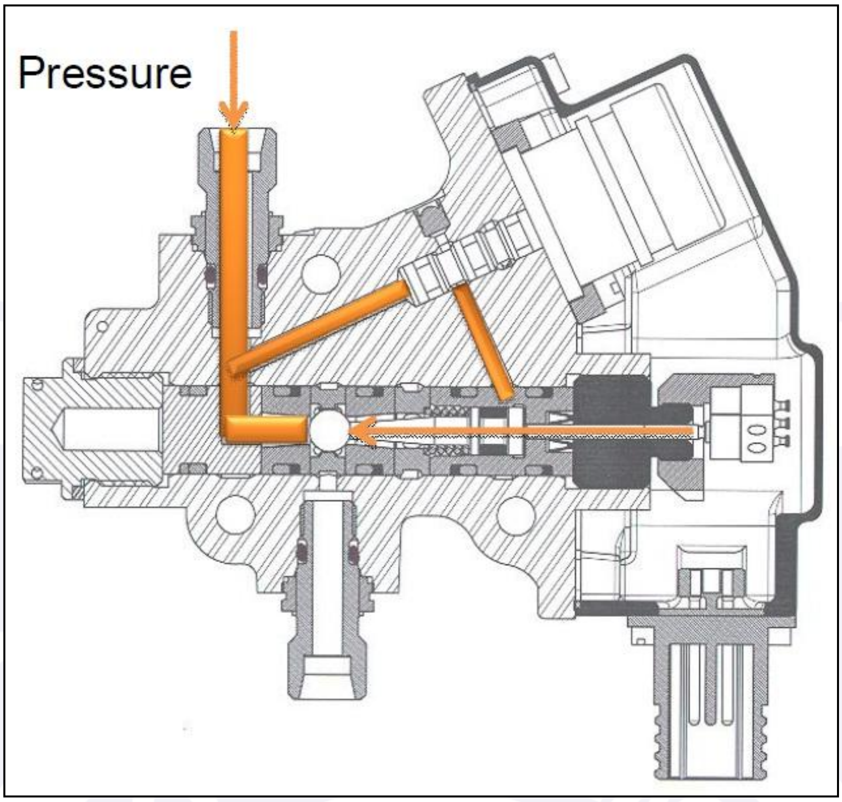

Figure 10 - TRSOV shut, with the *pilot valve* energized.

The function of TRSOV installed in the hydraulic system n° 2 is to discontinue the flow of hydraulic fluid to the pressure line of the tail-rotor control if there is leakage of fluid through this line, thus preserving the hydraulic energy for the main rotor control servos.

In functional terms, the two main hydraulic systems monitor the correct functioning of the aircraft hydraulic system by means of the PCM's, controlling the pressure in the system, the temperature of the fluid, and the variation of the volume of the fluid in the hydraulic reservoir of the PCM's.

However, if there is leakage in the pressure lines of the tail rotor actuator, only the hydraulic system n° 2 has the function of discontinuing the loss of fluid by means of activation of the TRSOV, when the level of the PCM2 reservoir reaches 28% during the loss of fluid.

The two main hydraulic systems have two more SHUT-OFF VALVES each (SOV1, SOV2, UTILITY SOV1 and UTILITY SOV2), but the description of the functioning is not relevant in the present investigation.

The temperature during normal operation of the AW139 hydraulic systems varies from -20°C to 119°C. On average, the temperature in flight stabilizes at about 70°C.

The temperature of the TRSOV in operation is the same temperature of the hydraulic fluid, which in normal operation may vary from -20°C to 119°C. It is estimated that the fluid temperature at the moment of the occurrence would be approximately 70°C.

During 7.5 seconds, the TRSOV performed as expected, and remained closed, discontinuing the flow of fluid from the hydraulic system n° 2, in order to guarantee the functioning of the helicopter flight control system.

After this time in operation, the valve had a failure due to the breakage of the wire wound up in the TRSOV pilot valve due to overheating. The immediate consequence was the drainage of the hydraulic fluid from the hydraulic system n° 2, followed by loss of aircraft control.

The overheating of the wire occurred in a limited punctual fashion, within a very specific area in the middle of coil, characterizing a punctual failure of the insulating material of the coil wire.

Factors, such as resistance to temperature, uniformity of the wire insulating material, and electrical stability in the operation, are decisive for the lifespan of the coil. Unfavorable associations of these factors are capable of negatively affecting the lifespan of electric coils.

In the laboratory, it was possible to verify that at each opening of the 28% micro-switch, there was de-energization of the coil. The faster the tension in the coil is cut off, the higher the peak of instantaneous tension auto-induced in it.

The tension-peak does not take place in a single event, but in innumerous oscillations caused by the continuous commutation of the micro-switch contacts, at each level variation of 28%. This produces a number of electrical discharges, and an increase of the electrical stress sustained by the coil.

The reason for the TRSOV coil failure was identified in a local wire overheating resulted in material melting. The root cause of the overheating could not be identified.

Tail Rotor Shut-Off Valve (TRSOV)

The TRSOV (PN 3G2910V00231, SN 2104) installed in the aircraft since its manufacture, is an ON CONDITION component. It is activated if a low level of hydraulic fluid is detected in the hydraulic system n° 2.

Until the date of the occurrence, the maintenance program of the manufacturer did not contemplate inspections of the TRSOV, but just an operational check at the 1,200-hours inspection of the Power Control Module - PCM.

The 1,200-hours inspection of the PCM was done by the *SENIOR* Company on 19 April 2011. The aircraft had 3,625 hours and 35 minutes of light. No discrepancies were found in the systems (PCM and TRSOV).

The thermal class of the TRSOV coil wire is the 200-type, which utilizes polyesterimide and polyamidimide as insulating material, with a maximum thermal resistance of 200°C.

Auto-Deployable Emergency Locator Transmitter (ADELT)

The ADELT system is the main means of the radio location system for search, rescue and assistance to aircraft in emergency.

The system is composed of the following basic components:

a) *System Interface Unit* (SIU): interface with the system by means of an *OFF/ARM switch.*

b) *Aircraft Identification Unit* (*Configuration Unit*): unit containing the identification of the aircraft.

c) *Beacon Release Unit* (BRU): unit that provides mechanical electric interface between the (radio) *beacon* and the aircraft. It is responsible for the launching and jetissoning of the beacon.

d) *Water Activated Switch* (WAS): water-sensitive activation *switch.*

1.17 Organizational and management information.

Nil.

1.18 Operational information.

After taking off in VMC at 16:42 local time, the aircraft made contact with *Enchova* Radio located on Platform P-15, to inform that they had taken off and were climbing to 3,500 ft.

At 16:48, as the aircraft was passing 1,800 ft, at a speed of 130 kt, and with the auto pilot engaged, one of the tail rotor blades separated, and, half a second later, the entire tail rotor assembly (the TGB included) detached from the aircraft.

The helicopter yawed to the right in an abrupt manner and rolled approximately 120° to the left.

Soon after the separation of the tail rotor assembly, there was an immediate loss of pressure in the hydraulic system n°1, and recovery from the abnormal attitude was made by means of application of the cyclic and collective controls, and the aircraft was stabilized in autorotation. Then, the copilot called Macaé Approach Control (APP-Macaé) to inform, three times in a row, that the aircraft was in emergency.

There was no immediate loss of the hydraulic system n° 2, due to the functioning of the TRSOV, which discontinued the flow of hydraulic fluid to the tail rotor control line, thus preserving the hydraulic energy for the main rotor control servos.

Such stabilized trajectory remained for 4.5 seconds, until pressure of the hydraulic system n° 2 was lost leading to definitive loss of aircraft control. Then, the copilot informed via radio that the hydraulic systems were lost. According to the company's cockpit doctrine, such task was responsibility of the pilot monitoring (PM).

The aircraft continued its uncontrolled trajectory until crashing into the sea, with its right side facing downwards, at a sink rate of about 8,000 ft/min.

APP-*Macaé* and *Enchova* Radio sent three helicopters which were in the vicinity, for assistance. While they were flying over the crash-site, two emergency boats deployed were sighted without signs of survivors, in addition to some floating debris and a stain of fuel on the surface of the sea.

- <u>Flight simulator training</u>

In January 2012, the investigator-in-charge went to Morristown, New Jersey, USA, for an evaluation of the emergency training relative to the control of the pedal and activation of the tail-rotor in the CAE SimuFlite.

He simulated maneuvers involving the sticking of the pedals in several positions (left pedal depressed, pedals in neuter, and right pedal depressed), as well as maneuvers involving failure of activation of the tail rotor (breakage of the activation shaft) at various speeds (hovering, climb, cruise flight).

In all the simulated emergency situations, the functioning of the systems is similar to what takes place in real aircraft. In the situations of stuck pedals, the simulator reaction is similar to the aerodynamic reactions occurring in the helicopter. In the simulator, emergencies resulting from the breakage of the tail rotor activation shaft show the aircraft making a quick yaw to the right, but without any lateral acceleration force or left roll tendency, even at high speeds.

