CIAIAC

COMISIÓN DE INVESTIGACIÓN DE ACCIDENTES E INCIDENTES DE AVIACIÓN CIVIL

Report A-004/2011

Accident occurred on 24th February 2011 to aircraft PZL W-3AS, registration SP-SYA, operated by LPU «Heliseco» Sp. z o.o., in Dos Aguas – La Caldera de Taburiente National Park. Island of La Palma (Santa Cruz de Tenerife)

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COMISIÓN DE INVESTIGACIÓN DE ACCIDENTES E INCIDENTES DE AVIACIÓN CIVIL

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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 accident object of the investigation, and its probable causes and consequences.

In accordance with the provisions in Article 5.4.1 of Annex 13 of the International Civil Aviation Convention; and with articles 5.5 of Regulation (UE) nº 996/2010, of the European Parliament and the Council, of 20 October 2010; Article 15 of Law 21/2003 on Air Safety and articles 1., 4. and 21.2 of Regulation 389/1998, this investigation is exclusively of a technical nature, and its objective is the prevention of future civil aviation accidents and incidents by issuing, if necessary, safety recommendations to prevent from their reoccurrence. The investigation is not pointed to establish blame or liability whatsoever, and it's not prejudging the possible decision taken by the judicial authorities. Therefore, and according to above norms and regulations, the investigation was carried out using procedures not necessarily subject to the guarantees and rights usually used for the evidences in a judicial process.

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° 00′ 00″	Grade(s), minute(s) & seconds(s) sexagesimal(s)
00 °C	Grade(s) Celsius
ATPL(H)	Airline Transport Pilot License (Helicopter)
AWC	Aerial Work Certificate
BFU	German Federal Bureau of Aircraft Accident Investigation
cm	Centimeter(s)
CVR	Cockpit Voice Recorder
E	East
EC	European Community
ENE	East Northeast
ESE	East Southeast
FDR	Flight Data Recorder
FEL	Flight Engineer License
FFF	Fire Fighting Rate
ft	Feet
ft/min	Feet/minute(s)
g	Gravity
h	Hour(s)
HASA	Hispánica de Aviación, S.A.
Heliseco	Helicopter Services
HHO	Helicopter Hoist Operations
hPa	Hectopascal(s)
IAS	Indicated Airspeed
IR	Instrumental Rating
JAR-FCL 1	Joint Aviation Regulations – Flight Crew Licenses
kg	Kilogram(s)
kHz	Kilohertz(s)
KIAS	Indicated Airspeed (knots)
km	Kilometer(s)
km/h	Kilometer(s)/hour
kt	Knot(s)
lb	Pound(s)
m	Meter(s)
m^2	Square meter(s)
mb	Milibar(s)
METAR	Aviation Routine Weather Report
Min	Minute(s)
mm	Milimeter(s)
N	North
NM	Nautical(s) Mile(s)
Nr	Main Rotor speed
ICAO	International Civil Aviation Organization
P/N	Part Number
QNH	Altimeter sub-scale setting to obtain elevation when on the ground
RPM	Revolutions per minute
S	South
s	Second(s)
S/N	Serial Number
TRI	Type Rating Instructor
UTC	Universal Time Coordinated
VFR	Visual Flight Rules
VHF	Very High Frequency
VOR	Very High Frequency Omnidirectional Radio Range
Vy	Best Climb Rate Speed
W	West

Synopsis

Owner and operator:	Pekao Leasing Sp. z o.o.
Operator:	LPU "Heliseco" Sp. z o.o.
Aircraft:	PZL W-3AS
Date and time of accident:	Thursday, 24 February 2011; 09:30 UTC
Site of accident:	Dos Aguas – La Caldera de Taburiente National Park. Island of La Palma (Santa Cruz de Tenerife)
Persons onboard:	2 crew, seriously injured
Type of flight:	Aerial work – Commercial – Construction/external load
Date of approval:	24 October 2012

Summary of event

The crew, which consisted on a pilot and a flight engineer, were performing external cargo transport with helicopter. The work consisted of ferrying various loads from the entrance of the ravine named Las Angustias (loading point) to three different places located inside the Caldera de Taburiente National Park, as well as the transport of waste material from these points to the loading one.

For the load transportation the crew was using a 20-m long steel cable that was attached via a free-rotating ring to the helicopter's barycentric loading hook.

They discharged a water purifier tank at P-3. The support personnel on ground informed the crew that they could not hook the bag with trash since it was at P-1, which was located some 300 m inside the gorge from their site, a distance that would take them some time to travel, so they asked the crew to return to the staging area without a load.

The crew agreed and initiated the return flight unloaded. Shortly after they heard a loud noise coming from the tailboom, immediately after which the helicopter started to rotate counterclockwise as seen from above.

The pilot instructed the flight engineer to stop the engines to enter in autorotation and perform an emergency landing. He managed to stop the helicopter turns after the aircraft made three complete turns. He then steered the unpowered helicopter toward the Dos Aguas area to perform the landing.

During the flare maneuver the forward speed of the helicopter was not fully neutralized and the helicopter crashed violently against the ground, and subsequently it overturned to the left.

Both aircraft occupants were seriously injured and the aircraft suffered important damages.

The investigation has concluded that the cause of the accident was flying at an altitude that did not ensure adequate separation with the surrounding terrain with the external sling unloaded, which allowed the lower end of the sling to get hooked somewhere along the terrain, with the ensuing destabilization of the helicopter.

The following factors contributed to the accident:

- Deficient work planning.
- Failure to adhere to operating procedures.
- The contradictions between the flight and operations manuals.

1. FACTUAL INFORMATION

1.1. History of the flight

The helicopter was leased by the company Hispánica de Aviación S.A. to transport external cargo loads inside the Caldera de Taburiente National Park. The work consisted of ferrying various loads to several points located inside the park and of transporting discarded material outside on the return flight.

The helicopter, which was based on the island of Tenerife, was flown the day before to the La Palma Airport with a pilot and flight engineer as the flight crew, a mechanic who worked for the operator and a technician from the leasing company.

The material to be transported had been taken to the parking area located at the entrance to the ravine named Barranco de las Angustias, in an area called "La Viña", which would be used as a staging area. The material would be transported to points P-1 and P-2 inside the caldera. Large bags with waste material would then be picked up at these points.

The day before the accident, a new point, P-3, was added near P-2, so that a tank for a water purifier could be transported there.

In order to transport the load, the crew was using a 20-m long steel cable that was attached via a free-rotating ring to the helicopter's barycentric loading hook. The other end of the cable had a standard hook that could only be opened manually, meaning that both the hooking and unhooking operations had to be performed by support personnel on the ground while the helicopter hovered.

At 08:12 on the day of the accident, the helicopter, with these four persons onboard, took off from the La Palma Airport and headed for the "La Viña" staging area, where it landed.

At around 09:00 the external cargo operations were begun with only the flight crew onboard the helicopter. The first such operation involved transporting a load of cement to point P-2. Once there, they picked up a load of waste and headed for point P-3 for the purpose of evaluating the viability of conducting operations there, since they had not previously inspected the area. They then proceeded to the staging area.

Support personnel on the ground unhooked the waste from the sling and then proceeded to hook the water purifier tank. Once the crew received the report that the load was properly hooked, they proceeded to point P-3.

A few minutes later they arrived at point P-3 and radioed personnel on the ground, who gave them instructions regarding the exact location of the drop-off point. They also

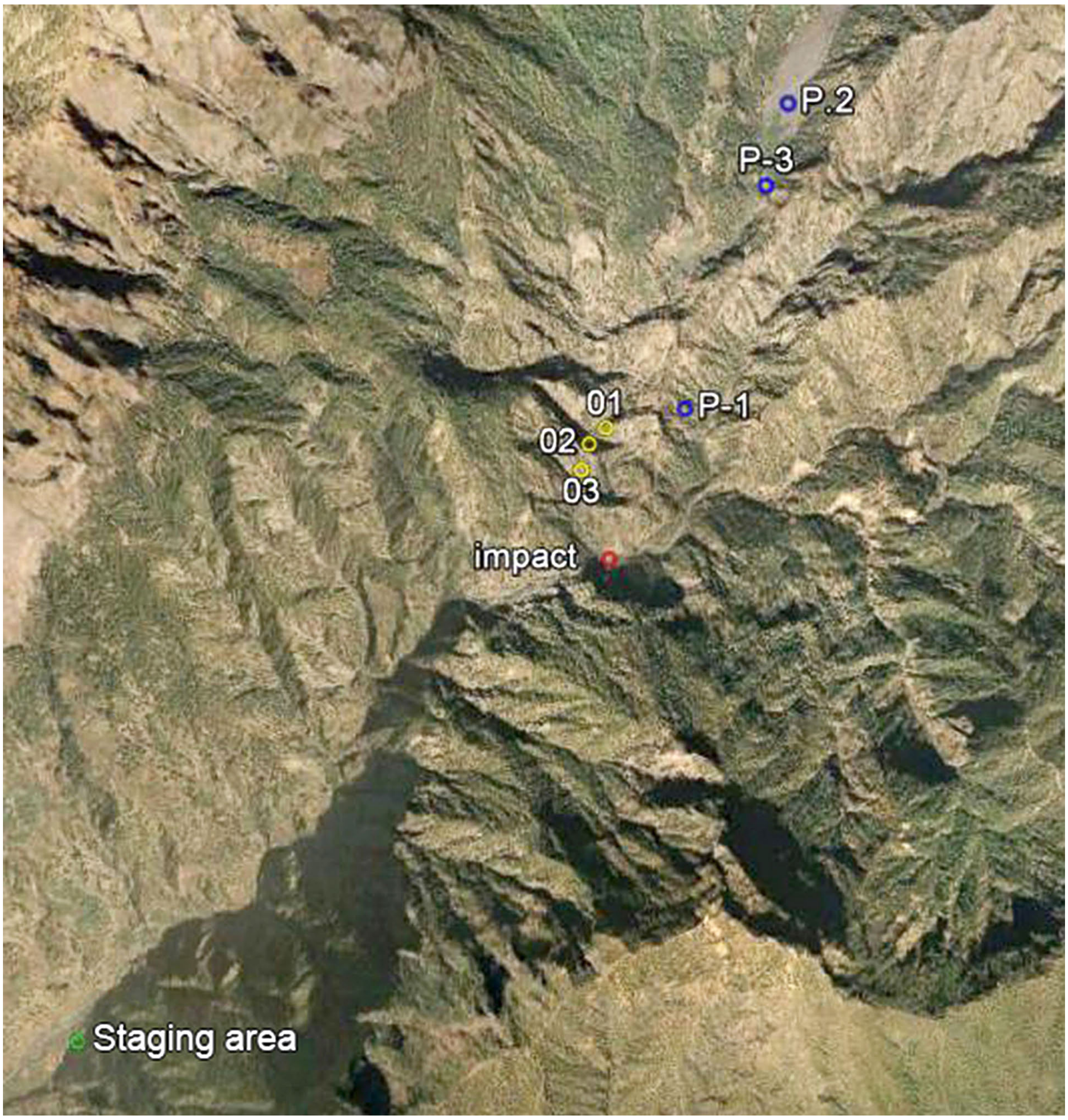

Figure 1. Location of the staging area and unloading points (P1, P2 and P3), as well as of main wreckage and other aircraft components

informed the crew that they could not hook the bag with trash since it was at P-1, which was located some 300 m inside the gorge, a distance that would take them some time to travel, so they asked the crew to return to the staging area without a load.

