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COMISIÓN DE
INVESTIGACIÓN
DE ACCIDENTES
E INCIDENTES DE
AVIACIÓN CIVIL

Report A-024/2006

Accident involving an Aerospatiale SA 316 B aircraft, registration F-GPJF, operated by Helicópteros de Cataluña, in La Pobleta de Bellveí (Lleida), on 25 April 2006

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Foreword

This report is a technical document that reflects the point of view of the Civil Aviation Accident and Incident Investigation Commission (CIAIAC) regarding the circumstances of the event and its causes and consequences.

In accordance with the provisions of Law 21/2003 and pursuant to Annex 13 of the International Civil Aviation Convention, the investigation is of exclusively a technical nature, and its objective is not the assignment of blame or liability. The investigation was carried out without having necessarily used legal evidence procedures and with no other basic aim than preventing future accidents.

Consequently, any use of this report for purposes other than that of preventing future accidents may lead to erroneous conclusions or interpretations.

This report was originally issued in Spanish. This English translation is provided for information purposes only.

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Abbreviations

00°	Sexagesimal degree(s)
00’	Minutes
00 °C	Degrees Celsius
ATC	Air Traffic Control
BTP	MGB (in French)
C.G.	Center of gravity
DGAC	Dirección General de Aviación Civil (Civil Aviation Authority)
EASA	European Aviation Safety Agency
ft	Feet
ft/min	Feet/minute
h	Hours
km	Kilometer(s)
km/h	Kilometers/hour
kt	Knot(s)
m	Meter(s)
m/min	Meters/minute
m/seg	Meters/second
MGB	Main Gear Box
MTOW	Maximum takeoff weight
OM	Operations Manual
rpm	Revolutions per minute
TBO	Time Between Overhaul

Synopsis

Owner and operator:	Société I.B.C. – Helicópteros de Cataluña, S. A.
Aircraft:	Aerospatiale SA 316 B, registration F-GPJF
Date and time of accident:	25 April 2006; 13:45 local time
Place of accident:	La Pobleta de Bellveí (Lleida)
Persons aboard and injuries:	Four, a pilot and three crewmembers, all fatally injured
Type of flight:	Aerial work – Commercial – Aerial patrol
Date of approval:	25 March 2009

Event summary

While carrying out scheduled inspection work on the high voltage line near the town of La Pobleta de Bellvei, the aircraft crashed into the ground and caught on fire, as a result of which it was destroyed. All four crewmembers were fatally injured in the event.

During an inspection of the terrain, a piece of the aircraft, the freewheel, was found. This part transfers power to the main gear box (MBG).

The report determined the most probable cause of the accident was the detachment of the freewheel in flight, which interrupted power to the main rotor while the helicopter was under flight conditions and in an area that did not allow for a safe emergency landing.

The detachment of the freewheel was caused by the fatigue failure of the bolts and the flange used to connect the freewheel to the engine coupling. The fatigue process was triggered by contamination from water and other impurities in the freewheel lubricant.

The lubricant was probably contaminated due to non-compliance with the instructions in the manufacturer's maintenance manual on storage.

Five (5) safety recommendations are issued with this report.

1. FACTUAL INFORMATION

1.1. History of the flight

On 25 April 2006 at 13:45 local time, an Aerospatiale SA 316 B aircraft, registration F-GPJF, crashed into the ground at the base of a high voltage tower as it was carrying out scheduled maintenance work on the electrical line joining the substations of Sentmenat and Sallente, in the provinces of Barcelona and Lleida, respectively. There were four people aboard the aircraft: the pilot, a video specialist and two technicians from the electric company; all were killed.

The people who saw the aircraft just before the accident stated that it was on a northerly course along the high voltage line. Later, after noticing a fire next to one of the power line towers, and after informing emergency services, they proceeded to the crash site and confirmed that the aircraft had been involved in an accident. All the occupants and the wreckage had been engulfed by a fire.

The aircraft wreckage was concentrated on the mountainside and had been affected by the fire that broke out (Figure 1). Emergency services responded immediately and were able to extinguish the fire before it spread.

Figure 1. Overview of the wreckage

The crew had been performing this type of activity routinely and the last such flight had taken place four days earlier along the same high voltage line. Work on the day of the accident had started an hour earlier in the town of Salars de Pallars, 17 km away from the accident site, with the fuel tanks at their maximum level. According to aircraft ground support personnel, no anomalies in the aircraft had been noted prior to the flight.

During the inspection of the accident site, a helicopter component, the freewheel, was found 27 meters away from the main wreckage, directly under the tower nearest the wreckage.

1.2. Injuries to persons

Injuries	Crew	Passengers	Total in the aircraft	Others
Fatal	4		4	
Serious				
Minor				Not applicable
None				Not applicable
TOTAL	4		4	

The crew consisted of four persons associated with different companies. Aside from the pilot, there were two technicians from the company that owned the high voltage line who were checking the condition of the line, and a video specialist who was operating the video camera installed on the aircraft.

1.3. Damage to aircraft and crash information

The aircraft was destroyed by the force of the impact and the subsequent fire that completely burnt the fuselage, with the exception of the tail rotor.

1.4. Other damage

Damage in the vicinity was limited to some 400 m^2 of scrub brush that had been burnt by the fuel fire.

1.5. Personnel information

Captain

Age: 45

Nationality: French

License:	Commercial pilot (helicopter)
Issuing state:	France
License valid until:	31/10/2006
Medical certificate	• Renewed on: 14/04/2006 • Valid until: 31/10/2006
Valid ratings:	S 315/316/319

The pilot had signed an indefinite work contract with the operator on 29 March 2006.

The experience recorded in the pilot's logbook, as of 14/04/2006, was of 3,681 h and 36 minutes, 70 h and 30 minutes of which had been as captain in the previous six months. Moreover, the operator credited him with 18 h and 26 minutes of flight time as a company pilot from the 18th to the 24th of April 2006.

1.6. Aircraft information

The aircraft belonged to a French company and was being used under a dry lease agreement with the Spanish operator. The original contract length was one month, to renew automatically for each month during a three-month period, starting on 20 March 2006.

According to the contract, the periodic maintenance and inspections of the aircraft were to be performed by a maintenance center authorized by France's Civil Aviation Authority, and with which the owner had a contract. During the contract period, both pre- and post-flight inspections were performed by the operator.

1.6.1. *Airframe*

Type:	Aerospatiale
Model:	Alouette III SA 316 B
Manuf. number:	1353
Registration:	F-GPJF
MTOW:	2,200 kg
Owner:	SARL IBC
Operator:	Helicópteros de Cataluña, S. A.

1.6.2. *Airworthiness certificate*

Number:	115836
Issue date:	29/01/2003
Expiration date:	20/03/2009

1.6.3. *Maintenance logs*

Total flight hours:	8,015 h
Hours since last overhaul:	1,074 h
Last 100-hr inspection:	19/03/2006
Hours on last 100-hr inspection:	67 h

1.6.4. *Engine*

Type:	Turbomeca
Model:	Artouste III B1
Serial number:	1751
Total flight hours:	7,387 h
Hours since last overhaul:	1,958 h
Last 100-hr inspection:	19/03/2006
Hours on last 100-hr inspection:	39 h

1.6.5. *Information on the mechanical transmission*

The main and tail rotors are mechanically driven by a transmission chain consisting of:

N 1 COUPLING GROUP
N 2 TRANSMISSION TO MAIN ROTOR
N 3 TRANSMISSION TO TAIL ROTOR

The coupling group (1) connects the turboengine group (ENGINE) to the main gearbox. It consists of two elements:

