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COMISIÓN DE
INVESTIGACIÓN
DE ACCIDENTES
E INCIDENTES DE
AVIACIÓN CIVIL

Report A–026/2016

Accident involving a PZL W-3AS aircraft, registration EC-LQA, operated by Hispánica de Aviación (HASA), in Villanueva de la Cañada (Madrid-Spain) on 17 July 2016

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MINISTERIO DE FOMENTO

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Notice

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.

Contents

Abbreviations

ºC	Degrees centigrade
AESA	National Aviation Safety Agency
AEMET	National Weather Agency
AGL	Above ground level
CDV	Challenge-Do-Verify method
CECOPS	Regional Government Emergency Service Coordination Center
cm	Centimeters
CM1	Pilot (on the ground)
CM2	Pilot (on the ground)
CRM	Crew resource management
CVR	Cockpit voice recorder
DV	Do-Verify method
EASA	European Aviation Safety Agency
FDR	Flight data recorder
FF	Firefighting
ft	Feet
ftp	Feet per minute
GPS	Global positioning system
h	Hours
Hb	Pressure altitude
Hz	Hertz
HP	Horse Power
HPa	Hectopascals
IFR	Instrumental Flight Rules
INFOSA	Ingeniería Forestal, S.A.
KIAS	Indicated airspeed in knots
Kg	Kilograms
km	Kilometers
Km/h	Kilometers per hour
kt	Knots
l	Liters
LDA	Landing distance available
m	Meters

MCC	Multi-Crew Cooperation
min	Minutes
MPA	Multi-pilot aircraft
MPO	Multi-pilot operation
MPP	Multi-pilot procedure
MVH	Helicopter Flight Manual
N	North
N1	Gas producer speed (in %)
Nr	Main rotor speed (in %)
OEI	One engine inoperative
OM	Operations Manual
PF	Pilot flying
PM	Pilot Monitoring
PNF	Pilot not flying
QNH	Atmospheric pressure at sea level
RD	Royal Decree
RFM	Helicopter Flight Manual
RH	Right Hand
RPM	Revolutions per minute
SAR	Search and rescue
SL	Service letter
S/N	Serial number
sec	Seconds
SOP	Standard Operating Procedures
SPA	Single-pilot aircraft
SPO	Single-pilot operation
SPP	Single-pilot procedure
TOT	Turbine outlet temperature
TQ	Torque
VFR	Visual flight rules
V_x	Best angle of climb speed
Vy	Best rate of climb
W	West

Synopsis

Owner and operator:	Hispánica de Aviación (HASA)
Aircraft:	WSK-PZL PZL W-3AS, registration EC-LQA
Date and time of accident:	Sunday, 17 July 2016 at 19:42 local time[1]
Site of accident:	Villanueva de la Cañada (Madrid, Spain)
Persons aboard:	2 pilots (slightly injured) 10 firefighting specialists (5 slighty injured, 5 uninjured)
Type of flight:	Aerial work – commercial – firefighting
Flight rules:	VFR
Phase of flight:	En route
Date of approval:	30 October 2018

Summary of accident:

On Sunday, 17 July 2016 at 19:42, helicopter EC-LQA, a PZL W3AS operated by Hispánica de Aviación (HASA) with 12 people aboard, made an emergency landing on a crop field while flying back from a fire due to an emergency in engine 1 (left).

Engine 1 had been stopped by mistake after closing its fuel shutoff valve while executing a routine procedure. The investigation has determined that engine 1 stopped, but that 50 sec after the valve was closed, the engine was running at idle. It was not possible to determine what caused it to restart. The crew did not notice that the engine was running again and continued to believe that the engine had stopped.

Faced with this situation, and after trying an in-flight engine restart, the crew decided to make an off-field landing and start the engine. During the landing, the helicopter tipped over on its right side. The persons aboard, two pilots and 10 firefighters, exited the helicopter under their own power.

The investigation has determined that the accident of helicopter EC-LQA was likely caused by the incorrect execution of an emergency landing after making an approach maneuver in which proper speed, altitude and flight path values were not maintained.

[1]. All times in this report are local.

The following potentially contributed to the accident:

- The failure to comply with the task allocation for "single-pilot operation with two pilots with procedures for one pilot".

- Inefficient crew training on technical skills (the helicopter's normal and emergency operating systems and procedures), as a result of which:

  - The nature of the emergency and the operational status of the engines were not identified.

  - Procedures were executed incorrectly, incompletely or not at all during the flight and the emergency.

  - Checklists were not used at any point during the operation.

- Inefficient crew training on non-technical skills (CRM) adapted to "single-pilot operation with two pilots with procedures for one pilot", which caused:

  - Both crewmembers to focus on the TOT and on looking for a field.

  - Basic flight activities to be ignored, such as maintaining speed or monitoring parameters and gauges in the cockpit.

  - A rush to land, affecting the choice of field.

  - A lack of leadership by the captain during the emergency.

  - The second pilot to supervise and instruct the captain during the emergency.

- Underestimation of the safety risk during the decisions made during the flight, as a result of which:

  - Safer landing areas were not evaluated.

  - The emergency was not reported to the squad or to the CECOPS.

- The ambiguous definition, description and documentation of the fire fighting (FF) operation by HASA in its FF and SAR Operations Manual.

- The lack of supervision in the reality of FF operations in terms of the theoretical operation designed and described in its FF and SAR Operations Manual.

This report contains 13 safety recommendations, issued to different entities: the manufacturer of the aircraft, PZL-Swidnik, the operator, Hispánica de Aviación (HASA), the Emergency Department of the Regional Government of Madrid, as the manager of the service, and the National Aviation Safety Agency (AESA).

1. FACTUAL INFORMATION

1.1. History of the flight

On Sunday, 17 July 2016 at 19:42, helicopter EC-LQA, a PZL W-3AS (SOKOL) operated by Hispánica de Aviación (HASA)[2], while flying back to its base after taking part in firefighting operations, made an emergency landing in a field due to an emergency in engine 1[3]. During the landing, the helicopter tipped over on its side. There were two pilots and ten firefighters aboard.

The helicopter, with callsign[4] 43.51, was stationed at the firefighting base in Valdemorillo (Madrid), owned by the regional government of Madrid. It was part of the forest firefighting squad of the Region of Madrid[5]. Stationed at the base, which was open and manned from sunrise to sunset[6], were a helicopter, its flight crew and a 10-person firefighting squad. The squad's response time, according to the technical requirements, is 11 minutes.

On the morning of Sunday, 17 July 2016, the crew arrived at the base at 11:25. On the evening of Sunday, 17 July 2016, CECOP (the regional government's 112 emergency service coordination center) activated the airborne squad at the Valdemorillo base to aid in fighting a fire in the town of Casarrubuelos (Madrid), 44 km away on heading 150º. The temperature at the base at that time was 32ºC.

The crew entered the helicopter and began the start-up, first engine 2 (right) and then engine 1 (left). Engine 2 was started normally and, by 18:50:21, it was at idle[7]. Engine 1 was then started, requiring two start cycles since during the first attempt, the process was not properly completed. According to the crew, before attempting a second start of engine 1, they had to lower the engine temperature (TOT)[8]. To do this, they "cranked"[9] the engine, which managed to lower the temperature of engine 1. Once the TOT was within limits, they re-started engine 1 at 18:52:31, this time normally. At 18:53:13 engine 1 was at idle.

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[2]. INFOSA (Ingeniería Forestal SA) was the company contracted by the regional government to provide firefighting services for the 2016 campaign. INFOSA had subcontracted this service to HASA, which provided the aerial resources and the flight crews required in the contract. The forest ranger squads were contracted directly by INFOSA.

[3]. Engine 1 is the left engine as seen from the pilot's seat.

[4]. Identification of helicopter EC-LQA within the firefighting service of the region of Madrid.

[5]. The technical requirements of this contract called for two helicopters and their corresponding squads for 107 days, and 170 flight hours per helicopter.

[6]. The manning requirement was based on the time of sunset. On the day of the accident, the base was required to be manned from 11:25 to 21:25, as defined in Section 5.2, Rules for the aerial resource campaign of the region of Madrid.

[7]. Control lever in Ground Idle.

[8]. Turbine outlet temperature. To avoid damaging the engine, the TOT before engine start must be below 270º C. In this case, the first engine start had caused the TOT to exceed this value.

[9]. "Crank" is a colloquial term to refer to the "Motoring the engine" procedure in the Flight Manual, which involves turning the engine by engaging the starter with the ignition off and the engine's shutoff valve closed. This procedure is explained in Section 1.16.5.

Figure 1. Full flight of the aircraft

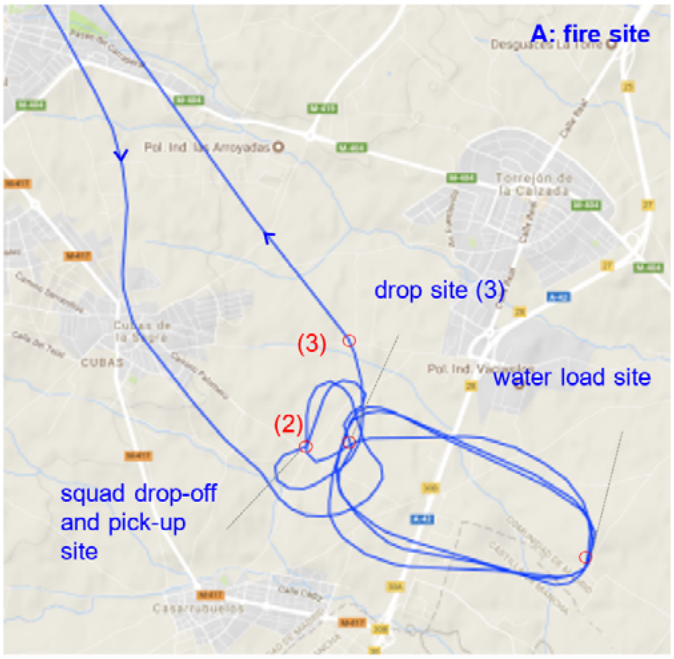
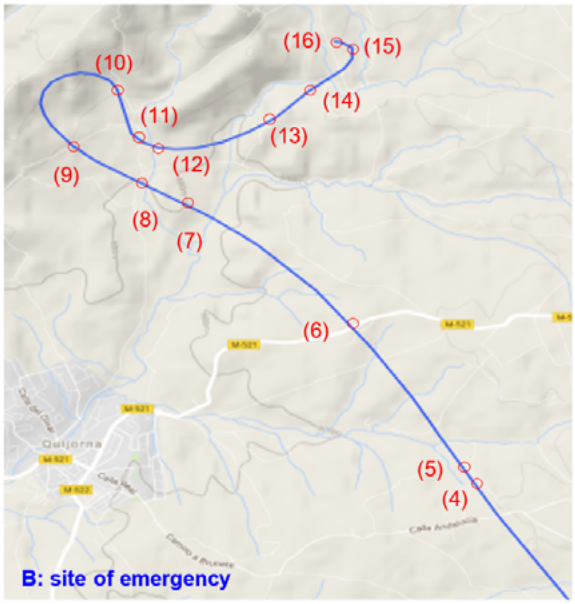


Figure 2. Flight in the area of the fire



(1) 18:55:19 Takeoff from base
(2) 19:26:20 First comment about fuel imbalance
(3) 19:29:16 Code 5
(4) 19:38:21 Engine 1 pump reported OFF
(5) 19:38:25 Close shut-off valve engine 1
(6) 19:38:56 Cranking started
(7) 19:39:38 Cranking completed
(8) 19:38:50 Captain PF
(9) 19:40:07 Decision to land and start engine on ground
(10) 19:40:41 First field selected
(11) 19:41:04 Second field selected
(12) 19:41:13 Confirmation of field
(13) 19:41:32 Wind information request
(14) 19:41:43 Decision to land and turn
(15) 19:42:05 "Too much slope"
(16) 19:42:26 Accident

Figure 3. Flight in the emergency site

The helicopter took off at 18:55:19. The flight to the site of the fire was uneventful and the crew dropped off the squad at 19:10:29. At 19:11:58, the helicopter took off again to commence its firefighting operations. The water loading point was 2250 m away, almost directly east of the fire site. The crew made three load/drop cycles.

Once its services were no longer required at the fire site, the helicopter landed at 19:25:52 in the same place where it had initially dropped off the squad. It remained on the ground for 2 min 16 sec picking up the firefighters, bambi bucket and all

of the squad's materials. With the helicopter on the ground, a conversation in the cockpit was recorded at 19:26:20 in which the second pilot asked the captain to balance the amount of fuel in the tanks[10]: "If you want, we can try to trim. There's a difference of 300l". Immediately afterwards they received calls from the squad and the fire coordinator that shifted their attention to other duties, and caused no action to be taken involving the fuel imbalance. The helicopter took off again at 19:28:08 to return to the base in Valdemorillo with the squad and all the material aboard.

This takeoff was carried out with the second pilot as the pilot flying. After taking off, the helicopter circled over the fire at the request of the fire squad specialist, and at 19:26:16 they reported to CECOP[11] that they were transitioning to code 5, *"CECOP, 43.51, code 5[12]"*. The helicopter was 43.8 km away from the base on heading 330º.

After flying for nine minutes, at 19:38:21, the captain decided to carry out the trim procedure between the fuel tanks and reported he was going to actuate the booster pump on engine 1: *"I'm going to cut the pump on 1, ok?"* This action was confirmed by the second pilot as follows: *"The pump on 1"*. But at 19:38:25, the fuel shut-off valve on engine 1 was recorded as being closed. One second later, the second pilot realized the mistake and said, *"That's the valve"*. The helicopter was 11.5 km southeast of the base flying at 73 KIAS and 180 m AGL. The valve remained closed for five seconds, after which it was re-opened, remaining in this position for the remainder of the flight.

At 19:38:35, the captain reported he was re-starting the engine: *"We're on a single engine. I'm going to start it"*. The following exchanges in the cockpit were initiated by the second pilot, who insisted on not restarting the engine, to wait until the engine temperature (TOT) fell and to crank the engine. The start of the crank procedure was recorded at 19:38:56. At 19:39:12 and 19:39:22, the captain was heard confirming that the temperature was not dropping, and at 19:39:38, the second pilot reported *"Cycle complete"*, referring to the completion of the crank. At 19:36:46, the two pilots confirmed for the third time that the engine temperature was at 500º C, and four seconds later, at 19:39:50, the captain decided to take control of the helicopter (*"I have control"*), a transfer that was acknowledged by the second pilot.

There were no more communications involving the engine. At 19:40:07, the second pilot proposed landing and starting the engine: *"Land then and we'll start it there in a clearing"*.

From then on, the communications in the cockpit focused on looking for a field, with one being selected by the second pilot. At 19:40:41, he identified a spot,

[10]. If the difference in fuel amounts between the tanks exceeds a certain value, the Flight Manual specifies the need to trim the fuel, which is what the crew wanted to do in this case. This procedure is explained in Section 1.16.4.
[11]. On the TETRA fire communications frequency. This communication was made by the squad specialist.
[12]. Code to indicate that the helicopter is disengaging from the fire.

which he ruled out four seconds later due to the excessive gradient. Finally, at 19:41:04, he selected the final landing site. At 19:41:13, the captain repeated for the second time that *"There's a field there"*. It was 1.7 km away from the site where they landed.

Two communications were recorded while making the approach to the field, one about the wind at 19:41:32, and another, about the landing point, at 19:41:43: *"I'm turning to my side", "I'm landing here, ok?"* The last communication before the impact was recorded at 19:42:05. In it, the second pilot said twice that the gradient was too steep and urged the captain to go to *"his side"*[13].

Contact with the ground was recorded at 19:42:26, and after impacting with the landing gear, the helicopter turned over on its right side. The landing site was in a crop field in which the soil had been plowed, and it was dotted with holes some 30 cm deep. All of the occupants exited the aircraft under their own power. The accident site was 7.5 km southeast of the base.

1.2. Injuries to persons

Injuries	Crew	Passengers	Total in the aircraft	Other
Fatal				
Serious				
Minor	2	5	7	
None		5	5	
TOTAL	2	10	12	

1.3. Damage to aircraft

The damage mostly affected the right side of the helicopter, on which it was resting. The cockpit retained its structure and showed no apparent deformation.

- Vertical stabilizer: completely separated from the tailcone. Half the surface of the left horizontal stabilizer was missing.

- Right engine: damaged, primarily in the fairing and exhaust nozzle.

- Rotors: all three main rotor blades detached at the root. The tail rotor blades were also damaged but to a lesser extent than the main rotor blades.

[13]. On this helicopter, the captain is in the LH seat and the second pilot in the RH seat.

Figure 4. Condition of aircraft EC-LQA after the accident

- Right-side windows: two of the three side windows were broken.
- Landing gear: there was damage to the main landing gear structure.

1.4. Other damage

None.

1.5. Personnel information

1.5.1. Captain

The 41-year old captain was a Spanish national. According to information provided by the operator, he had a Commercial Helicopter Pilot License and a total of 1245[14] flight hours, of which 1052 had been on the model he was flying on the day of the accident. He had been working for the operator since 2007, flying on that model ever since. At the time of the accident, he was the Safety Manager for HASA.

Since the start of the 2016 campaign, he had been stationed at the base in Valdemorillo. On the day of the accident, he was returning to duty after a 10-day rest period. He knew the base and the area from previous campaigns.

Four months before the event, he had taken the refresher training on firefighting (1-h duration) on a helicopter with the same characteristics as the accident helicopter.

[14]. The minimum required by AESA for this operation is 600 h and 10 h on the type.
The operator's FF and SAR Operations Manual defined a highly experienced pilot as one with more than 600 h as pilot in command, 100 h of which must be in the activity. This is a literal transposition of what is contained in RD 750/2014. An inexperienced pilot is one who is rated but who has not flown 50 h in the previous 60 days or 100 h on the type (no time limit).

1.5.2. Second Pilot

The second pilot[15], under supervision (company pilot who is being supervised by an instructor) was a 36-year old Spanish national. He had a Commercial Helicopter Pilot License and had a total of 682 flight hours, of which 429 had been on the type.

One month before the event, he had taken the refresher training on firefighting (1:30-h duration) on a helicopter with the same characteristics as the accident helicopter.

1.6. Aircraft information

The helicopter, a WSK-PZL, model PZL W-3AS (SOKOL) S/N 310306, is certified by the European Aviation Safety Agency (EASA)[16] and can transport 14 individuals, including the pilots. It has two PZL Rzestow PZL-10W engines. It is approved to fly under visual flight rules (VFR) and its minimum crew is one pilot flying from the LH seat (in the direction of flight[17].

It was owned by Hispánica de Aviación (HASA) and was registered as EC-LQA in 2012[18]. This company had a special operator certificate (ES.COE.H04) to engage in firefighting and search and rescue activities. This permit included helicopter EC-LQA, which could be used to, among other activities, do helicopter water drops and transport additional specialized personnel. This permit was valid at the time of the accident.

Since 31 October 2016, the helicopter had been used to transport the airborne squad in Valdemorillo, whose code was 43.51, as part of the forest firefighting service of the Regional Government of Madrid.

1.6.1 Maintenance and operational history of the helicopter

The helicopter had a total of 3740 hours. The left engine (1) had 1307 h and the right engine (2) 271 h, as counted since the last overhaul. All of the helicopter activity reports since the start of the campaign were reviewed (from 1 May until 17 July).

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[15]. The operator's FF and SAR Operations Manual specified a minimum crew of one pilot and one crewmember for FF with the SOKOL helicopter until 2017, after which two pilots would be required (pursuant to Royal Decree 750/2014).

[16]. Certified in category A and B. This classification has to do with the design of the helicopter (redundancy of systems, etc.). This classification indicates that in the event of an engine failure, flight continuity is guaranteed for a category-A helicopter, whereas a category-B helicopter will be required to make a forced landing. In fact, the Flight Manual contains sections devoted specifically to operations based on the certification category.

[17]. Section 1-Limitations (Flight Manual).

[18]. Its previous registration had been SP-SUN (Poland).

- The helicopter flew a total of 33 h and was dispatched a total of 30 times[19]

- Scheduled maintenance:

- 25-h, 15-d, 30-d and 90-d checks and lubrications: 14/05/2016, 29/05/2016, 13/06/20106 and 13/07/2016.