The crew agreed and started to climb. After climbing a few meters, the helicopter started moving forward as the pilot increased the speed gradually. They flew to the ENE, toward the caldera, and a few seconds later they made a 180° left turn to head to the staging area.

According to the flight engineer's statement, less than a minute after this turn they heard a loud noise from the tailboom, immediately after which the helicopter started rotating counterclockwise as seen from above.

The pilot instructed the flight engineer to stop the engines in order to remove the torque input and stop the rotation, which he managed to do after the aircraft made three complete turns. He then steered the unpowered helicopter toward the Dos Aguas area, where he auto-rotated to the ground, landing on its left side on the side of a mound.

1.2. Injuries to persons

Injuries	Crew	Passengers	Total in the aircraft	Others
Fatal				
Serious	2		2	
Minor				Not applicable
None				Not applicable
TOTAL	2		2	

Both crew members were seriously injured.

1.3. Damage to aircraft

As a result of the impact with the ground, the aircraft suffered heavy damage that affected mainly the following areas:

- Main rotor: detachment and fragmentation of the four blades.
- Tailboom: detached from the frame after breaking near the junction with the frame. The aft portion also broke near the 42° gear box.
- The front and underside of the cockpit were heavily damaged.

1.4. Other damage

There were no other damage.

1.5. Personnel information

1.5.1. *Captain (JAR-FCL)*

- Age: 56 years old
- Nationality: Polish
- License: ATPL (helicopter), valid until 21/03/2011

- Ratings:
  - W-3 Sokol, valid until 18/01/2012
  - MI2, valid until 11/01/2012
  - TRI W-3 Sokol, valid until 18/10/2013
  - IR, valid until 29/01/2011
  - FI, valid until 1/10/2012
  - FFF (firefighting), valid until 11/01/2012
  - Agro (agricultural spraying) valid until 19/02/2013
- He had an English competency level of 4.
- Total flight hours: 7,703 h
- Flight hours on the aircraft type: 3,560 h

1.5.2. *Flight engineer (ICAO) (non JAR-FCL)*

- Age: 53 years old
- Nationality: Polish
- License: FEL (flight engineer license), valid until 19/05/2014
- Ratings: W-3 Sokol, valid until 15/10/2011
- Total flight hours: 5,343 h
- Flight hours on the aircraft type: 4,525 h
- He had taken and passed the flight engineer license proficiency test (WZÓR No. 62 (02.04.2010)) on 15/10/2010.

1.6. Aircraft information

Manufacturer:	PZL Swidnik
Model:	W3AS
Serial number:	31.02.04
Year of manufacture:	1988
Airworthiness certificate:	Valid until 9/06/2011
Left engine:	PZL-10W, S/N: 219954017AS
Right engine:	PZL-10W, S/N: 219954018AS
Dry weight:	3,850 kg
Maximum takeoff weight:	6,400 kg
Airframe hours:	3,103.98 h

1.6.1. *Maintenance information*

According to the maintenance plan, the aircraft has 25-hr, 50-hr, 100-hr, 300-hr, 600-hr, 12-month and 24-month inspections.

The maintenance status at the time of the accident was as follows:

Inspection type	Date conducted	Airframe hours	Next
24 month	7/04/2010	3,057.06	6/04/2012
12 month	7/04/2010	3,057.06	7/04/2011
600 h	7/04/2010	3,057.06	3,657.06 h
300 h	7/04/2010	3,057.06	3,357.06 h
100 h	22/02/2011	3,102.31	3,202.31 h
50 h	22/02/2011	3,102.31	3,152.31 h
25 h	22/02/2011	3,102.31	3,127.31 h

1.6.2. *Flight manual*

1.6.2.1. External cargo operations

The Aircraft Flight Manual has a supplement for external cargo operations that provides instructions on limitations, normal and emergency procedures and performance that replace some of those contained in Part 1 of the flight manual.

Section 1 of the supplement is devoted to "Limitations" and contains the following operating limitations and restrictions:

- Except for hover and hover maneuvers operations with a loose sling cable are prohibited.
- Maximum allowable bank angles in flight with external cargo:
  - 20° for helicopters gross weight of 13,450 lb (6,100 kg) or less.
  - 15° for helicopter gross weight above 13,450 lb (6,100 kg).

1.6.2.2. Emergency procedures

1.6.2.2.1. *Tail rotor fault*

Section 3, Emergency Procedures, of the Aircraft Flight Manual has a sub-section dedicated to tail rotor faults. It states that for the purposes of the manual, a tail rotor fault is regarded as a loss of tail rotor control, a loss of power to the tail rotor or damage to its blades.

It states that a loss of tail rotor power is more critical than a control system malfunction. It likewise notes that if the tail rotor blade pitch control mechanism breaks, the blades will remain at a 7° angle, which allows for straight flight without slippage in the 22 to 32 kIAS speed range.

It distinguishes between four failure modes:

- Tail rotor drive failure in hover;
- Tail rotor control failure in hover during take-off or in forward flight;
- Tail rotor drive failure in forward flight; and
- Tail rotor damage.

As concerns the loss of tail rotor power during forward flight, it provides the following instructions regarding how to recognize the fault and what steps to take:

- Indications:
  - Excessive noise and vibration in the tailboom area.
  - Sharp left yaw and right roll.
  - Lack of helicopter response to pedal inputs.
- Procedure:
  1. Reduce the collective as necessary to arrest yaw.
  2. Establish flight at Vy[1] airspeed.
  3. Control the yaw with collective.
  4. Land as soon as possible[2].
- When a landing is to be made:
  1. Enter a power-on autorotation at Vy airspeed.
  2. When landing is assured, shut down the engines.
  3. Accomplish autorotative landing.

1.6.2.2.2. *Landing with auto-rotation*

The flight manual describes the maneuver for landing using auto-rotation as follows:

1. Establish autorotative glide at Vy airspeed and, preferably, 105% Nr.

[1] Vy – Best climb rate speed.
[2] According to the definition in the flight manual, this means land without delay in the nearest suitable area where the approach and landing can be reasonably assured.

2. At an altitude of 100 ft (30 m) above touchdown, or below if the helicopter gross weight is less than the maximum allowed one, execute a flare[3] by 20° nose-up attitude by moving cyclic control stick bar in 2 or 3 s with no change in collective.
3. At an altitude 23...16 ft (7...5 m) level nose to 8° nose up attitude and simultaneously increase the collective to maximum at touchdown.
4. Minimize ground roll by pulling back the cyclic control stick by no more than ½ of travel from neutral with the collective reduced by 1/2.
5. Lower the collective control lever and use maximum wheel braking to bring the helicopter to a stop.

1.7. Meteorological information

The La Palma airport METARs from 07:00 UTC until 10:30 UTC on the day of the accident were as follows:

240700Z 32008KT 290V360 9999 BKN030 18/12 Q1021
240730Z 32006KT 9999 BKN030 18/12 Q1021
240800Z 35007KT 9999 BKN030 18/12 Q1022
240830Z 34007KT 9999 BKN030 18/12 Q1022
240900Z 33007KT 310V010 9999 BKN030 18/12 Q1022
240930Z 34008KT 300V360 9999 BKN030 19/12 Q1023
241000Z 35008KT 320V030 9999 BKN030 20/12 Q1023
241030Z 36008KT 330V040 9999 BKN030 20/12 Q1023

The METARs indicate that during the time period in question, the wind was predominantly from the north (between 40° and 320°) at low speeds (less than or equal to 8 kt), visibility was in excess of 10 km, the sky was cloudy (5 to 7 octas) with the cloud base at 3,000 ft, the temperature was between 18 and 20 °C, the dew point was 12 °C and the QNH was between 1,021 and 1,023 hPa.

Meteorological information was also available from a station situated in the locality of El Paso, which is on the island's west slope and closer to the accident site than the airport.

Time	Temperature (°C)	Dew point (°C)	Average wind speed (km/h)	Maximum wind speed (km/h)	Wind direction
07:30	8.6	–1.0	3.2	6.4	ESE
08:00	9.2	–0.4	4.8	8.0	ESE
08:30	9.2	0.1	3.2	8.0	E
09:00	11.4	1.1	4.8	8.0	ESE
09:30	14.9	4.3	3.2	6.4	ESE
10:00	17.9	4.4	1.6	4.8	ESE

[3] The flare maneuver consists of raising the nose of the helicopter in order to stop its forward speed and lower the descent rate.

Information provided by eyewitnesses is also available and indicates that there was very little wind and visibility was good.

1.8. Aids to navigation

Not applicable. The flight was conducted under VFR rules.

1.9. Communications

Support personnel for the loading and unloading operations at both the La Viña staging area and in the three points located within the Caldera had radios that they could use to establish two-way communications with the crew.

There were no plans to record the conversations, meaning there is no system on which they are recorded.

Despite this, the cockpit voice recorder (CVR) did record several exchanges between the crew and support personnel on the ground.

1.10. Aerodrome information

Not applicable.

1.11. Flight recorders

The aircraft was equipped with a cockpit voice recorder (CVR) and a flight data recorder (FDR).

1.11.1. *Flight data recorder (FDR)*

The aircraft was outfitted with a BUR-1-2 flight data recorder, P/N MLP-23-1 and S/N: 10453, which was downloaded at the laboratory of German Federal Bureau of Aircraft Accident Investigation (BFU).

It had recorded data on 78 parameters, 24 analog, 44 discrete and 10 descriptive, from a little over 44 hours of flight.

It was noted that toward the end of the recording, at t = 1,803 s, high values were recorded for several parameters, after which the aircraft's flight parameters evidenced signs of a loss of control. So as to facilitate its analysis here, the flight is divided into three phases: before, around and after timestamp t = 1,803 s.

A) Before the event

The period analyzed spans from the time the aircraft started hovering to off-load the water purifier tank until the instant when the high vertical acceleration values were recorded (t = 1,803 s).

As the graph in Figure 2 shows, at time t = 1,756 s the helicopter stopped hovering once ground personnel unhooked the tank and reported this to the crew. The helicopter's speed and altitude increased and it proceeded on an approximate course of 60° for 9 seconds, after which it started a turn to the left, reaching a heading of 210° 14 s later. This means that the helicopter went further into the valley until it reached a wider area, where the crew made a turn of almost 180° to head down the valley toward the staging area. While it hovered the altitude value recorded on the FDR was 2,520 ft. By the end of the turn the helicopter had climbed to an altitude of 2,904 ft, a difference of 384 ft. Its indicated airspeed (IAS) at that point was 79 kt.