Although manageable, depending on the flight condition, tail rotor system failures were considered catastrophic. The Rotor Flight Manual (RFM) and the Training Program did not have a procedure contemplating the loss of the entire tail rotor assembly, for which the emergency procedure to be adopted is the same of the Tail Rotor Drive Failure included in RFM.

1.19 Additional information.

This item of the report was divided into four parts: AW139 Type Design Certification, Certification Requirements, other similar occurrences worldwide, and previous experience of the aircraft captain.

AW139 Type Design Certification

The AW139 aircraft received its original certification on 18 June 2003 from the Italian aeronautical authority (ENAC), and the certification was based on the *JAR 29 Amdt 3*, dated 1 April 2002. Then the Type Certificate Data Sheet (TCDS) n° R.006 was issued by EASA.

In the USA, the AW139 certification was granted on 20 December 2004 (B-category) and on 10 April 2006 (A-category). The basis for the American certification was the FAR 29 Amdt 45 of 25 October 1999. The TCDS n° 00002RD was issued for validation.

In Brazil, the certification (via validation) was granted on 12 April 2007. The certification basis, however, was not perfectly referenced, considering the contents of the item 2.7.2 of the Manual of Procedures of the Airworthiness Superintendence (MPR-210/SAR). The TCDS n° ER-2007T04-04 did not mention the TCDS issued by the ENAC/EASA, which was the basis for the validation.

The investigation commission observed that the TCDS n° ER-2007T04-04 mentioned the certification basis FAR 29 Amdt 82. However, this amendment to the FAR 29 had not yet been issued at that time.

Certification Requisites

This item presents the original certification requisites of the AW139 design. They are listed in the JAR 29 - Large Rotorcraft (currently, CS 29) pertinent to the analysis of the accident. The item also presents information on the primary certification granted by the aeronautical authority, as well as information on the secondary certification granted by the American authority (FAA).

The AW139 design utilized a hydraulically-operated flight control system. One of the requisites for the certification of systems like this one is described in the JAR 29, Section 29.695 - Power Boost And Power Operated Control System

> **29.695 Power boost and Power Operated Control System**
>
> (a) If a power boost or power-operated control system is used, an alternate system must be immediately available that allows continued safe flight and landing in the event of -
>
> (1) Any single failure in the power portion of the system; or
>
> (2) The failure of all engines.
>
> (b) Each alternate system may be a duplicate power portion or a manually operated mechanical system. The power portion includes the power source (such as hydraulic pumps), and such items as valves, lines, and actuators.
>
> (c) The failure of mechanical parts (such as piston rods and links), and the jamming of power cylinders, must be considered unless they are extremely improbable.

The item 29.695 (a) prescribed that an alternative system had to exist allowing for the safe continuation of the flight and landing if a failure occurred in one of the power portions of this flight control system.

The item 29.695 (b) prescribed that the alternative system had to be either a duplicate power portion of the system or a mechanical system operated manually. The same item also stated that the power portion included the power source, such as hydraulic pumps, and other components, such as valves, lines and actuators.

The AW139 helicopter design utilized the second type of the alternative system described, that is, a duplicate power portion of the system, since the forces in action in the rotors are so high that they cannot be mechanically controlled by human strength.

The item 29.695 (c) observed that failure of the mechanical parts of the system (power cylinders) had to be taken into account, unless it was calculated extremely unlikely.

This requisite had the objective of guaranteeing a safe continuation of the flight and subsequent landing, with a redundant power portion necessary for maintaining controllability of the aircraft.

The Advisory Circular (AC) 29-2C - *Certification of Transport Category Rotorcraft*, issued by the *Federal Aviation Administration* (FAA), had the objective of establishing acceptable means for compliance with the FAR 29 requisites. In the section AC 29.695(c)(2), it ratified the need of a redundant Power *Operated Control System,* as shown below:

> "(2) If a duplicate power portion of the system is used to meet the requirements of the rule, the requirements may be met by providing a dual independent hydraulic system, including the reservoirs, hydraulic pumps, regulators, connecting tubing, hoses, servo valves, servo-valve cylinder, and power actuator housings. There must be no commonality in fluid-carrying components. A break in one system should not result in fluid loss in the remaining system."

The rotor blades of any helicopter were designed for minimising the likelihood of failure in order to comply with the certification requirements.

The process of manufacture of the AW139 tail rotor blade by the AgustaWestland was certified at first by the ENAC and, at the time of the accident, was under EASA POA still oversight by ENAC.

As with any certification, there are audit processes conducted by the certifying aeronautical authority and by the manufacturer, aiming at guaranteeing the quality standard obtained during the process of certification of production. The processes in place at the time of blade manufacture were not robust enough to identify the occurrence of failures in the structure of the tail rotor blades.

<u>Other similar occurrences worldwide</u>

On 3 July 2010, an AW139 aircraft, registered as B-MHJ, made an emergency landing in the Bay of *Hong-Kong* - China.

After taking off from the *Sheung Wan* Heliport, the aircraft was approximately at 350 ft AGL at a speed of 70 kt, when one of the tail rotor blades separated, causing a dynamic unbalance followed by separation of the aircraft tail rotor assembly and TGB.

The crew realized that they had lost tail rotor effectiveness, and maneuvered the aircraft in autorotation, shutting down both engines before impacting the water. All aircraft occupants were rescued alive, although some of them with minor injuries.

In this occurrence, the TRSOV installed in the hydraulic system n° 2 was in operation during the entire maneuver, and the aerodynamic reactions were less abrupt than the ones sustained by the PR-SEK (Figure 11).

Figure 11 - Accident involving the B-MHJ aircraft in Hong Kong, China.

The tail-rotor assembly of the B-MHJ aircraft was found with the three remained blades, but the part of tail rotor blade which separated was never found.

Later, three blades and the fragment of the broken blade which remained in the tail rotor assembly were sent to the QinetiQ Laboratory in England.

According to the information provided by EASA, it became informed shortly after the occurrence on 5 July 2010. At that time the investigation was focused on a possible bird strike event on the base of witnesses reporting and therefore the CAD Authority was investigating on aircraft bird strike vulnerability assessment.

On 27 July 2010, the CAD issued the *Preliminary Report* 2/2010, which described the B-MHJ aircraft accident and surrounding conditions, without raising any hypotheses for the case.

In September 2010, a meeting was held at the Air Accidents Investigation Branch - AAIB in the United Kingdom, with participation of the following entities: CAD, AAIB, AACM (Civil Aviation Authority of Macau), ANSV (Italian Air Accidents Investigation Agency), Agusta, and QinetiQ. The meeting had the objective of defining the scope of the QinetiQ work to be done in the retrieved components of the B-MHJ aircraft.

In Qatar, on 2 May 2011, another AW139 aircraft, registration A7-GHA, while operating an off-shore flight with eleven POB, had one of the tail-rotor blades separated, and this was followed by separation of the whole tail rotor assembly and TGB (Figure 12).

The investigation of this accident was conducted by the Qatar Civil Aviation Authority, with participation of the EASA, ANSV, and AGUSTA.

Figure 12 - Accident involving the A7-GHA aircraft in Doha, Qatar.

On 6 May 2011, AGUSTA issued the Mandatory Technical Bulletin BT139-251, which introduced a periodical preventative inspection of AW139 aircraft tail rotor blades. The bulletin introduced a visual inspection and a hammer-tapping check on the root of the tail rotor blades, with the objective of identifying cracks or signs of damage. The area to be inspected was exactly the same area fractured in PR-SEK aircraft accident (Figure 13).

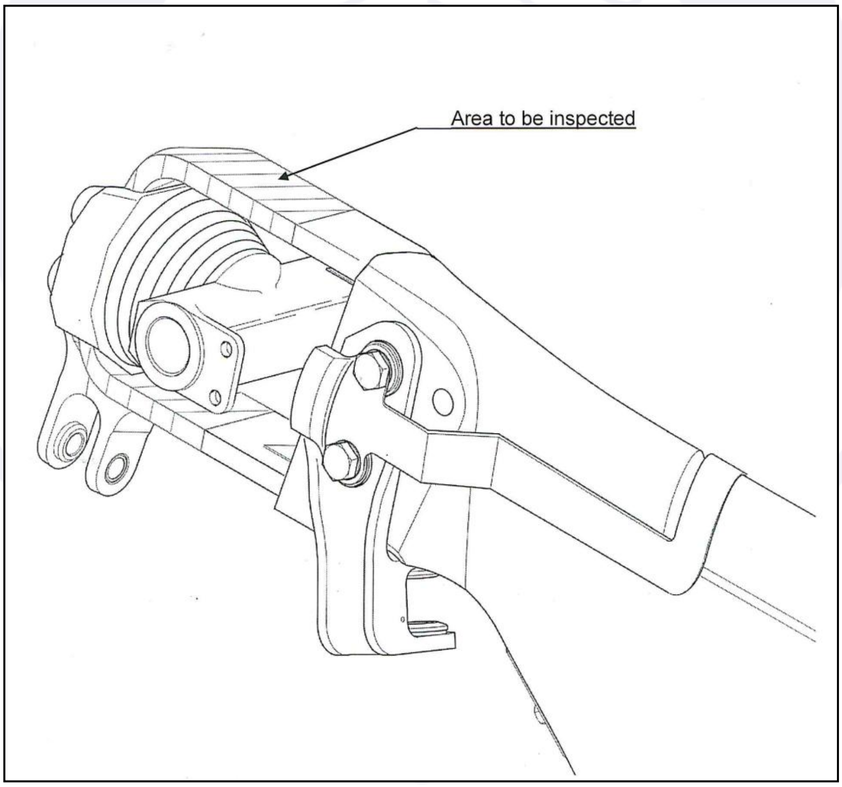

Figure 13 - Area to be inspected by the Technical Bulletin 139-251.