- Implementation of SL to look for cracks: 13/06/2016 and 13/07/2016.

- 25-h check of engine, compressor cleaning and other tasks: 28/05/2016 and 28/06/216,

- Unscheduled maintenance (as a result of discrepancies noted in the reports):

- Work on the engine TQ gauge, the artificial horizon and/or needle separation: 06/06/2016, 14/06/2016, 02/07/2016, 04/07/2017 and 11/07/2017.

- Engine 2 (right) replaced after failed start on 29/06/2016. This engine replacement was carried out between 29/06/2016 and 01/07/2016.

The week before the accident the helicopter had flown every day except Wednesday.

Based on the fuel amounts entered in the reports, it is estimated that the helicopter consumed some 400 l on the accident flight. An entry in the report from the accident flight recorded an initial fuel quantity of 1050 l, meaning that at the time of the accident, there would have been approximately 650 l of fuel in the helicopter.

1.6.2 Helicopter power maximums

Due to the helicopter's design, there are three engine operating modes:

- normal with two engines running,

- increased mode with one engine inoperative for 30 minutes (OEI 30 min): if one engine fails, the second engine will automatically start to operate in an increased power mode that provides N1=98% and TQ=121%,

- one engine inoperative for 2.5 minutes (OEI 2.5 min): if one engine fails, the second engine can be selected to run at maximum power for 2.5 min, providing N1=102% and TQ=139%. Operation in this mode is only allowed if N1 in one engine is below 58% (engine inoperative) and a button (labeled as 2.5 OEI) on the collective grip is kept depressed.

[19]. A check of the helicopter's activity and operations report provided by the Government of Madrid matched the flight reports in terms of hours on duty, off duty (code 5), inoperability (code 0) and arrival times at the base (code 6).

1.7. Meteorological information

In light of the data from the AEMET station 10 km away from the accident site, satellite images, radar data and adverse phenomena warnings, the most like conditions at the time of the accident were as follows:

- Very weak wind from the N (around 6 km/h), gusting up to 12 km/h.
- Good visibility on the surface with no clouds.
- 36º C, QNH 1016 HPa and 22% relative humidity.

1.8. Aids to navigation

Due to the nature of the flight, it was not recorded by the air traffic control system.

1.9. Communications

Due to the nature of the flight, it was not in contact with any air traffic control station. The communications to coordinate with the fire director and the other air units were made on the fire frequencies. These communications were recorded on the CVR, and those of interest to the investigation are included in Section 1.1, History of the flight, and Section 1.11, Flight recorders.

1.10. Aerodrome information

The firefighting base and heliport at Valdemorillo is owned by the Regional Government of Madrid[20]. It was built in 2005-2006 and in 2013 a study was conducted in order to certify the heliport. This study analyzed the condition of the heliport against the applicable regulation and concluded that work had to be done to bring it up to code. This work involved expanding the perimeter of the security area, upgrading the signage, modifying the fence and cutting down and/or transplanting 33 trees that encroached on the obstacle-free areas for the primary and secondary approaches.

The work to upgrade the base was completed in November 2015, with the exception of the work involving the trees, which had to be authorized by the Valdemorillo town hall. This work was finally completed in November 2017.

On the date of the accident, the heliport's characteristics were as follows:

[20]. The base is owned and managed by the Civil Protection Office.

- Elevation: 868 m
- Orientations for approach/takeoff: 13-31 preferred and 28-10 secondary
- Design helicopter: PZL W3A
- Type of operation: visual flight
- Performance class[21]: 2
- LDA: 37.7 m.
- Use: restricted to emergency and fire prevention and extinction operations.

The field where the helicopter landed was a rectangular crop field. The landing point was at an elevation of 640 m. Its orientation was practically north-south (350º). The field was 206 m wide by 600 m long, with a 2.9% crosswise gradient (rising toward the west) and a 3.7% lengthwise gradient (rising toward the north). The maximum gradient specified in the Flight Manual for the weather conditions present on the day of the flight is 5%.

1.11. Flight recorders

The aircraft was equipped with two flight recorders: a FDR (flight data recorder) made by NAVCOM SYSTEMS, model BUR-1 2 296, S/N 60148, and a CVR (cockpit voice recorder) by the same manufacturer, model MARS 70A-10M and S/N 275031. Both recorders provided information on the flight. The FDR had 50 h of recordings[22]. The CVR had 39 minutes, spanning from 19:05:04 (5 min before the helicopter reached the fire site) until the end of the flight. Also recovered was a GARMIN 296 GPS unit, S/N 10704013, which contained a file with several flights on it, including the accident flight. This section presents integrated information from all three devices: FDR, CVR and GPS.

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[21]. Although part of the documentation checked states that it is designed for performance classes 2 and 3, the official documentation from the regional government only indicates performance class 2. In addition to the A and B certification categories for helicopters, three performance classes are defined from an operational standpoint: class 1, 2 and 3. Helicopters certified in category A can engage in operations classes 1, 2 and 3. Helicopters certified in category B can engage in operation class 3. The performance refers to operating capabilities of the helicopter based on engine capabilities as a function of weight, temperature, decision altitudes to maintain the line of flight, the ability to safely abort or continue a takeoff or landing maneuver. Performance class 1 operation implies that the helicopter, in the event of an engine failure, will be able to land in the distance available to abort the takeoff or continue the takeoff safely. Performance class 2 operation means that the helicopter, in the event of an engine failure, will be able to continue the flight safely unless the failure occurs early in the takeoff or late in the landing, in which case it must make a forced landing. Performance class 3 operation means that an engine failure at any time during the flight requires a forced landing.

[22]. The 50 h were from 43 flights. The FDR recorded 24 continuous and 44 discrete parameters. All were determined to be consistent except the Hb (pressure altitude) parameter, which exhibited sharp changes during level operations (up to ±20 m over a 1-second interval with the helicopter on the ground). The altitude information was taken from the GPS.

As concerns the FDR, at the start of the flight the parameters were recorded continuously (one entry per second), but after the second landing to pick up the squad, there were many interruptions in the recorded data, sometimes as far as 10 seconds apart. Even so, the data available were enough to determine the operations carried out during the flight. The information on the flight is presented in three phases: flight before the event, event, and flight after the event. In general, and unless specified otherwise, the references to engine parameters involve engine 1 (left).

1.11.1 Flight prior to the event

Engine start and takeoff:

- 2 min 10 sec elapsed between successive starts of engine 1 (below the 3 min specified in the Flight Manual).

- The cranking between engine starts showed that the maximum N1 reached was around 20% (the procedure in the Flight Manual specifies reaching a minimum of 14%).

- When the fuel was ignited during the two starts of engine 1, the TOT rose to 636º C and 679º C.

- During the start process (with the engine lever in the START position), TQ was equal to 2%.

- Once the start process was complete (with the engine lever in the GROUND IDLE position) and with the helicopter on the ground before takeoff, the values stabilized at N1=71% TOT=476ºC TQ=20%.

- The helicopter took off on a course of approximately 100º, in the secondary takeoff direction at the base.

- While engine 1 was being started, a low oil pressure warning was received, which cleared when N1 exceeded 41%.

Transfer flights prior to closing the fuel shut-off valve for engine 1:

- The transfer flight to the fire site was made at an average indicated airspeed of 72 KIAS, and the return flight from the fire at 68.5 KIAS.

- The operating parameters for both engines were similar: N1=90% TOT=580-600ºC and TQ=76%.

1.11.2 Event

The description of the event is provided in terms of the time elapsed since its occurrence. Therefore, the t=0 sec timestamp refers to the time of the event.

t=0 sec (19:38:25) Fuel shut-off valve for engine 1 closed:

- When the shut-off valve to engine 1 was closed, that engine was at N1=92%, TOT =585º C and TQ=73%. The helicopter was flying at 73 KIAS and 180 m AGL.

- t=+1 sec. The TQ, N1 and TOT immediately began to fall and the second pilot confirmed the closing of the valve.

- t=+5 sec. The values had fallen to TQ=1%, N1=24% (below the 58% corresponding to one engine inoperative) and TOT=420º C. The speed dropped to 66 KIAS (4 kt below the Vy speed given in the Flight Manual for the conditions on the day of the accident).

- Since N1 had fallen below 58%, the engine stopped acoustic warning (4-second tone) sounded and the low pressure warning for engine 1 appeared.

- The N1 and TQ parameters for engine 2 immediately increased and then fluctuated before stabilizing, supplying the missing power from engine 1 and keeping the main rotor RPM (Nr) at normal operating levels.

t=+6 sec (19:38:31): Fuel shut-off valve opened:

- 6 sec later, the captain reopened the fuel shut-off valve. This valve would not change position again during the flight. The helicopter was flying at 61 KIAS.

- t=+9 sec. Three seconds after the recorded opening of the valve, the TOT had risen sharply to 623º C, higher even than the temperature before the event. This temperature was in the range of the temperatures reached during the ignition cycles at the start of the flight (636ºC and 679ºC). The TOT continued rising to 650º C.

t=+10 sec (19:38:35 h): Decision to start engine and interrupt start process:

- 10 sec after the start of the emergency, the captain said "We're on a single engine. I'm going to start it". At that moment, N1=25% TOT=628ºC and TQ=1%. The helicopter's speed was 60 KIAS and it was at 178 m AGL.

- Following this decision, there was a conversation involving the engine temperature. For 13 sec the second pilot repeatedly insisted on waiting, on lowering the

temperature on 1 and motoring the engine.

- T=+21 sec. At 19:38:46, as part of this discussion between the second pilot and the captain, the former said, "Lower, lower the lever on 1. No, no, don't start, lower. That's it". N1=25% TOT=628ºC and TQ=1%. The speed was 56 KIAS.

t=+31 sec (19:38:56 h): Execution of "crank" or "motoring the engine" procedure:

- t=+25 sec. Second pilot said: "Wait, wait, crank on 1, very good".

- t=+31 sec. N1 started increasing as a result of carrying out the crank or motoring the engine procedure. This increase went from 25% to 73%. The helicopter's speed was 52 KIAS and its AGL 166 m.

- t=+39 sec. As a result of this increase in N1 above 41%, the oil pump started, and the low oil pressure alarm cleared.

- t=+50 sec. Conversation between the two pilots involving the temperature of engine 1, which started to drop at 19:39:15 from 681º C to 474º C, but went no lower than that (the Flight Manual specifies a temperature below 270º C to start the engine).

t=+64 sec (19:39:29 h): End of "crank" and decision to change control:

- The engine parameters stabilized after 19:39:29 at N1=73% TQ=11% and TOT=474ºC, values that would not change until the end of the flight.

- Seconds later, the second pilot announced "cycle complete", referring to the crank, and both pilots verified that the temperature was 500º C.

- t=+86 sec (19:39:59). Given this situation, the captain decided to take control of the helicopter. Its speed was 39 KIAS and its altitude 187 m AGL.

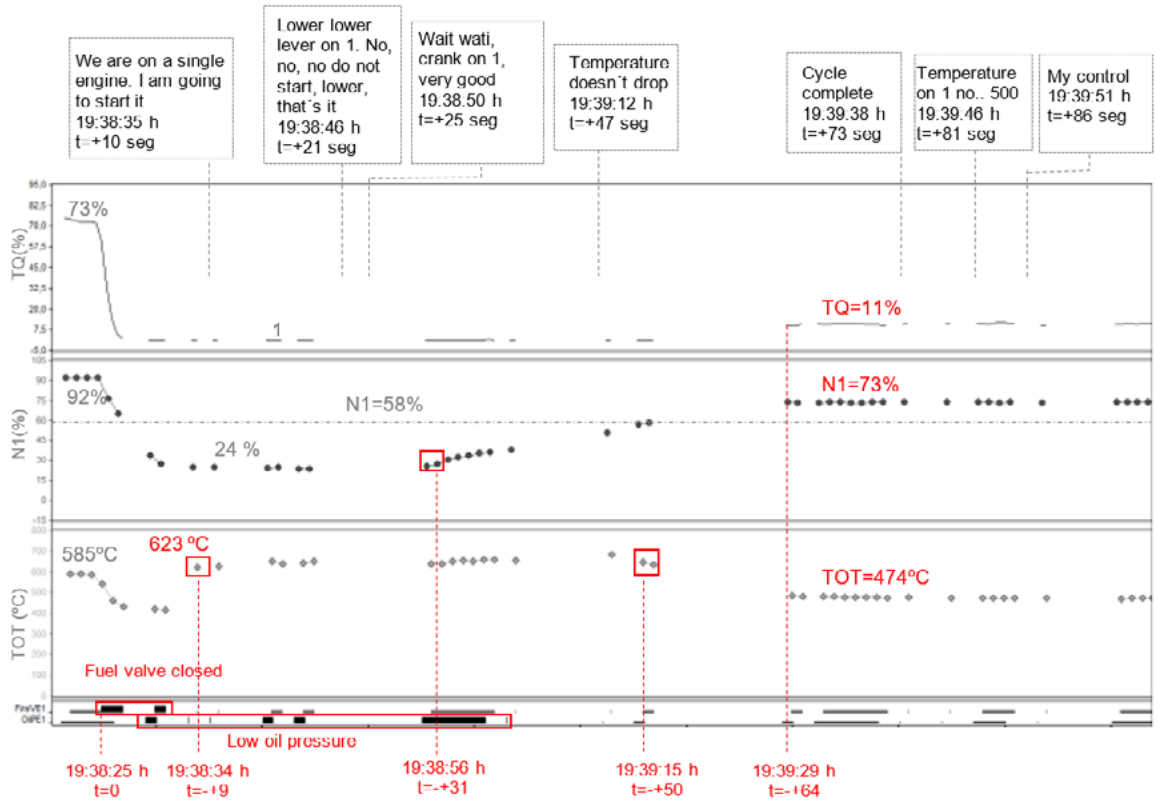
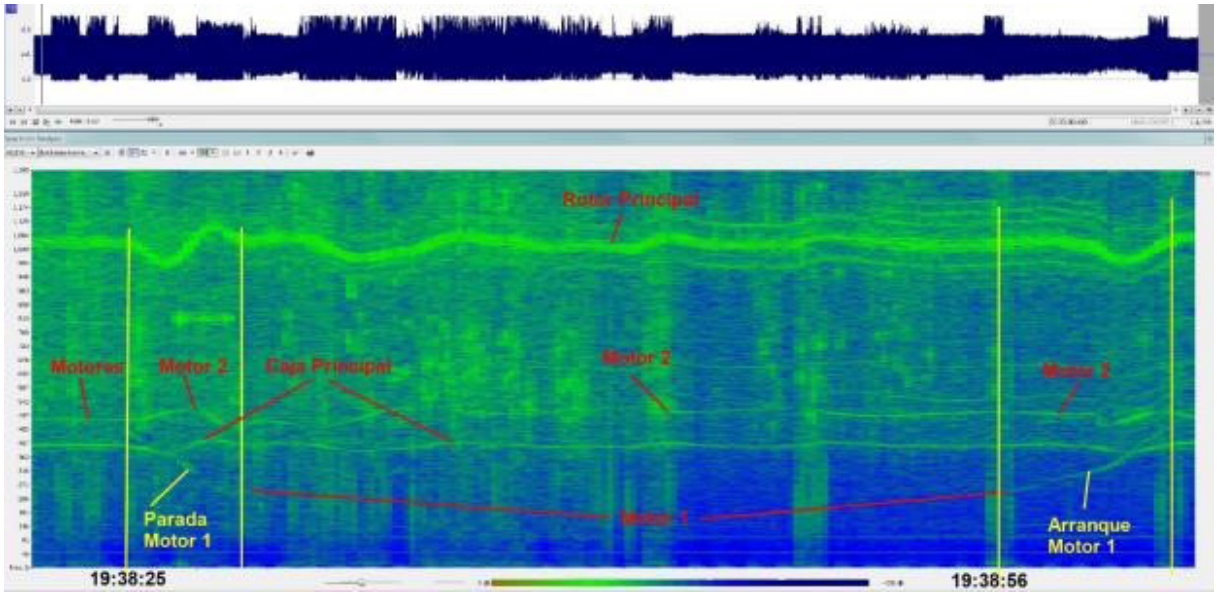


Figure 5. Behavior of engine 1 (left) during the event

An analysis of the CVR's sonogram[23] confirmed the data shown on the FDR in terms of the behavior of N1 during the event. Three frequencies of interest were identified:

- 1029 Hz: corresponds to the normal operation of the main rotor (100%)
- 407 Hz: corresponds to the main gearbox, proportional to the main rotor.
- 497 Hz: corresponds to the accessory box, driven by the gas turbine and proportional to N1. This frequency line clearly shows a drop when the valve is closed and a subsequent increase in frequency once the crank, associated with N1, is commenced.

[23]. Represents the noises visually, with time on the X axis and the frequency in Hz on the Y axis. The intensity of each pixel's color represents the decibels.



1.11.3 Flight after the event

Decision to land to start the engine and turn to the right (19:40:07 – 19:40:41):

- After the captain took control (19:39:29), he did not say anything and the helicopter remained on the same course as before the event, nearing an area where the elevation of the ground rises to 710 m.

- At 19:40:07, the second pilot proposed landing and starting the engine on the ground, which the captain immediately agreed to do. The helicopter was at 41 KIAS and 149 m AGL.

- The captain made a turn to avoid entering the mountainous area, ending up in an opposite heading from the original. During this turn, the speed remained at around 40 KIAS.

Left turn and drop in speed (19:40:41 – 19:41:28):

- After completing the right turn, the captain started a left turn (19:40:41), skirting around the elevated terrain. During this turn, the second pilot proposed two landing fields. The helicopter's speed during this segment dropped significantly, from 40 KIAS to 25 KIAS.

- This drop in speed to 25 KIAS (19:41:08) resulted in the main rotor RPM (Nr) decreasing to 96%, with engine 2 reacting by increasing N1=98% and TQ=107%.

- As the turn was completed, the speed recovered somewhat, as the captain

confirmed seeing a field (19:41:13). The helicopter's speed was 31 KIAS and its AGL 83 m.

- The turn ended at 19:41:28 with the aircraft at 42 KIAS and 97 m.

Decision to land and approach (19:41:28 – 19:42:26):

- After completing the turn, the helicopter began a phase of the flight on a steady course with the speed held at 42 KIAS. Planning the landing, the captain requested wind information from the second pilot, though they were unable to use any references (vegetation) to estimate it.

- At 19:41:43, the captain decided to land: *"I'm turning to my side and landing here, ok?"* They were 620 m away from the final landing spot at 43 KIAS and 81 m AGL. From this point on, the approach phase began, with a drop in speed and altitude.

- The following parts of the approach are identified:

- Start of the approach (19:41:43): helicopter at 43 KIAS and 81 m AGL.

- Descent (19:41:43 – 19:42:04): for 21 sec, course of approximately 050º maintained. Speed dropped from 43 KIAS to 11 KIAS. At the end of this phase, the helicopter was 58 m AGL. The estimated descent rate was 1-1.29 m/sec.

- Flare and turn (19:42:04): after this descent, the helicopter altered course with a left turn to a northerly heading, aligned lengthwise with the field. This course, however, was not maintained until landing; rather, a second left turn was made to course 306º while performing the flare. The data recorder logged inputs to the cyclic (moved toward the pilot) and collective (upward shift) controls, causing an increase in the helicopter's pitch angle from 5º to 11º, and a drop in speed to 11 KIAS. The helicopter was at 58 m AGL 130 m away from the landing point at 11 KIAS. This turn coincided with the second pilot's comment about the gradient of the terrain, *"Too much slope, too much slope, come over to my side"*. This last turn oriented the helicopter to be perpendicular to the field that is, aligned with its width, in the direction of the upward slope.

- Landing (19:42:23 – 19:42:26): The landing was initiated at 4 KIAS and 5 m AGL, with a +13º pitch angle, the collective lever fully displaced on a course of 286º. RPM decreased to 88%, TQ on engine 2 rose to 108%. Engine 1, which had been at the same levels since the event started, saw a rise in TQ from 11 to 21% and a slight increase in TOT. After the helicopter fell on its side, engine 1 continued running for 20 sec more, with the values of TQ, N1 and TOT rising and then falling.