The aircraft's speed continued to increase gradually as the altitude dropped to a relatively stable value at the end that oscillated around 2,750 ft.

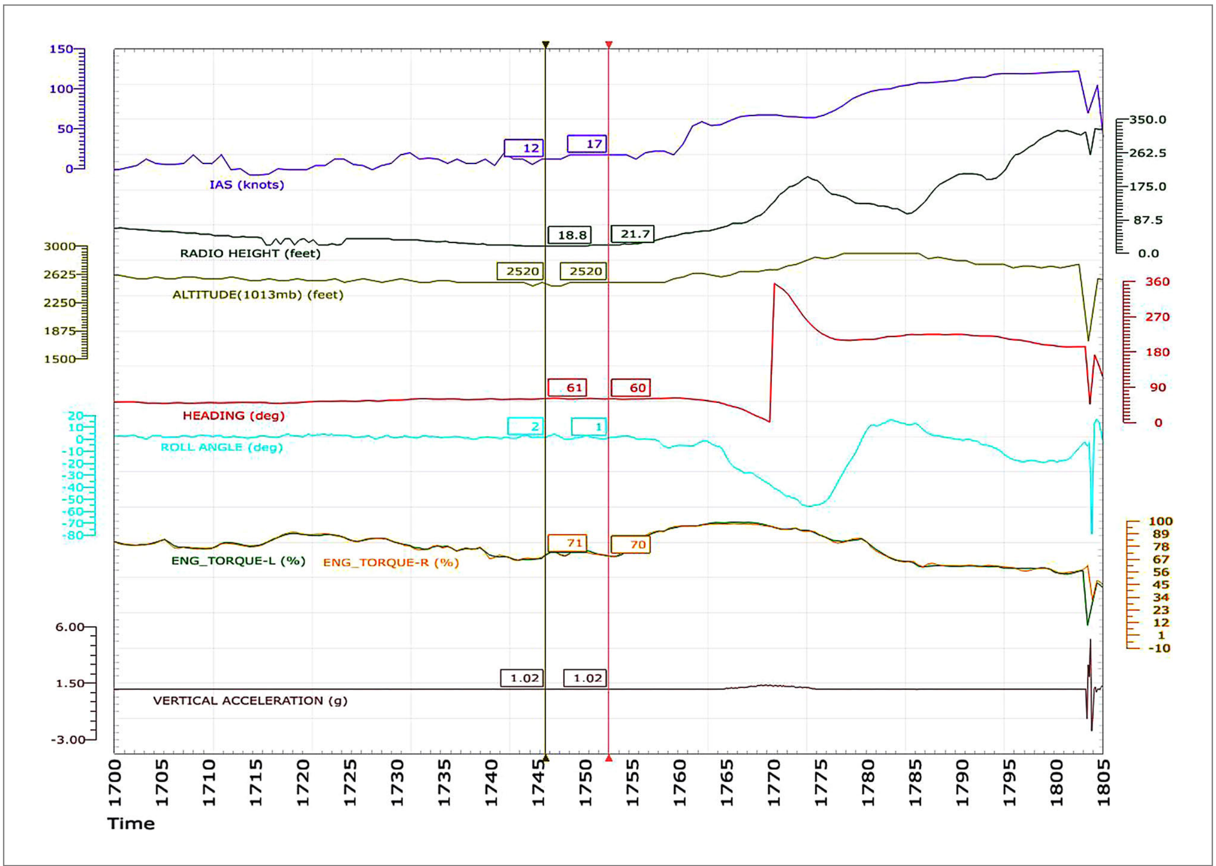

Figure 2. Indicated airspeed, radioaltitude, altitude, heading, bank angle, engine torque and vertical acceleration over 105 s

During the hover the engine torque supplied by each engine was practically identical, their values ranging between 65 and 75%. Once the helicopter stopped hovering and started to gain speed and altitude, the torque supplied by the engines increased to a maximum value of 99% during the 180° turn. From then on the torque values decreased to around 60% as the IAS increased.

The behavior of the aircraft's control systems can be evaluated by comparing the position of the control levers with the position of their corresponding control surfaces. The parameter pairs analyzed were as follows:

- Position of the collective lever – movement of the swash plate.
- Longitudinal displacement of the cyclic stick – longitudinal tilt of the swash plate.
- Lateral displacement of the cyclic stick – lateral tilt of the swash plate.
- Displacement of the right pedal – displacement of the actuating rod for the tail rotor pitch control mechanism.

It was noted that throughout this phase of flight, there was consistency between the pilot's inputs to the flight controls and the positions of their corresponding control surfaces.

The aircraft's response was also consistent with the inputs made.

The parameter "Altitude (1,013 mb)" records the value of the altitude-pressure, which is the altitude associated with the average static pressure in standard conditions. Thus, to determine the actual altitude based on this parameter, a correction must be applied. In this case, to do this calculation, the data can be used for the barometric altitude values recorded during the two hover phases in the staging area, which showed 720 ft, versus the actual altitude of the site which is 730 ft.

The fact that the altitude recorded was while the helicopter was hovering at an altitude of some 15 m above the ground also has to be taken into account, meaning that the helicopter's real altitude is the result of adding the radioaltitude, 50 ft, to the terrain elevation, 730 ft, which yields a value of 780 ft. Since the altitude reading was 720 ft, the difference between the real and indicated altitude was 60 ft (780 ft-720 ft).

Therefore, to determine the real altitude at which the helicopter was flying based on the barometric altitude value (Altitude (1,013 mb)) recorded on the FDR, 60 ft must be added to the latter.

B) Around t = 1,803 s

In this phase the goal is to conduct a detailed study of the trend in the flight parameters around the time of the high recorded vertical acceleration values. This period spans 10 s, from t = 1,800 s to t = 1,810 s. Figure 3 shows a graph of the values of several parameters over a 20 s period that starts 3 s before t = 1,803 s and ends 17 s later.

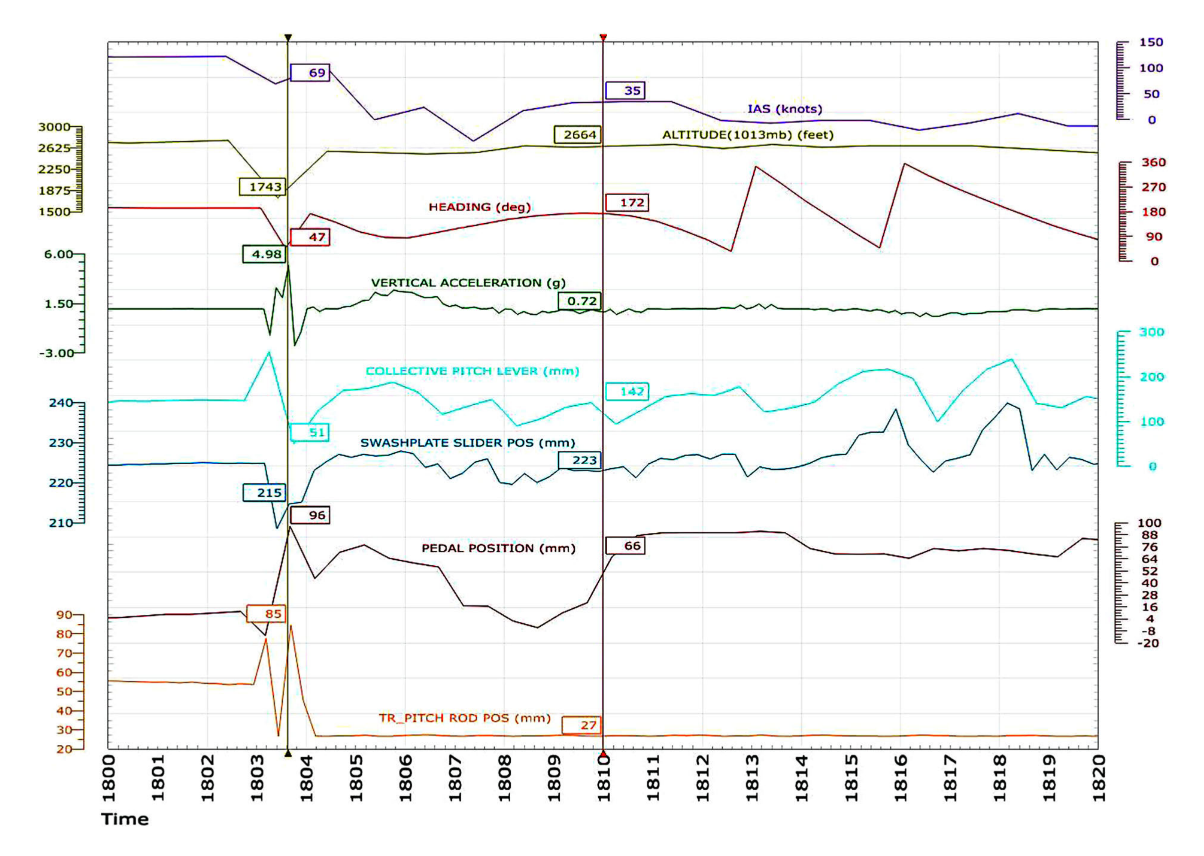

Figure 3. Indicated airspeed, altitude, heading, vertical acceleration, collective lever position, swash plate displacement (collective), right pedal position and displacement of the pitch control actuating lever for the tail rotors blades between t = 1,800 s and t = 1,820 s

According to these data, in the second immediately prior to t=1803 s, the aircraft was flying on a heading of 193° at an IAS of 122 kt, an altitude of 2,760 ft (1,820 ft corrected), the main rotor RPMs were 105%, the bank angle was 6° left, the pitch angle –4° and the engine torque for both engines was 56%.

At t = 1,803, very high vertical acceleration values started to appear. Note also that in the time interval between this timestamp and 2 s later, several parameters exhibited very high values, so high in some cases that they would be physically impossible to attain.

For example, the barometric altitude reading over 3 successive seconds, specifically at t = 1,803 s, t = 1,804 s and t = 1,805 s, was 2,760 ft, 1,750 ft and 2,520 ft, respectively.

The heading, main rotor speed and IAS parameters also exhibited apparently anomalous readings during this time interval.

Experience has shown that errors in the readings and/or recordings of some parameters are not infrequent when an aircraft is subjected to high acceleration values. As for the acceleration parameter itself, it tends to be more reliable since the accelerometers are designed to measure high acceleration values.

In light of the above, it may be concluded that the values for the parameters other than the accelerations recorded between t = 1,803 s and t = 1,805 s cannot be regarded as reliable from a quantitative standpoint, though they may be from a qualitative standpoint. In other words, while the values recorded are outside the operating range, they may properly reflect the order of magnitude or the trend in the parameter variation.