On 9 May 2011, EASA issued the Airworthiness Directive n° 2011-0081, making reference to the BT139-251 issued by AGUSTA.

The issuance of the AD followed the 2 May 2011 occurrence with the A7-GHA aircraft, and had a preventative purpose since the investigation was still in progress.

At the time, EASA had not yet established a connection between the A7-GHA and B-MHJ accidents.

On 6 June 2011, a meeting was held at the premises of the QinetiQ, and EASA was invited by the AAIB to participate, together with the other authorities involved in the investigation of the B-MHJ accident. In the meeting, EASA learned that the loss of the B-MHJ tail rotor blade was associated with the manufacturing quality of the tail rotor blades.

On 23 June 2011, EASA and AGUSTA reviewed several aspects of the tail rotor blades' certification, such as, among others, damage tolerance testing and bird-strike resistance testing. Among the main conclusions of the meeting, the only one unfavorable to the airworthiness of the tail-rotor blades is described below:

> "Because of the potential degree of discretion associated to the X-ray inspection applied to the strap, EASA CA Team came to the conclusion that there could be a possibility that TR blades installed on the AW139 fleet could contain defects and flaws in excess of those assumed during the static and fatigue tests performed for the certification."

On 29 June 2011, the CAD issued the Interim Statement 2/2011, which described investigative actions, but was not specific in relation to the loss of the tail-rotor blade and did not raise hypotheses for the occurrence, either.

On 4 July 2011, on account of the previous meetings, EASA and ENAC met with the exclusive purpose of evaluating the manufacturing deficiencies identified by the QinetiQ Laboratory. The main decision made at the meeting was to request from AGUSTA a re-evaluation of the tail rotor blade manufacturing process for identification of possible failures.

On 14 July 2011, QinetiQ submitted its report to the CAD (item 5 of the CAD Accident Bulletin 4/2011). Samples of the blades that had not separated in flight, as well as the recovered part of the blade which separated, examined by QinetiQ, revealed that they did not fully comply with the certified specifications in the manufacturing process. Discrepancies were found in the manufacturing process. The data of this report were presented at the meeting of 6 June 2011.

Both of the accidents aforementioned have, as a primary event, the loss of one of the tail rotor blades and consequent dynamic unbalance of the tail rotor, leading to the loss of the entire assembly.

The aforementioned accidents occurred outside of the EASA's area of jurisdiction.

<u>Aircraft captain's previous experience</u>

The experience of the pilot in command included a previous accident in the 1980's, in which the helicopter caught fire in flight, and was flown by him in a severe emergency condition.

On that occasion, the pilot successfully performed an autorotation, landing the helicopter on the sea with the use of floats.

Although seriously injured, he played a prominent role in the rescue of the other aircraft occupants, by inflating the life-boat and rescuing the survivors from the sea water.

1.20 Useful or effective investigation techniques.

Nil.

2. ANALYSIS.

Two other previous accidents involving AW139 helicopters had, as a “root cause”, the failure of the same type of component, namely, the tail rotor blade PN 3G6410A00131. This third accident was the only one involving loss of control in flight and fatal injuries.

The helicopter flight theory and the emergency procedures of the AW139 in response to tail rotor failure demand the crew to perform a powerless autorotation, with shut down engines, for an emergency landing. However, there was not a procedure prescribed in response to the loss of the whole tail rotor assembly.

However, in the first accident (B-MHJ aircraft), in which the tail rotor assembly separated, the crew flew the aircraft utilizing the procedures prescribed for failure of the tail rotor activation shaft, and managed to perform a controlled autorotation, followed by engine shut-down prior to ditching.

The second accident (A7-GHA aircraft) occurred when the aircraft was taxiing, without any serious consequences for the aircraft and its occupants.

In the case of the accident with the PR-SEK aircraft, the crew also maneuvered the aircraft considering the procedures for failure of tail-rotor activation-shaft, but the pilot lost control of the aircraft after losing the hydraulic system n° 2 following the loss of system n°1.

The PR-SEK aircraft accident cannot be analyzed based just on the active failures of components and events of the time of the occurrence, since latent failures ranged from previous occurrences to compliance with, and interpretation of, requirements during the process of certification.

Thus, based on the investigation elements already described, the analysis of this accident clarifies the main events and conditions present at the time of the occurrence:

a) Structural failure of the tail-rotor blade;

b) Abnormal attitude of the helicopter after the structural failure;

c) Training of emergencies in the flight simulator;

d) Loss of both hydraulic systems and, consequently, loss of efectiveness of the helicotper flight controls, leading to loss of control in flight;

e) Failure of the TRSOV coil (*pilot valve*);

f) Connection between the tail rotor failure and the loss of both hydraulic systems;

g) Connection between the certification of the flight control system (*power operated control system* type) and the ripple effect of the failures mentioned;

h) The fact that the investigation of the two previous accidents did not prevent the third accident from happening; and

i) The possible reason why the floats and the ADELT were not automatically activated after impact with the water.

This analysis is presented in sections, with the objective of allowing for a better understanding and identification of the factors present at the moment of the occurrence, besides following a chronological sequence of the facts that have had either a direct or indirect connection with the accident.

Structural failure of the tail-rotor blade.

The AGUSTA blade manufacturing process was at first certified by the ENAC, and, on the date of the accident, was under the responsibility of EASA, as the aeronautical authority. Even so, the audits conducted by EASA and AGUSTA for assurance of quality during the process of manufacture certification did not prove effective for the identification of the structural failures found in the tail rotor blade of the AW139 helicopter, resulting in three events of failure in a period of little more than thirteen months.

The breakage of the blade was the first event triggering the PR-SEK accident. The lack of one of the blades of the tail rotor while it was rotating at high speed was the origin of the collapse of the whole assembly, leading to the separation of the TGB on account of severe unbalance.

The loss of components had an immediate effect on the helicopter flight trajectory and on its flight characteristics. The analysis of these effects was based on the data of the flight recorders and on technical information on the aerodynamics of helicopters.

Helicopter abnormal attitude following structural failure

The CVFDR data show that the pilot took off from the P-65 Platform at 16:42 local time, and made radio contact with *Enchova* Radio (located on the P-15 Platform) to inform that they had taken off and were climbing to 3,500 ft, bound for SBME.

At 16:48, as the aircraft was passing 1,800 ft, one of the pilots informed *Macaé* Approach Control, three times in a row, that they were in emergency, and stated that the hydraulic system was lost.

During the search for the wreckage, the tail rotor was found separated from the aircraft, and also a blade of the tail rotor separated from the assembly.

The CVFDR and the wreckage distribution show that the aircraft was stabilized on the climb when it lost one of the tail-rotor blades, which was later found at the bottom of the sea, away of any other component.

The loss of one of the four tail-rotor blades represented a significant instantaneous decrease of the antitorque force which was being produced to maintain stability during the yaw. Such reduction of the antitorque force caused an immediate yaw to the right, with a lateral force of approximately .367 G and a yaw rate of approximately 33°/s.

This explains the loss of heading with moderate intensity, which was corrected with a 60% application of the left pedal. There was not activation of the pedal FTR (force trim release), which is activated concomitantly with the physical activation of the very pedal.

Considering that the helicopter was flying with the autopilot engaged it is possible that the control input of the pedal to the left was made by the autopilot, which promptly reacted and stabilized the initial heading change (Figure 14).

Figure 14 - Image of the FDR data animation immediately before and during the first event - separation of the tail rotor blade. The cyclic remained stable, and the left pedal was depressed to 60% of its course.

At this first moment, which lasted just half a second, there was no failure warning concerning any of the aircraft systems.

It is possible to consider that, with the first unexpected instantaneous variation of the helicopter trajectory and heading, the normal reaction expected from the aircraft captain (*pilot flying*) would be placing his hands and feet on the aircraft controls, even without disengaging the autopilot.