- Clutch
- Coupling shaft - freewheel

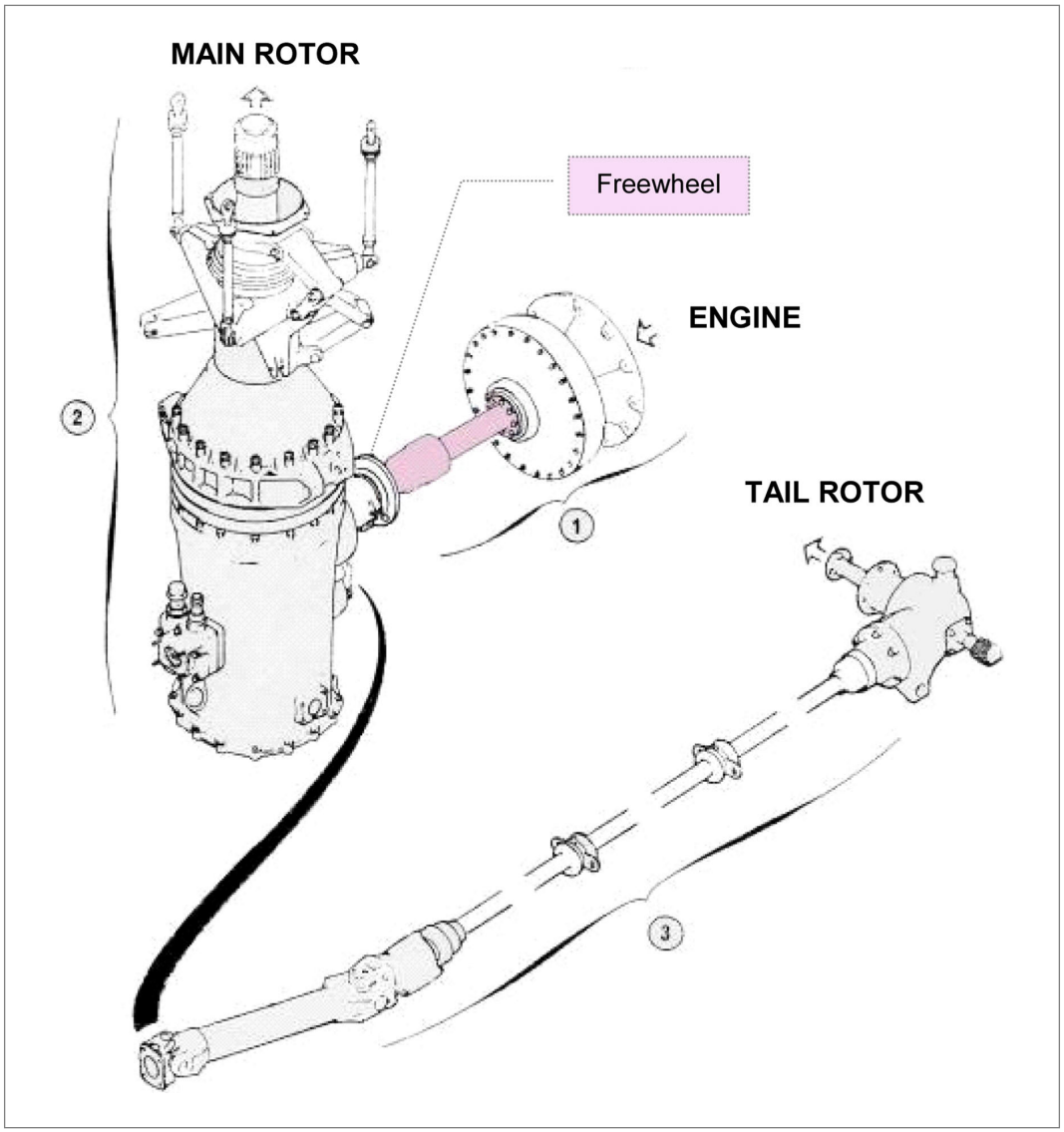

Figure 2. Diagram of the mechanical transmission

The dry centrifugal clutch serves to decouple the engine from the transmission chain on engine startup and allows the engine to progressively actuate the transmission. Synchronization of the speeds (engine output to transmission) takes place between 19,500 and 24,000 rpm.

The coupling shaft, or freewheel, is installed between the clutch and the main gear box (MGB). It allows motion to be transmitted only from the ENGINE to the ROTOR. During autorotation, as soon as the rotor becomes the "engine", it prevents motion in the opposite direction, ROTOR to ENGINE. The freewheel has the following parts (see Figure 3):

- A motor part, fixed at one end by screws in the clutch coupling gear, and at the other by a cam with eight projections. (Element A)

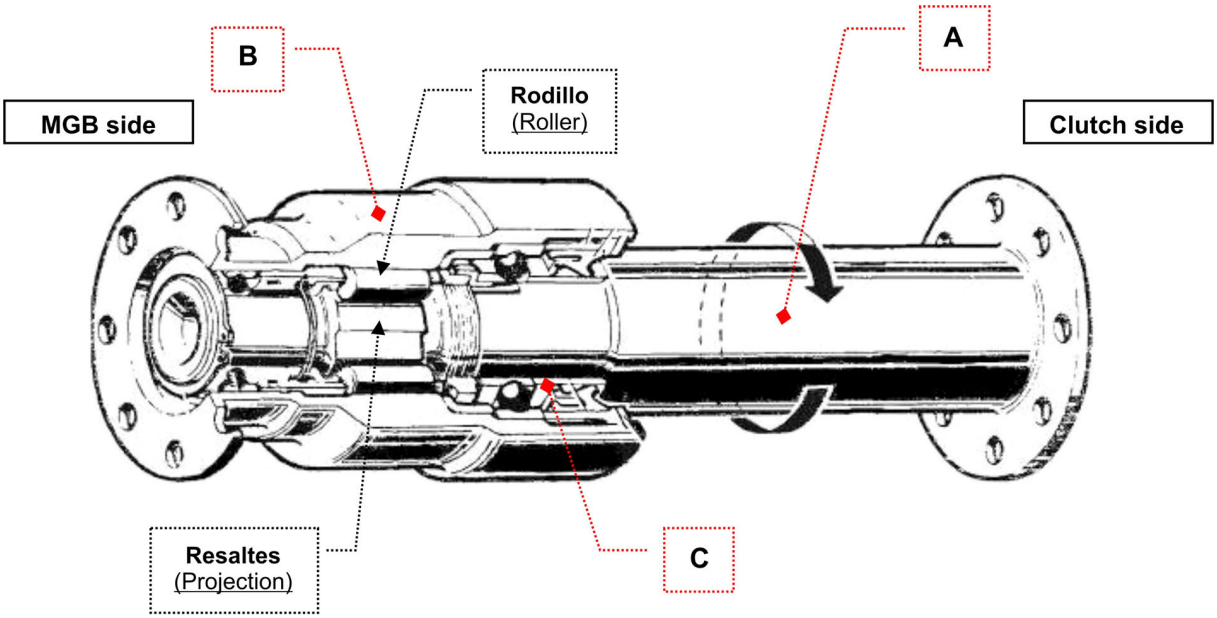

Figure 3. Diagram of the freewheel

- A sleeved driven part into which the motor part fits and which at the other end is attached by bolts to the MGB toothed coupling flywheel. (Element B)
- An intermediate part, made up of eight caged rollers and rotated in the opposite direction by two springs. (Element C)

The roller-bearing assembly is lubricated by the MGB oil system through the inside of the motor part (A).

During normal operations, the application of engine torque to the motor part causes the rollers to stay locked in the incline between the projections and the sleeve. The sleeve is non-slip actuated, and the freewheel is then clutched. During autorotation, as soon as the rotor becomes an "engine," the torque applied to the sleeve frees the rollers and the freewheel functions as a normal bearing and is no longer clutched.

In addition, springs keep the rollers in contact with the inclined face on the projections and the driven sleeve, thus preventing the freewheel from abruptly clutching during variations in engine torque.

1.6.6. *Maintenance of the mechanical transmission assembly*

The helicopter was equipped with a coupling shaft (freewheel) with serial number A 696 and reference number 3160-60100002.