From t = 1,805 s on, the parameters regain values close to those exhibited prior to t = 1,803 s, except for the following, which show significant variations:

- The altitude, which dropped 240 ft.
- The IAS, which fell to 24 kt.
- The tail rotor blade pitch control actuating rod moved to a value of 26 mm, where it remained until the end despite the variations recorded in the pedal positions.
- The heading continued increasing to a value of 174.5° at t = 1,809 s, after which it started to descend.

C) After the event

From t = 1,810 s until t = 1,845 s. Even though the recording ends at t = 1,850 s, the values recorded after t = 1,845 s were not taken into consideration since they were regarded as not valid.

The heading decreased (indicating a left turn) sharply between timestamps t = 1,810 s and 1,811.5 s, with four readings whose values were 172.5°, 163.4°, 144.9° and 114.2°

By t = 1,813 s the heading had already gone past magnetic north. The helicopter continued turning left such that by t = 1,814.5 s, the helicopter had already turned over 360°. The aircraft continued turning and made two more full turns, with the first one taking 4 s and the second one 10 s. The helicopter made a total of three full turns about its vertical axis in 18.5 s. After t = 1,829 s, the aircraft's heading remained relatively stable until the end of the recording. The last recorded heading was 151.5°.

Parameter trend:

- Pitch angle: remained negative (nose down) until 8 s before the end of the recording, at which time it changed sign (nose up) and remained that way until the end. In the final 8 s the pitch angle reached a value of 57°.
- Roll angle: predominantly negative (left bank).
- Engine 1 torque: at t = 1,810 s it was slightly below 10% and decreasing.

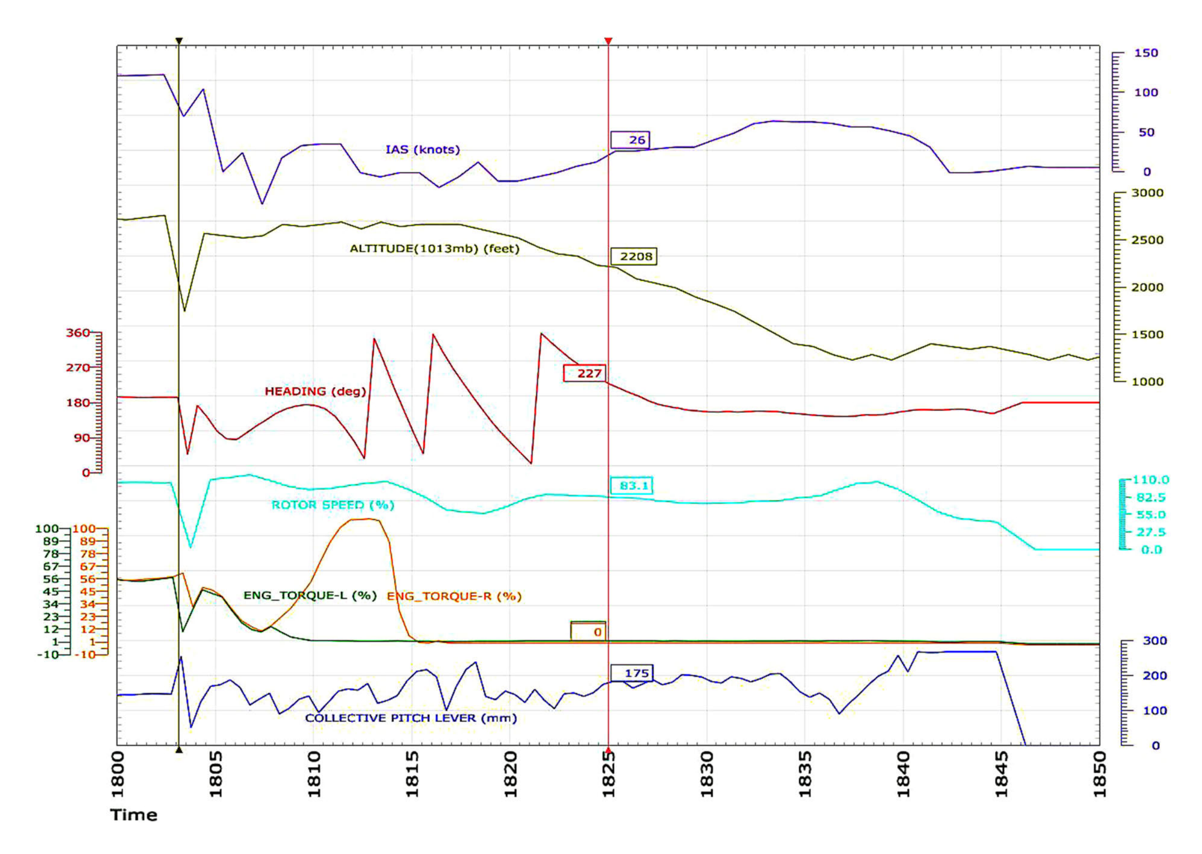

Figure 4. Indicated airspeed, altitude, heading, rotor speed, engine torques and position of collective lever during the final phase of the flight

- Engine 2 torque: at t = 1,810 s it was 22.84% and increasing. At t = 1,815 it reached its maximum value, 107.46%, after which it started to decrease such that 3 s later it was below 5%.
- Main rotor RPMs: at the start of this period they were at 99.06%. Over the next two seconds they dropped slightly to 94.16% before increasing again to a maximum of 106.79% at t = 1,813s. Over the next four seconds they dropped to 57.10%, at which time they recovered to reach a value of 106.79% at t=1836 s and t = 1,837 s. From then until the end of the time period (8 s), rotor RPMs decreased gradually to the final recorded value of 43.54%.
- Collective: between t = 1,815 s and t = 1,833 s the lever was moved upward and downward from its middle position. From this last period on, there was a noticeable move downward for two seconds, followed by an increase toward the upper part of the range of motion, where it stayed until the end of the recording.
- Altitude: at t = 1,810 s it was 2,664 ft. It remained stable for the 7 subsequent seconds. From then on until t = 1,839 s, it dropped to a value of 1,228.6 ft at an average descent rate of 3,900 ft/m. From there until the end of the recording, there are five more readings ranging in value from 1,400 to 1,342.9 ft, this being the last recorded value.

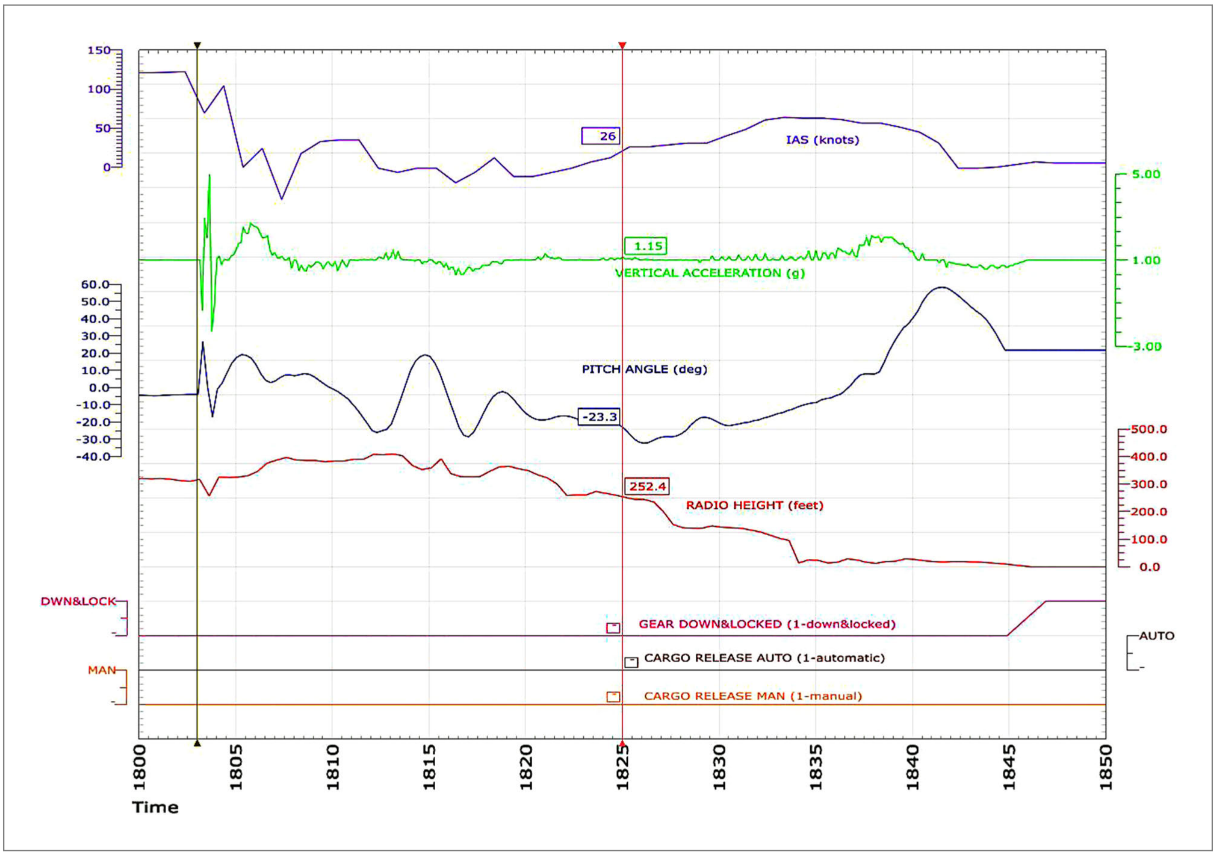

Figure 5. Indicated airspeed, vertical acceleration, pitch angle, radioaltitude, gear down and locked and automatic and manual openings of the load hook during the final phase of the flight

- IAS: at t = 1,810 s, the value recorded for this parameter was 34.80 kt. Until t = 1,822 s, negative values were recorded for IAS. Starting with t = 1,823 s, the values were positive and increasing such that at t = 1,832 s, IAS was above 60 kt, remaining around that value for the next 6 s. Then, until the end of the recording there were six readings indicating a drop in speed to virtually zero.
- Vertical acceleration: throughout this phase the value was near 1, except for a 3-second interval between t = 1,837 s and t = 1,839 s, which saw higher values that peaked at 2.11 g's. In the 5 s remaining before the end of the recording, the values were primarily below 1, with a minimum of 0.68 g's.
- Radioaltitude: at the start of this phase the radioaltimeter reading was 348.1 m. It increased slightly over the next three seconds, after which the readings trended downward, interrupted by occasional increases. From t = 1,826 s on there was an increase in the descent rate such that over 8 s it went from 244 m to 25 m. Toward the end of the recording there are 10 s during which the altitude dropped to 11.3 m, which was the last value recorded.
- Opening of the load hook: during this phase, neither of the two discrete parameters that record the load hook opening, one electrical and the other in emergency (manual), indicated the opening of the hook.

- Gear down and locked: this is a discrete parameter that records the state, open or closed, of a switch located on the right main gear leg. This switch is open during flight and closes on landing when the gear supports the weight of the aircraft. During this entire phase this discrete parameter recorded an open switch state, corresponding to the helicopter being airborne.