Half a second after this first event - failure of the tail-rotor blade - there was loss of the whole tail rotor assembly and TGB, caused by a severe unbalance resulting from the separation of the first blade. Consequently, the antitorque force was totally lost, leading to a new variation of heading, three times higher than the first one (.976 G) with a yaw-rate of 74°/s.

The separation of the TGB led to the breakage of the lines of both hydraulic systems, causing an instantaneous (.27s) loss of pressure in the hydraulic system n° 1, which does not have a TRSOV valve.

The abrupt yaw of the aircraft, centered in the main rotor mast, produced a lateral deceleration force of 1G in the pilot cabin, which is located approximately two meters ahead of the mast.

This movement of the aircraft to the right around its vertical axis, without a significant change of the flight trajectory, drastically increased the fuselage drag, generating longitudinal deceleration while disengaging the autopilot.

The longitudinal deceleration was measured based on the observed reduction of the ground speed from 130 kt to 95 kt in just 1 second. Considering only this parameter, its intensity would be around 18 m/s^2, that is, a deceleration of approximately 1.84G.

The exposure of the left side of the fuselage to the relative wind (on account of the right yaw) generates, in a helicopter, a roll to the left. Such roll is explained by means of the sum of two components: the difference of the areas below and above the center of gravity in the fuselage, and the aerodynamic reaction of the main rotor to the deceleration caused by the fuselage drag (Figure 15).

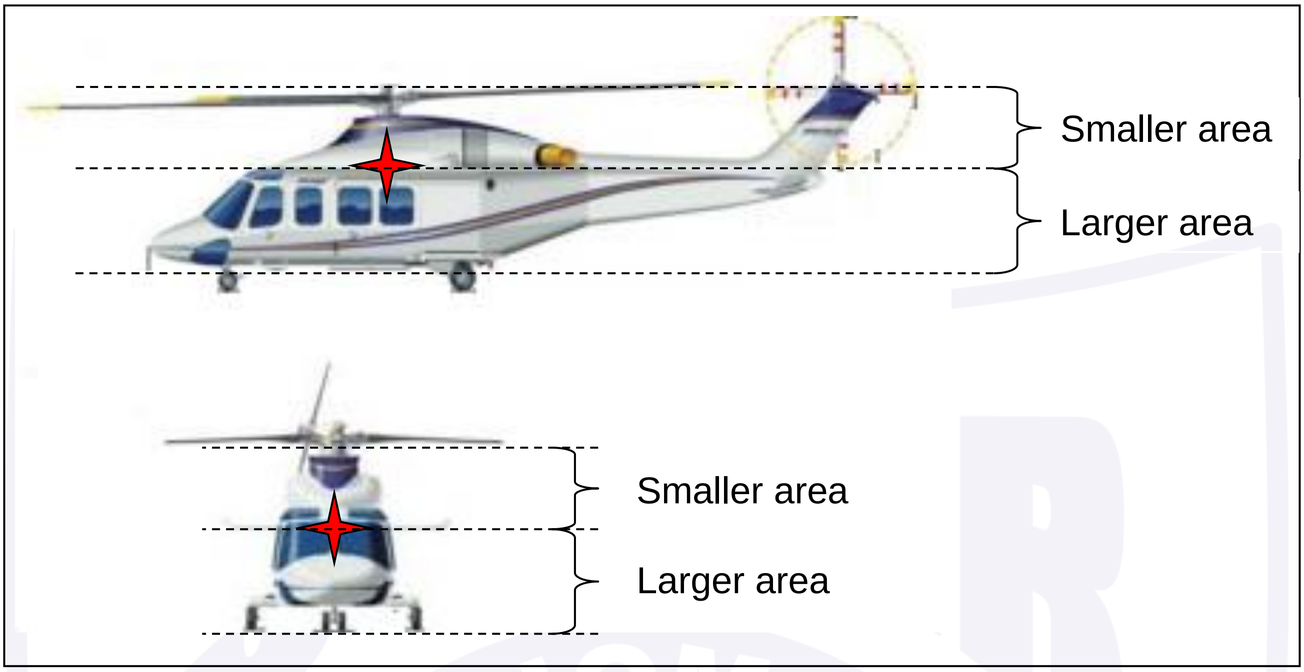

Figure 15 - Effect of the fuselage areas' law in relation to the helicopter's CG along the vertical axis.

These two forces combined (the yaw to the right and the longitudinal deceleration) resulted in a diagonal throwing of all the objects inside the helicopter (forward left direction).

Considering a time-interval of .8 second for a person in a state of attention to react, it is possible that the captain reached the flight controls after the first event in a fraction of a second before the occurrence of the second event, or even simultaneously. The CVFDR data show that, in .8 seconds, the cyclic was broadly and swiftly moved forward and to the left, while the collective was moved downward.

In consequence of the difference between the upper and lower parts of the fuselage in relation to the center of gravity, and on account of the pilot's control inputs, the helicopter increased the amplitude of the roll, reaching 120° to the left in relation to the longitudinal axis (Figure 16).

Figure 16 - Image of the CVFDR data animation in the second event - separation of the TGB - the cyclic moved forward and to the left, and the collective moved downward, with a roll of up to 120°. The low-pressure warning light illuminates, indicating loss of the Hydraulic System n° 1.

When the roll reached 120° to the left, the cyclic control was moved to the right in a broad and coordinated manner. The helicopter responded to this input by undoing the pronounced roll to the left, diminishing the yaw-rate to the right. During this recovery, an NR surge (Main Rotor rotation) occurred, reaching 112%. These collective and cyclic control inputs are compatible with the recovery from abnormal attitude and abrupt start of autorotation. The NR surge is compatible with a sudden decrease of the rotor aerodynamic load.

In 2.0 seconds, the helicopter reached the level altitude with a (controlled) high-angle descent, and the collective was pulled to 70% again, neutralizing the NR surge; this was followed by movements of the collective between 0% and 20%.

In 3.5 seconds after the first event (blade separation), and 3.0 seconds after the separation of the tail rotor at 142 kt, with the collective fully downward, the helicopter reached a zero yaw-rate, maintaining a stabilized trajectory with a sink rate of 3,900 ft/min.

During the descent, the NR maintained values above 105%, reaching a peak of 123%, and the pedals were moved to a position between 10° to the right and neuter (centralized).

It is possible that the captain used the pedal controls without being aware of the tail rotor separation or on purpose in order to check the lack of activation of the tail rotor, as prescribed in the emergency maneuver related to loss of the tail rotor practiced in the simulator.

This stabilized trajectory remained for 4.5 seconds, after which there was loss of the hydraulic pressure of the hydraulic system n° 2 (which possesses a TRSOV valve). After another period of half a second, control of the aircraft was definitively lost.

From the flight recorder data, it was possible to observe that, after the separation of the tail-rotor assembly, the crew was able to recover control of the helicopter, stabilizing the descent in autorotation for a moment until the hydraulic system n° 2 was lost, when control of the aircraft became no longer possible.

The maneuver for tail-rotor loss and autorotation, which is prescribed in the flight manual and is extensively practiced in the initial training of helicopter pilots and in the flight simulator, would allow an emergency ditching on the sea. The helicopter captain had already experienced a similar situation in another accident in the 1980's, an indication that, if the hydraulic system n° 2 had not been lost, he would have had enough experience for performing the maneuver, even in a condition of real emergency.

Training of emergencies in the flight simulator

The analysis of the flight simulators of AW139 helicopters showed that the simulation does not represent in a faithful manner the sequence of events which occurs when there is a failure of the tail-rotor activation shaft at high speed.

The simulation could not replicate the very strong lateral acceleration experienced in the cabin. In other words, the flight simulator could not physically reproduce the high level lateral acceleration experienced in tail rotor failures. There is no reference to these load factors in the training manuals or in the chapter relative to emergencies of the AW139 flight manual.

Thus, it is not possible to prepare the crew for avoiding the tendency to move the cyclic all the way to the left, since it aggravates the emergency condition, leading the helicopter to an abnormal attitude. The roll resulting from inadvertent control inputs causes a high variation of positive and negative vertical G loads, besides facilitating loss of control of the NR.

Loss of both hydraulic systems

Although independent of each other, the hydraulic systems n° 1 and n° 2 have the same function, that is, they are the source of the energy necessary for the operation of the main rotor and tail rotor by means of flight control inputs. This characteristic is present in all helicopters certified in the transport category (FAR 29) which utilize hydraulic energy as the source of energy for the aircraft control system.

In this type of aircraft, the utilization of hydraulic energy is indispensable for the operation of the flight control system. In other words, human strength is not compatible with the demand of the energy necessary for controlling the aircraft, on account of the rotors' aerodynamic forces.

So, the certification requires the portion of energy to be duplicated and independent, in addition to attributing an extremely improbable probability of occurrence to the combination of failures of the components of the hydraulic system, such as pumps, valves, lines, etc.