It was installed on 21/10/1999 at the 7,300 total-hour mark. Considering that at the time of the accident the total hours had increased to 8,015, the freewheel's hours in operation was 715 (see Table 1).

The maintenance manual shows a time between overhaul (TBO) of 1,800 flying h for the freewheel (+30 hour allowance) and an 800-hour maintenance interval since new or overhaul.

Other maintenance tasks are the replacement of the MGB lubricant every 300 hours (following the 100 first hours of the MGB) or 24 months. The maintenance requirements also include complying with airworthiness directive No. 79-51-39.

This last directive was issued following several events in which the freewheel had detached from the aircraft due to a lack of lubrication. The modification proposed in the directive includes two steps: improved sealing of the freewheel junctions to the MGB and to the clutch; and, to verify the freewheel is lubricated. The first step was described in service bulletin 65.81, and the second in service bulletin 05.65. This last bulletin also lists the 100-h periodic verification requirement.

Part of the work performed during the May 2005 inspection, as shown in Table 1, included replacing the MGB lubricant. Therefore, considering the aircraft had 7,932 flight hours on that date, the lubricant was in service for 83 hours before the accident.

The maintenance work performed on the aircraft by the maintenance center is as follows:

Date	Task	Work performed	Total aircraft hours	Time elapsed (hours)
21-10-1999	Assembly of new Free Wheel		7,300	0
29-01-2003	Annual Periodic Check T1 + T2	AD 79-51-39	7,687	387
17-07-2003	100-hour Periodic Check	AD 79-51-39	7,807	120
20-08-2003	200-hour Periodic Check	AD 79-51-39 (SB 05.65)	7,895	88
Change of maintenance center (24-01-2004)				
24-03 to 14-04-2004	Annual Visit T1	AD 79-51-39	7,924	29
01-05 to 11-05-2005	Annual + systematic visit	AD 79-51-39 (SB 05.65) (Including BTP oil change)	7,932	8
19-03-2006	100-hour Periodic Check	AD 79-51-39 (SB 05.65)	7,949	17
20-03-2006	Dry Lease to Helicasa			
03-04-2006	25 h visit according to the maintenance program		7,976	27
19-04-2006	**Last mention on the log:** 25 hours visit according to the maintenance program		8,004	28
25-04-2006	Accident		8,015	11

Table 1. Aircraft maintenance log

Another maintenance task required for the aircraft is the inspection of the condition of the rotor mast dust cover, which was performed during the annual and the basic daily inspections. The information from the latter did not make any reference to the dust cover possibly being in bad condition nor to any other noteworthy findings.

As for cleaning tasks on the mechanical transmission assembly, these were done by hand without the use of high-pressure systems.

Likewise, according to above table, the aircraft was flown for 17 hours between May 2005 and March 2006, though their exact distribution is unknown.

As for the inspection activities concerning the condition of the MGB lubricant, the helicopter manufacturer's maintenance manual provides for, among others, checks during the 25-hour inspection and the daily inspection following the last flight. In accordance with the instructions in Section D of the maintenance manual, these checks require a visual verification that the lubricant does not show any signs of deterioration, specifically: opacity, darkening or strange odor. If any of these signs are evident the following corrective actions are specified: drain and rinse out the system with used lubricant and refill with new lubricant. If degradation of the lubricant is observed again at the next 100-hour inspection, the system is to be inspected in the workshop.

The aircraft operator had these instructions in its maintenance documentation, as part of the inspection lists to be performed after the day's last flight, which included a check of the MGB lubricant for level and leaks and a check of its magnetic plug. These inspections were usually performed by unqualified personnel which had been contracted by the operator a few days before the start of operations with this helicopter, and who were assisted by the pilot. One of the operator's maintenance technicians, qualified on this type of helicopter, would periodically visit the base. The operator did not keep records of these daily inspections.

The last two 25-hour inspections prior to the accident were carried out by technicians from the French maintenance company, in keeping with the conditions of the lease contract with the operator. No anomalies in the MGB oil were detected during these inspections.

Over the course of the investigation, the manufacturer, as an operational safety measure, proposed extending these instructions, incorporating to the existing procedure a specific action to flush the freewheel assembly, considering that said assembly forms part of the MGB lubrication system.

1.6.7. *Information of the sealing of the MGB, rotor mast and swashplates*

The aircraft's maintenance manual requires that the assembly formed by the mast, swash plates and the MGB be checked for oil leaks around screws, connectors, tubing couplings, and so on. This leak control program is intended to prevent misalignments, abnormal wear, loss of adjustments, etc.

There are also points in the assembly which are prone to allowing substances, normally in the liquid state, to enter inside. These include the dust cover, the seal between the mast and the MGB and the holes which keep the inside of the assembly at atmospheric pressure.

They must be checked for cracks or tears and they have to be properly attached to the moving parts. There are two 3-mm diameter orifices at the top part of the mast which allow for atmospheric pressure to be maintained inside the MBG. These orifices are drilled at a 15° incline to keep water from entering (Figure 4).

Figure 4. View of the top part of the mast and of the drilled component used on this type of helicopter

1.6.8. *Aircraft storage*

The aircraft maintenance manual defines several types of storage, depending on the following conditions:

- The length of storage
- The weather conditions in the location where the aircraft is stored

The storage may involve the aircraft as a whole or of its separate components.

When the aircraft is to be immobilized for more than a month, it must be placed in one of the following configurations:

- "short-term" storage if between one and six months
- "long-term" storage if over six months

There is also a "non-storage" condition for when the aircraft is immobilized for less than a month which doesn't require a specific upkeep before its return to service, though it is necessary to perform a point fix with the rotor turning once a week. This "non-storage" mode maintains the aircraft in an airworthy condition without the need for any additional actions before flight.

Both the short- and long-term storage must adhere to an inspection schedule which, when applicable to the entire helicopter, is as follows:

Short-term storage	Long-term storage	
	Outdoors	Indoors
2 months	2 months	4 months

The short- and long-term storage conditions involve different protective actions, releases, checks, controls and reconditioning procedures in order to return the helicopter to service. One of the steps indicated prior to short-term storage is the drainage of the MGB lubricant. We should point out that in the event at hand, the lubricant was not drained from the MGB. The main difference between the two types of storage is that for long-term, the various helicopter assemblies are dismounted and stored in containers.

In this respect, the dry lease agreement required that, for the duration of the contract, the aircraft be sheltered from inclement weather and that the engine be protected with a cover.

1.6.9. *Aircraft loading and equipment*

The aircraft was carrying filming equipment that consisted of a camera located in front of the main landing gear left skid and an electrical junction box placed between the pilot's and copilot's seats.

The last weight and balance calculation on the aircraft was done on 20 March 2006, and included the filming equipment mentioned above. The weight and balance calculation obtained at the time of the event is shown in Table 2:

Configuration	Weight in kg	Arm in mm	Moment (kg × mm)	Location of CG (mm)
Weight on 22-12-1987	1,254.00	3,213.00	4,029,102.00	
EMPTY WEIGHT	1,254.00	3,213.00	4,029,102.00	
Wescam equipment rack Wescam camera + stand	74.00 75.00	2,300.00 3,000.00	170,200.00 225,000.00	
BASIC WEIGHT	1,403.00	3,153.46	4,424,302.00	**3,153.46**
Fuel kg Pilot and passenger (copilot's seat)	214.00 160.00	3,407.01 1,385.00	729,100.00 221,600.00	
B WEIGHT + FUEL	1,777.00	7,945.47	5,375,002.00	**3,024.76**
Passengers	160.00	2,195.00	351,200.00	
TOTAL WEIGHT	**1,937.00**	**10,140.47**	**5,726,202.00**	**2,956.22**