1.11.2. *Cockpit voice recorder (CVR)*

The aircraft was equipped with a three-channel Mars-BM cockpit voice recorder, P/N: 70A-10M and S/N: 275032. Channels 1 and 2 received signals from the crew members' communications and radio microphones, and channel 3 recorded the sounds from the area microphone.

The recorder was downloaded at the laboratory of German Federal Bureau of Aircraft Accident Investigation (BFU).

The three channels contained 28 minutes each of medium-quality audio information.

The conversations recorded were in both Spanish and Polish. The transcription of the latter required the assistance of the Polish accident investigation commission, as well as of one of the operator's pilots.

The "VHF key" parameter recorded on the FDR, which indicates when the crew presses the radio button to talk, was used to synchronize the communications recorded on the CVR with the data on the FDR.

The four transmissions that took place during the last hover phase, during which the tank was off-loaded at point 3, were used. The table below shows the CVR timestamp for each transmission, its duration, the FDR timestamp when the transmitter button was keyed, how long it was keyed and the time difference between the two recorders.

FDR timestamp	FDR duration	CVR timestamp	CVR duration	Difference[4]
1,648 s	8 s	2,091 s	7-8 s	443 s
1,662 s	3 s	2,105 s	3 s	443 s
1,756 s	1 s	2,198 s	1 s	442 s
1,778 s	6 s	2,220 s	6 s	442 s

As the data in the table above show, the duration of the transmissions recorded on both devices is fully consistent, as is the time lapse between them. This allowed investigators to establish the time difference between the two recorders (FDR time = CVR time – 442 s).

[4] CVR time – FDR time.

The most significant conversations recorded from the time the aircraft arrived with the tank in the vicinity of P-2 until the end of the recording are shown below. The "time" indicated on the table corresponds to the FDR timestamp, determined based on the CVR timestamp and corrected for the difference between the two.

Time	Source	Message	Remarks
16:40	Flight engineer	I see two guys (*)[5]	
16:43	Ground personnel	So, helicopter, do you see us yet?	
16:48	Pilot	Yes, but this one (garbled) has to be further away from me. Go forward.	
16:55	Ground personnel	(Garbled) if I'm out of sight. I don't know if you see me. I'm the one furthest away but if I hide more, you won't see me.	
16:63	Pilot	OK, that's good now.	
16:64	Ground personnel	I'm going to signal you.	
16:73	Pilot	See what I have to do.	
16:74	Flight engineer	For 1:07 s the mechanic gives the pilot indications during the descent maneuver to drop off the load (*).	
17:41	Flight engineer	It's on the ground. (*)	
17:44	Ground personnel	Climbing, climbing.	
17:48	Flight engineer	Up. Let's go, let's go. (*)	
17:63	Flight engineer	Should we go get the trash? (*)	
17:64	Ground personnel	They're asking if you could go back down empty, pick up a cement load and take it to point one, because the load you have to take from point three we'll have to take up and it'll take us a while to get there.	
17:78	Pilot	Roger, so, uh, another flight with cement to point one.	
17:83	Ground personnel	Yes, the closest to you (garbled).	
17:99	Pilot	And what?	
18:03			A clicking sound is heard.
18:06	Pilot	(Expletive), damn it! (*)	Hard breathing sound
18:10			0.8 kHz noise
18:11	Pilot	Stop the engines! (*)	
18:14			Drop in engine speed
18:33	Ground personnel	Helicopter! Helicopter!	
18:36	Pilot	Stop the engines! (*)	
18:40			Drop in engine speed
18:50		End of recording	

[5] (*)Indicates that this conversation is in Polish on the CVR.

1.12. Wreckage and impact information

1.12.1. *Crash site and wreckage information*

The helicopter wreckage was scattered over a 2,000 m^2 area on terrain at two different altitudes at the bottom of a gorge created by the confluence of the Almendro and Las Traves streams, at coordinates 28° 42′ 24.72″ N - 17° 52′ 59.04″ W. This point, called "Dos Aguas" (Two Waters), is at an elevation of 430 m (1,410 ft).

Figure 6. Aerial view of the helicopter wreckage

The terrain where the aircraft crashed is very rocky and features loose, hard rocks of various sizes with very sharp edges. The hillsides are extremely craggy and are also covered in loose rocks at lower elevations. Due to the steep incline of the mountain side these rocks are very unstable, making them susceptible to rock falls.

As a result of these characteristics, the impacts made by the various parts of the helicopter are hard to discern, either because the impacts are not evident on the hard stones or because any rock falls caused by the impact could result in other rocks covering the marks. Some of the wreckage could also have impacted the stream.

This could explain why no clear signs of the aircraft's impact were noticeable on the ground. There was one impact site on the hillside next to the main wreckage was found that uprooted a shrub in the area and caused a landslide of dirt and stones that ended up at the bottom of the valley.

Part of the main wreckage was located atop a small hill. It was resting on its left side with the helicopter's longitudinal axis facing 060°, which nearly coincides with the direction in which the valley is oriented in that area.

The front and lower part of the cockpit was resting atop the hill and exhibited heavy damage with multiple impact fractures. The nose gear landing leg was folded to the back and left and was touching the underside of the fuselage. There were no impact marks on the wheels of this leg.

The cargo hook was open. The aft tube on the trapeze to which the hook is attached had broken at both ends and detached. The part of this tube that detached was not found among the wreckage.

The tailboom, which had broken off near the area where it is attached to the fuselage, was at the lower elevation and lined up with the helicopter's longitudinal axis but rotated 180° about its own longitudinal axis with respect to its normal position.

There was another fracture at the aft end of the tailboom just at the start of the vertical stabilizer.

The support plate on the tail skid exhibited scratches and one of its corners was bent. The two front bars were broken and badly bent.

All four main rotor blades had broken near their roots, possibly when they impacted the terrain as the helicopter overturned. They were found a few meters away from the main wreckage.

No anomalies were found in the main rotor head or in its control mechanisms.

The following helicopter components were found piled up in and around the bottom of the south hillside, close to an impact zone:

- The aft end of the tailboom, including the tail rotor.
- The cargo hook sling, and
- Miscellaneous parts like the left and right front doors, the fairing from the front lower part of the cockpit, the left horizontal stabilizer, and the VOR antenna cover, which had been moved to this location to facilitate rescue efforts.

All three tail rotor blades were broken, two practically at the root and the third some 25 cm away from the root. The missing blade fragments were not found at the impact site. The load sling was found wrapped around the rotor head and shaft. The rotor turned freely. When turned, it was noted that it dragged the part of the transmission shaft that was still attached to it. It was also noted that the pitch control mechanism on the tail rotor head was working properly despite the damage and warping exhibited by some of the connecting rods in its mechanism.

After the sling was uncoiled, it was noted that its bottom portion was missing. The length of this section was determined to be 19.80 m.

The flight engineer's seat, which had detached when the components securing it to the aircraft's structure broke, was found forward of the main wreckage.

The outer part of the right horizontal stabilizer was not found among the main wreckage.

This component, along with a tail rotor blade segment and the lower portion of the load sling, was found in the Las Traves ravine, at the following coordinates:

- Blade fragment: 28° 42′ 44.83″ N – 17° 52′ 59.82″ W
- Stabilizer segment: 28° 42′ 42.23″ N – 17° 53′ 02.70″ W
- Lower portion of sling: 28° 42′ 38.26″ N – 17° 53′ 04.00″ W

1.12.2. *Workshop inspection of wreckage*

The aircraft wreckage was recovered from the crash site and taken to a hangar, where it was examined in greater detail.

The leading edges of the tail rotor blades exhibited clear signs of having impacted a cable.

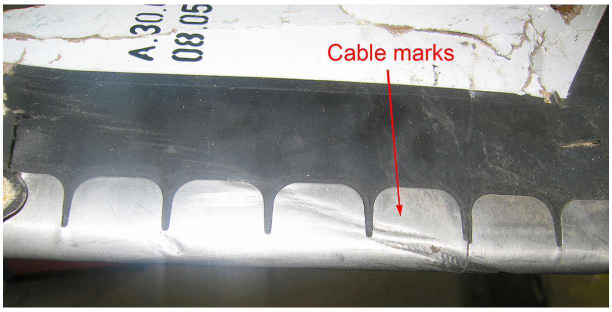

Figure 7. Cable marks on the leading edge of the tail rotor blade

It was noted that the bar that joins the barycentric hook to the trapeze was bent as a result of having been pressed against the trapeze. The hook position that could have caused this damage would be consistent with the sling being pulled from the rear of the helicopter. It was also noted that in that position, the lower part of the hook would interfere with the trapeze bar that broke, and which was not recovered from the wreckage. An analysis of that part of the hook revealed that the paint had been stripped and the metal showed clear signs of friction.

On the lower aft portion of the fuselage, where the aircraft registration was painted, there was a mark left by a cable. This mark was almost parallel to the aircraft's longitudinal axis.

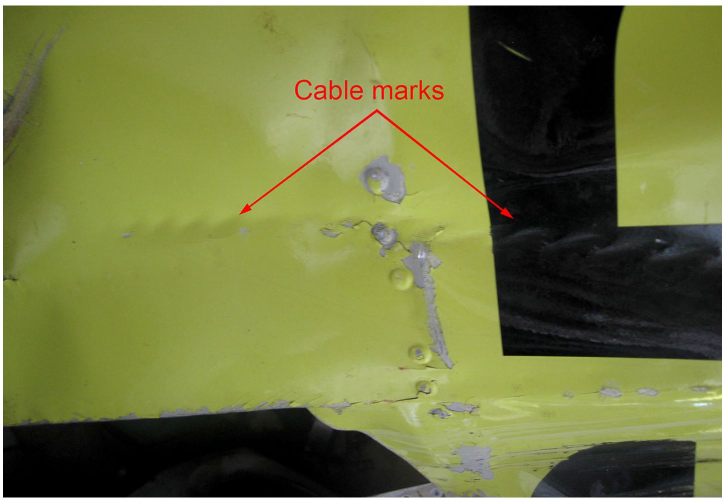

Figure 8. Cable marks on lower aft section of fuselage

In both engine control units, the metering needles for the various engine operating positions were found in the 30° position, corresponding to ground idle.

The transmission shaft to the tail rotor was broken in three points that basically coincided with the areas where the tail fuselage broke – one where the tail fuselage joins the airframe and the other two at the start of the vertical stabilizer, one at the inlet to the 42° gear box and the other at the outlet. In addition, the segment between the inlet to the 42° gear box and the fuselage was completely loose, since the intermediate support points were broken.

Inspection of sling cable

A detailed analysis was conducted of the 14-mm diameter braided steel sling cable.

Figure 9. Photographs of the cable break. Top part at left and bottom at right

This cable consists of a central core made of plant fiber. Wrapped around it are six 4.6-mm diameter cords, each consisting of thirty wires, each one measuring 0.7 mm in diameter.