In this accident, all the components of the hydraulic systems n° 1 and n° 2 were functioning normally until the breakage of the pressure lines and return of the hydraulic fluid from the tail rotor control, as a consequence of the losses of the TGB and tail rotor assembly.

In accordance with the concept of the AW139 hydraulic systems, if there is simultaneous leak of hydraulic fluid in the two systems (in the lines of the tail-rotor control), an immediate exhaustion of fluid takes place in the hydraulic system n° 1, since it does not have a TRSOV.

The hydraulic system n° 2 has a shut-off valve in the pressure line of the tail rotor with the function of discontinuing the fuel leak when the level of fluid in the reservoir reaches 28%.

After the loss of the tail rotor blade, the TGB resisted only half a second before separating. At that moment, both hydraulic systems remained intact. With the separation of the TGB, there was an immediate loss of the hydraulic system n° 1, followed by activation of the TRSOV, which preserved the hydraulic pressure of the hydraulic system n° 2.

The amount of fluid preserved in the hydraulic system n° 2 (28% of the volume) proved sufficient for the operation of the helicopter in the emergency condition, since it allowed recovery of a normal attitude and conduction of an autorotation descent, despite the utilization of large amplitudes in the cyclic and collective controls.

Failure of the TRSOV coil (*pilot valve*)

During 7.5 seconds, the TRSOV worked as expected and remained closed, blocking the leak of fluid from the hydraulic system n° 2, so as to guarantee the functioning of the helicopter flight control system.

Then, the valve had a failure due to the breakage of the wire of the TRSOV pilot-valve coil on account of overheating. The immediate consequences were the exhaustion of the hydraulic fluid of the hydraulic system n° 2 and loss of aircraft control.

The root cause which led to the failure of the TRSOV coil could not be determined although the failure mode can be associated to a local overheating. Lack of electrical stability during the operation, non-uniform isolation of the coil wire, local under dimension of the wire are examples that could lead to a failure associated with an overheating condition.

It is worth highlighting that all the tests prescribed for certification were conducted as soon as the accident TRSOV was manufactured, and no indication of latent failure was found in the electric coil. This gives rise to two possibilities: either the acceptance test is not adequate, or the TRSOV was not adequately dimensioned to endure the emergency condition present in the accident with the aircraft.

Connection between the failures of the tail rotor and of both hydraulic systems

The tail rotor blade was designed to remain intact and in normal operating order until the time programmed for overhaul, inspection, or life limit, for compliance with the certification requirements. As certification requisite, the combination of rupture of hydraulic lines and loss of TRSOV operation was assessed as an extremely improbable failure condition. Nonetheless, the failures of the tail rotor blade and of the TRSOV occurred one after the other, in sequence.

First, there was structural failure of the blade and then, approximately 8 seconds later, the failure of the TRSOV. Although it is difficult to conceive the idea that, in just one accident, two distinct catastrophic failures occurred, this became evident in the case of the PR-SEK accident.

Initially, the commission considered the hypothesis that the two failures were not related to each other, but the analyses and tests performed identified the possibility of connection between the failures, in a ripple effect.

In the bench test of the hydraulic system functioning, it became evident that the closing of the TRSOV does not take place immediately. Three successive ON-OFF-ON commutations were observed in the test conducted by the aircraft manufacturer.

The explanation for this phenomenon requires understanding of the functioning of the hydraulic system as a whole. The Power Control Module (PCM) stores fluid that will feed the entire system. In addition to the fluid existing in the PCM, there is fluid distributed in the hydraulic lines and in the pistons of the servos of the main and tail rotors, besides other systems which utilize hydraulic force, such as the landing gear system, for example.

When there is a breakage of the hydraulic system line following the detachment of the TGB, the level of the PCM2 reservoir quickly drops to 28%, in approximately .27

seconds. When such level is reached, the 28% micro-switch is activated, energizing the TRSOV, which closes to prevent exhaustion of the PCM. In a post-accident bench test, the time demanded by the TRSOV to close was 4.5 milliseconds (.0045 seconds).

There is a normal variation of the hydraulic fluid level in the PCM during the flight, because the fluid is continuously pushed to the pistons of activation of the rotors' servo-controls, which are varying in accordance with the movements of the flight controls, therefore the return line of the hydraulic system can feed fluid back to the PCM reservoir. The level may either go below the 28% amount or slightly rise in relation to the point of closure of the TRSOV, triggering its reopening. This allows a very small leak of the hydraulic fluid, just sufficient for the level in the PCM to reach 28% again, with a further activation of the micro-switch and consequent closure of the TRSOV. This phenomenon takes place more frequently when the PCM level is at 28% due to the decrease of the pressure on the PCM diaphragm.

In this accident, the analysis of the trajectory and of the flight control actuation records during the 7.5 seconds of functioning of the TRSOV shows extensive use of the cyclic and collective. Cyclic fully to the left and forward, cyclic to the right and back, collective control from 80% to 20%, again collective at 70% and then collective close to 0%. All of these movements were performed for recovery of normal attitude and control of the NR.

The cycles of commutation of the TRSOV on account of the variation of the hydraulic fluid level in the PCM are too short to be either recorded by the CVFDR or perceived by the pilots, but they result in electric power ON and OFF of the pilot valve coil. At every commutation cycle, there is a tension peak induced on the coil, leading this component to an electric distress, whose immediate consequence is an increase of the component temperature. The recurrence of this phenomenon may lead to failure of the coil.

The possible connection existing between the failures of one of the tail rotor blades and the burn of the pilot valve coil can be demonstrated by the sequence of events which occurred between the failures, as shown in Figure 17.

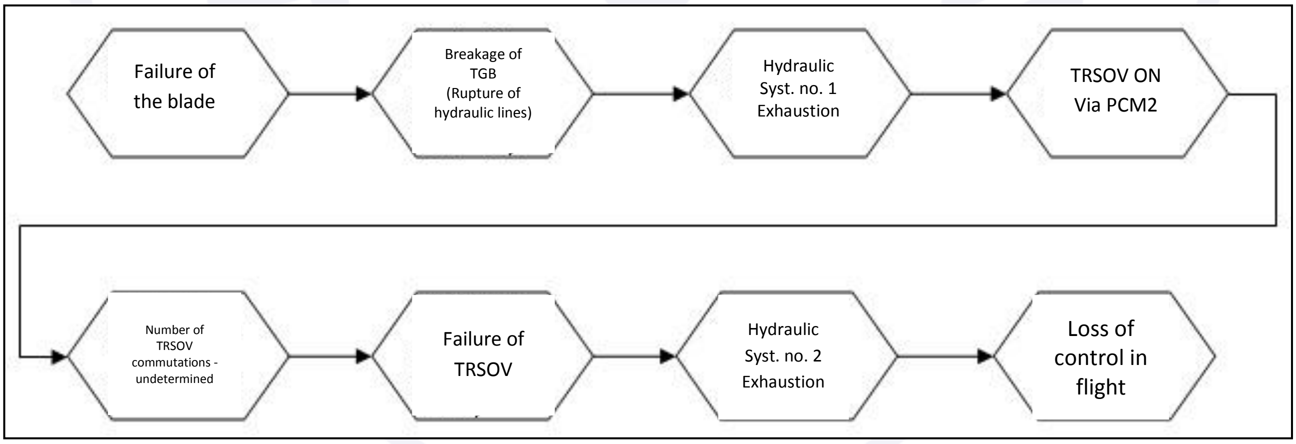

Figure 17 - Possible connection between the failure of the tail rotor blade and the burn of the pilot valve coil.

The other hypothesis, namely, that the failure of the pilot valve has nothing to do with the failure of the tail rotor blade, although possible, is much less probable.

Connection between the certification of the flight control system (*Power Operated Control System* type) and the ripple effect of the failures

The design of an aircraft, while it is operating during an emergency, must comply with requirements which guarantee safe continuation of the flight and subsequent landing, even in adverse conditions.

The description of the functioning of the hydraulic system n° 2 in emergencies determines that the TRSOV, once closed, is supposed to remain closed, considering that the exhaustion of hydraulic fluid cannot be corrected during the flight, and results directly in loss of aircraft control.

The activation of the TRSOV in an emergency after loss of the hydraulic system n° 1 is critical for the continuation of the flight and landing. If there is rupture of the tail rotor hydraulic pressure lines, the TRSOV is the last and only safety barrier for preventing loss of control of the aircraft.

The requisite of Section 29.695 of JAR 29 requires an extremely unlikely failure mode for the components of the Power Operated Control System, including its valves.

The analysis of compliance with the requisite 29.695 must be understood through the historical standpoint of the transport category helicopter certification and through the facts present in the PR-SEK aircraft accident.

The first aspect to observe is the lack of a clear indication in the aircraft systems concerning the limit between the Power Operated Control System and the ordinary hydraulic system of the AW139. The absence of such definition allows one to consider the TRSOV as composing either the first or the second system.