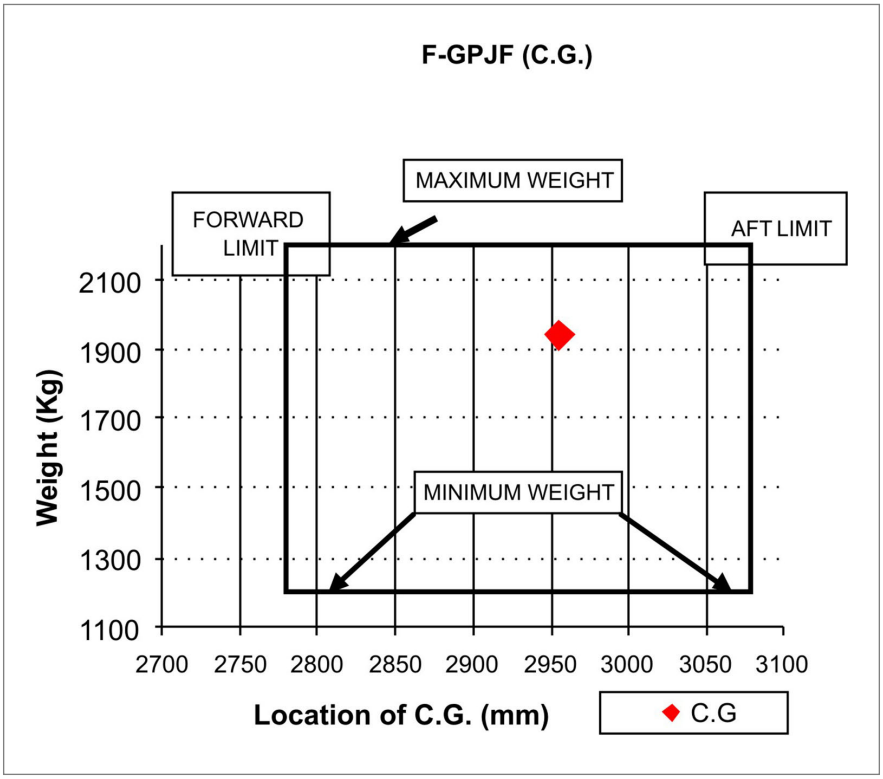

Table 2. Weight and balance calculation

According to these data, the aircraft's center of gravity was within the forward and aft limits and its weight was within allowable values.

1.6.10. *Altitude - speed diagram*

The altitude-speed graphic informs the pilot of the difficulty in safely landing the helicopter in case of a complete interruption of power from the engine to the main rotor. In the above conditions, other factors may come into play which could hinder a safe landing, such as: type of terrain within reach, influence of the wind, aircraft weight and pilot response time.

Though impossible to ascertain with certainty, the altitude of the aircraft at the time of the accident must have been between 30 and 50 m, which corresponds to the height of the lines supported by the high voltage towers. The flight speed can be estimated at between 0 and 20 km/h, given that its location with respect to the tower would have had the aircraft in hover or near-hovering flight.

Given this scenario and the probable values for speed and altitude, the helicopter would have been in the no-operation zone of the flight envelope. See the curve shown in Figure 5 below.

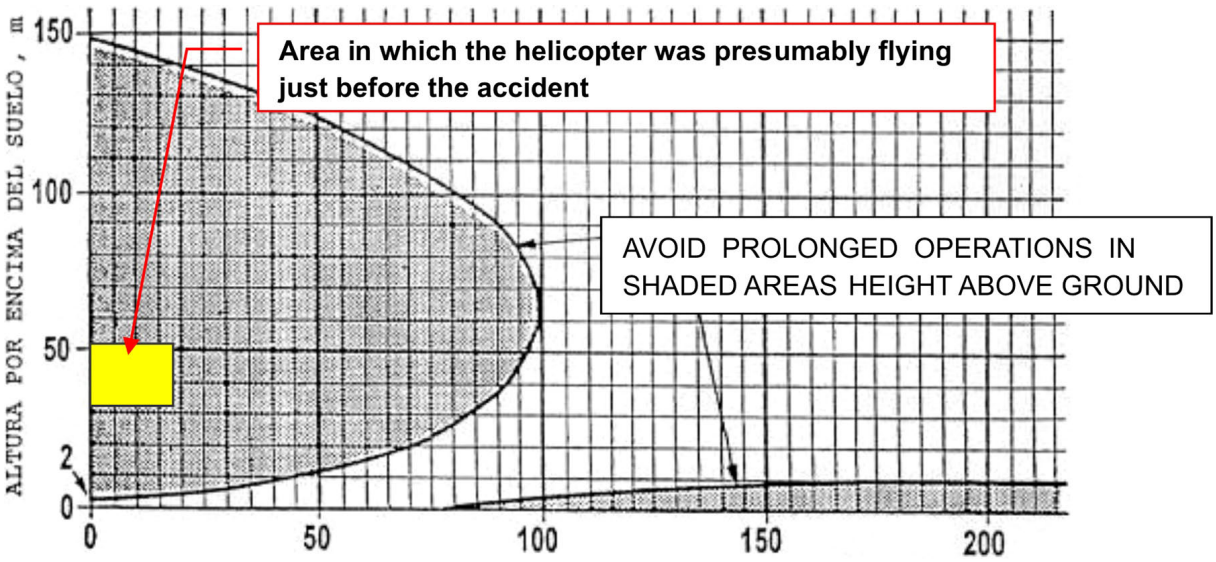

Figure 5. Altitude (m) - speed (km/h) diagram

1.6.11. *Autorotation*

Autorotation is a flight condition in which the main rotor is moved solely by aerodynamic forces, without engine power. In certain conditions, this maneuver allows the helicopter to descend safely following a complete loss of applied power to the main rotor.

The SA 316B flight manual states that after an instantaneous loss of power to the main rotor, the nose of the helicopter will turn to the right.

The manual also considers three flight conditions under which a total loss of applied power to the main rotor can occur:

1. Up to an altitude of 3 m at zero or low speed (under 27 kt (50 km/h)).
2. At an altitude between 3 and 50 m.
3. And at altitudes over 50 m.

In the second case, at altitudes between 3 and 50 m, the flight manual states that it is necessary to first reduce the collective as permitted by the altitude margin available and, to soften the landing, to then increase the pitch again. When flying at speed with respect to the ground, it will be necessary to perform a flare, which will be more pronounced the greater the speed and proximity to the ground of the helicopter.

1.7. Meteorological information

The nearest weather station was 12 km away from the crash site. It recorded the following data between 12:30 and 13:00:

- Temperature 27.2 °C
- Relative humidity 31%
- Wind speed 5.2 kt
- Wind direction 166°
- Maximum wind gusts 32 km/h (17 kt)

Data gathered from other stations are comparable, though with winds from the south-southwest.

The maximum wind gusts on that day were recorded at nightfall.

The first people to arrive at the crash site noted a slight breeze toward the higher elevations (toward the north), as confirmed by the propagation pattern of the fire in the affected area.

1.8. Aids to navigation

Not applicable

1.9. Communications

Communications were not established with ground support personnel, nor were any transmissions recorded with any ATC center.

1.10. Aerodrome information

The accident occurred during the inspection of an electrical installation. The aircraft had taken off from an unprepared field 17 km away from the accident site. The accident did not involve the approach to, landing at or takeoff from any aerodrome.

1.11. Flight recorders

The aircraft was not equipped with either a flight data recorder or a cockpit voice recorder. Neither was required by regulations.

Due to the filming operations of the high voltage electrical lines, the aircraft was equipped with a camera operated by a video specialist from inside the helicopter. None of the filmed material could be recovered, however, as it was destroyed by the fire.

1.12. Wreckage and impact information

1.12.1. *Description of site*

The place where the wreckage was found is next to tower no. 305 for the high voltage line that joins the Sentmenat and Sallente substations, between the provinces of Barcelona and Lleida.

The terrain is mountainous and covered by shrubs. The wreckage was scattered along the side of a mountain with an irregular slope that reached a maximum value of some 40°. The terrain is at an elevation of 873 m, and its geographical coordinates are 42° 21.266' North and 0° 58.023' East.