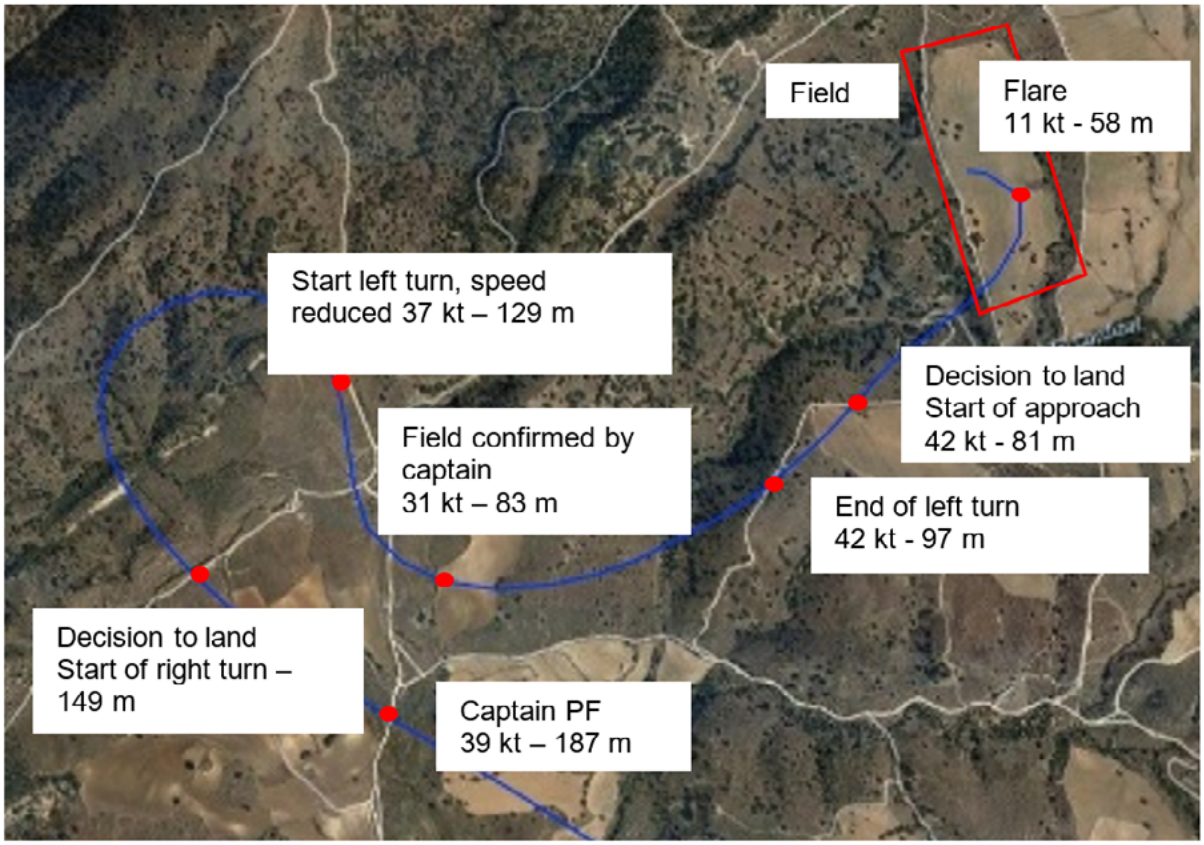


Figure 6. Final minutes of the flight (speeds and altitudes with respect to ground)

1.11.4 Communications during the fire

The communications during the firefighting activity are presented using the different phases of the FF operation that are defined in the HASA OM, in the procedure "PROCEDURE FOR MANAGING THE AIRSPACE, CAROUSEL AND WATER LOADING OPERATIONS" HASA-OPS.SOP10, edition 2 of 2016 (included in section 1.17.2). This procedures states that for each phase of the FF operation, the crew (PF and PNF) must make certain reports. These reports are included in section 1.17.2 and referenced here using numbers at the start of each report.

- Reports during approach to loading areas. Three approaches were made, two of them (1 and 3) by the captain and one (2) by the second pilot. The operator defines ten reports for this phase. During the fire, the following were made. At no point was the check of the emergency water release completed:

    1. "Clear of traffic, clear of cables" (on approach 1), "clear" (on approach 2)
    2. "Following preceding traffic" (on approach 1)

4. "Your side OK and tail clear" (on approach 2 and 3) "tail clear" (on approach 3)

5. "Bambi clear" (on approach 1 and 2)

6. "OK" (on approach 1)

8. "OK" (on approach 1)

- Reports during drops of extinguishing agent (there were 3 drops). In this phase, the operator specifies 8 reports. In the second drop, with the second pilot as the PF, the drop was made by the captain without being reported to the second pilot. The following reports were made:

  33. Follow preceding traffic (on drop 1)

  39. "It was good" (on drop 1) and "Did you make the drop yet?" (on drop 2)

- Reports on landings with Bambi bucket stowed (there was 1 landing). Associated with the arrival at the fire to offload the squad. The technician exited the helicopter without informing the crew that they had left everything in order (door closed, etc.). The operator specifies ten reports for this phase. The following were made at the fire site:

  11. "Only one in sight"

  12. "I'm going in behind the helicopter making the drop"

  16. "Tail OK"

  20. "I'm opening mine" (referring to the door to verify the squad exits). "We're OK"

- Reports on landings with Bambi bucket not stowed (there was 1 landing). Associated with the arrival to pick up the squad. The operator specifies 11 reports for this phase. The following were made at the fire site:

  11. "Clear of traffic, clear on this side if you don't move"

  12. "To the corner"

  16. "Clear on this side" "You're clear on this side if you don't move"

  25. "Set your brake, I'll release mine, ok?" "Releasing my brake"

- Reports when boarding the fire squad (there was 1 boarding). The operator specifies three reports for this phase. The following were made at the fire site:

    28. "We're ready back here" (report made by the squad)

- Reports on takeoffs (there were 2 takeoffs, one after dropping off the squad and another to return to base). In the second takeoff, two events took place: the transfer of control, on takeoff, from the second pilot to the captain to close the door, and the second when the takeoff was interrupted by the technician to request a reconnaissance flight of the fire. The operator specifies four reports in this phase. The following were made at the fire site:

    29. "I'm ready to take off" (takeoff 2)

    30. "OK, taking off" (takeoff 1)

1.11.5 Analysis of the 42 previous flights

The 42 previous flights recorded in the FDR were reviewed. The data do not indicate the need to use the crank procedure used in any flight except for the accident flight. The approach and takeoff paths used at the base were reviewed, yielding the following results:

- Approaches: secondary approach (28) used a low percentage of times. The preferred approach was not used any of the times (13).

- Takeoffs: completely random. No prevailing pattern identified either in the preferred (31) or secondary (10) orientation. In a large number of cases, the takeoff heading was in direction of the fire.

1.12. Wreckage and impact information

The helicopter landed on a fallow field with lumpy soil containing holes up to 30 cm deep. The coordinates of the impact site were 40º27'47" N 4º02'05" W, located in the municipality of Villanueva de la Cañada. The helicopter came to rest facing 310º.

All of the fuel was removed from the helicopter, 100 l from the front tank and none from the rear tank, since the tank had ruptured and the fuel had spilled to the ground, leaving a strong smell of fuel at the accident site.

At the site where the helicopter was found on its side, the tracks on the ground formed by the main landing gear legs were clearly identifiable. The left track was shallower than the right, and in fact, the right leg was half buried in the ground. Moving backwards from the direction of flight another two marks were identified 9 m apart and left by the right wheel. On the left side of the helicopter, near the tail cone, was the tail assembly, which had completely detached.

Most of the blade fragments were found forward of the helicopter, although one blade fragment was found 100 m behind it.

There were oil stains on the fuselage. These stains were vertical, not horizontal, indicating they were made on impact, not during the flight.

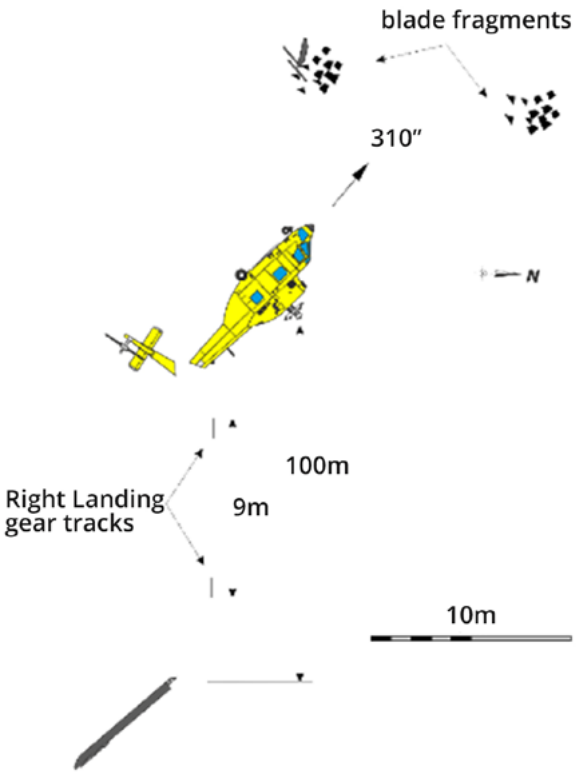


Figure 7. Debris field

1.13. Medical and pathological information

Seven people were injured as a result of the accident. Two of the firefighters were taken by helicopter from the accident site to the Puerta de Hierro Hospital. The rest were taken by car to the hospital at different times throughout that day, all with minor bruises.

1.14. Fire

The aircraft was not affected by fire during the accident. A small fire did break out after the helicopter fell on its side due to the fuel spill, but it was extinguished by the fire squad.

1.15. Survival aspects

The cockpit and passenger cabin retained their integrity. Neither the seat belts nor the seats broke or buckled. The personnel located on the left side of the helicopter was left hanging by their belts and harnesses, which held them firmly. The left rear

side door was used to evacuate the helicopter. There was no need to open the emergency door.

As for the passenger cabin, the information obtained from the statements (Section 1.16) indicates that when the helicopter fell on its side, the implements used by the squad (fire swatters and box with cutting tools)[24] were ejected and thrown about the cabin. The fire swatters were not secured. They were placed underneath the seats and thus free to move, with no physical restraint. In the case of the cutting material, it was in a box tied to the helicopter by a bungee cord. This cord did not withstand the impact, which allowed the material to fall atop one of the firefighters.

1.16. Tests and research

1.16.1. Analysis of the fuel

In order to rule out the condition of the fuel contributing to the accident, two samples of JET A1 fuel were taken, one from the helicopter's front fuel tank and another from the tank at the Valdemorillo base, where the helicopter had been refueled. The analysis of both samples revealed no degradation or contamination of the fuel.

The autoignition temperature of JET A1 is 210º C.

1.16.2 Statement from the pilot

The pilot sent in an initial description of the event, he was then interviewed in person and he subsequently sent a follow-up description. The information he provided was as follows.

He said the summer had been uneventful. The helicopter was refueled, since it is refueled after every mission. The rear tank is filled first and then the front. The flight started out with 1050 l of fuel. The first problem with the 1 engine occurred on start-up. First they started engine 2 and then engine 1, but it did not complete its start-up cycle. They started it again and after checking with the mechanic at the base, they decided to cool it with a crank, after which the engine started up. They had no further problems with it.

Their actions at the fire were normal. At the fire site, the second pilot informed him they had a 300-l imbalance between the rear and forward fuel tanks. But "with a 300-l imbalance between the rear and forward tanks, they were within the limits, according to the aircraft manual and they did not take any corrective action"

[24]. Tool to smother a fire. It has a handle and a swatter at the other end that is usually made of rubber. It is approximately 2 m long and weighs around 2 kg. The cutting tools include axes, clubs, wire cutters, saws and pickaxes.

(verbatim extract from his written statement). During the interview, in the explanation of the fuel procedure, he again noted that the imbalance limit is 300l. As they were returning with the squad to the base, the second pilot informed him that the imbalance between the tanks was now 400 l[25]. He decided to correct the situation but made a mistake while doing so, and instead of operating the pump, he closed the valve. This caused engine 1 to stop before he could react and re-open the valve. After this they decided to start the engine again, but the temperature was too high, so to reduce it they motored the engine. He pulled back on the throttle lever from the flight to the shut-off position[26]. They did the crank procedure but the engine's temperature did not drop below 500º C, so they were unable to start the engine. He stated that the helicopter was flying well on one engine.

The idea of crossing Valdemorillo on a single engine did not appeal to him, and there was an oak tree on the go-around path at the base, so he decided to land and start the engine there. At that point he was the pilot flying. They made an initial approach to one location but as they drew closer they saw that it was on an incline, so they decided to look for another field. After selecting one, they flew a new approach. The helicopter did not have any problems. They saw that it was a plowed field, with the furrows perpendicular to the flight path, so they decided to reduce their speed. By that point they would have been unable to climb up again. As they were 2-3 m above the ground, at a speed of 15 kt, the helicopter lost lift and they impacted the ground. They hit the ground hard with the main and nose gear, followed by an initial bounce, during which he felt he had control of the helicopter. There was a second bounce and he lost control of the helicopter, which fell on its right side. The ground was full of furrows that were not visible from the air.

When the helicopter was on its side, he was left hanging by his harness. He did not recall how he exited the helicopter, even though he did not lose consciousness. He remembered hearing the firefighters. He cut the engine 2. He smelled kerosene and a small fire broke out in the engine 2, which they extinguished by throwing dirt on it.

Everyone exited the helicopter and gathered around a tree, where they called 112 and the company. The other firefighting helicopter flew over them and landed, and the firefighters quickly arrived.

Two firefighters were taken to a hospital by helicopter. The pilots were taken by ambulance. Later, three more firefighters were taken to a hospital.

He stated that the imbalance between tanks and the crank are very common procedures. He also stated that the extra power (2.5 OEI) is not used for a running landing. He said it was only suitable for taking on water and that he, after

[25]. This comment was not recorded on the CVR.
[26]. This action was not taken, as the FDR data confirmed.

experiencing a mishap once, also used it on takeoffs.

Months afterward the captain expanded his statement, stating that the operator's financial situation in the years leading up to the accident had been bad, and this had affected the pilots and mechanics. Six months after the accident, the captain stepped down from this job as Safety Manager due to differences with management.

1.16.3 Statement from firefighters

Six firefighters were interviewed. They all gave similar information. All stated they were very worried about the helicopter. They had experienced several code 0[27] before. Practically all exhibited "some apprehension". The foreman and technician, seated at the front of the passenger cabin, were watching the lights that were turning on in the cockpit and noticed how, during the emergency, the pilots kept turning off the orange caution light repeatedly.

They felt the loss of power and in comparison to other similar situations (specifically, once there was a fire in the turbine[28] and they had to return to base on just one engine), they felt that something was not right with the helicopter. When they felt the loss of power, the technician told the foreman to notify the rest of the squad using hand signals so they could fasten their seat belts and assume the brace position. The pilots, technician and the person at the rear door are in communication, the rest are not. They described how the turbine seemed to cut out as they were about the land, followed by a bounce and then the sudden stop.

As for the situation in the cabin, they provided the following information:

- Of the six firefighters interviewed:

  - Two were not wearing their helmets, which were on their knees (as they stated, it is optional en route, and must be worn when taking off or landing), and they had the 2-l Camelbak on their backs. They thought it was positive that they were wearing the Camelbak because the water cushioned the impact.

  - One was not wearing a helmet or Camelbak (which contained water and a small cutting tool). He had left the Camelbak on the floor. He thought he was lucky not to have anything on his back because that allowed him to place it flush against the seat back. He also stated that the helmet does not fit in the headrest, and he thought it was good not to have it on during the accident so he could better adjust his head to the headrest.

[27]. Code 0 indicates the helicopter is grounded.
[28]. A review of the flight logs showed that this reference to a "fire in one turbine" was not recorded as such anywhere. Based on the firefighters' description of the event, it was identified as having occurred on 29/06/2016, when, according to the flight logs, the number 2 engine was replaced after a "failed start".

- One had his helmet on but not the Camelbak; instead, he had on a belt pouch with gels and energy bars.

- Two were wearing their helmet and Camelbak.

- The fire swatters were unrestrained beneath the seats (6 on one side and 4 on the other).

- The box with the cutting tools was attached to the wall using bungee cords.

- The bucket with two water backpacks was next to the box with the cutting tools and also restrained using bungee cords.

The tool box fell on one of the firefighters, striking his ribs and shoulder.

The entire squad exited via the technician's door (on the left side), which they opened normally, not using the emergency procedure.

As for their training, they stated that at the start of the campaign, they had a training session one morning at the base that was given by the company's Safety Manager (the captain), who discussed boarding and disembarking procedures and brace positions.

1.16.4 Fuel system and umbalance procedure

The part of the fuel system that is of interest to the investigation is described next. The system consists of two main tanks (a front tank with a 710-l capacity and a rear tank with a 610-l capacity), which supply fuel to two supply tanks (front and rear, 200-l capacity each), located under the cabin floor. In normal operating conditions, each engine is fed from its own supply tank, the left (1) engine from the rear tank and the right (2) engine from the front tank. Each supply tank has its own booster pump, which delivers fuel from each supply tank to the engine inlet, where there is a shut-off valve.

Closing this shut-off valve completely interrupts the flow of fuel to the engine, causing it to stop. Turning off the booster pump causes the fuel to both engines to be fed from a single supply tank.

The booster pumps and the shut-off valves are actuated from the central overhead panel in the cockpit. The switches for the two shut-off valves (one for each engine) are protected by a red switch guard that has to be lifted before the valve switch can be accessed.

During operation, an imbalance can occur between the amount of fuel in the main forward and rear tanks. This imbalance is allowed up to a certain limit, and the emergency procedure in the Flight Manual for restoring the balance in the tanks (Excess of Fuel in Either Engine Group of Cells) specifies the following:

• When the quantity in the main (rear) tank supplying the 1 (left) engine exceeds the forward tank that supplies the 2 (right) engine by 200 l, turn off the booster pump for the tank with more fuel (BOOSTER PUMP 1 to OFF), and turn it on again when they equalize.

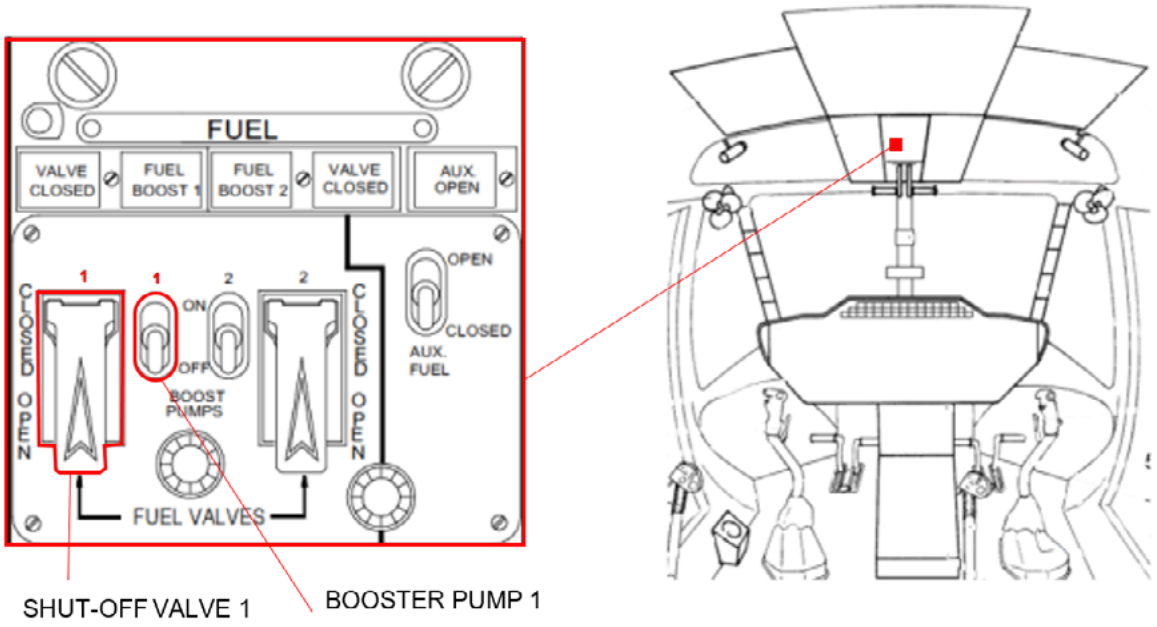


Figure 8. Location of fuel pump and shut-off valve controls for the engines

• When the quantity in the main tank for the 2 (right) engine exceeds the tank for the 1 (left) engine by 300 l, turn off the booster pump for the tank with more fuel (BOOSTER PUMP 2 to OFF), and turn it on again when they equalize.