In the certification of AW139 aircraft and similar models, hydraulic energy is used for operating the aircraft flight controls. All of them have two independent hydraulic systems possessing safety shut-off valves which, among other functions, have the purpose of guaranteeing hydraulic energy in the servo-controls of the main rotor in situations involving hydraulic fuel leak.

If there is simultaneous leakage in the pressure lines of the tail rotor control, there will be just one shut-off valve, installed in one of the systems. In the AW139 aircraft, the TRSOV is installed in the hydraulic system n° 2.

In this accident, with the rupture of the pressure lines of the tail-rotor control, the TRSOV initially maintained the hydraulic energy for the main rotor for 7.5 seconds, until the valve failed, allowing complete exhaustion of the hydraulic fluid from the hydraulic system n° 2. The consequence was the loss of aircraft control due to lack of hydraulic energy in the servo-controls of the main rotor, since the hydraulic system n° 1 is not protected by a TRSOV.

If the TRSOV was considered a component of the Power Operated Control System, it would have to be duplicated by virtue of the Section 29.695. It is important to stress that the function of the TRSOV is to preserve the hydraulic force for the operation of the main rotor servo-controls in case of a catastrophic failure of the tail rotor. In other words, it protects part of the flight control system to make it possible to continue the flight and land.

From this perspective, it is understood that the duplication of the TRSOV in consonance with the Section 29.695 would guarantee hydraulic energy in the main servo-controls of the aircraft, preventing loss of control of the aircraft.

Traditionally, certifying authorities have had distinct interpretations on this theme, and there are helicopters with redundant TRSOV’s and others with a TRSOV in just one of the systems.

There are no grounds for questioning the level of safety demonstrated by the manufacturer to the certifying authority in relation to the extremely improbable condition observed in the design concept of the AW139 power operated control system. Nevertheless, the installation of just one TRSOV in one of the hydraulic systems signals to the understanding that there is no guarantee of redundancy for containment of simultaneous failures in the tail rotor hydraulic pressure lines, even if designed with an extremely improbable failure mode. The objective of the duplication required in Section 29.695 is to guarantee redundancy for the Power Operated Control System.

Once there is a simultaneous rupture of the tail rotor pressure lines' actuator, with the sources of energy (hydraulic pumps) operating normally, the required redundancy will depend exclusively on the functioning of the one TRSOV. This means that when a simultaneous rupture of the hydraulic lines occurs, the desired redundancy is immediately lost, and control of the flight will depend exclusively on the functioning of the one TRSOV installed in the hydraulic system n° 2.

If one considers that the objective of Section 29.695 is to establish requisites capable of ensuring both flight and landing safety by means of redundancy of the Power Operated Control System, in the case of the AW139 aircraft, if there is rupture of the tail rotor hydraulic lines, with the sources of energy (hydraulic lines) functioning normally, the hydraulic system n° 1 will be lost instantaneously, and the hydraulic system n° 2 will depend on the functioning of the TRSOV.

Although this type of occurrence may be within an acceptable number in relation to the probability of failure in the certification, there is the possibility of a dynamic unbalance, and it may occur again in a way similar to the accident in question, i.e., detachment of the TGB and rupture of pressure lines.

In this sense, a re-evaluation is necessary in relation to the effective redundancy of the AW139 aircraft hydraulic system based on the Section 29.695, considering the TRSOV as a component of the Power-Operated Control System.

<u>Investigation of both previous accidents did not prevent the third accident</u>

The first accident in which there was structural failure of AW139 helicopter tail-rotor blades occurred on 3 July 2010 in Hong-Kong, China (aircraft registration B-MHJ). This accident happened more than thirteen months before the one involving the PR-SEK.

At the beginning of the investigation, the Chinese investigation authority stated that the main hypothesis for the accident would have been a birdstrike event. This fact made the tail-rotor blade failure become a latent condition, with the entire fleet of AW139 helicopters operating unsafely for approximately ten months until the occurrence of the second accident on 2 May 2011, involving the A7-GHA helicopter in Doha, Qatar. This second accident occurred three months before the accident with the PR-SEK aircraft.

In the period between July 2010 and May 2011, CAD, EASA, and AGUSTA did not take any direct action for mitigation of the AW139 tail-rotor blade failure. The reason was the fact that birdstrike had been the only hypothesis initially considered for the 2010 accident in China.

According to EASA and AGUSTA, the investigation of the accident in China was not monitored on account of the statement delivered by CAD that birdstrike had been considered the main hypothesis for the occurrence.

The birdstrike hypothesis in the first accident may have induced EASA and AGUSTA to re-evaluate the tail-rotor blades in terms of resistance instead of manufacture process. This fact may have contributed to the delay to suppress the unsafe condition, which remained latent.

After the A7-GHA accident on 2 May 2011, EASA issued the AD 2011-0081 (9 May 2011). At the time, EASA was not yet knowledgeable of the result of the analysis performed in the tail-rotor blades of the first accident.

Only in June 2011, did the EASA become aware that the B-MHJ aircraft tail-rotor blade failure had occurred due to manufacture problems, when they related that accident with the occurrence involving the A7-GHA aircraft.

With the publication of the AD 2011-0081 by EASA, the PR-SEK aircraft underwent inspection in May 2011 in accordance with the prescriptions of the directive, and was approved for return to service. During the inspection (monitored by AGUSTA technicians), cracks were found in two of the blades, which were withdrawn from service. In the other blades, including the one which separated in the accident in question, no discrepancies were found.

In July 2011, EASA reviewed the certification of the tail-rotor blades manufacture before ENAC and AGUSTA, while the fleet of AW139 aircraft was considered airworthy under the airworthiness directives of AD 2011-0081.

The publication of the AD 2011-0081 had the objective of mitigating the unsafe condition posed to the AW139 fleet. However, the procedures for compliance with the AD by means of the Technical Bulletin n° 139-251 were not enough to suppress the unsafe condition, since the accident occurred when the aircraft had 254 flight hours after compliance with the AD.

Time elapsed between the occurrence of the July 2010 accident with the B-MHJ aircraft and the presentation by QinetiQ in June 2011 of the results concerning the blade-manufacture problems. In the meantime, there was the accident with the A7-GHA aircraft, and some time later the accident with the PR-SEK.

Possible reason why the floats and the ADELT were not automatically activated after impact with the water

The analysis of the accident conditions showed that the aircraft was out of control at the moment of impact. According to the CVFDR data, the angle of the impact trajectory was approximately 80°, at a sink rate of about 8,000 ft/min. The aircraft was at a roll-angle of about 80° to the right, at a pitch-down attitude of 15°, with low angular speed in relation to the vertical axis.

The damage observed in the wreckage as a result of the impact is consistent with the data obtained from the flight recorder. The places with a higher degree of damage are the front and right side of the aircraft fuselage, an indication of the accuracy of the flight recorder data.

The fact that the tail-boom remained attached to the aircraft fuselage is evidence that at the moment of impact the aircraft was at a low angular speed in relation to its vertical axis, as shown in the flight recorder readout.

The catastrophic failure led the aircraft to impact the sea surface completely out of control, decreasing significantly the occupants' chances of surviving. The *causa mortis* of the four occupants was brain hemorrhage due to traumatic brain injury.

The impact of the aircraft with the water was so violent that it possibly broke the electric connection between the control box of the cabin and the ADELT deploy-unit before it could be activated. However, the failure in the activation and operation of the ADELT did not affect the wreckage search activity.

In a similar fashion, it is possible that the aircraft automatic floating system failed to work on account of the impact, although without any influence on the survivability of the aircraft occupants.

Even though, in this case, the lack of TPL did not hamper location of the aircraft, it is highly desirable that the ships involved in the search of crashed aircraft be equipped with TPL for detecting the emission of Underwater Locator Beacons, mainly considering the off-shore transport.

Therefore, it is vital for the Response-to-Emergency Plan of off-shore operators to consider the utilization of the TPL or similar equipment.