The electrical line in this section runs practically in a northerly direction (course 012°).

1.12.2. *Wreckage description and distribution*

The wreckage of the aircraft were confined to an area of terrain situated to the right of the high voltage line, facing toward the north. Only the coupling shaft (freewheel), from the transmission assembly situated between the engine and the main gearbox, was found elsewhere, 27 m away.

The aircraft, with the exception of the tail rotor, was affected by the fuel fire that broke out after it impacted the ground.

Figure 6. View of the accident site looking south

The terrain showed no evidence of significant aircraft movement on the site. The front part of the aircraft pointed toward the bottom of the hill and the tail rotor was at a higher elevation. An analysis of the wreckage likewise indicates that at the moment of impact, the angle of the aircraft's longitudinal axis was slightly greater than that of the terrain.

The main rotor was leaning forward and tilted to the left. The main rotor blades, although affected by the fire, retained their shape and barely showed signs of impact on the leading edge. One of them was slightly damaged at one end.

The aft end of the aircraft was resting upright on the ground. The impact with the ground had bent the tail skid by 90 degrees and the rotor blades were bent near the axis of rotation. They did not show any signs of having been under rotation at impact.

In the cockpit the cyclic control was bent forward at the base. The needles of the next instruments pointed out frozen of the following values:

- Compass: 137°
- VSI 800 m/min: (2,625 ft/min)
- Anemometer: 97 km/h (52.4 kt)

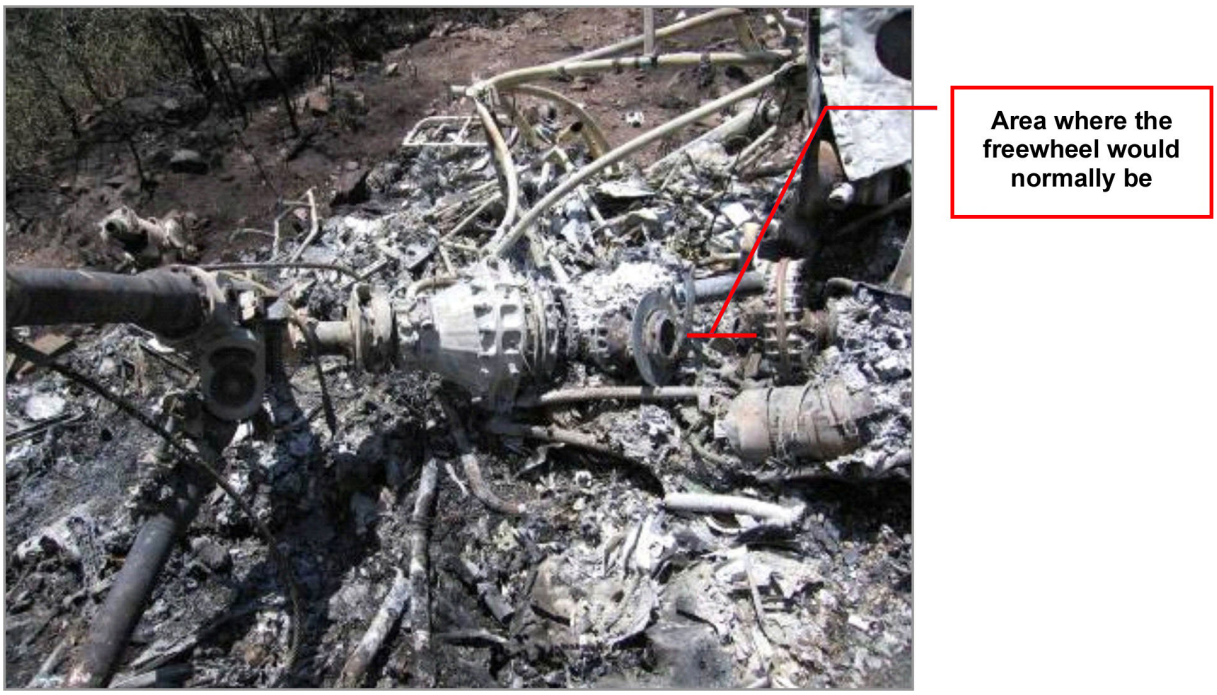

Figure 7. Wreckage of the main transmission

1.12.3. *Significant wreckage found*

The freewheel was found during an inspection of the accident site. It showed signs on its side of having struck a nearby rock.

At one end of the component there was a fracture along the orifices used to join it to the engine transmission mechanical assembly. At the other end was the gear band used to join it to the MGB.

1.13. Medical and pathological information

The fall of the aircraft to the ground resulted in fatal injuries to the occupants with the exception of the pilot who, according to the forensic report, survived the impact. The subsequent fire, however, affected all the occupants and made survival impossible.

The forensic report did not reveal any other data of importance to the investigation.

1.14. Fire

The fire, started by the ignition of the fuel aboard by the aircraft, was visible to people near the crash site, who alerted emergency services.

Emergency firemen crews from two nearby towns were dispatched to the accident site and prevented the fire from spreading throughout the mountainside. The fire affected approximately 400 m^2 of terrain.

1.15. Survival aspects

The fire must have started immediately after impact. The first people to notice the smoke climbed up to the wreckage site, only to realize that the fire had affected all of the aircraft's occupants.

Neither the pilot nor the crew were wearing safety gear such as a helmet or a fireproof jumpsuit.

1.16. Tests and research

1.16.1. *Aircraft trajectory*

The aerial work consisted of filming and visually inspecting the electrical line and towers. The helicopter was flying alongside the electrical line at a speed no greater

than 30 km/h. The tower work involved hovering from the upper to the lower conductor and up again to film the insulator connections before proceeding to the next tower. During this operation, the helicopter stayed at or below the height of the tower being inspected. As stated in the normal procedures, a 7-m separation was to be kept between the line and the tips of the main rotor blades. This operating procedure was checked against recordings made by the same aircraft and pilot on previous days.

The aircraft was flying alongside the line on a heading of 12°. Given the location of the video camera, halfway up the left side of the airframe, the aircraft was forced to fly on the right side of the line. Thus, when the emergency occurred, the presence of the high voltage line forced the aircraft to fly to its right, initially on a heading of 12° and ending up on a heading of 137°, as evidenced by the orientation of the wreckage.

Keeping in mind the limited reliability of the data shown on the flight instruments following the impact with the ground, the speed of the aircraft appears to have increased to 97 km/h (52.4 kt), as did the descent rate, reaching a value of 800 m/min (2,624 ft/min). The wreckage was some 30 meters away from the high voltage line. These values seem consistent with the impact forces as the helicopter struck the ground and which led to the fatal injuries in the passengers, and with the bending of the cyclic control, which may have been produced by an impact with a solid component that struck it as it moved forward.

The pitch angle required to reach a speed of 97 km/h could also be consistent with the helicopter attitude at the moment of impact, given the lack of damage to the tail protector on terrain that sloped in the direction of flight.

1.16.2. *Inspection of the engine*

The aircraft's engine was inspected during the course of the investigation with assistance from the manufacturer. The accessories and gear housings were damaged by the fire, but an internal inspection did not reveal any evidence that their operation contributed to the accident in any way.

1.16.3. *Inspection of the high-voltage line*

The operator of the high-voltage line reported that no incident alarms were received on the line around the time of the accident.

On 9 May a visual inspection of the tower and its conductors was performed at every height possible from the frame of the tower. There were no signs of contact or abrasions from external sources.

1.16.4. *Inspection of the freewheel*

The freewheel recovered from the crash site was inspected with the help of the manufacturer at its specialized aircraft laboratory, resulting in the following findings:

1.16.4.1. Visual inspection

The freewheel surface connecting the coupling pinion to the clutch and engine was broken. The fracture line extended along six of the eight drill holes used to attach it. The other end was still attached to the main gearbox coupling pinion.