In the case at hand, the tank with the higher fuel quantity was the one supplying the 1 (left) engine, meaning the control for the 1 booster pump should have been actuated when the imbalance reached 200 l..

The operator had transcribed this procedure to its checklist exactly as described in the Flight Manual.

1.16.5 MOTORING THE ENGINE ("CRANK") procedure

The start system for the PZL-10W engines allows cranking[29] the engine in addition to the normal start method. The cranking procedure is used, as per the engine

Maintenance Manual, in the following cases: to cool the engine, after a false start, after a failed start, after maintenance on the lubrication system and after having burned fuel in the chamber. The procedure uses the starting motor to make the engine's gas producer turn and force air to enter the engine without supplying fuel and without combustion. This is done by inhibiting the spark plugs and closing the fuel valve. This start cycle lasts 24 seconds, after which the starting motor automatically stops working.

[29]. The engine Maintenance Manual uses the term "motor", while the Flight Manual and the helicopter Maintenance Manual use the term "crank". They both refer to the same thing.

In the Flight Manual, cranking the engine is referred to as "motoring the engine" and is located in the section on normal procedures for starting the engines. The first item in the engine start section is a caution indicating to use this procedure

STARTING ENGINES
(battery or external power)

CAUTION

Motor the engine (by operating the starter with ignition switched off and fuel shut off) prior to starting whenever:

- *the engine failed to lightoff within 15 s;*
- *TOT is above 270°C;*
- *the engine oil system was subject to maintenance;*
- *the engine was wet motored.*

Motoring the Engine

1. **ENGINE START 1 - OFF - 2** switch - Set to **1**.
2. Start mode selector – Set to **CRANK**.
3. **START** push-button - Depress.

NOTE

At the end of motoring cycle, the N_1 speed should be at least 14% and the oil pressure - minimum 0.25 kp/cm^2 (0.25 kG/cm^2).

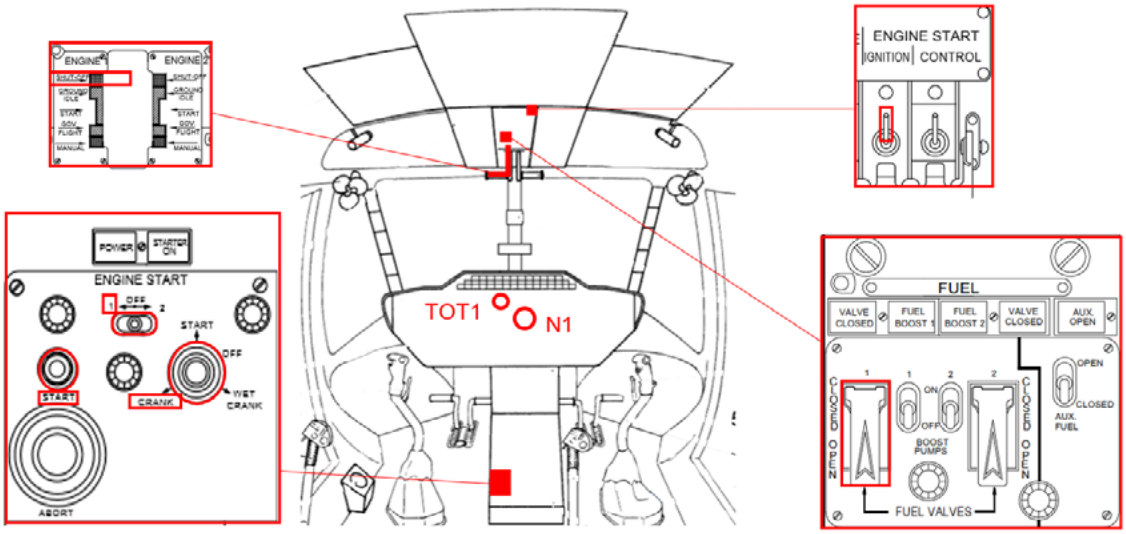


Figure 9. MOTORING THE ENGINE (CRANK) procedure

(motor the engine) before starting whenever any of these conditions exists: TOT above 270º C, failed start, maintenance of the lubrication system or if the engine was wet motored. Since the procedure is included in the engine start section, the engine power lever is in the SHUT-OFF position as a consequence of the "Before starting engines" procedure. Therefore, of the six steps required in the procedure, one is not included as it is a condition of the previous sequence, and two are included in parentheses before the procedure proper. The procedure as contained in the Flight Manual is shown in figure 9.

This "Motoring the engine" procedure is only mentioned twice in the Flight Manual, the first as part of the engine start (described in this section) and the second as part of the procedure for turning off the engine after landing. In this second case, the Flight Manual instructs to perform the "Motoring the engine" procedure if the TOT remains constant or is rising after the engine is turned off. None of the in-flight emergencies (and specifically the procedure for re-starting the engines in flight) mention this procedure.

The operator had included this procedure as part of the "Engine start-Before start-motor the engine" procedure. In was in the same location as the manufacturer's Flight Manual and with the same content, except for the term "CRANK" (which is the one shown on the helicopter's instrument panel), which had been replaced by the term MOTOR (term that is only used in the engine Maintenance Manual).

The aircraft manufacturer, in reply to a query posed during the investigation regarding the use of this procedure in flight, stated that it may be performed in flight if any of the conditions specified in the procedure apply, including a TOT in excess of 270º C. It also stated that the incident air stream has the same cooling effect on the engine as the procedure.

As for the consequences of performing the procedure with the shut-off valve open, it stated that it would not have any effect since the procedure requires the engine lever to be in the SHUT OFF position, which would inhibit the supply of fuel to the engine, and operating the starter in the CRANK position prevent the generation of sparks in the spark plugs.

1.16.6 Engine emergencies

General

The engine is equipped with two engines. In the event of a failure in one of the engines[30], the helicopter can safely fly with one engine operative. The most critical situation would be during takeoff. The helicopter has an additional power system

called 2.5 OEI (section 1.6.2) that, in the event of an engine failure, allows the operative engine to generate extra power (1150 HP) for 2.5 minutes. This system requires pressing a pushbutton on the collective grip. Pressing this pushbutton does not entail its use: rather, this "extra" power will only be used if demanded by the engine and under certain conditions (section 1.6.2). The use of the 2.5 min OEI system, in the case of those procedures in the Flight Manual where this operation applies, is left to the pilot's discretion[31]. Its activation is recommended, but not required, during:

- takeoff (TAKEOFF list, pp. 3-22) in the normal procedures
- landing (PRELANDING list, pp. 3-24) in the normal procedures
- Engine emergencies (ENGINE EMERGENCIES – GENERAL, pg. 3-2), introduction to emergency procedures, which states that in an engine emergency, the pilot can use the system. There is no other specific mention in any of the emergency procedures.

Operator's emergency procedures

The operator had prepared laminated checklists[32] on A4 paper containing the emergency procedures for this helicopter. The first sheet of these lists included a box referencing the allocation of tasks in the cockpit for two-pilot operations: "IF TWO PILOTS ARE FLYING, THE EMERGENCY WILL BE HANDLED BY THE PF. THIS MEANS THAT THE PF WILL CONTINUE FLYING AND THE PNF WILL READ THE CHECKLIST FOR THE PF TO EXECUTE".

It also added three basic rules for handling an in-flight emergency:

- Keep control of the aircraft
- Analyze the situation
- Take the appropriate action

The checklists of interest to the investigation, along with the corresponding Flight Manual lists, are shown in the sections that follow in the same sequence as they

[30]. The Flight Manual, in Section 3 on emergency-general procedures, specifies that the indications of an engine failure are as follows: a yaw to the right, a drop in Nr, N1 below 58%, rapid needle separation, ENGINE 1 OUT light on and 4-5 second acoustic warning.

[31].However, the procedures in section 1 of the Flight Manual, on performance, requires as part of the procedure to have the 2.5 OEI button pressed on takeoff and when landing after an engine failure.

[32].There were two lists, for one pilot and two pilots (see section 1.17.2), although their contents were exactly the same.

should have been applied in the accident flight:

- 1st the engine failure during cruise procedure
- 2nd the in-flight re-start and engine motoring procedure
- 3rd the procedure for landing on a single engine

Engine failure during cruise:

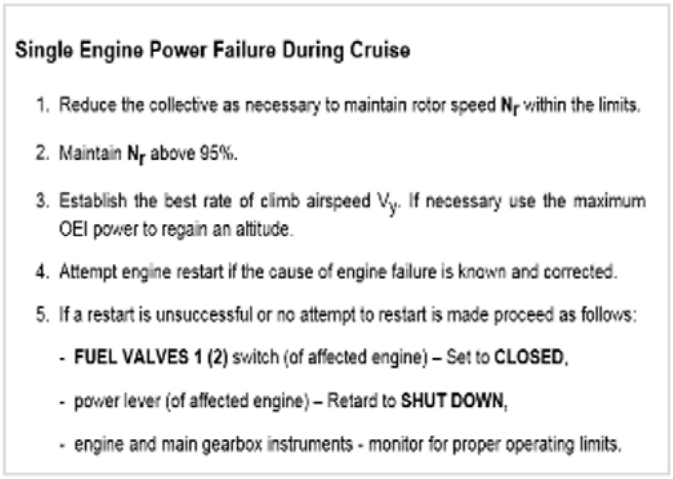
The procedure for an engine failure during cruise contains immediate actions (keep Nr above 95% and establish Vy), then attempt an engine restart (if no internal damage or fire is suspected) and third, if a restart is unsuccessful, to ensure the engine is stopped by cutting the fuel (using the engine lever and the shut-off valve).

The operator had added to the above procedure in the Flight Manual one last item, "land as soon as it is safe to do so"[34] and "conditions" to help identify an engine failure:

- yaw to the right and possible change in nose angle
- ENG 1/2 (understood to refer to the light)
- ENG 1/2 OIL PRESS (understood to refer to the light)
- gauges indicate loss of power

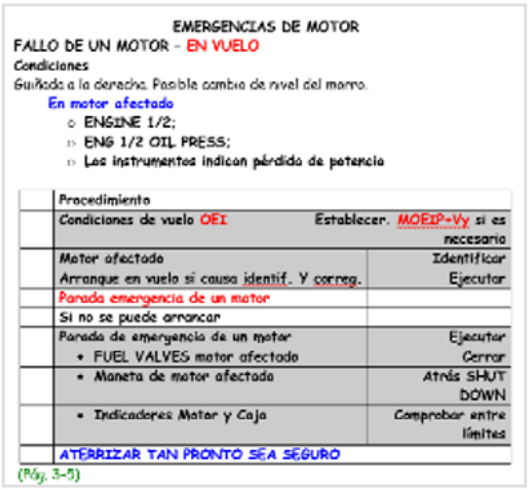
[33]. Speed for best rate of climb and least descent in the event of an engine failure. According to Section of the Flight Manual (Section 4 – DATA PERFORMANCE, pp. 4-11), Vy is 70 KIAS for the pressure altitude on the accident flight.

[34].According to the operator, "land as soon as it is safe to do so" means that "the landing site and flight duration are left to the pilot's discretion". Prolonging the flight beyond the closest suitable area where help is available is NOT RECOMMENDED". Landing as soon as it is safe to do so is the least urgent of the three possible instructions: "land immediately" and "land as quickly as possible".



Single Engine Power Failure During Cruise

1. Reduce the collective as necessary to maintain rotor speed N_r within the limits.
2. Maintain N_r above 95%.
3. Establish the best rate of climb airspeed V_y. If necessary use the maximum OEI power to regain an altitude.
4. Attempt engine restart if the cause of engine failure is known and corrected.
5. If a restart is unsuccessful or no attempt to restart is made proceed as follows:
   - **FUEL VALVES 1 (2)** switch (of affected engine) – Set to **CLOSED**,
   - power lever (of affected engine) – Retard to **SHUT DOWN**,
   - engine and main gearbox instruments - monitor for proper operating limits.



EMERGENCIAS DE MOTOR

FALLO DE UN MOTOR - EN VUELO

Condiciones

Guiñada a la derecha. Posible cambio de nivel del morro.

En motor afectado

- ENGINE 1/2;
- ENG 1/2 OIL PRESS;
- Los instrumentos indican pérdida de potencia

	Procedimiento	
	Condiciones de vuelo OEI	Establecer. MOEIP-Vy si es necesario
	Motor afectado Arranque en vuelo si causa identif. Y correg.	Identificar Ejecutar
	Parada emergencia de un motor	
	Si no se puede arrancar	
	Parada de emergencia de un motor • FUEL VALVES motor afectado	Ejecutar Cerrar
	• Maneta de motor afectado	Atrás SHUT DOWN
	• Indicadores Motor y Caja	Comprobar entre límites
	ATERRIZAR TAN PRONTO SEA SEGURO	

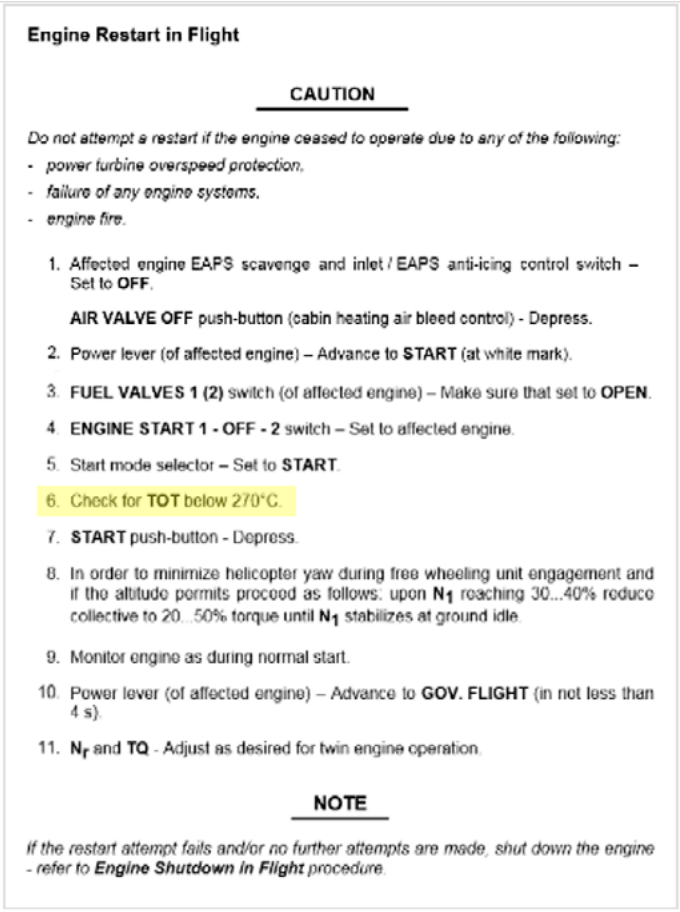
(Pág. 3-5)

In-flight engine restart procedure

The in-flight engine restart procedure contains an initial caution involving the situations in which not to conduct a restart: fire or structural damage. This caution does not make reference to any value for the engine TOT to perform the procedure; instead, this value appears instep 6 of the procedure.

Neither the Flight Manual nor the operator's manual, which had transcribed into Spanish the manufacturer's procedure, indicate what to do if the TOT is higher, which would be to apply the "Motoring the engine" procedure or, as the manufacturer clarified, wait until the incident air cools the engine.

At the end of the procedure in the Flight Manual, there is a note that redirects to the engine shutdown in flight if a restart was not possible. The checklist written by the operator included all the steps in the Flight Manual, with the exception of the engine shutdown procedure.



Engine Restart in Flight

CAUTION

Do not attempt a restart if the engine ceased to operate due to any of the following:

- *power turbine overspeed protection,*
- *failure of any engine systems,*
- *engine fire.*

1. Affected engine EAPS scavenge and inlet / EAPS anti-icing control switch – Set to **OFF**.

   AIR VALVE OFF push-button (cabin heating air bleed control) - Depress.

2. Power lever (of affected engine) – Advance to **START** (at white mark).
3. **FUEL VALVES 1 (2)** switch (of affected engine) – Make sure that set to **OPEN**.
4. **ENGINE START 1 - OFF - 2** switch – Set to affected engine.
5. Start mode selector – Set to **START**.
6. Check for **TOT** below 270°C.
7. **START** push-button - Depress.
8. In order to minimize helicopter yaw during free wheeling unit engagement and if the altitude permits proceed as follows: upon N_1 reaching 30...40% reduce collective to 20...50% torque until N_1 stabilizes at ground idle.
9. Monitor engine as during normal start.
10. Power lever (of affected engine) – Advance to **GOV. FLIGHT** (in not less than 4 s).
11. N_f and **TQ** - Adjust as desired for twin engine operation.

NOTE

*If the restart attempt fails and/or no further attempts are made, shut down the engine - refer to **Engine Shutdown in Flight** procedure.*

EMERGENCIAS DE MOTOR

REARRANQUE EN VUELO

Nota

El rearranque en vuelo puede ser realizado después de apagarse la llama o una parada, tras ser evaluado por el piloto cual fue la causa y corregida

PRECAUCIÓN

NO INTENTAR UN REARRANQUE EN VUELO SI LO QUE CAUSO EL FALLO FUE, OBVIAMENTE, MECÁNICO, PROTECCIÓN DE SOBREVELOCIDAD O FUEGO

	Procedimiento	
	Colectivo	Ajustar a MCP en OET o menos
	Consumo eléctrico	Reducir
	Interruptor EAPS motor AIR VALVE OFF	Comprobar OFF PULSAR
	Maneta de gases	Avanzar a START
	FUEL VALVE motor afectado	OPEN
	ENGINE START 1-OFF-2	En posición de motor afectado
	Selector de modo arranque	Colocar en START. Comprobar TOT < 270°C
	Botón START	Pulsar
	VER NOTA	
	Vigilar como un arranque normal	
	Maneta de gases	Avanzar hasta GOV. FLIGHT (no en menos de 4 seg)
	Nr y TQ	Ajustar como se desee

Nota

Al objeto de minimizar la guiñada durante el acoplamiento de rueda libre, y si lo permiten las circunstancias, cuando N1 alcance 30 40%, reducir el colectivo al 20 30% de TQ hasta que se estabilice la N1. (Pág. 3 6)

Son necesarios 45 seg. y 1300 pies a Vy para hacer un arranque en vuelo

Procedure for landing on a single engine

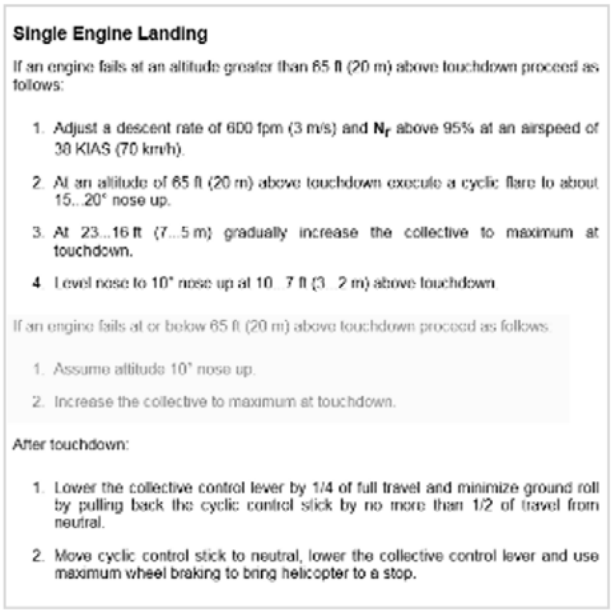
The procedure established by the Flight Manual had been expanded and modified by the operator.

The operator had added a pre-approach phase in the event that the engine failure occurs much higher than 65 ft. It had also specified a fixed Vy of 65 kt[35] (value that was left as generic in the Flight Manual), but only for that procedure. For the "In-flight Engine Failure" procedure, the operator had maintained the term Vy and not replaced it with the 65-kt value. The procedure in the Flight Manual also included an option if the failure occurred above or below 65 ft. Even so, the operator had preferred to include a preliminary step, which was to establish a Vy of 65 kt. That step would already have been performed in the "In-flight Engine Failure" procedure, whose first step is to establish a Vy speed.