3. CONCLUSIONS.

3.1 Facts.

a) The pilots held valid Aeronautical Medical Certificates (CMA);

b) The pilots held valid Technical Qualification Certificates (CHT);

c) The pilots had qualification and enough experience for the type of flight;

d) The aircraft had a valid Airworthiness Certificate (CA);

e) The aircraft was within the weight and balance, as well as Center of Gravity, limits;

f) The airframe, engine, and rotor logbook records were up-to-date;

g) Two other previous accidents involving the same type of aircraft had had tail-rotor blade structural failure as a contributing factor;

h) The AGUSTA quality control system did not detect certain blade manufacturing defect exceeding the allowable limits;

i) Preliminary information relative to the first accident indicated tail rotor blade failure on account of a possible birdstrike event;

j) The second accident had had tail-rotor blade structural failure as a contributing factor;

k) The analysis of these two earlier accidents resulted in the issuance of the EASA AD 2011-0081 based on the Technical Bulletin 139-251, establishing visual inspection and hammer-tapping test procedures;

l) The procedures performed in compliance with the AD 2011-0081 did not detect the manufacturing defects that originated the tail rotor blade cracks in the PR-SEK aircraft because they were aimed to timely identify progressive failure not manufacturing defect;

m) The procedures prescribed in the AW139 Inspection and Maintenance Program did not detect the blade manufacturing defect bacause they were aimed to identified in service damage and progressive failure not manufacturing defects ;

n) One of the aircraft tail-rotor blades separated in flight, detaching from the rest of the assembly;

o) The loss of a tail rotor blade caused the TGB to be torn away on account of severe unbalance;

p) The TGB tear-away caused rupture of the hydraulic lines of both independent hydraulic systems of the aircraft;

q) The absence of the TRSOV in the hydraulic system n° 1 caused immediate loss of the hydraulic fluid of the system;

r) The presence of the TRSOV in the hydraulic system n° 2 preserved 28% of the hydraulic fluid volume, allowing the aircraft to be flown;

s) The flight simulator training would not accurately reproduce the tail-rotor failure that occurred at high speed;

t) The loss of the tail rotor with the aircraft at high speed made it yaw violently to the right;

u) The helicopter yaw to the right at high speed caused an abrupt speed reduction, a left-roll tendency, and a high G lateral force;

v) The left-roll tendency caused by the yaw to the right at high speed, associated with to the forward/left cyclic input led the helicopter to assume an abnormal attitude;

w) The crew controlled the abnormal attitude by means of the flight controls;

x) The helicopter maintained a stabilized autorotation during the time the hydraulic system n° 2 supplied hydraulic energy to the Power-Operated Control System;

y) The operation of the hydraulic system with 28% of the hydraulic fluid volume caused successive ON-OFF-ON commutation cycles in the TRSOV;

z) The pilot-valve coil wire of the TRSOV in the hydraulic system n° 2 broke due to overheating after 7.5 seconds of continued use;

aa) The hydraulic system n° 2 lost the remaining 28% volume of the hydraulic fluid;

bb) The failure of the hydraulic system n° 2 on account of lack of fluid caused total loss of the Power-Operated Control System;

cc) The total loss of the Power-Operated Control System made it impossible to control the aircraft in flight;

dd) The aircraft crashed violently into the sea;

ee) The aircraft was totally destroyed;

ff) All the aircraft occupants perished in the crash.

3.2 Contributing factors.

- **Manufacturing - a contributor.**

The manufacturing process of the tail-rotor blades was not capable of preventing the making of a tail-rotor blade in discordance with the certification specifications, something which resulted in the breaking of one of the tail-rotor blades with the aircraft in flight. The direct consequence was the abrupt separation of the TGB and rupture of the tail-rotor hydraulic lines.

- **Design - a contributor.**

The application of the EASA AD 2011-0081 did not mitigate the unsafe condition associated with the structural failure of the tail-rotor blades. The blade of the PR-SEK aircraft was approved for returning to service after compliance with the procedures described in the AD.

Design - undetermined.

During the AW139 aircraft certification process, the certified compliance of JAR 29.695 requirement may not have met the required duplicity. The lack of a TRSOV for each of the two hydraulic systems may have contributed to the loss of control of the aircraft in flight due to the failure of the single TRSOV installed.

4. SAFETY RECOMMENDATION.

A measure of preventative/corrective nature issued by a SIPAER Investigation Authority or by a SIPAER-Link within respective area of jurisdiction, aimed at eliminating or mitigating the risk brought about by either a latent condition or an active failure. It results from the investigation of an aeronautical occurrence or from a preventative action, and shall never be used for purposes of blame presumption or apportion of civil, criminal, or administrative liability.

In consonance with the Law n°7565/1986, recommendations are made solely for the benefit of the air activity operational safety, and shall be treated as established in the NSCA 3-13 "Protocols for the Investigation of Civil Aviation Aeronautical Occurrences conducted by the Brazilian State".

Recommendations issued prior to the publication of this report:

To the National Civil Aviation Agency (ANAC):

A-181/CENIPA/2011 Issued on 25/08/2011

Taking into account the issuance of the Agusta Technical Bulletin n° 139-265, the issuance of the EASA Emergency Airworthiness Directive AD 2011-0156-E, the reports of in-service difficulties and the facts currently known relative to the tail-rotor blades of the AW139 helicopter: - evaluate before the Primary Certification Authority (EASA) whether the mitigating measures adopted are sufficient for ensuring adequate control of the failures affecting the aforementioned blades, as well as for allowing this type of aircraft to be operated in Brazil in conformity with the applicable type aircraft certification requisites.

Recommendations issued at the publication of this report:

To the National Civil Aviation Agency (ANAC):

A-546/CENIPA/2015 - 01 Issued on 22/06/2017

Re-evaluate, in conjunction with EASA and AGUSTA, the AW139 helicopter process of certification in relation to the compliance with the section JAR 29.695 (b), so as to consider the need of TRSOV redundancy in both hydraulic systems.

A-546/CENIPA/2015 - 02 Issued on 22/06/2017

Re-evaluate, in conjunction with EASA and AGUSTA, the TRSOV test prescribed upon completion of manufacture, with the purpose of verifying its dependability under the conditions encountered in the accident in question.

A-546/CENIPA/2015 - 03 Issued on 22/06/2017

Verify, in conjunction with EASA and AGUSTA, the need to include, in the recommended AW139 aircraft training program, exercises to drill crews in relation to strong lateral forces affecting the aircraft when a tail rotor failure occurs at high speeds.

5. CORRECTIVE OR PREVENTATIVE ACTION ALREADY TAKEN.

During the investigation of the accident, the following corrective and/or preventative actions were taken:

- On 25 August 2011, the Technical Bulletin n° 139-265 was issued by the aircraft manufacturer. The purpose of the Bulletin was to introduce a preventative inspection and a quarantine limit for tail-rotor blades with suspected defects originated in the process of manufacturing. On the same date, the Bulletin became mandatory by means of the AD 2011-0156-E. This AD superseded the AD 2011-0081, issued after the Doha, Qatar, accident with the A7-GHA aircraft (2 May 2011);
- On 30 September 2011, the Technical Bulletin n° 139-269 was issued by the aircraft manufacturer. The purpose of the bulletin was to confirm the correct operability of the hydraulic systems n° 1 and n° 2, as well as introduce the periodic 600-hours operational inspection aimed at verifying the correct functioning of the components of the hydraulic systems. On 20 October 2011, the Bulletin became mandatory by virtue of the AD 2011-0207;
- On 3 October 2011, the ANAC informed that the Safety Recommendation n° 181/CENIPA/2011 had been partially complied with, due to the issuance of the Emergency Airworthiness Directive n° 2011-0156-E, of 25AUG2011, and, since the required actions were considered provisional, the ANAC responsible sector had the understanding that the recommendation could be left open until a final solution was provided by the manufacturer;
- On 11 February 2012, the aircraft manufacturer issued the Technical Bulletin n° 139-285. The objective of the bulletin was to introduce a preventative inspection and a quarantine limit for tail rotor blades suspected of having had defects in the manufacturing process. On 17 February 2012, this bulletin became mandatory, when the AD 2012-0030 was made active;
- On 13 April 2012, the aircraft manufacturer issued the Technical Bulletin n° 139-286. Its purpose was to introduce a new blade, with preventative inspection, in addition to a quarantine limit for the new blades of the tail rotor. In May 2012, this bulletin became mandatory when the AD 2012-0076 was made active;
- On 26 November 2014, the aircraft manufacturer issued the Technical Bulletin n° 139-391. The objective of the bulletin was to check the TRSOV integrity and enhance its protection against corrosion;
- On 21 September 2015, the ANAC informed that the AD 2012-0076 had already undergone its revision n° 2, dated 20 February 2014, and that it had superseded the AD’s issued earlier. The ANAC also informed that they were monitoring the item before the primary certification authority (EASA), and that the agency, since the occurrence of the accident in 2011, had already carried out several tests and analyses necessary for the solution of the problem.

On June 22nd, 2017.

APPENDIX A - COMMENTS BY THE ANSV NOT INCLUDED IN THE FINAL REPORT

Below, there is a list of all the comments made by Leonardo Helicopter (former Agusta Westland) and forwarded by the *Agenzia Nazionale per la Sicurezza del Volo* (ANSV) which were not included in the text of this Final Report.

COMMENT 1

In relation to the following portion of the item "1.16 - Tests and research / Tail-rotor blade":

"The exams and tests of the fractured blade confirmed the presence of defects during the process of manufacture. Porosity, blank areas, and delamination in the structure of the blade gave rise to cracks, which propagated to the point of breakage".

Text proposed by Leonardo Helicopter

The exams and tests of the fractured blade confirmed the presence of defects during the process of manufacture. Porosity, blank areas, and delamination in the structure of the blade gave rise to cracks, which propagated to the point of breakage.