The body of the wheel was dented as a result of having impacted the terrain. The paint on the outer surface was worn, partially revealing the primer, Figure 8.

Figure 8. Freewheel

1.16.4.2. Findings from the inspection of the freewheel and coupling assemblies

A) The materials from which the freewheel components were made were in compliance with the manufacturer's specifications.
B) There was no evidence of an over-torque condition or that the freewheel or its couplings shifted.
C) The disassembly of the freewheel revealed the existence of generalized corrosion on the inside, as well as the presence of lubricant, water and ferrous oxide.
D) The localized corrosion on the bearings had not formed recently.
E) The seal between the two main sections dividing the freewheel was in good condition and had its original grease. No leaks were noted from the inside of the freewheel to the outside or vice versa. The possibility that water or other contaminants found their way inside at this location can be discounted.
F) There was no evidence of a malfunction in the coupling between the pinion and bell housing to the MGB, though there were marks from when the bell housing detached.

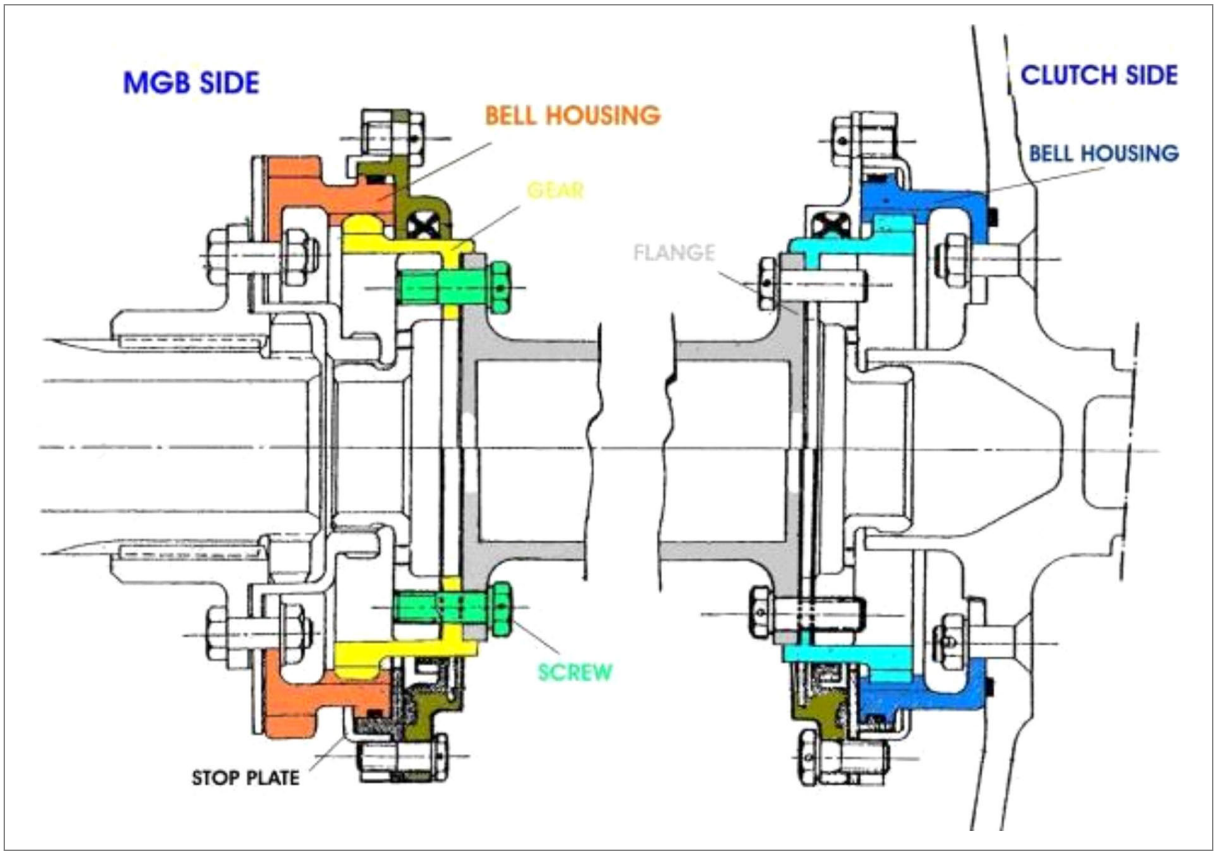

Figure 9. Detail of the freewheel connections

G) The coupling on the clutch side showed signs of corrosion, of wear on the pinion teeth and of residue at the base of the teeth. These all point to an abnormal operation at this end of the freewheel.

H) A check of the fractures at the freewheel flange, which is attached via eight holes, and of the bolts used to connect it to the pinion, revealed that the fracture was the result of a fatigue process.

I) Lastly, there were areas of corrosion, but no cracks, on the connecting ring flange between the freewheel and the MGB.

As mentioned previously, it has been determined that the freewheel had been a poor lubrication and that corrosion had developed in its interior, resulting in generalized corrosion, wear of the gear teeth and deposits of metallic particles which, in turn, increased friction and limited the movement between the pinion and the bell housing at the clutch end of the freewheel.

As a result of this seizure, the misalignment between the engine and the MGB during the flight could not be absorbed by the MGB coupling. This induced excessive strain on the mounting bolts and the connecting flange, which resulted in primary fatigue cracks and the fracture of the bolts and the coupling flange.

1.16.4.3. Other observations

An analysis of the deposits from the inside of the freewheel determined that their water content was 730 parts per million.

The maximum value in the tolerance criteria for the AIR 3523 mineral oil used to lubricate the MGB is 300 parts per million.

1.16.5. *Information about tower 305 on the Sentmena-Sallente high voltage line*

The base of the tower used to support the high voltage line is at an elevation of 876 m. It has a total height of 48.6 m and the heights above ground of each of the three phases it supports are 30, 37.8 and 48.6 m.

1.16.6. *Aircraft protection during out-of-service periods*

As already stated, the aircraft had flown 17 hours in the time frame between May 2005 and March 2006. During that time, it had been parked at the Persignan-Rivesaltes Aerodrome in France, protected only by a cover over the engine while the mast and the MGB were left unprotected (see Figure 10).

Figure 10. Condition of the aircraft at the Persignan-Rivesaltes Aerodrome

Weather data from the period between May 2005 and March 2006 indicate an average relative humidity of around 64%.

1.17. Organizational and management information

1.17.1. *Information listed in the operator's Operations Manual (OM)*

There were no detailed procedures in the operator's OM for inspecting electrical lines.

1.17.2. *Information on the technical document titled "Helicopter inspection of high voltage transmission lines" drafted by the company that owned the high voltage lines*

This document mainly details the points to be checked, the inspections to be made and the actions to be taken by the technicians in case any discrepancies are found. It also recommends a flying speed of between 20 and 30 km/h (10 and 15 kt), so as to allow for a proper visual inspection. This way, it also lets the captain of the aircraft plan the inspection (schedule, distance, estimated flying time) so the work is done properly.

After the event, the company that owns the line performed a study on "The maintenance of high voltage transmission lines with helicopters," which lists the tasks involved in maintaining an electrical line and the most used and best means for accomplishing these tasks. In the section on safety, it identifies the risks of flying a helicopter for the performance of this work. The study proposes the drafting of a Manual which defines the routines, protocols and requirements for this task.

1.18. Additional information

1.18.1. *Safety and health regulations on the use of personal protective equipment (PPE)*

The use of personal protective equipment is intended to protect workers from those health or safety risks that cannot be avoided or sufficiently limited through the use of collective protective measures or through the adoption of organizational labor practices.

Labor legislation in Spain[1] regulates affairs involving the protection of workers health against risks stemming from occupational conditions. This legislation decrees that the employer must determine and select those job categories requiring individual protection

[1] Law 31/1995, de Prevención de Riesgos Laborales and Royal Decree 773/1997, May 30th.

and specify, for each of those categories, the risk or risks to be protected against, the parts of the body to protect and the type of personal protective equipment to be used. There are no exceptions to this regulation which might exempt aircraft pilots and the rest of the flight crew while in the performance of their duties. The Spanish aviation Authority has not issued any regulations on the subject of protective equipment for operations involving aerial work.