From that speed, the pilot would have to reduce it to the 38 kt specified by the manufacturer, which must be reached by 20 m (65 ft) AGL.

[35].The operator had specified a speed of 65 kt as the valid reference speed for all cases since, in its area of operation, Vy varies between 63 and 70 kt. In the case of the accident, the value of this speed, as per the Flight Manual, for the environmental conditions in which the accident took place, was 70 kt (note 32).

From that point (20 m or 65 ft and 38 kt) until landing, when the nose should be at a 10º attitude, the operator's description varied from that in the Flight Manual.



Single Engine Landing

If an engine fails at an altitude greater than 65 ft (20 m) above touchdown proceed as follows:

1. Adjust a descent rate of 600 fpm (3 m/s) and N_r above 95% at an airspeed of 38 KIAS (70 km/h).
2. At an altitude of 65 ft (20 m) above touchdown execute a cyclic flare to about 15...20° nose up.
3. At 23...16 ft (7...5 m) gradually increase the collective to maximum at touchdown.
4. Level nose to 10° nose up at 10...7 ft (3...2 m) above touchdown.

If an engine fails at or below 65 ft (20 m) above touchdown proceed as follows:

1. Assume attitude 10° nose up.
2. Increase the collective to maximum at touchdown.

After touchdown:

1. Lower the collective control lever by 1/4 of full travel and minimize ground roll by pulling back the cyclic control stick by no more than 1/2 of travel from neutral.
2. Move cyclic control stick to neutral, lower the collective control lever and use maximum wheel braking to bring helicopter to a stop.

ATERRIZAJE CON UN SOLO MOTOR

Condiciones

Un motor inoperativo OEI.

	Procedimiento	
•	APROXIMACIÓN PARA ATERRIZAR	
	Calefacción	Comprobar OFF
	Velocidad	Ajustar 65 KIAS (V_y)
	Aproximación tendida	Establecer
•	EN FINAL A 65FT AGL	
	Velocidad	38 KIAS
	Régimen de descenso	600 ft/min
•	TOMA	
	Velocidad	Reducir al mín. Según potencia disponible
	Actitud de aterrizaje	Establecer: morro 10º
	Colectivo	Levantar como sea necesario para parar descenso y amortiguar la toma
•	TRAS LA TOMA	
	Colectivo	A 1/4
	Cíclico	Atrás NO MÁS 1/2
	Tras parada	Cíclico neutral Colectivo Abajo Aplicar frenos

Precaución	Al objeto de reducir el rodaje, dejar el colectivo a ¼ del recorrido y colocar el cíclico atrás no más de ½ del recorrido desde neutro. PRECAUCIÓN CON LA COLA

(Pág. 3-7)

Section 4 of the Flight Manual specified a landing distance required, for the temperature and pressure altitude on the day of the accident and operating on a single engine, of 85 m. The Flight Manual emphasizes that this single-engine landing distance is achieved when at 100 ft AGL at a speed of 38 KIAS and a descent rate of 600 fpm.

1.16.7 Fields along the flight path

The map below shows the location of the airfields and runways in the vicinity of the flight path at two times during the flight: when the engine stopped and when the crew decided to land in order to start the engine on the ground. It shows the length of the runways and the distance to them from the time the crew decided to land to start the engine and how long it would have taken to reach them. This time was calculated by maintaining the 41-kt speed the helicopter had when they decided to land, and if they had been flying at 65 kt, which the operator specifies as Vy.

In addition to these airfields, the Cuatro Vientos and Casarrubios del Monte airports were also in the vicinity.

(1) Aerodrome of Villanueva de la Cañada.
Cross runways 200 m and 160 m long.
3.2 km away
2.5 min away at 41 kt (1.5 min at 65 kt)
(2) Aerodrome of Brunete:
370-m runway
6.5 km away
5.3 min away at 41 kt (3.2 min at 65 kt)
(3) Private aerodrome:
250-m runway
3.4 km away
2.6 min away at 41 kt (1.7 min at 65 kt)
(4) Aerodrome of Villanueva del Pardillo:
Cross runways 360 m and 160 m long
7.5 km away
5.9 min away at 41 kt (3.7 min at 65 kt)

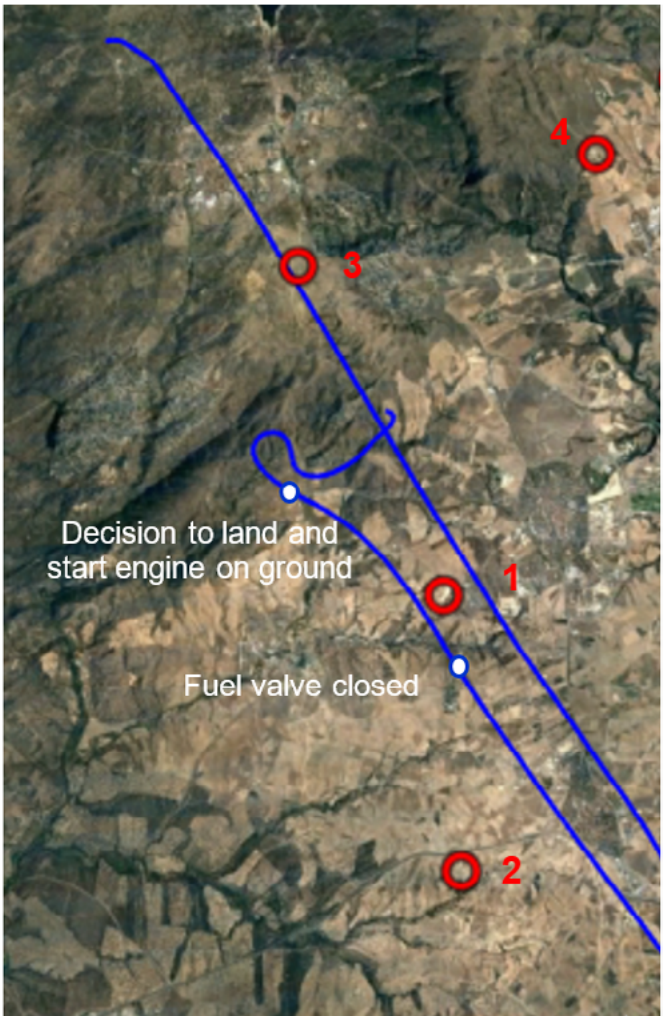


Figure 10. Alternate fields along flight path

1.17. Organizational and management information

1.17.1 Royal Decree 750/2014 and its guidance material

Since 5 September 2014, Royal Decree 750/2014 and the guidance material for applying it[36] have governed aerial firefighting activities. The material published in the law involving the types of operations[37] that can arise when fighting fires, pursuant to this law, and that is of interest to this investigation is provided in this section.

[36].AESA Resolution of 25 May 2015.
[37].TAE.ORO.GEN.010: Definitions (e) and (f)
TAE.ORO.FC.LCI.200: Crew make-up (g).
AMC1 TAE.ORO.FC.LCI/SAR.200: Crew make-up –OPERATION WITH TWO PILOTS SPA (pg. 77).

In the case of helicopter EC-LQA, with a certified takeoff weight in excess of 4000 kg and used to drop water and transfer specialized personnel, the RD requires that the operation be done with two pilots. However, having two pilots on board the aircraft does not imply multi-pilot operation, since the RD allows for another possibility: single-pilot operation with two pilots.

All of the information included in the regulation for each of these two options is shown below:

• Multi-pilot operation, MPO (2P): defined as the operation of an aircraft (which may be certified to operate with one or two pilots) that requires at least two pilots, who are using crew cooperation techniques, and for which suitable procedures have been defined, in which duties and responsibilities are assigned to the two pilots, both of whom are involved in the conduct of the operation. One of the pilots will act as the pilot flying and the other as a second pilot. This operation will require an MCC course and the operator will have procedures suited to the operation type, which will be included in the Operations Manual. Even though two cases are defined for multi-pilot operation depending on the aircraft's certification (for one or two pilots), the operating procedure is clear and the same in both cases:

- MPA MPO MPP	Operation:	multi-pilot
	Pilots on board:	2
	Procedures for:	2
	Aircraft certified for:	2 or more

- SPA MPO (2P) MPP	Operation:	multi-pilot
	Pilots on board:	2
	Procedures for:	2
	Aircraft certified for:	1

• Single-pilot operation with two pilots, SPO (2P): defined as the operation of an aircraft certified to operate with a single pilot by using two pilots, and for which the procedures are defined for operating with a single pilot. The guidance material expanded this option with the following: in the case of SPA SPO (2P) SPP, and in particular for SPA SPO (2P) MPP, although MCC as intended for MPA MPO MPP and/or SPA MPO (2P) MPP would not be applicable, procedures must be developed, based on the activities/duties that each pilot might carry out at any point during the operation, that are in keeping with said activities/duties, along with the relevant coordination elements. When training the crews that carry out this type of activity, the aforementioned procedures and coordination elements must be taken into account.

-	SPA SPO (2P) MPP	Operation:	single pilot
		Pilots on board:	2
		Procedures for:	2
		Aircraft certified for:	1

-	SPA SPO (2P) SPP	Operation:	single pilot
		Pilots on board:	2
		Procedures for:	1
		Aircraft certified for:	1

There is a fifth category, which would not be applicable to the flight of EC-LQA (it is included here to show all of the possible FF operations), which involves single-pilot operation with a single pilot, which would be defined as follows:

- Single-pilot operation with one pilot, SPO (1P):

-	SPA SPO (1P) SPP	Operation	single pilot
		Pilots on board:	1
		Procedures for:	1
		Aircraft certified for: 1	

Therefore, the RD combines three concepts when defining the operation: the minimum number of pilots specified by the aircraft certification (SPA or MPA), the operation (SPO or MPO) and the procedures (SPP or MPP). As a result, specifying solely whether to operate with one or two pilots when describing the FF operation of an aircraft is not sufficient according to the RD, since the type of operation being conducted, and how many pilots the procedures are defined for, must also be specified.

1.17.2 Firefighting operations at HASA

Firefighting operations at HASA were, according to information provided by the operator itself and confirmed by AESA, "single-pilot with two pilots", as per RD 750/2014. According to the guidance material, the operation was carried out using the SPA SPO (2P) SPP option; that is, single-pilot operation with two pilots with procedures for one pilot.

The HASA Operations Manual was combined for FF and SAR activities. The FF and SAR activity for the SOKOL was described over 45 pages, which comprised part B of the OM. Attached to this main document were protocols (PROT, containing the

checklists) and general procedures (SOP). The sections from this Operations Manual that are of interest to this investigation are provided below.

Normal Procedures (literal copy from OM)

FF and SAR OM - PART B. SOKOL (pp. 24 and 25 of 45)

2. Section 2- Normal procedures.

2.1 Normal procedures and functions assigned to the crew – guidelines for pilots

Hispánica de Aviación has not defined normal procedures different from those contained in the RFM (Helicopter Flight Manual) approved by the competent authority.

- *In general, operations will be single-pilot, with the lone pilot being responsible for self-supervision and self-verification and doing the checks and procedures as per the checklists attached in the Annexes: "Normal Checklists Sokol 1 pilot" (this was the list that the operator provided to the investigation as being applicable during the event). In this case, the "do-verify" (DV) method will be used, which consists of completing the list in a variable sequence without having requested it first. After all the items on the list are done, the list is read again as each element is verified. The DV method allows the flight crew to do the procedures from memory in order to carry a series of actions quickly and efficiently.*

- *For operations with two pilots, the procedures described below[38] will be used and the lists attached in the Annexes, "Normal Checklists Sokol 2 pilots", will be done. In this case the "challenge-done-verify" (CDV) method will be used, in which one crewmember calls out the action before it is initiated, and the other one carries out the action and replies to the first.*

Using the lists:

- *The PF will be responsible for:*

  - *Overseeing, verifying and managing the performance of the checklist*

  - *At all times maintaining…*

  - *While the PNF reads the list, the PF performs it…*

[38].Refers to the description for "using the lists" shown immediately afterward.

- *The PNF will be responsible for:*

  - *At the end of each phase, saying "phase-name of phase complete…"*

  - *Call the attention of the PF and of the rest of the crew to any deviation observed during the procedures.*

- *The hands and fingers should be used to touch or point to controls, switches and displays while doing the list ….*

- *Starting, performing and completing the normal lists:*

  - *They must be requested by the PF and read by the PNF/PM*

Abnormal and emergency procedures (literal copy from the OM)

FF and SAR OM - PART B. SOKOL (pp. 24 and 25 of 45)

3. Section 3- Abnormal and emergency procedures

3.1. Abnormal and emergency procedures and functions assigned to the crew

Hispánica de Aviación has not defined abnormal and emergency procedures different from those contained in the RFM (Helicopter Flight Manual) approved by the competent authority.

In the event of an emergency, the checklists will be used, following the same procedure described in point B2 (normal procedures).

In emergency situations, there are items that the pilot must know from memory, since they must be executed immediately in response to the emergency: for example, going into auto-rotation in the event of a dual engine failure. In these cases, the PF will always act as indicated in the MVH (helicopter flight manual), while the PNF will assist and attempt to identify the cause of the failure, call out the engine and flight parameters and, once the flight is under control, resort to the easy-access checklists.

In general, operations will be single-pilot, with the lone pilot doing the checks and procedures as per the checklists attached in the Annexes "Emergency checklists Sokol 1 pilot".

For multi-pilot operations, the procedures described below will be followed and the checklists attached in the Annexes, "Emergency checklists Sokol 2 pilots" will be done (this was the list that the operator provided to the investigation as being applicable during the event).

- *Sokol: RFM section 3 Emergency Procedures*

Pilot flying: *Continue flying and start the emergency procedure.*

Pilot not flying: *Read the emergency procedure and carry out the necessary operations*

Pilot not flying: *Call on radio to report the emergency*

Pilot not flying: *Alert passengers (…)*

Checklists for normal and emergency procedures

The FF/SAR OM makes reference to four checklists:

- Normal checklist Sokol 1 pilot
- Normal checklist Sokol 2 pilots
- Emergency checklist Sokol 1 pilot
- Emergency checklist Sokol 2 pilots

- Normal checklist Sokol 1 pilot[39]

Published with the reference HASA-OPS.PROT 09. The current edition at the time of the accident (Edition 1 of 2014) had a total of 18 pages. On pages 1-7 the heading read "SOKOL CHECKLIST NORMAL PROCEDURES ONE PILOT", on pages 8 to 16 the heading changed to "SOKOL CHECKLIST" and on 17 and 18 the heading changed to "SOKOL CHECKLIST TWO PILOTS". The procedures were a Spanish translation of the Flight Manual, where the tasks were not numbered, certain items were redirected to the Flight Manual ("See MVH pg. 2-16", for example) and references were made to IFR operations, which are not approved for FF. This list, before landing and after takeoff, specifically included "THE 2.5 OEI BUTTON SHOULD BE KEPT DEPRESSED".

Edition 2 of 2018 of this list had corrected the headings from edition 1, standardizing them so that all the pages were titled "SOKOL CHECKLISTS NORMAL PROCEDURES

ONE PILOT", and it had numbered the items. The rest of the content was similar to that in edition 1.

- Normal checklist Sokol 2 pilots

Published with the reference HASA-OPS.PROT 10, edition 2 of 2018 had 19 pages. The list was titled "SOKOL CHECKLIST NORMAL PROCEDURES TWO PILOTS" on pages 1 to 7, and "SOKOL CHECKLIST TWO PILOTS" on pages 8 to 19. The list was the same as the one-pilot list, with the exception of the added terms CM1, CM2, PF and PNF, including specifying which of these four positions performs the tasks. This list did not contain numbered items and redirected to the flight manual, as did the single-pilot list.

- Emergency checklist Sokol 1 pilot

Published with the reference HASA-OPS.PROT 11, edition 2 of 2018 has 47 pages. The list was titled "SOKOL CHECKLIST EMERGENCY PROCEDURES 1 PILOT" on pages 1 to 5, but in the rest of the document the heading changed to "CHECKLIST SOKOL EMERGENCY PROCEDURES TWO PILOTS".

Page 3 of this list contained the note, "IF FLYING WITH TWO PILOTS, THE EMERGENCY WILL BE MANAGED BY THE PF. THIS MEANS THAT THE PF WILL CONTINUE FLYING AND THE PNF WILL READ THE CHECKLIST FOR THE PF TO PERFORM".

On page 12, "Engine emergencies", General, it stated that the procedures did not include the use of the 2.5 min OEI feature because the engine allows doing a running landing if below the maximum weight, but that, in any event, "THE PILOT CAN DECIDE TO USE IT".

- Emergency checklist Sokol 2 pilots[40]

Published with the reference HASA-OPS.PROT 12, edition 1 of 2014 had 47 pages. It was exactly the same as edition 2 of HASA-OPS.PROT 11.

Version 2 of 2018 was exactly the same as edition 1, with the exception of numbered items. The headings on both editions changed on page 6 from "SOKOL CHECKLIST EMERGENCY PROCEDURES 2 PILOTS" to "CHECKLIST SOKOL EMERGENCY PROCEDURES TWO PILOTS".

[39].This is the list that the operator provided to the investigation as being applicable during the event.

Procedures specific to firefighting

The "GENERAL FF PROCEDURE", published as HASA-OPS.SOP01, edition 2 of 2016, in effect at the time of the accident, had 23 pages. It had general explanatory content on firefighting and its organization. Over the course of seven items, it described the firefighting activity, the use of helicopters in the operation, the nature of the operation, the hazards of water drops and on the ground, the various firefighting techniques, types of fires, types of drops and techniques, among other topics. This specific procedure made reference to the normal and emergency procedures in the helicopter Flight Manual.

The "PROCEDURE FOR MANAGING THE AIRSPACE, CAROUSEL AND WATER LOADING OPERATIONS", published as HASA-OPS.SOP10, edition 2 of 2016, in effect at the time of the accident, had 21 pages. It contained a description of the different spaces defined for a fire and the procedures to follow in each area. Section 4.3 FERRIS WHEEL OR CAROUSEL PATTERN, included a section called "FF phases of operation" (pp. 14 to 17 of 21), which described, for each phase of flight in a fire, the actions to take, by way of guidelines. It was not a procedure or a checklist per se, but it described general action criteria. This description included:

- The roles of the PF and PNF.

- The need for acknowledgment during decision making and in-flight actions by crewmembers.

- The acknowledgments required by the PF and PNF during the different phases of a fire. These reports are as shown in the items below, and which are used in section 1.11.4 to reference the reports during the accident flight.

- Reports during the approach to loading areas will be made in the following order:

  1. "Clear of traffic, clear of cables, clear of birds, material that can fly, dust…"
  2. "Visibility to the point and entry, exit and escape routes OK"
  3. "Headwind or acceptable wind for loading"
  4. "Close to hovering point, tail rotor clear"
  5. "Slings and bambi not hooked on ropes, cables or any other material that is floating or tied to the pond"
  6. "Commencing loading" "Parameters OK" "Water drop test OK"

[40].This list (edition 1) is the one that the operator provided to the investigation as being applicable during the event.

7. "Load again"

8. "Parameters OK and clear of traffic"

9. "Leaving, watch out for possible actuation of emergency systems and procedure to abort current maneuver"

10. "Leaving pond"

- Reports on landing will be made in the following order:

11. Same as 1

12. Same as 2

13. Same as 3

14. "Parameters OK"

15. "Terrain on positive slope and compact, free from potential dust particles of material that can fly and cause damage"

16. "Close to hovering point, tail rotor clear"

With bambi stowed:

17. "Sufficient clearance for firefighters to safely lower the bambi"

18. "Clear of rocks or any material that can damage the aircraft on landing"

19. "Land and secure aircraft with brakes"

20. "Operations personnel can descend"

With bambi not stowed:

21. "Slings and bambi clear, not getting hooked on cables, bushes (…)"

22. "Hovering with bambi clear and not touching the surface"

23. "Bambi to the ground"

24. "Clear of rocks or any material that can damage the aircraft on landing"

25. "Land and secure aircraft with brakes"

When boarding firefighters:

26. "Giving OK for boarding"

27. "Bambi in basket and secure, guitar hooked"

28. "Operations personnel ready for takeoff"

- Reports on takeoff will be made in the following order:

29. "All green, fuel OK, systems needed for flight ON, sufficient takeoff power"

30. "Starting takeoff run"

31. "Looking for Vy/Vx speed"

32. "Establishing straight and level flight, all green"

- Reports when dropping the extinguishing agent will be made in the following order:

33. "Clear of traffic"

34. "Approach with power margin OK"

35. Reporting to personnel "entering drop…"

36. "Headwind"

37. "Cleared to enter for drop"

38. "Ready to drop and preparing assistance systems to restart and release bambi in case of emergency"

39. "Dropping"

40. Report to personnel "Clearing area"

Procedures for reporting emergency situations

The FF and SAR OM - PART B. SOKOL (pg. 42 of 45)-Section 11- Emergency evacuation procedures, states that "the second pilot, if present, will make the relevant emergency calls and wait for a reply…".