A visual inspection revealed that the cords were not all broken in the same area.

The following table shows the distance from the section with the break to the section called "s", which corresponds to that section of the cable where the cords start to unbraid, as well as a description of the wires around the break sections.

Bundle	Distance	Extent of unbraiding around the break	Extent of stretching of cords aroung the break
N.° 1	50 cm	Almost all wires unbraided	Outer wires stretched
N.° 2	53 cm	All wires unbraided except some in center	All wires stretched except some in center
N.° 3	60 cm	Almost all wires unbraided	Almost all stretched
N.° 4	65 cm	Almost all wires unbraided	All stretched
N.° 5	64 cm	Almost all wires unbraided	All stretched
N.° 6	66 cm	All wires unbraided except some in center	All wires stretched except some in center

At the macrofractographic level the fracture surfaces on the wires were observed to be primarily of the cup and cone type, though a small percentage of bevel fractures were also observed.

These characteristics indicate that the fracture was caused by tensile load.

1.13. Medical and pathological information

Not applicable.

1.14. Fire

There was no fire in the aircraft nor in the sorrounding area.

1.15. Survival aspects

Not applicable.

1.16. Tests and research

1.16.1. *Crew statements*

1.16.1.1. Pilot

Due to the injuries sustained in the accident, the pilot was unable to be interviewed until several months later. He could not provide any relevant information since he remembered absolutely nothing about the day of the accident.

1.16.1.2. Flight engineer

He started his account by saying that they had left the staging area located in "La Viña" with a load of cement that they dropped off at point 2. They then went to another point located deeper within the caldera where they picked up a load of trash, after which they flew back to the staging area, where they left the trash and picked a tank weighing some 400 kg, which they took to point 3.

During the flight he was monitoring the load in the mirror. Whenever they had a load suspended he watched it in the bottom of the mirror that was in the front right of the helicopter. When they were not carrying a load he saw the hook in the top part of the mirror. He monitored ground personnel as they unhooked the load and would tell the pilot “load clear” when they were done. Once the load was released, they climbed and started to gain speed. He watched the hook, which was flagged with a piece of red cloth, for about 30 s, at which point he stopped looking at it. They proceeded to point 3, where they had to pick up another load of trash, by flying through the Las Traves ravine, through which one of the two streams that converges at Dos Aguas flows. He was planning to monitor the hook once more as they neared point 3.

They were flying at a speed of between 30 and 40 kt and an altitude of 100-140 m above ground level.

When they reached Dos Aguas, they started to turn left to continue down the Las Angustias ravine toward point 3. During this turn they heard a loud noise from the tail rotor area and the helicopter started rotating in the opposite direction as the main rotor.

They reduced engine thrust, which decreased the speed of rotation. They could not dive to gain speed since the cliff wall was ahead of them. He also stated that they had no yaw control.

They saw two mounds at the bottom of the valley and led the helicopter toward them with the intention of landing atop them such that the main landing gear legs would settle on the upslope, which would help brake the aircraft.

He estimated that the helicopter made six or seven full turns and added that before reaching the ground, they managed to stop the helicopter’s rotation and approach the mounds in straight flight, though slipping to the right.

He added that four or five seconds before reaching the ground, he moved the throttle levers to increase thrust and thus stop their descent rate. Just before landing he cut the engines.

He thinks they miscalculated when landing atop the mounds and that the helicopter was not properly supported. This is why, together with helicopter rotor turn, the helicopter turned over on its left side.

He did not recall how he exited the aircraft. In his first recollection after the accident he was already out of the aircraft. Some 10 minutes after the accident the first people arrived and moved him some 20 meters away from the helicopter.

He was asked what they had based the length of the sling on, and he replied that at point 1 there were tall trees and that although there was no wind on the day of the accident, the terrain in the area was conducive to gusts, and it was those two reasons that made them opt for a long sling. He added that they were used to working in mountain areas in Poland with slings measuring up to 50 m.

With regard to whether they opened the cargo hook, he replied that he did not, he was busy with the engine levers, but that the pilot may have. He added that the release switch is on the collective lever under a switch guard. If it was actuated, the guard would have been raised. He also noted that there is a manual release lever at floor level.

Asked if they felt a shudder or anything else of note around the time they heard the noise coming from the tail rotor, he answered that everything had been normal until they heard that noise.

Finally, he was asked if they were wearing their helmets, to which he replied no.

1.16.2. *Eyewitness statements*

1.16.2.1. Operator 1

He was next to another coworker at point 1, very close to the river though at a higher elevation.

He stated that the helicopter had carried a load to point 2 and should have been on the way back to the staging area to pick up another load.

At some point he heard a call from the helicopter on the radio, though he could not discern the message, but he interpreted it as a call for help. He then looked up and saw the helicopter rotating and something detaching from the rear rotor. There was also white smoke coming out. Seconds later the helicopter went out of sight behind a mountain.

When he saw the helicopter it was practically overhead at an altitude of about 300 m. It was flying very close to the mountaintop, so much so that he thought it was going to hit it.

He and his coworker started running in the same direction as the helicopter and after a while they reached the site where they found the wreckage. He called in the accident on his radio.

He did not know how many people were onboard. As he approached the helicopter he looked left and saw an individual outside the helicopter seated on a seat. He also noticed that fuel was leaking from one of the helicopter’s tanks and he heard a constant buzzing noise coming from the helicopter.

They unbuckled the seatbelt of the person who was outside the helicopter and moved him away from it.

He radioed the foreman to ask how many people were inside the helicopter, and he replied two. He looked inside the cockpit and saw the pilot inside, noticing a short while later that he was moving an arm.

They started moving stones from underneath the helicopter to clear a path and extract the pilot. Two more people arrived a short time later.

In the meantime they radioed the mechanic and asked about how to turn off the helicopter (the buzzing sound coming from inside). He told them to disconnect the battery by looking for a switch labeled "Bat" or "Battery" and placing it in off. His coworker went in the cockpit and disconnected the battery, which immediately stopped the noise.

They continued making room under the helicopter and managed to extract the pilot, whom they took to where the mechanic was. They stayed there until medical assistance arrived.

When asked if any of the occupants was wearing a helmet, he replied that they only had on their communications helmets.

As for the direction in which the helicopter was rotating when he first saw it, he said the nose was turning from right to left.

With regard to the prevailing wind conditions, he said there was practically no wind.

When asked if he had seen the load sling, he replied that he was not aware of having seen it.

1.16.2.2. Operator 2

He was with a coworker at point 1, which is located in the Taburiente ravine, near the Roque de las Piteras. At one point they heard on the aircraft band what sounded like a call for help from the helicopter. He looked up and saw the helicopter and noticed that something was coming out of the tail rotor area, and maybe some smoke. He added that the helicopter was rotating left.

When asked to specify the location of the helicopter when he first saw it, he indicated that it was over the ravine located on the other side of Roque de las Piteras (the Traves ravine), since he saw it above the Roque.

With regard to whether they had a load for the helicopter to pick up and take to the staging area (La Viña), he said no, that they only had to receive some material, adding that they only had to remove things from "Casas de Taburiente".

He added that when two other individuals arrived at the helicopter, they opened the cockpit and unfastened the pilot's harness and all four of them then pulled him out.

1.16.3. *Test on a similar helicopter*

A test was run on a helicopter of the same model as the accident aircraft that consisted of attaching the end of a rope to the barycentric hook and pulling from the other end such that the rope went through the tail rotor (see Figure 10). The rope made contact with the fuselage in the same area where the cable marks were found and the load hook rested against the trapeze bar that detached in the accident.

Figure 10. Photographs of the rope linking the load hook to the tail rotor on a helicopter of the same model as the accident helicopter

1.17. Organizational and management information

1.17.1. *Information on the operator*

1.17.1.1. Aerial work certificate

The operator of the aircraft, Heliseco, had an aerial work certificate (AWC), number 124/09, issued by the Civil Aviation Office of the Republic of Poland, that was valid until 28/02/2011 (subsequently renewed until 25/02/2013). This AWC allowed the operator to do aerial work pursuant to Part VII of the Air Law Act of 3 July 2002, with the following limitations:

1. Geographical area

   ICAO AIR NAVIGATION REGIONS
   EUR Europe

AFI Africa
SAM South America

2. Type of navigation

   VFR (D2)

3. Aerial works operations, other than commercial air transportation:

   a) Agriculture and environment recovery operations (AGRO) (AW-1);
   b) Helicopter hoist operations (HHO) (AW-3);
   c) Firefighting operations on the aircraft modified for such operations (AW-5);
   d) Search and rescue flight (AW-6)
   e) General aerial works operations, other than commercial air transportation, without aircraft equipment modification (AW-7).

4. Type of aircraft

Mi-2	(AW-1) (AW-3) (AW-5) (AW-7)
PZL W-3A, model PZL W-3AS	(AW-3) (AW-5) (AW-6) (AW-7)
PZL W-3A, model PZL W-3A	(AW-3) (AW-5) (AW-6) (AW-7)

The certificate contains a listing of those operator aircraft to which the certificate applies, and includes the accident aircraft.

1.17.1.2. Operations Manual

Part 14 of the Heliseco Operations Manual is devoted to the loading and transport of logs, and contains a section on safety measures that includes the following instruction:

So as to keep the sling from striking the tail rotor or the tailboom, the helicopter's forward speed when flying unloaded (only with the sling hooked to the helicopter) must be limited to an airspeed of under 100 km/h. The recommended speed when transporting tree trunks is under 100 km/h, though the actual value will depend on the flying conditions and on the size of the load being transported.

1.17.1.3. Work plan

1.17.1.3.1. *Initial plan*

The work consisted of transporting a total load of 32,500 kg, comprising 30,000 kg of cement, 2,000 kg of fuel and an empty 500-kg tank with a diameter of 2 m and a length of 5 m.

The associated contract was signed between the client and Hispánica de Aviación S.A. (HASA) as the company responsible for the operation. The work was scheduled to be done in late January 2011 with a PZL W-3AS helicopter, as per the work plan drafted by HASA personnel, which specified the following:

- Equipment required:
  - Long sling.
  - Short sling.
  - Rotating hook.
  - Weight.
  - Emergency net in the event the rigging systems failed.
- Personnel:
  - HASA: 2 pilots + 1 mechanic.
  - Client:
    - ☐ 2/4 people at the departure point.
    - ☐ 2 people at arrival point 1.
    - ☐ 2 people at arrival point 2
- Areas of operation:
  - Departure:
    - ☐ Coordinates: 28° 41′ 08″ N 17° 54′ 34″ W.
    - ☐ Entrance parking lot, national park.
    - ☐ Sandy ground. The client will water to avoid dust.
    - ☐ Clear.
    - ☐ Elevation: 730 ft.
  - Arrival 2:
    - ☐ Coordinates: 28° 43′ 33″ N 17° 52′ 29″ W.
    - ☐ Halfway.
    - ☐ Rocky terrain. Stream bed.
    - ☐ Restricted access. See first.
    - ☐ Elevation: 1,500 ft.
    - ☐ Number of loads to deliver: 24.
    - ☐ Distance from departure: 4 NM.
    - ☐ Maximum time per cycle: 15 min.
  - Arrival 1:
    - ☐ Coordinates: 28° 42′ 31″ N 17° 52′ 46″ W.
    - ☐ Base of the caldera.