At the European level, the European Aviation Safety Agency (EASA) is drafting standards to regulate the commercial operations of activities that do not involve public transportation[2] (commonly known as aerial work). This proposal envisages the requirement that the flight crew and remaining crew members be provided with personal protective measures. The preliminary material and the acceptable means for compliance anticipate that this equipment not be solely limited to flight suits, helmets, gloves or footwear.

1.18.2. *Risk prevention system of the operator*

On requesting information from the operator regarding the risk assessment for its workers, the operator noted that, for the job of pilot, said assessment had not been conducted as it understood that the conditions in which they perform their tasks, that of providing aerial services, are subordinate to the stipulations of the Civil Aviation Authority (the DGAC in Spain), and that lacking specific regulations, no risk assessment is required from the standpoint of the Law on the Prevention of Occupational Risks.

The company has nevertheless reported that there are rules in place for the use of protective gear by its crews, some of it required (flight suits, life vest, reflective vest for platform work and hearing protection helmet) and some recommended (flight helmet, fireproof gloves, survival vest and dry suit).

1.18.3. *Risk prevention system at the company operating the high voltage power lines*

The organization of the company that operates the high voltage power lines includes a division and a manager charged with overseeing the safety and health conditions of its employees.

As a result of the accident, the company has implemented actions to improve protective measures for its employees while working onboard aircraft. These measures include,

[2] Notice of Proposed Amendment (NPA) No 2009-02B.

among others: training courses, the drafting of action plans in case of an accident, equipment (insulated clothing, anti-glare glasses, non-slip footwear, safety helmet with radio, cotton or Nomex clothing, safety harness and protective gloves), activity planning, etc. The internal contracting policy also suggests that the aircraft and pilots operating always be those designated by the operator, and that audits be conducted on the safety and operations of contract operators.

1.19. Useful or effective investigation techniques

Not applicable.

2. ANALYSIS

2.1. General

The aircraft was contracted under a dry lease agreement dated 20 March 2006, signed between the owner, a company based in France, and the operator, a Spanish company. One of the conditions in the contract regarded the periodic maintenance, to be performed by the aircraft owner, who had arranged for a maintenance center certified by France's Civil Aviation Authority to perform the work.

The aircraft pilot had recently been hired by the owner. He held a valid commercial pilot's license (helicopter), issued by the French authority, which allowed him to operate the SA 316 helicopter. He also had almost 3,700 h of experience.

The investigation initially focused on the appearance of an aircraft component in the vicinity of the accident site, separated from the main wreckage and presumably above where the aircraft was involved in the inspection of electrical lines just before falling to the ground.

Concerning the maintenance of the aircraft, a point to consider is the contribution to the accident of the way in which the aircraft was parked out in the open for a period of 10 months and during which it was flown for only 17 hours. It is not known how those 17 hours were distributed.

As for the crew, of relevance is the number of crewmembers and the various functions they were performing onboard.

2.2. Analysis of the flight and operation

Given the location of the wreckage, next to tower no. 305 of the Sentmena - Sallente high voltage line, it is estimated that at the time of the accident, the helicopter was hovering or moving forward at a very low speed alongside the right side of the transmission line being inspected and at the halfway point of a hillside with a gradient near 40°.

Considering the usual procedure followed by crews during the inspection of towers and their proximity to the towers, the helicopter is estimated to have been at an altitude no higher than that of the tower (48.6 m) and was aligned with the uphill direction on a heading of 12°.

The topography of the terrain where the accident took place and the flight conditions of the aircraft made it impossible to find a suitable place to perform a safe emergency

landing[3] as required by the loss of power to the rotor. The difficulty of landing on a strongly sloping hillside increased the possibility of the helicopter turn over at the moment of touchdown and its subsequent movement downhill.

The path taken by the aircraft from the time of the emergency, as described in Section 1.16.1, indicates that the maneuver described in the helicopter's Flight Manual (see paragraph 1.6.11) was probably not performed. This procedure requires reducing collective and later increasing collective to soften the landing.

It is possible that the pilot, on seeing there was no suitable landing site, tried to reach the lowest part of the hill. This decision would have been influenced by the down slope to the right, the obstacle posed by the electric lines to the left and by the view he had from his vantage point, some 48 meters above the ground.

The turn to the right[4] could have reduced the main rotor rpm's. The pitch angle probable also increased the helicopter's translational velocity.

The final outcome was an impact against the ground at a high descent rate.

2.3. Analysis of the components inspected

The aircraft wreckage was seriously affected by the fire that broke out following the impact. It did not, however, impede investigators from finding the freewheel, a component that allows for the power of the engine to be transmitted to the main rotor.

The inspection of the aircraft wreckage revealed that the engine was running when power to the MGB was interrupted. Though the fire had damaged the engine components extensively, there were no signs of any malfunctions. It can be concluded, therefore, that the engine was not the cause of the sudden loss of power to the rotor and the subsequent drop in its rpms.

The analysis mentioned in point 1.16.4.2 reflects the findings of the freewheel inspection, as a result of which it may be determined that the interior of the freewheel had been exposed to a generalized corrosion process, while at the same time different internal components had worn due to the appearance of a metallic residue, resulting in friction and restricted normal movement between the pinion and the bell housing at the clutch end of the freewheel.

[3] Safe emergency landing: unavoidable landing or water landing with a reasonable precaution in order not to cause injuries to persons, damage to aircraft or terrain (Air Traffic Regulation (BOE Nº 17/2002), First Book, Definitions and Abbreviations)

[4] In helicopters with main rotor turning clockwise, the action on the right pedal requires a greater power application in the tail rotor, to the detriment of the main rotor.

Figure 11. Example of the corrosion found on the inner race of the freewheel

The resulting stresses led to the formation of fatigue cracks at the mounting bolts and at the flange through which they were threaded. The propagation of the cracks resulted in the freewheel detaching from the aircraft.

An analysis of the above data revealed that the corrosion was most likely triggered by the contamination of the MGB lubricant.

2.4. Aspects of the MGB lubricant and its contamination

The data indicate that the MGB lubricant was changed in accordance with manufacturer's instructions and that it flew for 83 h following said replacement, the maximum usage time being 300 h. The time elapsed since its replacement was 11 months (from May 2005 to April 2006), as compared to the maximum replacement period of 24 months. Despite not having exceeded either of these periods, though, the lubricant was contaminated by water.

The lubricant is subject to different effects which degrade its characteristics. The causes which most affect its service life are high temperatures, material incompatibility with system components, condensation, the loss of corrosion and rust inhibitors, etc. The effects of each of these factors lead to processes which have a definite modifying effect on the lubricant.

In the event in question, the MGB lubricant could not be recovered. The only data available came from an analysis of the residue on the freewheel, which showed a water content 240% above the maximum allowed.

Therefore, considering that the lubricant used was of the correct type and within its useful life span, an attempt was made to identify the circumstances that could have resulted in such high water content in the lubricant.

This was done by considering the points through which water in any of its physical states could be introduced into the MGB and contaminate the lubricant. In theory, those points which are most vulnerable to letting water in the MGB are: the ventilation holes located at the top of the mast, a bad seal at any of the MGB joints, and those areas covered by dust caps. As concerns the latter, the preflight inspection of the condition of the dust cover was satisfactory and the lubricant level was within limits. In addition, the post-accident inspection of the freewheel revealed that the seals were in good condition and did not have any lubricant leaks.

It can be concluded, then, that the water had accumulated in the MGB as the result of condensation.