In keeping with the above, the FF and SAR OM - PART B. SOKOL (pp. 24 and 25 of 45)-Section 3- Abnormal and emergency procedures, in the description of duties in multi-pilot operations, assigns the following actions to the pilot not flying (pp. 24 to 26 of 45):

- "Call on the radio to report the emergency"

- "Alert passengers"

- "Mayday reports must be made by the reserve pilot, who will request authorization from the captain when the latter is the pilot flying"

This information, however, contradicts HASA-OPS.PROT07 and HASA-OPS.SOP02, which state that "in case of emergency, when the helicopter is required to make a forced landing, the captain will inform the squad of the situation…" (pp. 32 of 46).

Procedures involving the transportation of squads

The reference document HASA-OPS.PROT07 "INSTRUCTION PROTOCOL FOR SQUADS IN FIRE BASES", edition 1 of 2011, had 46 pages. This document included the content of the training that HASA gives to squads. Specifically, it described the helicopter and all of those components that squads must be familiar with, safety zones, boarding and disembarking procedures in different conditions, the procedures for releasing or picking up the bambi, internal and external communications and a final chapter on restrictions (transporting hazardous materials like gasoline, the use of electronic devices, in-flight incidents and rules and regulations). There was a six-page document, HASA-OPS.FORM05, "SQUAD INSTRUCTION PROTOCOL", edition 3 of 2015, which outlined most of the contents of the previous document and was used to train the squads (and even contained attendance sheets). These documents indicated that:

- "The captain is responsible for the passengers and cargo…" (pg. 5 of 46).

- "The squad foreman or technician is responsible of the selection of the tool (pg. 10 of 46).

- "Tools will be securely fastened and protected with blade covers to prevent cuts" (pg. 20 of 46).

- "The tool must be fastened in the specified location. The space under the seats may be used as long as the tool is securely fastened" (pg. 3 of 6).

- When boarding, "squads will have their helmet on, they will bend down when walking in front of the helicopter, they will use both doors and carry tools below head height and horizontally" (pg. 26 of 46).

- Boarding procedure, "inside the helicopter, everyone will fasten their safety harness and wear a noise protection headset" (pg. 27 of 46).

- Disembarking procedure: "squad members will don their helmets and protective goggles" (pg. 28 of 46).

- Regarding the use of the doors for boarding and disembarking, the two documents give different criteria. One document states that "in general, it will be done using the left door" (pp. 6 and 7 of 7), and the other that it will be done using both doors at once (pp. 26 and 29 of 46).

- Emergency situation and evacuation of the helicopter (pg. 32 of 46) "if the helicopter is required to make a forced landing, the captain will inform the squad and give the order to prepare the passenger cabin for an emergency landing:

  - All loose objects must be secured to keep them from being thrown about by the impact and injuring the passengers.

  - The passengers will ensure their seatbelts and shoulder harnesses are properly fastened.

  - Passengers will keep their backs straight and against the seatback, and place their heads against the headrest to avoid whiplash and injury to their cervical vertebrae.

  - They will keep their arms folded across their chest during the maneuver.

- Inform the other personnel in the passenger cabin of the emergency (via the technician or foreman) (pg. 4 of 6).

- Brace position: back supported, head supported, use of helmet not specified, only that the head be supported with the neck straight, feet and knees together, arms around the neck holding on to the suspenders at their highest point (pg. 4 of 6).

In addition to these documents, there was a three-page procedure published as HASA-OPS.SOP02 "PROCEDURE FOR EMERGENCY IN OPERATIONAL PERSONNEL CABIN", edition 2 of 2016. This procedure stated that "in the event of an in-flight emergency, the captain will inform the passengers "This is an emergency. Emergency position" (pg. 1 of 3). Upon hearing this report, passengers will assume the relevant emergency position", which, in the case at hand, is the one described in the last bullet point above (brace position).

1.18. Additional information

1.18.1 Accident A-031/2016 of the operator HASA

On 10 August 2016, one month after the accident of EC-LQA, the operator had another accident investigated by the CIAIAC, reference A-031/2016. The helicopter, a SOKOL W3AS, registration SP-SUC, was also engaged in firefighting operations in Pico de Cabrito, in the municipality of Villa de Mazo (Santa Cruz de Tenerife). The cockpit communications during this accident recorded a total of five water load/drop cycles on the fire before the accident.

The operation that was being carried out, as with helicopter EC-LQA, was a single-pilot operation with two pilots for FF, as per RD 750/2014. On board were two pilots, one with over 5000 flight hours (four campaigns, 360 h FF and 388 in the SOKOL), and the second pilot had 200 flight hours (not rated on the helicopter and two FF campaigns). In an effort to identify similarities or differences in the methods used in the two cockpits (EC-LQA and SP-PC), the communications in accident A-031/2016 were analyzed in relation to the procedures of the operator, HASA.

The 30-minute recording of the communications in the cockpit of A-031/2016 showed that:

- Of the five load/drop cycles recorded, two were done by the second pilot.

- During the periods when the second pilot was flying, the pilot was instructing the second pilot, with constant indications, instructions and explanations on how to proceed (both during the load and drop, speeds, releasing the drop, etc.).

- Given the transitional period of RD 750/2014, and since he was not rated on the helicopter, the second pilot was considered a crewmember (a rating is needed to be both a back-up pilot under instruction and a PICUS).

- The communications held during the five cycles revealed:

  - Changes in control between the two pilots with the use of different terminology in some cases.

  - During the load and drop processes, none of the checks or communications specified by the operator, HASA, in its procedure HASA-OPS.SOP.10 were carried out.

  - The communications focused on finding drop points. One was about the fuel remaining so they could report on their time remaining on station, and another was about the intensity of the headwind.

- The communications with the fire director were generally, but not always, handled by the pilot not flying. In the accident of EC-LQA, fire communications were handled by the captain, whether or not he was the pilot flying.

1.19. Useful or effective investigation techniques

Not applicable.

2. ANALYSIS

On Sunday, 17 July 2016, aircraft EC-LQA, a PZL W3AS helicopter, made an emergency landing in a crop field during the return flight from a fire. The weather conditions were not limiting to the flight, the helicopter had sufficient fuel to make the flight and no technical problem was identified that could have contributed to the accident. The pilot in command was the Safety Manager at the operator and he had twice the experience of what RD 750/2014 considered a highly experienced pilot.

The analysis considered the following areas:

- 2.1: Start of the event, when the fuel shut-off valve was incorrectly closed as part of an improperly internalized and executed procedure, with a doubly deliberate action.

- 2.2: The analysis of the engine data for the first 64 sec after the event, which confirmed that 3 sec after reopening the valve, there was combustion in the engine.

- 2.3: The engine was running and operating at idle. It was kept this way until the end of the flight, a condition that was not identified by the crew.

- 2.4:The focus of the crew on the engine temperature and searching for a field on which to land had effects on the speed and heading during the event and complicated the subsequent flight.

- 2.5: The decision to make an off-field landing was made without evaluating other available options.

- 2.6: The approach and landing maneuver did not satisfy the shallow approach criteria, as the aircraft was turning at varying altitudes and speeds.

- 2.7: The failure to report the emergency to the squad, so the firefighters could prepare for landing, or to the emergency coordinator (CECOP).

- 2.8: Transport of the squad and its material, in which the firefighters exhibited a lack of knowledge about the procedures to be used in flight, and with material being transported unstowed, in violation of the procedures defined by the operator.

- 2.10: Review of HASA's FF operation, as a result of the existing gap between the reality of FF flights and the activity as described and explained in its Operations Manual, as well as the need to improve how this operation is defined in the documentation.

2.1. Event initiation: Closing of fuel shut-off valve in engine 1

The event that triggered the accident was the closing of the fuel valve for the 1 (left) engine. This action closed off the fuel supply to engine 1, causing it to stop.

This action is not in any established procedure and was intended to be the execution of an emergency procedure (Fuel imbalance), contained in the Flight Manual and in the operator's procedures. The following deviations occurred during the execution of this action:

- It was initiated with a faulty fuel reference.
- It was initiated later than specified in the procedure.
- The wrong switch was operated, which stopped the engine.
- It was done by the pilot not flying, in violation of the single-pilot with two pilots operational mode.

The cockpit communications, the description of the accident written by the crew and the information collected during the interviews indicate that the procedure had not been learned correctly by the crew:

- First of all, the procedure should have been initiated at 200 l, not 300 l. The 300 l used as a reference by the crew is the applicable value when the excess fuel is in the forward tank, which was not the situation in this case. In other words, either the crew confused the values or the 300-l value has been taken as the reference to apply in every case.
- Secondly, the procedure should have been carried out when the imbalance exceeded the value specified in the procedure. In this case, the procedure should have been executed when the imbalance reached 200 l; in the case of the flight, and based on the erroneous value being used by the crew as a reference, at 300 l. The term "exceeds" was interpreted differently by both pilots: the second pilot understood it as the value that, once reached, required the procedure to be executed, which he tried to do when he first proposed it. But the captain thought the procedure was not required when this value was reached, since it was "within limits", as he stated in writing and confirmed during the interview, and they could let it continue to increase. While it is true that the term "exceeds" can give rise to different interpretations, this value must refer to the limit, and this number should be taken as a reference for starting the procedure.

However, when this imbalance appeared, with the helicopter on the ground and ready to pick up the squad, the water bucket and the materials, it was impossible to execute the procedure since the workload at that time was high and they were in the area affected by the fire.

Even though the captain did not acknowledge it, the procedure was not forgotten, since it was the captain himself who brought it up again after the work load decreased and they were in a less demanding phase of the flight, namely the transfer.

The captain verbally announced his execution of the procedure, and the second pilot also confirmed it: "pump on 1". The switch to be operated and the associated engine were correctly identified, but the execution was faulty and did not correspond to what had been verbally announced, even though a dual action was required:

- first, lifting the red switch guard, and

- second, modify the position of the switch.

Despite the dual action necessary, the captain failed to realize that he was operating the shut-off valve (which, due to its consequences, is protected by a switch guard). This indicates the lack of attention to what he was doing. The second pilot, who was the pilot flying at the time, also did not identify the switch that the captain was operating.

Although it was an emergency, the procedure they were carrying out was "routine" and was done with no type of external pressure or critical situation, since it had been initiated by the crew. They were returning to the base during a straight and level phase of flight. The captain was just returning from a rest period, meaning that factors such as work overload or the presence of stressors that could have influenced the condition of the crew during the execution of the procedure can be ruled out. The mistakes and deviations that occurred during the execution of this procedure (starting the procedure with a faulty fuel reference, after it should have been executed and operating the wrong component) indicate that it was done from memory, that the checklists were not used and that there was no visual or conscious check (or oversight) of the execution of the procedure.

In addition to the above is the fact that the execution of this procedure by the pilot not flying violated the work method on this flight: single-pilot operation with two pilots with procedures for one pilot. The duties are not allocated between the two crewmembers in this operation, meaning it should have been the pilot flying, the second pilot in this case, who should have executed the fuel imbalance procedure.

As the pilot not flying, the captain was not allowed to "touch" anything in this type of operation.

Despite being the Safety Manager, it was the captain himself who took the initiative to violate the method of operation, making no comments in this regard. The second pilot also made no comments and accepted this method of operation. At this point the situation was not critical (they were still en route back to the base and there was no emergency), and there was no exceptional element that required the captain, who is always empowered to take any actions he deems necessary for flight safety reasons, to do part of the tasks that the second pilot, as the pilot flying, should have carried out.

2.2. Combustion in engine 1 nine seconds into the event

Both the captain and the second pilot were convinced that the engine 1 was stopped, so much so that it conditioned all of their subsequent decision making: starting the engine (first in flight and then on the ground).

However, an analysis of the data shows that while the engine did stop after the fuel valve was closed, it then restarted and remained at flight idle or start (engine lever at FLIGHT IDLE or START) for the remainder of the flight.

After the event (closing of the fuel valve), the engine's values were consistent with being stopped: N1 fell from 58% (which is the reference value), TQ remained at 1%, the acoustic engine stopped warning sounded, engine oil pressure dropped and the visual engine inoperative and low oil pressure for the engine 1 must have turned on in the cockpit. This all happened in the first 5 seconds, and caused the crew to incorrectly conclude that the engine had stopped.

However, 3 sec after the captain opened the valve (9 sec after closing it), the temperature (TOT) data for engine 1 showed a different situation: the temperature registered a peak from 420º C to 623º C, which not only persisted, but increased to 681º C.

In other words, 3 sec after the valve was opened (9 sec after closing it), there was combustion in the chamber, and, moreover, this combustion was maintained over time. The fact that the temperature reached these values 3 sec after opening the valve means two things: that fuel was flowing in, and furthermore, that at some point, the fuel had combusted:

- Flow of fuel into the chamber: the only two components that keep fuel out of the engine were opened 6 sec after the event:

- The shut-off valve, which was opened by the captain after he realized his mistake, and

- The engine 1 power lever, which was in the FLIGHT position.

- Ignition: as concerns when the fuel combustion took place, there are two possibilities:

  - Autoignition, which would be possible because the temperature in the combustion chamber was well above the autoignition temperature of JET A1 (210º C). The TOT temperature, which was not the same as the combustion chamber's but lower, was 420º C, meaning the temperature in the chamber would be far higher than 420º C, more than sufficient to cause the incoming fuel to autoignite. Moreover, the engine was only without fuel for 5 sec.

  - The sparking in the spark plugs during the start process (as long as the start selector was in the START position and the captain had pressed the START button). The captain initiated the start process immediately, but he was interrupted by the second pilot, as evidenced by the CVR recordings. There are no FDR recordings of the positions of these switches to confirm it, but one possibility is that the captain initiated the start process and that the spark plugs produced sparks at the spark plugs.

  - These two options are both probable, though the investigation was unable to obtain data to confirm either one. The short time (3 sec) that elapsed between the opening of the valve and the engine temperature reaching 623º C could make the autoignition option more likely.

What the data do confirm is that regardless of the condition that produced combustion (a spark or autoignition), nine seconds into the event the engine 1 maintained a combustion process that was consistent with start temperatures.

2.3. Engine operating at idle

The conversations in the cockpit in the first 25 seconds after the event indicate discrepancies in the procedure to use (starting or motoring the engine) between the captain and the second pilot. The captain, operating the helicopter, had initiated the start cycle but it was the second pilot who interrupted the start process[41], insisting on the need to crank it due to the engine temperature. The second pilot repeatedly gave instructions and corrected the captain on the procedure to perform. Both pilots focused all of their attention on this gauge. Based on the behavior of the engine parameters, it is considered very likely that from these initial moments,

[41].Starting the engine requires placing the engine lever in the START position and, once started, in IDLE.

when the captain was starting the engine and the second pilot interrupted this process, that the engine 1 lever remained in the START position and was left that way for the remainder of the flight.

The engine lever is located in the central overhead panel (Figure 9). It is a lever that is not normally operated in flight, since under normal conditions it remains in the FLIGHT position. Their monitoring of the temperature reading and the actions to operate the start system panel (Figure 9) require the head to be tilted down and to the front, beyond the visual range of the engine levers, which require raising and turning the head.

The data show that, in effect, the "Motoring the engine" or crank procedure was performed in an effort to lower the TOT. As a result of this procedure, N1 rose to 73%, with the needle moving into the green arc. The engine inoperative light (OEI 1) should have turned off (due to N1 rising above 58%[42]), and the low oil pressure light should also have turned off (when the value rose above 41%[43]).

Therefore, 50 sec after the event, the status of the engine gauges in the cockpit unmistakably showed that the engine was running. However, neither of these visual indications were noticed by the pilots, who, at that point, focused on the engine temperature.

When the crank procedure was completed, 64 sec after the even, TQ rose (1 to 11%), another sign that the engine was running. From that time until the end of the event, the engine parameters essentially indicated that the engine was at idle. Had they advanced the engine lever to the FLIGHT position, the emergency would have ended and the helicopter would have continued flying on two engines.

The crank procedure was not executed as specified in the Flight Manual. Even though the crew's statement indicated that the engine lever was placed in the SHUT OFF position, this could not have been the case, since this position completely closes the supply of fuel to the engine, which would have prevented the temperature values that were recorded from occurring. As stated in the preceding paragraphs, the most likely situation is that the engine lever was kept in the IDLE or START position, in which the amount of fuel injected into the engine is the minimum needed to maintain combustion.

This same crew had performed the same crank procedure at the start of the flight, during which they would have verified that the N1 values had increased to 20% (above 14%, according to the reference in the Flight Manual). This radically different behavior of the engine for the same procedure could have alerted the crew to the fact that the situation was not the same.

[42].Reference limit for considering an engine as operative or not.

Since the crank procedure was incorrectly executed, it did not achieve the desired objective. There was still combustion in the engine and the engine temperature could not decrease. In light of this, the crew ruled out the possibility of starting the engine. At this point in the emergency, they should have secured the engine by placing the fuel shut-off valve and the engine lever in CLOSED and SHUT OFF, respectively. The FDR recording confirmed that the valve remained open, and the data that indicated combustion was still occurring in the engine, show that the lever was also not placed in the SHUT OFF position.

The crew's actions during the emergency were in violation of the task allocation specified for this single-pilot operation with two pilots. The captain, who was not the pilot flying, operated the helicopter (in the procedure to turn off the booster pump, when he reset the position of the shut-off valve, when he initiated the engine restart procedure and when he motored the engine). These actions should have been carried out by the pilot flying at the time (the second pilot). While it is certainly within the captain's prerogative to take whatever actions he deems necessary in emergency situations, the emergency procedures are in place to systematize the response in the face of undesired events, and to make sure that these situations are handled correctly by crews. The response will be as desired if crews perform the actions in the way they are designed and trained.

Moreover, in this case, the captain initially did not take full control of the aircraft (he would do so 86 s later); instead, he operated the helicopter while the second pilot, in theory, was still the pilot flying, since the captain had not asked to take back control. Both were operating the helicopter for 86 sec. Again, this was not how the operator, in its Operations Manual, intended for its crews to manage emergencies. It was also not how they were trained, since in a single-pilot operation with two pilots, it is the pilot flying who must fly the aircraft and manage the emergencies. And if there is a change in control, it must be complete.

At no point during the emergency was the "Single-engine power failure" checklist used, required or mentioned by either pilot. Only the part of this list associated with the engine start was done, omitting the checks of the engine failure conditions, maintaining Vy and securing the engine. As for motoring the engine, as stated previously, this was done but it was done from memory and the checklist was not mentioned or used. At no time was reference made to the name of the procedure as contained in the operator's lists ("Motoring the engine"); instead, they used the term "crank" and this procedure, as noted earlier, was done incorrectly.

The fact that the captain took over some of the flight duties deviated from the normal, expected and trained operating procedure, which could have affected the fact that neither pilot did a basic check of the engine parameters. In the second

[43].The oil pressure light is another indication used to determine if the engine is operative or not, as per the operator's procedure.

pilot's case, this may have been caused by this new assignment of duties during the emergency, and in the captain's case, by a possible initial reduction in his analysis and decision-making capacity due to having caused the initial error. Due to operating in this manner and to how the tasks were assigned, neither pilot noticed that the engine was running.

2.4. Focus and consequences on the speed and heading

The CVR recordings showed that:

- During the emergency, as both pilots were operating the helicopter, the second pilot was mindful of the actions that the captain was taking and both were completely focused on the temperature for engine 1.

- In the ensuing part of the flight, when the captain assumed full control of the flight, both pilots focused on finding a field on which to land.

One consequence of this focus is that both ignored the flight in terms of:

- Speed: at no time after the emergency was the Vy speed maintained.