- ☐ Rocky terrain. Stream bed.
- ☐ Clear.
- ☐ Elevation: 2,500 ft.
- ☐ Number of loads to deliver: 4.
- ☐ Distance from departure: 5 nm.
- ☐ Maximum time per cycle: 15 min.

- Loads. The maximum load weight planned was 1,400 kg.

For various reasons, it was impossible to make the deliveries on the scheduled dates, and it was proposed to postpone them until late February.

Since the operator did not have aircraft on those dates, it opted to wet lease (with crew) an aircraft from the Polish Helicopter Services Company (Heliseco) that was identical to the one initially planned.

Before its flight to Tenerife, HASA had provided information on the work planned to the crew of the leased aircraft. It also required the pilot to fly over the unloading areas first to check the viability of the operation, determine the length of the sling and arrange with the client the loading order and the coordinates of the unloading point for the tank.

1.17.1.3.2. *Revised plan*

The helicopter, crew and a mechanic belonging to Heliseco and a HASA technician arrived on the island of La Palma the day before the accident and proceeded to the Caldera de Taburiente to fly over and inspect the work area. They then went to the La Palma Airport, where they landed. Subsequently they drove to Los Llanos de Aridane, from where they were driven to the parking lot at La Viña by an employee of the client.

They inspected the cement loads, which had been arranged in 1,400-kg sacs, which the pilot requested be reduced to 1,200 kg. The fuel loads and the tank were properly arranged.

They then held a meeting with the client’s representative to work out the details of the operation, one of which was to define a new point within the caldera for unloading the tank, the coordinates of which were 28° 43’ 20.55” N 17° 52’ 32.66” W at an elevation of 2,530 ft.

The rigging of loads at La Viña and the unrigging at the various off-loading points were the responsibility of the client’s personnel.

Since some of the unloading areas were narrow and had tall trees, they decided to use a 20-m sling.

1.18. Aditional information

1.18.1. *Flight Engineer License (FEL)*

The Flight Engineer License issued under the regulations in ICAO Annex 1, Personnel Licensing, entitles the holder the right to act as flight engineer of any type of aircraft on which the holder has demonstrated the level of knowledge and skill required by the Licensing Authority.

As regards the emergency procedures, Annex 1 requires the holder to have demonstrated an appropriate level of knowledge on normal, abnormal and emergency procedures and on operational procedures for the carriage of freight in general and of dangerous goods.

As regards the knowledge of emergency procedures, Annex 1 requires the holder to have demonstrated the ability to exercise the functions and carry out the procedures for the recognition of emergency conditions and to use the proper emergency procedures.

Poland’s Civil Aviation Authority requires the holder to demonstrate his skill by taking a test to maintain the flight engineer rating. This test is called WZOR No. 62 (02.04.2010), item 4c of which requires approving the procedure to be used during in-flight emergencies.

1.19. Useful or effective investigation techniques

Not applicable.

2. ANALISIS

2.1. General considerations

The helicopter was taking part in an operation to transport an external cargo from the outside to the inside of the Caldera de Taburiente, and to remove trash from the Caldera. The operation had been scheduled ahead of time and modified the day before to add a new point at which to off-load a purifier tank.

Once the tank was transported to the new location and dropped off, the flight crew radioed ground personnel for information on hooking the trash load to the hook and removing it. Said personnel informed them that they could not do it because they had to go to a different point, so they asked the crew if they could return unloaded to the staging area.

Following this change, the helicopter took off from an elevation of 2,540 ft, the plan being to return to the La Viña staging area. The takeoff was conducted at a climb rate of 1,200 ft/min to a maximum altitude of 2,864 ft, which was maintained for 10 seconds. The pilot then descended to an average altitude of 2,700 ft, which he maintained for 17 seconds until the helicopter became unstable. Six seconds later the helicopter started to rotate about its vertical axis.

The crew managed to stabilize the helicopter by reducing engine power to eliminate the engine torque. They then performed an emergency landing that ended with the helicopter impacting the ground and turning over on its left side.

Contractor personnel, who were at one of the points chosen for transporting materials, were able to report the emergency immediately and proceed to the scene in just a few minutes. These same personnel disconnected the battery in accordance with the mechanic's instructions.

2.2. Destabilization of the helicopter

As reported by the flight engineer, the event began when they heard a loud noise from the tail rotor area and the helicopter started rotating about its vertical axis in a direction opposite that of the main rotor. As described in Section 1.11.2, a noise can be heard on the CVR at t = 1,803 which could match that reported by the flight engineer. The rotations were recorded on the FDR starting six seconds after the noise was heard.

At t = 1,803 s, when the helicopter became unstable, it was flying at a real (corrected) altitude of 2,820 ft and an IAS of 122 kt.

Under these conditions and with no load on the hook, the sling would have been behind the helicopter at a certain angle from the vertical. This angle was estimated to have been 45°, in which case the lower end of the sling would have been some 40 ft below the helicopter at an altitude of 2,780 ft.

The vertical acceleration values recorded on the FDR at that time were very high, almost –5 g's. In the two seconds that followed the helicopter's altitude dropped 240 ft and its IAS went from 121 to 24 kt.

A force of considerable strength is required to produce such high acceleration values and the large changes seen in the aircraft's speed and altitude.

While no information is available to determine the helicopter's precise location at that moment, an approximate location can be established based on the location where the tank was dropped off and the locations of the eyewitnesses, the main wreckage and the fragments that detached in flight. Based on this information it may be concluded that the aircraft was probably in the Las Traves ravine, very close to or even flying over the mountainous edge that runs between Roque de la Brevera Macha and Dos Aguas. The elevation of the peaks along this edge where the helicopter could have been flying over reach a maximum value of 862 m (2,828 ft).

As concerns the breaking of the load sling, it is worth recalling that the break took place at its lower end. An analysis of the fracture surface determined that it broke due to excess tension. A tensile fracture requires the application of two opposing forces, one at each end of the fracture area.

At this juncture the possibility should be considered that the break was caused solely as a result of the helicopter's actions.

As such, there are two hypotheses: the first involves having the sling wrap itself around the tail rotor and snapping, and the second involves the sling impacting one of the blades and breaking.

In the first case, the break would have occurred at the top end of the sling.

The second hypothesis can also be discarded for two reasons. First is that the main rotor blades do not show any evidence of having impacted the cable and the tail rotor blades are not strong enough to break it. Second, even if they could have broken it, the break caused by a blade impact would not show signs of axial loading.

In addition to these reasons, there is one more, namely that none of these scenarios would have been capable of producing the high vertical acceleration values that affected the aircraft, nor the large drop in speed nor the loss of altitude.

The sling, then, could only have been broken by an external element.

We know that the helicopter was traveling at an altitude of 2,820 ft (lower end of the sling at 2,780 ft) in an area where the mountain peaks reach a height of 2,828 ft. The possibility exists, then, that the lower end of the sling got caught on the ground somewhere.

Had this happened, the lower end of the sling would have remained stationary while the top end would have continued moving with the helicopter until the cable tensed, tugging on the sling and causing it to break under tension. This force was transmitted to the helicopter, generating the extremely high vertical acceleration values and the subsequent loss of speed and altitude.

Once the cable broke, the tension to which it was subjected caused the lower end to snap upward until it impacted the tail rotor blades, resulting in the gradual breakage and loss of the blade segments and in the winding of the sling around the rotor.

Since the rotor continued turning, the cable kept winding around it until all of the available cable was reeled in (the other end of the cable remained attached to the helicopter's barycentric hook). As a result, the cable was once again under tension, leading to the scuff marks found on the underside of the helicopter's fuselage.

Initially the helicopter responded to the movement of the right pedal by counteracting the first rotation to the left, but six seconds later the helicopter once more started rotating left, and this time the pilot was unable to control the rotation using the pedals. This behavior could have been caused by the gradual breakage of the rotor blades leading to a progressive loss of tail rotor effectiveness.

Such uncommanded rotations take place when the helicopter is under powered flight or is flying at a speed below Vy and loses the thrust from the tail rotor (see Section 1.6.2.2.1). In these cases the rotation can only be stopped by increasing speed above Vy or cutting the torque applied to the main rotor.

Also, as the cable tensed by the effect of being wound around the rotor, it approached the horizontal stabilizer until it contacted it, causing a fragment to break off and detach in flight. The tension present in the cable could also have caused bending of the tail structure, which would have had an adverse consequence on the effectiveness of the pitch control mechanisms for the tail rotor blades.

In light of the above, it may be concluded that the hypothesis involving the lower end of the load sling getting caught somewhere along the terrain is fully consistent with the cable fracture characteristics, with the parameter values recorded on the FDR, with the fractures of the components detached in flight, with the marks left by the cable on the fuselage and with the general subsequent behavior of the helicopter.

The pilot managed to stop the aircraft's rotation after three full turns and 18.5 seconds by reducing the torque supplied by the engines.

Once the rotation was stopped, the helicopter remained unstable since the tail rotor was no longer supplying thrust. In addition, the engines were at idle and the descent rate was high, with an IAS of 31 kt and a –18° pitch angle at a low altitude above ground level.

2.3. Handling of the emergency

The first yaw to the left could have been counteracted when the helicopter responded to the right pedal input from the pilot, which indicates that at that moment there was still continuity in the tail rotor blade pitch control mechanism.

This continuity was lost immediately afterwards, as evidenced by the FDR data, when the actuating linkage failed to move despite the pedal input. A loss of tail rotor control, however, does not imply a loss of tail rotor thrust, since in this condition the blades would be positioned at a 7° angle, meaning they still provide thrust as long as the rotor keeps turning. That is why the helicopter's heading remained relatively stable over the next few seconds, though this stability was lost gradually, possibly as a consequence of the fracture and gradual loss of the tail rotor blades.

In contrast, the altitude and speed could not be controlled, as evidenced by the sharp drop in altitude and by the sudden reduction in speed to 24 kt.

This second uncommanded left rotation by the helicopter required that the crew cut the torque being applied by the two engines to the main rotor. According to the data recorded, the pilot instructed the flight engineer to stop the engines. He put them at idle instead, and the helicopter's rotation stopped a few seconds later.

The helicopter's new flight configuration and its altitude above the valley floor kept it from gaining speed above Vy and from applying thrust so that the helicopter could be flown to a safe landing location, meaning that the pilot had to perform a forced landing using auto-rotation.

The pilot handled this last part of the emergency by maneuvering the flight controls to increase speed from 30 kt to 60 kt, at which point he raised the helicopter's nose smoothly and gradually. Before the flare and while gaining speed, the pilot maintained the collective lever in a position that prioritized reducing the descent rate versus increasing main rotor RPMs while attempting to maintain said RPMs.