2.5. Maintenance actions

According to the information available, the maintenance tasks performed on the transmission's mechanical assembly did not reveal any anomalies. One of these tasks, which was completed during the last 100-hr inspection in March 2006, was a lubrication check of the freewheel. This task is used to determine whether lubricant is reaching every part of the freewheel, but does not allow for a check of its condition. Nevertheless, other inspection tasks specified in the manufacturer's maintenance manual, such as the 25-hour inspections performed by the maintenance center and the daily inspections, carried out starting on 20 March by the operator, could also have detected any degradation of the lubricant if present.

The oil recovered from the freewheel after the accident exhibited a high degree of water contamination, as stated above (see 2.4). This fact indicates that the corrosion process noted in the interior of the freewheel had been in progress for some time. Regardless of how the water penetrated inside the freewheel assembly, it seems that the signs of corrosion at the levels shown by these data would have been transferred to the oil, such that the symptoms of its degradation should have been detectable at both the 100-hr and subsequent inspections. The maintenance instructions refer to characteristics such as odor and color as ways to detect degradation of the lubricant during a visual inspection. It is these properties that are qualitatively evaluated; as such, the results depend on factors such as the experience and skill of the mechanics.

It might be that in this accident, the scheduled inspections, whether the 100-hr or the subsequent 25-hr or daily inspections, were not performed correctly, although the chances of not noticing the problem with the oil during at least one of these activities were small, since they involved several technicians from various organizations, including

the usual maintenance center and the operator. On the other hand, the visual inspection method specified may not be ideal, and analytical methods are available which would increase the reliability. As such, a safety recommendation is issued to the aircraft manufacturer to revise existing maintenance actions to ensure a more reliable check of the condition of the MGB lubricant is performed.

The above notwithstanding, the maintenance methods employed by the operator for the post-flight daily inspections exhibited certain deficiencies. These checks were usually performed by inexperienced personnel who lacked specific technical training, even if they were assisted by the pilot in this task. There were also no procedures in place for logging these inspections. A safety recommendation is issued in this regard to the operator.

2.6. Effects of prolonged out-of-service periods

During storage, an aircraft must have its airframe and all of its components protected from any physical-chemical alterations brought on by humidity, airborne pollutants, solar rays, temperature variations, etc.

The aircraft was parked outdoors for an extended period of time at the Perpignan aerodrome, during which time (ten months) it only flew for 17 hours. In addition, the method used to protect the helicopter during storage did not conform to any of those listed by the manufacturer in its maintenance manual, nor were the recommended steps taken to protect the rotor head against rain. It should be noted that "short-term" storage calls for draining the lubricant from the MGB, which was not done in this case.

The weather conditions in the area, then, along with the protection methods used during the time period in question, among other reasons, are considered to have had a direct bearing on the contamination of the MGB lubricant. Safety recommendations are made to both the manufacturer and to France's Civil Aviation Authority in this regard.

2.7. Aspects for improving operations and safety

No specific or adapted procedures for the inspection of electrical transmission lines could be found in the operator's OM. There is only a superficial mention of minimum distances to be kept from the line and conditions for crossing over the line, but not aspects such as a reconnaissance flight; the modification of the line in flight , searching the best aircraft position for dealing with an emergency; minimizing the time spent hovering, the use of aircraft which allow for the installation of cameras on the nose such that their position with respect to the line can be adjusted; an in-depth analysis of possible filming techniques, etc. are considered.

In this case involving the mechanical failure of the freewheel in an area with no usable emergency landing spots nearby, it is unlikely that any operational procedure would have lessened the damages. Despite this, it would be of benefit to provide more detailed procedures for the operation that was being carried out. A safety recommendation is issued in this regard.

2.8. Analysis of aspects concerning protective equipment for the crew

The section on additional information lists aspects involving the personal protective equipment of the accident aircraft's crew, as well as the criteria followed by the companies for which said employees worked.

The operator believes that the issues regarding the personal protective equipment of onboard personnel should be normalized by the aviation Authority. The relevant labor regulation (RD 773/1997), however, makes no exceptions for sectors such as civil aviation, where flight personnel are subject to risks in the performance of their duties onboard the aircraft. Consequently, there is no reason to assume that the general conditions imposed by the labor regulation on risk prevention are not applicable. Although these risks have not been assessed by the operator, it has defined certain protective equipment as being of mandatory use by pilots and other equipment whose use is recommended. During the accident in question, however, neither the pilot nor the other occupants were wearing protective gear, so that in practice no effective protection was being provided.

In the aftermath of the accident the company that operates the power line established equipment guidelines for its workers based on a risk assessment conducted in accordance with the process specified in the prevention regulation, in an effort to redress this deficiency. The operator deviated from its own instructions, however, as the pilot was lacking the equipment that the company itself had mandated. As a result a safety recommendation is issued so as to have the operator ensure that its personnel make use of the protective measures available.

At the time of the accident there was no aviation statute in Spain on the use of protective equipment by crews involved in aerial work. Regulatory initiatives are currently being proposed within the European Aviation Safety Agency in an attempt to regulate such activities. Consequently, it is not considered necessary to issue a safety recommendation at this time.

3. CONCLUSION

3.1. Findings

- The pilot of the aircraft held licensed and qualified for the flight in accordance with regulations.
- The aircraft had a valid airworthiness certificate issued by the State of registration.
- The aircraft was under an initial 1-month dry lease agreement between the French owner and the Spanish operator, signed on 20/03/2006, subject to automatic renewal for three months.
- The operator of the aircraft had been issued an Operator's License by Spain's Civil Aviation Authority.
- The operator was authorized to use the aircraft under a dry lease agreement for the inspection of electrical lines until 20/04/2006.
- The aircraft maintenance was performed by a maintenance center certified by the State of registration.
- The instructions in the manufacturer's aircraft maintenance manual concerning storage of the aircraft had not been properly followed.
- During the visual inspection of the terrain, the freewheel, used to transmit power from the engine to the main gearbox, was found 27 m away from the main wreckage.
- An inspection of the freewheel determined that its detachment in flight was caused by fatigue failure process resulting from corrosion inside the freewheel.
- The lubricant remaining in the freewheel had a water content of 730 parts per million. The maximum allowable is 300 parts per million.
- The speed of the aircraft with respect to the ground when the loss of the freewheel caused the rotor to stop rotating was outside the safe limits indicated on the altitude-speed graphic.
- An inspection of the engine after the accident did not show any evidence of a malfunction. The engine accessories were destroyed by the fire.

3.2. Causes

The cause of the accident is considered to be the in-flight detachment of the freewheel, which interrupted the power to the main rotor while the helicopter was engaged in flight conditions and over terrain which did not allow for a safe emergency landing.

The detachment of the freewheel was caused by the fatigue failure of the bolts and the flange used to connect the freewheel to the engine coupling. The fatigue process was triggered by generalized corrosion resulting from water and other impurities in the freewheel lubricant.

4. SAFETY RECOMMENDATIONS

REC 02/09. It is recommended that the operator (HELICOPTEROS DE CATALUÑA, S.A.) establish detailed procedures for the performance of aerial work involving the helicopter inspection of electrical lines.

REC 03/09. It is recommended that the operator (HELICOPTEROS DE CATALUÑA, S.A.) ensure that all personnel aboard during the performance of aerial work wear appropriate safety gear (helmet, fireproof jumpsuit, etc.).

REC 04/09. It is recommended that the operator (HELICOPTEROS DE CATALUÑA, S.A.) improve its maintenance methods in the daily inspections, specifically regarding the use of qualified technical personnel and the establishment of a method to record and log the results.

REC 05/09. It is recommended that the maintenance center (AERO MAINTENANCE MEDITERRANEE) ensure compliance with all the maintenance manual requirements concerning aircraft work to be done either in storage or in low use conditions, as well as with periodic maintenance tasks involving checks of the condition of the MGB lubricant.

REC 06/09. It is recommended that Eurocopter France modify those maintenance instructions aimed at detecting and correcting any contamination of the main gear box (MGB) lubricant so as to increase the reliability of the methods employed.