- Course: they remained on a course that drew them closer to an area of rising terrain.

The procedures (Single Engine Power Failure and Single-engine landing) specify that after the engine fails, to establish speed Vy, in this case, 70 KIAS, as per the Flight Manual for the conditions on that day. There is no indication that the crew looked in the associated tables (which is also not conducive to operations). At no other point during the flight was a reference made to this speed or to the term Vy in the cockpit. There was also no reference made to the 65-kt value that the operator had specified for Vy in the procedure for landing on a single engine (but not in the Single Engine Power Failure procedure).

In any case, the FDR data show that neither the 70-KIAS speed calculated by the Flight Manual nor the 65-kt specified by the operator was maintained. Even though the helicopter was flying at an indicated airspeed of 73 KIAS (3 knots above the calculated Vy and 8 knots above the Vy specified by the operator) when the valve was closed, the speed decreased gradually. This descent was such that by the time the second pilot had fully transferred control to the captain, 86 sec after the event, the speed had fallen from 73 KIAS to 39 KIAS, for a total loss of 34 kt. This significant reduction in speed was not detected by either crewmember, and is indicative of a failure to monitor the basic flight parameters. Both pilots focused on

the engine temperature, which affected their ability to maintain the basic flight parameters.

The same course was maintained before, during and after the emergency, even though they were approaching an area of rising terrain. The crew never considered turning around and going toward a flatter area, like the terrain they had flown over prior to the event. This situation forced them to make two tight turns, which made them lose even more speed, in order to skirt around the elevated terrain and land on a field inside that same area. These types of maneuvers could have been avoided since the surrounding terrain offered multiple options for flying over much more favorable areas.

2.5. Decision to make off-field landing

The cockpit recordings show that the leadership role throughout the emergency was exercised by the second pilot. He made every decision: the execution of the crank procedure, the decision to land and the selection of two fields for the landing. The decision to land and start the engine on the ground was not questioned by the captain since, as he indicated in his statement, he was considering this option when it was proposed by the second pilot, although the CVR did not contain any comments in this regard.

By design, the helicopter has systems that allow it to generate extra power (for 30 and 2.5 min) on a single engine. Even though in this flight neither system was able to be used because both engines were running (N1 above 58%), the crew did not know this. The engine failed in the least critical situation of all (returning to base in an area known to the crew due to its proximity to the base and in straight and level flight), and thus there was no great urgency to land. The helicopter was flying, it exhibited no problems or control issues, the cause of the emergency was known, they knew there would be no subsequent complications, and they had time. Only four minutes elapsed between the engine failure and the landing. That is, the situation, the area and the helicopter's performance would have allowed for a more calm assessment of the best place to land.

The CVR did not reveal any communications related to the ability to land elsewhere (nearby runways). And if either pilot did evaluate this internally, it was not reported to or shared with the other pilot. The crew neither considered nor confirmed, at least verbally, the distance needed for a single-engine landing, though it is true that the field selected was, in terms of its size, suitable for landing. Section 1.16.7 shows the location of four fields (apart from the Cuatro Vientos and Casarrubios airports), one of which they had just flown over after the event occurred. Every field had dirt runways that were long enough for a single-engine landing. At their speed,

they would have reached them in the same amount of time that it took them to make the landing (the furthest field was 6 min away and the nearest was 2.5 min away). The entire area they had flown over before also exhibited better conditions due to the lower elevation than the field where they eventually decided to land.

Despite the proximity of the base (only 7 km, equivalent to a 4-min flight), it would not have been possible to land there due to the landing distance available (LDA), which is only 37.7 m, and the helicopter needed at least 85 m, which made landing at the base impossible, as the captain stated. But it was not, as the captain explained, because of the presence of an oak tree, but because the LDA was not long enough.

In conclusion, all of these issues indicate that during the flight, they had not identified fields or areas in which to make an emergency landing, and that they also had not identified in the vicinity of the base any fields or runways that could be used to make a single-engine landing, considering that the helicopter cannot land on a single engine at the base. Or if they knew of such a field, the crew did not consider using it at any point despite its proximity. Landing on one of those fields would not have required prolonging the flight and would have facilitated the landing and a potential subsequent rescue.

Both pilots accepted the decision to land on a field despite the proximity to several dirt runways, which would have allowed for a safer landing of a helicopter with 12 persons on board. It is believed that this decision was influenced by the nature of the crew's daily activity. Firefighting and transport flights require landings to drop off and pick up personnel in unprepared areas. The assessment of the risk of this decision was highly conditioned by the routine nature of this type of maneuver in FF activities.

2.6. Approach and landing maneuver

Even though landing on a single engine is, according to information provided by the operator, the most practiced maneuver during type checks and training, its execution during this accident did not satisfy any of the specifications that is contained in the procedure. It included tight turns, changes in speed and altitude and no checklists were used.

The data contained in Section 1.11.3 show that during the final approach phase, the helicopter was at a higher altitude, a lower descent rate and a lower speed than required by the procedures. The fact that the crew had opted to land on sloped terrain without reconnoitering the field first resulted in complications:

- The field, which was large enough for the landing, sloped in both directions, though it was within the limits in the Flight Manual.

- The initial landing direction selected (306°, along the length of the field) had to be corrected (based on the CVR) due to the excessive gradient and to the furrows that were detected by the crew once they were already very close to the ground (as per the crew's statement).

- The final direction chosen (286°, along the width of the field) was better suited to landing in terms of the direction of the gradient, and in the direction of the furrows, since it was less favorable to tipping the helicopter over.

- This correction in the final landing course required a turn that coincided with a flare at almost three times the recommended altitude (58 m instead of 20 m).

All of this resulted in the landing commencing 5 m AGL, after turning, at 4 KIAS. The engine 2 was unable to maintain rotor RPM, and the helicopter impacted the ground. Since the engine 1 remained operative, the helicopter was not within the 30 min OEI operating conditions, which would have provided additional power.

The second, and maximum, operating mode, corresponding to the 2.5 min OEI option, was also not available because both engines were running above 58% N1.

As concerns the use of the 2.5 min OEI system, the crew did not know that engine 1 was running. They were making an emergency landing on a single engine in sloping, unprepared terrain with a squad of 10 persons on board. These conditions, which the crew thought existed, are deemed appropriate for using the extra power provided by this system, but they did not use it. In fact, neither pilot made any comments regarding its use. The use of this system is specified in the operator's procedures and in the Flight Manual as optional, at the pilot's discretion during engine emergencies. The failure to use the procedures and checklists, as well as excessive confidence, resulted in the crew underutilizing the helicopter's capabilities for the situation they thought they were in.

2.7. Reporting the emergency: to the squad and others

At the start of the emergency, while they were trying to restart the engine, the crew were focused on the event itself. However, more than 2 min elapsed between when they decided to land until they did so. Considering that the crew consisted of two pilots, the lack of information provided to outside parties involving the maneuver they were making is difficult to justify.

Outside parties refers to:

- The squad, firstly, and
- The CECOP, secondly.

Even though the crew probably did not expect the outcome that eventually occurred, the lack of any outside communications shows that they underestimated the risks of the operation they were undertaking.

First, there were ten people inside the helicopter who were at no point informed by either pilot of the nature of the emergency, or at least that they would be making an emergency off-field landing. Such a report is necessary because it allows the passengers to prepare themselves for the landing by assuming the brace position. In this case, because the firefighters seated close to the pilots sensed what was happening, they signaled the others, who were able to prepare for the landing.

Similarly, reporting to the CECOP that they were making an off-field landing due to an engine problem would also have been necessary in anticipation of the future need to locate and rescue the helicopter.

The operator specifies as required (section 1.17.2) the making of these two reports, using the instruction "call on the radio to report the emergency", which would have pertained to the CECOP, and "alert the passengers", which affected the squad. As for who has to make these reports, the documentation is inconsistent and should be revised by HASA so that the same criterion is used throughout its documentation, since depending on the document, this task is assigned to the:

- Second or stand-by pilot (FF and SAR OM-PART B.SOKOL), or to the
- Captain (HASA-OPS.PROT07 and HASA-OPS.SOP02).

The failure by both pilots to make these reports or to even mention this communication is regarded to be a consequence of the excessive confidence that the landing would be like any other and of their underestimation of the risk at hand.

2.8. Transporting the squad and its material

The operator had procedures (HASA.OPS.PROT07, HASA.OPS FORM05 and HASA. OPS.SOP02) on the transport of squads and their materials. It also had a course it taught squads on the procedures and safety measures to use when entering, exiting

and flying on the helicopter. At the start of the campaign, the squads had received this training, which had been provided by the operator's Safety Manager. This training was mentioned by the squad members during the interviews.

As for the aspects identified during the accident (use of helmets and Camelbaks and securing their tools on board), the operator's procedures specify the following:

- The helmet is only required when entering and exiting the helicopter.
- Whether a helmet is worn or not, the head must be placed firmly against the headrest so the neck is not bent.
- The back must be kept straight and against the seatback.
- Tools must be securely fastened and restrained.

With respect to these directives laid out by the operator and conveyed to the squads, the situation present in the cabin during the accident revealed that:

- The squad members did not know if they had to wear their helmets or not, as evidenced by the fact that some were and some were not. Those who provided more details about the procedure stated that it had to be worn when taking off and landing. If, as they all stated, the helmet does not fit in the headrest and prevented them from properly supporting their necks, the criterion should be to remove the helmet while in flight, in which case the operator should specify when and how to wear the helmet.
- The firefighters did not know if they could wear their Camelbaks or not, as evidenced by the fact that some were wearing it and some were not. The contents of the Camelbaks also varied between squad members, some of whom carried cutting materials in them. The operator should specify what materials for personal use squad members can have on board and how best to transport it. As with the helmets, the operator should define what can be carried in flight and how.
- The fire swatters were not tied down, even though the operator's procedure clearly states that all materials must be secured.
- The restraint used for the tool box was shown to be inadequate during the accident, since it broke loose and the material impacted a squad member.

In light of these results, it is deemed necessary to issue a recommendation to the

Regional Government of Madrid to have it, in concert with INFOSA and HASA, revise, expand and complete the procedures that are in place for transporting squads and their materials, in light of the lessons learned from this accident:

- What work material the squads can transport in the passenger cabin.
- What securing methods should be used to tie down this material, in light of the lessons learned in this accident.
- What personal material squad members can transport to ensure it complies with the brace position criteria. If the helmets and Camelbaks are not deemed compatible with the brace position, a determination must be made as to how and where to transport them in flight.

Moreover, steps must be taken to ensure that these criteria are known by the squads by enhancing the training they receive in this area, since despite the procedures in place and the training given, this accident showed that some of the procedures were not known or were not being applied.

In addition, the procedures mention the use of a hearing protection headset and goggles by the squad members, and a discrepancy involving which door (left or both) to use when entering and exiting, that HASA has to review.

2.9. Design and documentation of HASA's FF activity

The reference documentation for the operation that HASA performs is the Operations Manual for the firefighting activity. It is the base document that the operator uses to define, describe and detail how it conducts its FF operations.

The Operations Manual in which HASA detailed its FF operations was shared with the SAR activity. These two activities were described in 45 pages (for the SOKOL), as well as in a set of protocols (PROT or checklist) and general procedures (SOP). The information analyzed in HASA's FF and SAR OM that is applicable to this accident is provided in sections 1.16 and 1.17.

Regarding the FF and SAR OM. PART B. SOKOL

Sections 2 and 3 in Part B of the FF and SAR OM, devoted to operations in normal and emergency conditions, does not differentiate between the FF and SAR activities, and thus the contents are assumed to be the same for both operations.

The manual does not clearly specify which operation HASA does for FF (or for SAR).

The sections on the tasks assigned to the crew in normal and emergency situations contain expressions like:

- "In general, this operation will be single pilot"
- "For operations with two pilots"
- "For multi-pilot operations"

As concerns these three expressions, and based on the information contained in section 1.17.1 on RD 750/2014 and its guidance material, they are regarded as ambiguous as they do not clearly indicate what operation is conducted and what tasks the pilots who are on board the helicopter have to perform:

- The term "in general" is not a suitable expression for describing an operation in the OM. The OM must clearly define the type of operation involved, whether it is done always or not, and it must be in keeping with the approval from AESA.
- The term "single pilot" is not specific because a single-pilot operation may be performed with one or two pilots, and if it is performed by two pilots, it can involve procedures for one or two pilots, based on the guidance material.
- The term "operations with two pilots" also does not define the type of operation done, since having two pilots on board means nothing, as the operation can be multi-pilot or single-pilot.
- The term "multi-pilot" refers to an operation for which HASA is not approved, at least as far as the FF activity is concerned. The OM does not specify the activity to which the multi-pilot operation applies.

As indicated in section 1.17.1, specifying whether an operation is conducted with one or two pilots is not enough to describe the operation since the type of operation must be specified, along with the number of pilots for which the procedures are defined.

It can be assumed that when the OM mentions "operations with two pilots", it is referring to multi-pilot operations, meaning that all of the explanations regarding the use of checklists and the duties assigned to the pilot flying in which duties are assigned to the pilot flying and pilot not flying (PF and PNF), only refer to multi-pilot operations, which HASA does not use for FF.

Regarding the PROT or checklists

The OM contained checklists for those procedures included in the Flight Manual; that is, for the normal and emergency procedures associated with handling the helicopter. There were no checklists for the FF activity per se that could be carried on the aircraft and used by the crews. For FF operations, the operator had an SOP containing a description and theoretical explanation of how to carry out FF activities.

The PROT or checklists analyzed during the investigation were an almost exact copy of those contained in the Flight Manual, with some modifications. As concerns the literal nature of the content of the checklists, the following aspects are noted:

- The Vy speed had been preset at 65 kt instead of checking the relevant tables for the operating conditions on that day. This speed had been preset only in the "Single-engine landing" list. In other lists where Vy is also used, such as the "Single-engine power failure", the term Vy was maintained.

- In the "In-flight restart" checklist, the item directing the crew to perform the "Emergency stoppage of one engine" procedure had been deleted for the case in which the restart failed.

- The "Engine motoring" procedure had used the term "motor" instead of "crank" to indicate the position of the start switch. This term (Motor) does not exist in this helicopter.

- The tasks to perform were not numbered in the lists.

- The lists included references to apply the Flight Manual.

- The lists either did not include or, if they did, did not identify the memory items to be performed in emergency situations. These memory items were mentioned in Part B of the FF and SAR OM – abnormal and emergency procedures.

- The lists that could supposedly be used in multi-pilot operations did not identify task assignments or who performed each action or item on the list.

- The recommendation to use the 2.5 min OEI system is included before every normal takeoff and landing list; however, in the emergency lists, which are literal copies from the Flight Manual, it is left in the introduction and not added before each list associated with engine emergencies, which makes it impossible to use this system.

The remaining lists were a Spanish translation of the ones in the Flight Manual. As concerns the literal use of these lists, the same remarks made in section 2.11 to improve the manufacturer's lists apply to these.

As concerns the content, a review of the lists defined as applicable for one pilot (assuming that these refer to single-pilot operations with two pilots with procedures for one pilot) with respect to those defined as being for two pilots (assumed to be those that apply to multi-pilot operations) shows that their contents were exactly the same as the lists defined in the Flight Manual for a single pilot. In other words, if HASA was doing multi-pilot operations with the SOKOL helicopter, the lists it had written for said operations were not adapted to this mode of operation.

There was disagreement between how the lists were identified in Part B of the FF and SAR OM and the names of the lists (PROT). In each list there were different names depending on the page of the list. Specifically, in the edition in effect at the time of the accident, the checklists for normal, single-pilot operations, assuming that the operator used this term to refer to "single-pilot operation with two pilots with procedures for one pilot" operation (HASA.OPS.PROT09), had three different headings, none of which matched how the list was identified in the OM, Part B:

- Checklist normal SOKOL 1 pilot (FF and SAR OM, PART B).
- CHECKLIST SOKOL NORMAL PROCEDURES ONE PILOT (pp. 1 to 7).
- CHECKLIST SOKOL (pp. 8 to 16).
- CHECKLIST SOKOL TWO PILOTS (pp. 17 and 18).

The lists for the emergency procedures for one pilot in use during the accident also had different names depending on the page, and included the notices and task allocations described for the multi-pilot operation, which were inconsistent with the directives given in Part B of the FF and SAR OM:

- Emergency checklist SOKOL 1 pilot (FF and SAR OM. PART B).
- CHECKLIST SOKOL EMERGENCY PROCEDURES ONE PILOT (pp. 1 to 5).
- CHECKLIST EMERGENCY PROCEDURES SOKOL TWO PILOTS (pp. 6 to 47).
- "If two pilots are flying, the emergency will be handled by the PF, this means that the PF will continue flying and the PNF will read the checklist for the PF to execute" (pp. 3 of 47).

- "In the event of an emergency, the checklists will be used using the same procedure described in B2 (normal procedures)". This sentence refers to the fact that it is a single pilot who does and reads the list, following the do-verify method.

In conclusion, the operator's documentation (Operations Manual and associated procedures and checklists) involving how to operate in FF operations with the SOKOL helicopter needs a thorough review in order to clarify and define aspects such as:

- The ambiguities related to the specific definition of the operation type, avoiding the use of terms that do not allow for a clear identification of the type of operation being done.

- Which checklists must be used for FF flights, since the Manual is shared with the SAR activity.

- The contradictions pertaining to the tasks assigned to the two pilots in abnormal and emergency operations in order to make them consistent with the operation that the operator itself says it engages in and for which it is approved: single-pilot operation with two pilots with procedures for one pilot.

Regarding the procedures specific to the Fire Fighting activity

As noted earlier, the only procedures that have an associated checklist for use by the pilots in flight are those that were already present in the Flight Manual. The procedures to be used in fires are defined in two HASA documents (HASA-OPS. SOP01 and HASA-OPS.SOP10), which have no associated checklists for the pilots to use. In the specific case of SOP10, in addition to a description of how to operate and act in a fire, it contains a series of reports that must be made in the different phases of the fire.

SOP10 literally states that both the PF and PNF must make these reports, transcribed in section 1.17.2 and which contain a list of 40 phrases.

The phraseology used during the three load/drop cycles in the fire shows that the reports specified by the operator in its SOP10 procedure were not used. The terminology used by the crew was different and not all of the specified reports were made. Considering those that were made and those specified by the operator in its procedures, 29% of the required reports were made, distributed as follows:

- reports on approaches to loading areas (3): 50%, 30% and 20%

- reports on drops (3): 25%, 12%, 0%
- reports when landing with the Bambi bucket stowed (1): 50%
- reports when landing with the Bambi bucket not stowed (1): 36%
- reports when loading the squad (1): 33%
- reports on takeoffs (2): 25% and 50%

In addition to the quantitative value of the percentage of reports made, which are relevant to safety, the communications during the fire showed that:

- There was no verbal confirmation from the squad leader that the squad had exited and the helicopter was ok.
- The water drop test was not conducted, not even during the first loading cycle.
- During the second drop, the pilot not flying (in this case the captain) executed an action to drop the extinguishing agent without informing the second pilot.
- During the last takeoff to return to base, the second pilot's door had been left open and it was closed with the helicopter already airborne, resulting in a change in control during this phase.
- The sterile cockpit concept was not observed by the squad technician during the return flight to the base when he requested doing a reconnaissance flight.

The accident involving aircraft SP-SUC, owned by the same operator, HASA, one month after this accident, which was also doing a FF flight, revealed an even worse situation since communications were non-existent and none of the reports specified by the operator was made during the load/drop cycles, not even using different terminology.

2.10. Review of HASA's FF operation

The above sections of this analysis identified errors and violations made by the crew, but the only purpose for characterizing the crew's actions is to explain why a qualified and experienced crew make these mistakes. No pilot who can do something well does it badly on purpose, which is why the errors and violations made during an event are considered, from an accident investigation standpoint, as consequences or symptoms.

Errors help explain what triggered the accident, but they must be regarded as the consequences of a way of doing things. From this approach, all of the information presented in the previous sections (decision making, application of procedures, use of checklists, use of reports during the fire, task allocation, design of checklists and definition of the operation) can yield conclusions about HASA's operating routine.