The pilot began the flare by raising the nose of the helicopter at first and then lowering the collective lever approximately half way to its lowest point. The main rotor RPMs reached a value of 106% at a pitch angle of 10° and an IAS of 56 kt. Immediately afterwards the pitch angle rose rapidly to a value of 57° and the pilot raised the collective lever to a high position, where he held it.

The descent rate stopped when the helicopter's pitch angle reached 10°, with the aircraft climbing somewhat before descending once more. The collective lever was raised rapidly resulting in a corresponding rapid increase in pitch angle.

By the time the pitch angle was 20° and rising, the IAS had dropped to 51 kt and the helicopter was once again climbing.

The increase in pitch angle above 20°, which is the standard value for a flare, was indicative of a lack of sufficient room to stop the helicopter's motion and land before reaching the valley's almost vertical cliff wall.

The period above 57° pitch angle was brief, with this value dropping to 29° in three seconds. The helicopter's heading was 154°, its IAS was 0 kt and the main rotor RPMs had fallen to 43%.

The helicopter was at a zero bank angle, meaning that the pitch angle transition from 57° to 29° with the cyclic control forward is consistent with a maneuver to position the helicopter as horizontally as possible in preparation for landing.

The data recorded conclude with the helicopter in this situation.

2.4. Descent to the ground

The time that elapsed between the last recorded position and the impact with the ground could not be determined, but is estimated to have lasted just a few seconds.

Also unknown is whether the turn toward the 060° heading on which the wreckage was found was due to an increase in engine thrust, as reported by the flight engineer and which could not be confirmed by the FDR due to the lack of data from this phase, or due to another cause when the helicopter impacted the ground.

2.5. Ground impact

The damage to the lower right front of the helicopter at cockpit floor level, along with the damage to the tail skid, indicates that the helicopter impacted the ground twice.

The damage to the tail skid, tailboom and its attachment to the main helicopter structure are consistent with the rear of the aircraft impacting the ground. In order for the tail skid to strike the ground, the helicopter must be in a significant tail-down, nose-up attitude, as would have been the case when the helicopter attained a 57° pitch angle.

The features of the terrain, comprised of loose rocks and a stream with stones and sediment at its bottom, made it impossible to locate the exact impact site.

The damage exhibited by the front part of the helicopter as well as by the lower right part of the cockpit, along with the shifting of the front landing gear leg backwards and leftwards with no damage to the wheels, are consistent with the right front part of the cockpit and floor impacting the top part of the mound. This impact stopped the helicopter, which would have been moving forward and to the right. The position of the flight engineer's seat outside the wreckage, with the flight engineer still seated in it, is also consistent with the impact as described.

This second impact indicates that the crew leveled the helicopter after the significant flare (57°) they executed.

The lack of damage to the main landing gear indicates that it did not impact the ground violently, possibly because the helicopter was very close to the ground at the conclusion of the maneuver to recover from the flare.

The vertical stabilizer and tail rotor assembly were found on an extension of the path possibly being taken by the helicopter (nearly 150° heading), beyond the main wreckage. Alongside it was a pile consisting of dirt, stones and shrub branches that had fallen from the hillside where the impact marks described in Section 1.12.1 were found.

Based on the above description, when the final data were recorded on the FDR, the helicopter would have had a practically level attitude and been very close to the ground after executing the flare.

2.6. Analysis and planning of the work to be executed

There was no mention found in the planning made for the work regarding the number of trash loads to transport or of their location.

This planning should have considered what loads had to be taken to each of the points inside the Caldera and how many loads of trash had to be removed from each of these points so as to determine whether all of the flights could be made with a load.

Had it been concluded that some of the flights would have been unloaded, this circumstance should have been anticipated and ballast prepared so as to avoid flying without any load.

Since the planning did not consider this much detail, it was impossible to foresee that there was no trash to be picked up at the point where the water tank was dropped off.

This circumstance was clearly evidenced by the crew's reaction when they went to pick up trash and the ground team informed them that they were told to relay to the crew if they could fly back unloaded to La Viña to pick up a new load.

Having to return unloaded could also have given rise to some unease in the crew, since this implied having to make a larger number of flights and employ more time than planned.

The proximity of the loading and unloading areas made it difficult for the helicopter to be able to climb to and maintain an altitude of 500 ft or more above ground level.

The work planning should have analyzed and considered the safety altitudes to be flown by the aircraft in order to maintain adequate separation with the mountaintops.

As a result of the above, a safety recommendation is issued aimed at improving the operator's procedures as regards the analysis and planning of operations involving an external load.

2.7. Operating procedures

The accident flight was being conducted with a load sling but without any load hanging from it.

As noted in 1.6.2.1, the Aircraft Flight Manual prohibits flying under those conditions. The Operations Manual does allow it, though it limits the speed to 100 km/h (54 kt).

Regardless of the contradiction present between these two documents, which will be discussed in Section 2.8, it is worthwhile to analyze the way in the accident flight was being carried out.

When the aircraft started to destabilize, it was flying with no load suspended from the sling at an IAS of 225 km/h (121 kt).

This situation is in violation of both of the manuals mentioned above: of the Flight Manual for flying without a load, and of the Operations Manual for flying at a speed that was twice the maximum speed envisaged in that document.

Also, as indicated in 1.6.2.2.1, Section 3 of the Emergency Procedures in the Aircraft Flight Manual contains a section on tail rotor failures that indicates the procedure to be used in the event of such a failure.

In cases like those involved in the accident detailed herein, the procedure states to turn off the engine when the landing is assured.

This action is to be carried out by the flight engineer. Consistent with this, the refresher training for this crewmember includes practicing such emergencies.

Point 1.11.2 on the cockpit voice recorder stated that based on the sounds recorded on this equipment, the pilot instructed the flight engineer to shut off the engines at t=1836 s.

In contrast, point 1.11.1, which discusses the flight data recorder, reveals that the engines were not shut off for the duration of the recording period, but rather that they were placed at idle.

In light of the above, the following conclusions may be reached:

The pilot's action was not in keeping with the instructions of either the Flight Manual or the Operations Manual.

The flight engineer did not properly execute the procedures by not adhering to the pilot's request to shut off the engines and by not adhering strictly to the procedure, which requires them to be turned off.

As a result, the operator should reinforce the training given to its crews as regards compliance with the operating procedures. A safety recommendation is issued in this regard.

2.8. Flying with a sling

During the accident flight the helicopter was flying with a 20-m long sling that had no load attached to the hook on its lower end.

The speed of the helicopter before and at the instant of the destabilization was 225 km/h (121 kt).

As concerns flying unloaded, the supplement to the helicopter's Flight Manual on operations with the external cargo hook specifies that "except for hover and hover maneuvers operations with a loose sling cable are prohibited".

The operator's Operations Manual (point 1.17.1.2) specifies that the helicopter's forward speed when flying unloaded (with only the sling attached to the helicopter) must be limited to an IAS of under 100 km/h (54 kt).

From the above one may conclude that there is a clear contradiction between the limits for operating unloaded as found in the Aircraft Flight Manual (prohibited) and in the operator's Operations Manual (allowed with restrictions).

Subpart P, Ops. 1.1040, letter k) of Commission Regulation (EC) no. 859/2008, amending Council Regulation (EEC) no. 3922/91 as regards common technical requirements and administrative procedures applicable to commercial transportation by aeroplane states that "An operator must ensure that information taken from approved documents, and any amendment of such approved documentation, is correctly reflected in the Operations Manual and that the Operations Manual contains no information contrary to any approved documentation. However, this requirement does not prevent an operator from using more conservative data and procedures".

The above clearly implies that an Operations Manual may not contain any instruction that contradicts or is less conservative than those contained in the Aircraft Flight Manual.

Therefore, the operator's Operations Manual should be modified so as to adapt it to the Aircraft Flight Manual as regards operations with an external load hook. A safety recommendation is issued in this regard.

3. CONCLUSIONS

3.1. Findings

Both crewmembers were licensed and had ample experience flying with external loads.

The aircraft was suitable for conducting flights with external loads and had passed its maintenance inspection.

The analysis and planning of the work to be done were not sufficiently detailed, as a result of which aspects that were essential to the safety of the operation were not considered. As a consequence of this, the flight crew did not know that after dropping off the water purifier tank they would be flying back unloaded.

During the accident flight the helicopter was flying with the sling attached unloaded to the barycentric hook at an altitude that was similar to that of the highest terrain in the surrounding area. The engines were under power and the IAS was 225 km/h (121 kt).

Flying under these conditions is in violation of both the Aircraft Flight Manual and the operator's Operations Manual.

The analysis of the FDR data and of the aircraft wreckage did not reveal the presence of any anomalies or faults before the impact.

The helicopter became unstable during the flight, which saw very high negative values for vertical acceleration, along with a noticeable reduction in the aircraft's speed and altitude and a severe yaw that caused the aircraft to make three full turns to the left.

The destabilization occurred when the lower end of the load sling got caught somewhere along the terrain.

The pilot ordered the flight engineer to stop the engines, but he placed them at idle instead.

By not stopping the engines, the flight engineer did not correctly follow procedures, first by not obeying the pilot's order to stop the engines, and second by not adhering strictly to the procedure that required them to be stopped.

Once the rotation was stopped, the crew found itself in a narrow valley without sufficient speed to apply thrust and continue flying to a safe spot where they could land using auto-rotation.

During the flare maneuver, the tail's helicopter may have dropped far enough to impact the ground, causing the damage seen on the tail skid and on the tailboom that supports the skid.

Although the flare maneuver was completed, the helicopter's forward speed could not be fully neutralized, as a result of which the helicopter contacted the ground violently.

The helicopter turned over on its left side, possibly because it was unevenly supported by the irregular terrain.

The operator's Operations Manual has instructions regarding flying unloaded that are less restrictive than those specified in the Aircraft Flight Manual.

3.2. Causes

The accident is regarded to have been caused by flying at an altitude that did not ensure adequate separation with the surrounding terrain with the external sling unloaded, which allowed the lower end of the sling to get hooked somewhere along the terrain, with the ensuing destabilization of the helicopter.

The following factors contributed to the accident:

- Deficient work planning.
- Failure to adhere to operating procedures.
- The contradictions between the flight and operations manuals.

4. SAFETY RECOMMENDATIONS

REC 94/2012. It is recommended that the aircraft operator, Heliseco, review its procedures as regards the analysis and planning of operations with external loads so as to ensure that all work involving external loads is subjected to proper analysis and planning beforehand.

REC 95/2012. It is recommended that the aircraft operator, Heliseco, ensure its crews receive training on adherence to operating procedures.

REC 96/2012. It is recommended that Poland's Civil Aviation Authority require the operator of the aircraft, Heliseco, to modify its Operations Manual as regards operations with external loads so as to bring it in compliance with the Flight Manual.