The elastomeric bearing installation was verified for the shimmings conformity, on one side could not be verified meanwhile on the other side was assessed slightly under dimension. A check performed by QinetiQ on another blade installed on the rotor identified a reverse and under dimension shimming installation. The proper shimming was identified as a key point contributor for inducing delamination in the blade root area.

Leonardo Helicopter's argumentation

The assessment on the failed blade was performed at CTA laboratory in Brazil.

CENIPA's comment

The DCTA was only in charge of the failed blade search. There was no participation of SIPAER Material Factor that could verify the checks made on the elastomeric bearing and the other blades of the tail rotor.

COMMENT 2

In relation to the following portion of the item "1.18 - Operational information / Flight simulator training":

"In all the simulated emergency situations, the functioning of the systems is similar to what takes place in real aircraft. In the situations of stuck pedals, the simulator reaction is similar to the aerodynamic reactions occurring in the helicopter. In the simulator, emergencies resulting from the breakage of the tail rotor activation shaft show the aircraft making a quick yaw to the right, but without any lateral acceleration force or left roll tendency, even at high speeds".

Text proposed by Leonardo Helicopter

In all the simulated emergency situations, the functioning of the systems is similar to what takes place in real aircraft. In the situations of stuck pedals, the simulator reaction is similar to the aerodynamic reactions occurring in the helicopter. In the simulator, emergencies resulting from the breakage of the tail rotor activation shaft show the aircraft making a quick yaw to the right, but without left roll tendency, even at high speeds.

Leonardo Helicopter's argumentation

Quick yaw variation is anyway expected to generate lateral acceleration possibly judged not representative of the real case by the pilot.

CENIPA's comment

The text refers to the tests performed in simulator. In these specific tests, the simulator did not show lateral acceleration or tendency to roll to the left.

COMMENT 3

In relation to the following portion of the item "2 - Analysis / Training of emergencies in the flight simulator":

"The simulation could not replicate the very strong lateral acceleration experienced in the cabin. In other words, the flight simulator could not physically reproduce the high level lateral acceleration experienced in tail rotor failures. There is no reference to these load factors in the training manuals or in the chapter relative to emergencies of the AW139 flight manual."

Text proposed by Leonardo Helicopter

The simulation could not replicate the very strong lateral acceleration experienced in the cabin. In other words, the flight simulator could not physically reproduce the high level lateral acceleration experienced in tail rotor failures. The Rotorcraft Flight Manual emergency procedure for the TR drive failure anyhow warns about the very high yaw rate and aircraft pitching and rolling to be controlled with use of large cyclic input.

Leonardo Helicopter's argumentation

The procedure published in RFM does not refer to load factors but high yaw rates and associated pitch and roll rate obviously result in associated accelerations and therefore in load factors. It is therefore believed that the description of the cues associate to a TR loss is properly described.

CENIPA's comment

The belief that the existing text allows for an interpretation that high yawing reasons imply acceleration are not obvious. The importance of this information stated clearly in the manufacturer's manuals is reinforced by the fact that these accelerations cannot be reproduced in simulator.

COMMENT 4

In relation to the following portion of the item "2 - Analysis / Training of emergencies in the flight simulator":

"Thus, it is not possible to prepare the crew for avoiding the tendency to move the cyclic all the way to the left, since it aggravates the emergency condition, leading the helicopter to an abnormal attitude. The roll resulting from inadvertent control inputs causes a high variation of positive and negative vertical G loads, besides facilitating loss of control of the NR".

Text proposed by Leonardo Helicopter

Withdrawn.

Leonardo Helicopter's argumentation

It is suggested to remove the statement because the RFM warns about the criticality of this emergency condition. In addition the statement of pilot improper movement induced by inertial forces generated by the failure is a possibility as well as for an over cyclic control input resulted by the pilot flying hands off and promptly catching the stick for managing the emergency condition.

CENIPA's comment

The text refers to the impossibility of preparing the crew for the situation experienced in terms of vertical and lateral acceleration forces. The inability to reproduce these forces in simulator and the absence of warnings in the manuals, does not allow the crew to know the characteristics of the event as studied in the investigation of this accident.

COMMENT 5

In relation to the following portion of the item "2 - Analysis / Failure of the TRSOV coil (pilot valve)":

"It is worth highlighting that all the tests prescribed for certification were conducted as soon as the accident TRSOV was manufactured, and no indication of latent failure was found in the electric coil. This gives rise to two possibilities: either the acceptance test is not adequate, or the TRSOV was not adequately dimensioned to endure the emergency condition present in the accident with the aircraft."

Text proposed by Leonardo Helicopter

It is worth highlighting that all the tests prescribed for certification were conducted as soon as the accident TRSOV was manufactured, and no indication of latent failure was found in the electric coil. This give the possibility the acceptance test could not catch a possible production quality escape.

Leonardo Helicopter's argumentation

The tests performed exclude either permanent or intermittent activation of the coil consistent with the accident can cause the coil failure. Continuous duty operation for 280 hours and 5000 hot cycling are considered in the specification. Both the requirements are enormously above the accident condition of seconds of continuous operation and few cycle of intermittent activation. The acceptance test procedure was in fact improved including an overvoltage proof test aimed to identify weakness in coil condition.

CENIPA's comment

This is a hypothesis raised in the analysis of the investigation. The tests performed did not reproduce the accident conditions in a way that could not exclude the possibility of an inadequate dimensioning.

COMMENT 6

In relation to the following portion of the item "2 - Analysis / Connection between the failures of the tail rotor and of both hydraulic systems":

"Initially, the commission considered the hypothesis that the two failures were not related to each other, but the analyses and tests performed identified the possibility of connection between the failures, in a ripple effect".

Text proposed by Leonardo Helicopter

Although the TR blade and TRSOV failure have no relation to each other, a ripple effect can be identify.

Leonardo Helicopter's argumentation

The proposed statement is considered more appropriate due to the certainty of no relation between the two failure modes although a ripple effect can be identified.

CENIPA's comment

It infers that there may have been a cascade effect. Although this question is not stated, the hypothesis is admitted.

COMMENT 7

In relation to the following portion of the item "2 - Analysis / Connection between the failures of the tail rotor and of both hydraulic systems":

"The possible connection existing between the failures of one of the tail rotor blades and the burn of the pilot valve coil can be demonstrated by the sequence of events which occurred between the failures, as shown in Figure 17."

Text proposed by Leonardo Helicopter

The ripple effect of the failures of one of the TR blades and the burn of the coil of the pilot valve is shown by the sequence.

Leonardo Helicopter's argumentation

The proposed statement is considered more appropriated because the sequence of the events was proved.

CENIPA's comment

The original text composes the analysis of the hypothesis. The modification would not address this analysis and the text would be meaningless. Technically the information about the cascade effect is the same.

COMMENT 8

In relation to the following portion of the item "2 - Analysis / Figure 17":

"Number of TRSOV commutations undetermined".

Text proposed by Leonardo Helicopter

TRSOV commutations

Leonardo Helicopter's argumentation

Although the number of activations could not be determined by FDR data, hydraulic rig test equipped with instrument at very high sample rate recording allowed to simulate the hydraulic systems failures and identify just three (3) TRSOV commutations.

CENIPA's comment

The table refers to the accident hypothesis, and not to the bench test.

COMMENT 9

In relation to the following portion of the item “2 - Analysis / Figure 17”:

“Possible connection between the failure of the tail rotor blade and the burn of the pilot valve coil”.

Text proposed by Leonardo Helicopter

Sequence of events between the failure of the tail rotor blade and the burn of the pilot valve coil.

Leonardo Helicopter’s argumentation

The proposed statement is considered more appropriated because the sequence of the events was proved.

CENIPA’s comment

The figure is intended to demonstrate the possibility of connection between events.

COMMENT 10

In relation to the following portion of the item “2 - Analysis / Investigation of both previous accidents did not prevent the third accident”:

“The publication of the AD 2011-0081 had the objective of mitigating the unsafe condition posed to the AW139 fleet. However, the procedures for compliance with the AD by means of the Technical Bulletin n° 139-251 were not enough to suppress the unsafe condition, since the accident occurred when the aircraft had 254 flight hours after compliance with the AD”.

Text proposed by Leonardo Helicopter

The publication of the AD 2011-0081 had the objective of mitigating the unsafe condition posed to the AW139 fleet. However, the procedures for compliance with the AD by means of the Technical Bulletin n° 139-251 were not enough to suppress the unsafe condition, since the accident occurred when the aircraft had 254 flight hours after compliance with the AD. Role played in crack propagation in the blade root area by the possible incorrect elastomeric bearing shimming installation, could not be assessed.

Leonardo Helicopter’s argumentation

The statement added is considered relevant as possible explanation of a different crack propagation affected by an improper shimming.

CENIPA’s comment

It does not accept because this would introduce a new data that was not previously searched.