Information was available on the actual practices during the normal phases of the transfer flight (two phases), the firefighting phases (eight drop cycles, three by EC-LQA and five by SP-SUC) during an emergency situation and by two different flight crews (crews of SP-SUC and EC-LQA) consisting of three captains, including the company's Safety Manager. An analysis of this information allows us to conclude that the mistakes made during the accident resulted from a routine working process established by the company. The operating procedures were not carried out as defined by the operator in its reference documentation. The use of checklists as a way to identify errors in the execution of these procedures was also not instituted. This working process meant that a mistake in the execution of a procedure resulted in subsequent actions not working (restart and engine motoring procedure) as a way to recover from the situation, since the procedures were improperly executed.

The "single pilot operation with two pilots with procedures for one pilot" mode was also not internalized. The fact that there were two captains on board without the tasks of each being clearly defined could result in situations like the one involved in this accident, with both pilots operating the helicopter during the emergency and ignoring basic activities like flying the helicopter or monitoring the basic flight parameters.

In this regard, the definition, description and implementation at the documentary level of HASA's FF operations contained ambiguities and there was no clear definition of the tasks that each crew member must assume in each phase of the flight. This was reflected in the operation during the accident flight, which saw a mix of single-pilot and multi-pilot operations.

In conclusion, this accident has highlighted the need to review HASA's FF operations on three levels:

- There was a great different between the HASA fire fighting theoretical design of the operation (as per documentation) with which was being performed during operations. This was evident not only in the transfer flight phases but in the fire fighting operations. In order to eliminate this gap, the regular supervision performed by the operator itself must be increased or improved, assuring HASA is capable to know how actual operations are performed.

- The operator, HASA, with the lessons learned from this accident and accident

A-031/2016, should review the contents of the documentation it has written for this activity, since one of the factors that could explain why crews do not apply a procedure may be that it is not easily applied to the operation. This review should cover two areas:

- A review to ensure that the procedures contain all the steps and tasks needed to achieve the goal pursued by each procedure and that the person responsible for doing each task is clearly defined.

- A review of the procedure's applicability to actual operations, considering, for example, the large number of reports to make during a fire and that makes compliance very difficult during each load/drop cycle.

- It is necessary that the operator enhance the theoretical and practical training of its crews in the following contents and areas:

  - Basic flight procedures of the W3AS SOKOL.

  - Emergency procedures of the W3AS SOKOL.

  - Performance of the W3AS SOKOL in normal and emergency operations.

  - Firefighting procedures.

  - Operating procedures at the firefighting bases where HASA operates.

  - The use of checklists and monitoring as barriers to errors in single-pilot cockpits with two pilots.

  - Error and threat management in the cockpit adapted to single-pilot operation with two pilots.

  - Crew resource management (CRM) adapted to single-pilot operation with two pilots.

  - Crew cooperation or coordination techniques adapted to single-pilot operation with two pilots.

In short, the goal is to ensure that the Operations Manual is adapted to the firefighting operation for which HASA is authorized in a way that reflects the reality of the operations, and that there are effective mechanisms in place to identify gaps between the reality of an activity and how it is designed.

2.11. Procedures in the Flight Manual of the PZL W-3AS helicopter

The investigation focused on the procedures applicable to the causes of this accident. As explained in the preceding analysis sections and in the factual part (sections 1.16.4 to 1.16.6), several areas of improvement were identified involving the procedures, and which are the subject of safety recommendations issued to the helicopter manufacturer:

2.11.1 "Excess of Fuel in Either Engine Group of Cells" procedure

In the procedure "Excess of Fuel in Either Engine Group of Cells" (Section 3-Emergency Procedures, pp. 3-32), the term "exceeds" is deemed to be ambiguous, and gave rise to different interpretations by the flight crew. The procedure should detail the specific value that, when reached, makes the procedure applicable. Replacing the term "exceeds" by "is equal to" would clarify this procedure.

2.11.2 "Engine Restart in Flight" procedure

The following changes should be made to the "Engine Restart in Flight" (Section 3-Emergency Procedures, pp. 3-5) procedure:

- Move the step to check the engine TOT. This step is now the sixth item, and it should be the first step in the procedure. This would avoid, for example, avoid wet motoring or the autoignition that may have occurred in this case when the second step in the procedure was performed (engine lever to START).

- Specify what to do if the TOT exceeds 270° C. There is no explanation or redirection to another procedure. The procedure should contain the steps to take in this situation, which, according to the manufacturer, are:

  - Either wait until the temperature drops, which will occur as the air flows over the engine in translational flight,

  - Or perform the Motoring the engine procedure.

Neither action is contained in the procedure. The flight crew were unaware of the first option, which is not mentioned anywhere in the Flight Manual.

2.11.3 Maximum TOT values for starting the engine

The value of 270° C specified as the maximum temperature value should be reviewed, considering that the autoignition temperature of JET A1 fuel is 210° C,

and the temperature of the combustion temperature will always be higher than than registered by the TOT sensors.

2.11.4 "Motoring the engine" procedure

This procedure, included in Section 2 as part of the normal procedures for starting the engines, has three prerequisites that are not included as part of the steps in the procedure; rather, they are contained in an earlier list (Before starting engines), but should be included in the procedure:

- Engine power lever OFF
- Shut-off valve CLOSED
- Ignition switch OFF

The last two steps are redundant to the actuation of the starter system in the START position, in which, theoretically, the ignition and the fuel are kept closed. However, they are included as part of the preliminary caution in the procedure. The manufacturer should review whether the last two switches should be placed in the position indicated in the caution.

2.11.5 Mandatory pre-activation of the 2.5 min OEI system

In comparison with the applicable procedures in performance 1 (those included in Section 5A of the Flight Manual), the applicable procedures in performance 2 (those included in sections 1 to 4 in the Flight Manual) did not include the obligatory use of the 2.5 min OEI maximum power device. Since its pre-activation, by pressing the associated button on the collective grip, does not require using the system, but rather leaves open the possibility of using it automatically if necessary, this Commission does not understand why it is not pre-activated in every case.

A safety recommendation is issued in this regard so that the procedures in sections 1 to 4 of the Manual include the mandatory use of this device for the same cases where it is pre-activated for performance 1 operations (Section 5A).

3. CONCLUSIONS

3.1. Findings

General:

- The helicopter was engaged in firefighting and personnel transfer operations.
- The operator and helicopter had all of the permits and licenses needed to carry out the flight.
- The weather conditions were not limiting for the flight.
- The accident flight was the first of the day for the helicopter and the crew.
- The helicopter had enough fuel to make the flight.
- No component or system on the helicopter failed during the flight, ruling out any such influence on the accident.
- No elements involving prior maintenance on the helicopter were found that could have had an effect on the accident.
- The crew consisted of a captain and a second pilot under supervision.
- The captain had a total of 1245 flight hours, double what RD 750/2014 considers to be a highly experienced pilot. He had experience in the area and was rested, having just completed a vacation period.
- The second pilot had a total of 682 flight hours.

On the flight prior to the event:

- The transfer flight was made at an average speed of 70 KIAS.
- The engines behaved normally.
- The pilot flying during the flight to the fire and during the first and third load/drop cycles was the captain.
- The pilot flying during the second load/drop cycle and the return flight was the second pilot.

- No checklists were performed during this phase.

- 29% of the reports specified by the operator in its Operations Manual were made during the fire, though these reports were made using terminology that differed from that specified in the Operations Manual.

On the event:

- The event started with a mistake in the "Excess of fuel in either engine group of cells" procedure, when the fuel shut-off valve for engine 1 (left) was closed, when the intention was to operate the booster pump for that engine.

- The fuel shut-off valve was closed for 5 sec, after which it was opened again.

- When the event occurred, the aircraft was flying at 73 KIAS and it was 180 m AGL.

- 8 seconds after the event, the operating parameters for engine 1 indicated that it was stopped, and the crew confirmed that the engine was stopped.

- 9 seconds after the event, the values for engine 1 indicated that there was combustion in the chamber (TOT=620 to 680° C), a condition that persisted.

- The crew tried to re-start the engine but the TOT exceeded 270°, so they decided to perform a crank or "motoring the engine" procedure, but this did not work since the engine was started and combustion was ongoing and the procedure had been performed incorrectly. Because of this, they stopped the re-start procedure.

- 50 sec after the event, all the parameters on engine 1 indicated that it was running and operating at idle: TOT= 474°C, N1=73% and TQ=11%.

- The crew did not recognize the mode of operation of engine 1, thinking it was still stopped.

- Despite thinking that engine 1 was stopped, the crew did not confirm this (engine lever and shut-off valve in SHUT OFF and CLOSED, respectively), and the engine remained at idle for the rest of the flight.

- The 30 min OEI power and 2.5 min OEI power on engine 2 never became available since engine 1 was not stopped; instead, it was operating at N1 levels in excess of 58%. For all intents and purposes, both engines were running, only one of them was at idle.

- The Vy speed was not maintained at any point in the flight.

- The crew focused solely on the TOT for engine 1, ignoring the other aspects of the flight.

- The second pilot determined the actions taken during the event: he decided what procedure to perform, interrupted the captain and supervised the captain's actions.

- The basic tasks of maintaining speed and planning the rest of the flight were ignored during the emergency. The speed fell from 73 KIAS to 39 KIAS, and the course was maintained, which brought the helicopter closer to an area whose elevation complicated the landing.

- For 86 sec, both pilots were operating the helicopter in violation of the task allocation specified in the "single-pilot with two pilots with procedures for one pilot" operation for which HASA is approved.

- The "Single-engine power failure" procedure was not done and the checklist was not used.

- The "In-flight restart" procedure was done but the checklist was not used.

- The "Engine motoring" procedure was done incorrectly and the checklist was not used.

After the event:

- 86 sec after operating jointly with the second pilot, the captain took control of the aircraft.

- The crew, convinced only one engine was running, decided to land in a field and start the engine there.

- Four minutes elapsed between the event and landing. The crew rushed to find a field, even though the helicopter was flying perfectly well and they had enough time and space to select a more suitable location.

- When selecting the field, they did not consider other, safer options (there were dirt tracks they had just flown over that were long enough to make a landing on a single engine).

- The field they chose was at a gradient and had furrows that had not been

noticed previously, which forced them to make a turn at the last moment.

- The decision to land was not reported to the squad or to the CECOP, which have slowed a subsequent search and rescue mission had it been necessary.

- The approach and landing did not satisfy the shallow approach and landing criteria for a single engine (in terms of speed, altitude, heading or descent rate). The helicopter was turning until the final moments of the landing.

- Engine 2 was unable to keep the RPM needed to execute the flare.

- The crew did not use the 2.5 min OEI system. Even though this system was not available, the crew was unaware of this fact.

- The working implements of the squads were either loose (fire swatters) or improperly secured (box with cutting tools), and detached and moved about during the accident, falling atop one of the firefighters.

- Everyone aboard exited the helicopter under their own power.

- The second pilot took charge during this phase: he decided to land in order to start the engine, he selected possible landing fields, and monitored and supervised the captain's actions.

- The "Single-engine landing" procedure was done incorrectly and the checklist was not used.

On the operator and the definition of its Fire Fighting operation:

- The operator had procedures and checklists for the firefighting operation as part of the FF Operations Manual that it shared with the SAR activity.

- The operator was approved for the "single-pilot with two pilots with procedures for one pilot" operation for FF.

- The FF and SAR OM did not clearly define which operation was being performed and contained ambiguous terms involving the operation (single pilot, two pilots, multi pilot).

- The FF and SAR OM did not indicate which procedures were applicable to FF flights.

- The FF and SAR OM did not indicate which tasks were assigned to the crew for each phase of the flight and had contradictions in this regard.

- The procedures and checklists reviewed during this investigation contained aspects or contents subject to improvement, completion or correction. In some cases, the lists were incomplete and did not achieve the objective (like the "Engine motoring" or "In-flight restart" procedures), and in others, there was an excessive number of actions to take ("Communications at the fire") or there were inconsistencies between procedures (for example, setting Vy to 65 kt in all of the applicable procedures).

- The work material of the squads should have been tied down and secured, which was not done in the accident flight.

- Despite the information provided by the operator to the squad, the criteria specified by the operator for the use of the helmet and Camelbaks (how and when to use them) in order to assume the brace position were either not known or not used.

- The crew did the procedures from memory.

- The procedures were not fully executed and mistakes were made.

- The crew did not use checklists at any point during the flight, either during or before the emergency.

On the manufacturer:

- It is not clear from the Flight Manual if the "Motoring the engine" procedure can be performed mid-flight.

- The "Motoring the engine" procedure is not complete.

- The "Restart the engine" procedure does not list the steps to take when the TOT exceeds 270º C, and places this step sixth, when it should be first.

- The "Excess of Fuel in Either Engine Group of Cells" procedure uses the term "exceeds", which is ambiguous and gave rise to different interpretations by the crew.

- The applicable chapters in the Flight Manual make the use of the 2.5 min OEI system optional, not obligatory.

3.2. Causes/ Contributing factors

The accident of helicopter EC-LQA was likely caused by the incorrect execution of an emergency landing after making an approach maneuver in which proper speed, altitude and flight path values were not maintained.

The following potentially contributed to the accident:

- The failure to comply with the task allocation for the "single-pilot operation with two pilots with procedures for one pilot".

- The ineffective crew training in technical skills (helicopter systems and normal and emergency procedures), as a result of which:

  - They did not identify the nature of the emergency or the operational status of the engines.

  - Procedures were executed incorrectly, incompletely or not applied during the flight and the emergency.

  - Checklists were not used at any point during the operation.

- The ineffective crew training in non-technical skills (CRM) adapted to the "single-pilot operation with two pilots with procedures for one pilot", as a result of which:

  - Both crewmembers focused on the TOT and on looking for a field.

  - Basic flight activities, such as maintaining speed or monitoring parameters and gauges in the cockpit, were ignored.

  - There was a rush to land, which affected the choice of field.

  - The captain did not exhibit leadership during the emergency.

  - The second pilot supervised and instructed the captain during the emergency.

- Underestimation of the safety risk during the decisions made during the flight, as a result of which:

  - The crew did not consider safer landing areas.

- The emergency was not reported either to the squad or to CECOPS.

• The ambiguity in the documentary definition, description and implementation of the FF operation by HASA in its FF and SAR Operations Manual.

• The lack of supervision in the reality of its FF operations in terms of the theoretical operation as designed and described in its FF and SAR Operations Manual.

4. SAFETY RECOMMENDATIONS

The investigation has identified a series of aspects that can be improved in the procedures in the Flight Manual for the PZL W-3AS helicopter, which are addressed in five safety recommendations.

REC 37/18. It is recommended that the helicopter manufacturer, PZL-Swidnik, revise the "Excess of Fuel in Either Engine Group of Cells" procedure (p. 3.32) in the Emergency Procedures section of the Flight Manual for the PZL W-3AS helicopter, as indicated below:

- Replace the term "exceeds" by a more specific term that avoids ambiguous interpretations.

REC 38/18. It is recommended that the helicopter manufacturer, PZL-Swidnik, revise the "Restart in Flight" procedure (pp. 3-5) in the Emergency Procedures section of the Flight Manual for the PZL W-3AS helicopter, as indicated below:

- Relocate step 6 "Check for TOT below 270° C" such that this check is made before the procedure is started.

- Define the steps to carry out if the TOT exceeds 270° C.

REC 39/18. It is recommended that the helicopter manufacturer, PZL-Swidnik, review the 270° C value specified in the Flight Manual for the PZL W-3AS helicopter as the maximum TOT value for starting an engine, considering that the autoignition temperature of JET A1 fuel is 210° C.

REC 40/18. It is recommended that the helicopter manufacturer, PZL-Swidnik, review and modify the "Motoring the engine" procedure (p. 2-12) in Section 2, Normal Procedures, of the Flight Manual for helicopter PZL W-3AS to include the necessary conditions as part of the procedure:

- Engine power lever in OFF position

- Fuel shut-off valve in CLOSED position

- Ignition switch in OFF position

REC 41/18. It is recommended that the helicopter manufacturer, PZL-Swidnik, amend sections 1 to 4 of the Flight Manual for the PZL W-3AS helicopter to

require the use of the 2.5 min OEI maximum power generation system for the same situations for which it is specified in Section 5A.

The investigation has served to highlight the deficiencies and ambiguities present in the firefighting operation defined by HASA in its documentation. Moreover, there was a large gap between the firefighting operation as defined in its documentation by HASA and the reality of this operation.

In order to ensure that this review of the operation is conducted at the documentary level, that this method of operation is in fact executed in the flights and that effective, long-term oversight is provided to guarantee that this gap between design and reality does not exist, the following safety recommendations are issued:

REC 42/18. It is recommended that the operator, HASA (Hispánica de Aviación), incorporate into its procedures and checklists the five modifications issued to the manufacturer (REC 37/18 to REC 41/18)

REC 43/18. It is recommended that the operator, HASA (Hispánica de Aviación), conduct a thorough review of the firefighting activity that is defined, described and implemented in its FF and SAR Operations Manual and associated documentation. This review should be in agreement with the "single-pilot operation with two pilots with procedures for one pilot" for which it is approved, and must consider all of the deficiencies identified in the analysis of this accident:

- Clear and unambiguous definition of the type of operation involved in FF to have it be consistent with the approved "single-pilot operation with two pilots with procedures for one pilot".

- Clear and specific definition of the tasks assigned to each crewmember for the "single-pilot operation with two pilots with procedures for one pilot" for the different phases and stages of the FF operation.

- Unequivocal definition and identification of the checklists that apply to the FF operation, making sure they are uniformly identified throughout the documentation.

- Review of the FF operation procedures to ensure they can be viably performed on flights.

- Review of the checklists applicable to HASA's FF activity to make sure they comply with the checklist writing recommendations not only in terms of format, but also of content, ensuring they contain all the information needed to carry out the procedure and the logical execution sequence.

REC 44/18. It is recommended that the operator, HASA (Hispánica de Aviación), enhance its theory and practical training for all its FF pilots who fly the PZL W-3AS SOKOL in the following areas:

- Basic flight procedures of the W-3AS SOKOL.
- Emergency procedures of the W-3AS SOKOL.
- Performance of the W-3AS SOKOL in normal and emergency operations.
- Firefighting operating procedures.
- Operating procedures at the firefighting bases where HASA operates.
- The use of checklists and monitoring as a barrier against errors in cockpits with "single-pilot operations with two pilots with procedures for one pilot".
- Error and threat management in the cockpit adapted to "single-pilot operations with two pilots".
- Crew resource management (CRM) adapted to "single-pilot operations with two pilots".
- Cooperation or coordination techniques among crewmembers adapted to "single-pilot operations with two pilots".

REC 45/18. It is recommended that the operator, HASA (Hispánica de Aviación), jointly with INFOSA and the Regional Government of Madrid, conduct a review of the procedures in place for transporting squads and their work material that considers the areas of improvement identified in the analysis of this accident:

- What work material of squad members can transport in the passenger cabin.
- What personal material of squad members must be used in every phase of flight to ensure it can be adapted to the brace position. If the helmets and Camelbaks are deemed to be incompatible with assuming the brace position, a determination must be made as to where and how to transport them in flight. Likewise, if the protective headset and goggles are not used, they must be removed from the applicable FF procedures.
- What methods are used to tie down work materials and any other personal materials, considering the lessons learned from this accident.

- The same criteria involving which door to use when entering and exiting the helicopter must be used throughout the documentation.

REC 46/18. It is recommended that the operator, HASA (Hispánica de Aviación), jointly with INFOSA and the Regional Government of Madrid, enhance the training received by squads on the procedures and safety measures they must use and apply during helicopter flights in FF activities.

REC 47/18. It is recommended that the operator, HASA (Hispánica de Aviación), set up effective, periodic and long-term oversight mechanisms for its FF activity in order to:

- Ensure that the actual operation of FF flights conforms to the design of the operation.

- Identify discrepancies between the reality of the flights and how the operation is designed.

REC 48/18. It is recommended that the Emergency Department of the Regional Government of Madrid, which is responsible for the service, set up periodic oversight mechanisms for the firefighting prevention service it has contracted that take into account the findings and analyses of this investigation.

REC 49/18. It is recommended that the National Aviation Safety Agency (AESA) enhance its supervision of HASA to ensure that the modifications proposed in this investigation are implemented by the operator, ensuring that the design of the FF operation agrees with the reality of said operation and is in keeping with the "single-pilot operation with two pilots" for which it is approved.