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# Report A-035/2005

Accident ocurred on 13 July 2005 to aircraft PZL Swidnik W-3AS Sokol, registration SP-SUB, operated by Hispánica de Aviación in Tineo (Asturias-Spain)

MINISTERIO
DE FOMENTO

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SECRETARÍA GENERAL DE TRANSPORTES

COMISIÓN DE INVESTIGACIÓN DE ACCIDENTES E INCIDENTES DE AVIACIÓN CIVIL

Edita: Centro de Publicaciones
Secretaría General Técnica
Ministerio de Fomento ©

NIPO: 161-07-031-2
Depósito legal: M. 47.617-2006
Imprime: Diseño Gráfico AM2000

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# Foreword

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

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

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

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

# Table of contents

# Abbreviations

| | |
|---|---|
| 00° | Degree |
| BFU | Bundesstelle für Flugunfalluntersuchung |
| CIAIAC | Comisión de Investigación de Accidentes e Incidentes de Aviación Civil |
| cm | Centimeter(s) |
| CRS | Certificate release to service |
| CVR | Cockpit voice recorder |
| EASA | European Aviation Safety Agency |
| FAA | Federal Aviation Administration |
| FDR | Flight data recorder |
| g | Normal acceleration |
| HS | Hydraulic System |
| HS1 | Hydraulic System number 1 |
| HS2 | Hydraulic System number 2 |
| IAS | Indicated Air Speed |
| ICAO | International Civil Aviation Organization |
| kg | Kilogram(s) |
| km | Kilometer(s) |
| kt | Knot(s) |
| MHz | Megahertz(s) |
| mm | Milimeter(s) |
| NM | Nautical mile |
| P/N | Part number |
| SAS | Stability Augmentation System |
| SCAAI | State Commission of Aircraft Accident Investigation |
| TWR | Control tower |
| UTC | Universal coordinated time |

# Synopsis

| | |
|---|---|
| Owner: | Heliseco |
| Operator: | Hispánica de Aviación, S. A. |
| Aircraft: | PZL Swidnik W-3AS Sokol |
| Registration: | SP-SUB |
| Date and time of the accident: | Wednesday, 13 July 2005; 12:45 UTC[1] |
| Place of the accident: | Tineo (Asturias) |
| Persons aboard: | 2 |
| Type of flight: | Aerial work – Fire fighting |
| **Date of approval:** | 31 January 2007 |

## Summary of the accident

The Civil Aviation Accident Investigation Commission was informed of the accident on the day after it took place. The same afternoon after being notified, an investigation team was sent to the crash site to begin the field investigation. The Polish SCAAI was notified of the accident as the investigating authority from the country of design and manufacture. The ICAO was also notified.

During the return flight from the site of the fire to the base at Tineo to refuel, aircraft SP-SUB was forced to make an emergency landing due to problems with the pressure in both hydraulic systems. As a result of the impact, the aircraft flipped over and came to rest on its left side. A fire broke out which resulted in the complete destruction of the aircraft. The two persons aboard, the pilot and the copilot, were able to get out under their own power. The copilot got out uninjured while the pilot suffered burns. The aircraft was completely destroyed.

The investigation has concluded that the probable cause of the failure in HS2 was a rupture in the ground circuit presure pipe P/N 37.59.006.00.00. The reason for the failure of the HS1 has not been determined. The report includes safety recommendations addressed to AENA, Heliseco, PZL, EASA and the Civil Aviation Authority of Poland.

[1] All times in this report are UTC. Local time is UTC + 2.

# 1. FACTUAL INFORMATION

## 1.1. History of the flight

On 6 July 2005, aircraft SP-SUB flew from Poland to Madrid for the purpose of performing fire extinguishing duties for the summer season out of the base in Tineo (Asturias), to where it flew on 7 July.

Six days later, on 13 July at 11:10 UTC, the Tineo base was notified of a fire in Candamo, 26 km away, to the north of Grado, to which two helicopters were dispatched, the accident helicopter and another helicopter, identified with the call signs B72 and B28, respectively.

At 11:13:48 UTC, when the FDR recording was initiated, the aircraft was at the Tineo base preparing for the flight. Two minutes later and with the aircraft still on the ground, the operational checks for both hydraulic systems were performed, first by disconnecting HS1 for two seconds, followed by HS2 for another two seconds. A second later the SAS was brought on-line.

At 11:17:50 UTC, the aircraft took off with a total of 11 persons on board: the pilot, the copilot, a fire coordination technician and eight firefighters. The aircraft headed for the fire on an average course of 65° and an IAS of 120 kt.

Two minutes after takeoff, at 11:19:55 UTC, the crew contacted Asturias TWR and notified it of their intentions. It stayed in contact with Asturias until 11:21:42 UTC. Afterward, it continued on course for five more minutes, changing to a heading of 080° with an IAS of 120-110 kt.

At 11:27:13 UTC, the aircraft arrived at the site of the fire and one minute later initiated a series of hovering maneuvers, first to unload the firefighters and then to start water drops with the bucket. The time between hovering maneuvers was of some 3 minutes and the aircraft reach airspeeds between the maneuvers of between 95 and 105 kt.

After making water drops for a little over an hour, it was agreed that SP-SUB would make one last water drop before going back to base to refuel and returning to the site to relieve the other helicopter that remained on station. At 12:36:36 UTC, after performing the last hovering maneuver, the aircraft informed that it was returning to Tineo to refuel. The return flight was initiated on a heading of 250° at 80 kt IAS.

At 12:42:46 UTC, at 1,121 feet AGL and an altitude of 2,300 feet, while flying at 83 kt IAS on a heading of 250°, problems appeared with the hydraulic system: for 39 seconds and on four consecutive occasions, there were intermittent low pressure indica-

tions on HS2. Thirty-nine seconds after the initial fault, the FDR recorded a continuous low pressure reading in HS2 until the time of impact. The aircraft was on a heading of 247° and the airspeed had increased to 100 kt. It was at about that moment that the pilot at the controls reported seeing hydraulic fluid falling from the overhead and right sections of the rear panel in the passenger cabin.

At 12:44:45 UTC, almost two minutes after the initial fault, a sustained low pressure indication came in for HS1. Course and airspeed parameters at that time were 257° and 90 kt and were maintained for another 18 seconds, indicating the flight was still under control.

Aircraft control became impossible after 12:45:03 UTC. The heading continued changing to the right until impact and the airspeed and altitude decreased. At 12:45:37 UTC, the helicopter made two radio communications of unknown content.

The aircraft finally impacted the ground at 12:45:46 UTC. The ground sensor had indicated initial contact 3 seconds before. The last recorded value for the heading was 101° with a 0 kt IAS. During the last few seconds prior to the accident, the FDR recorded a roll attitude of up to 20° to the right and 25° nose up, though the impact took place with a 22° left roll attitude and a 9° nose down angle.

The crash site was 2 km from the base at Tineo.

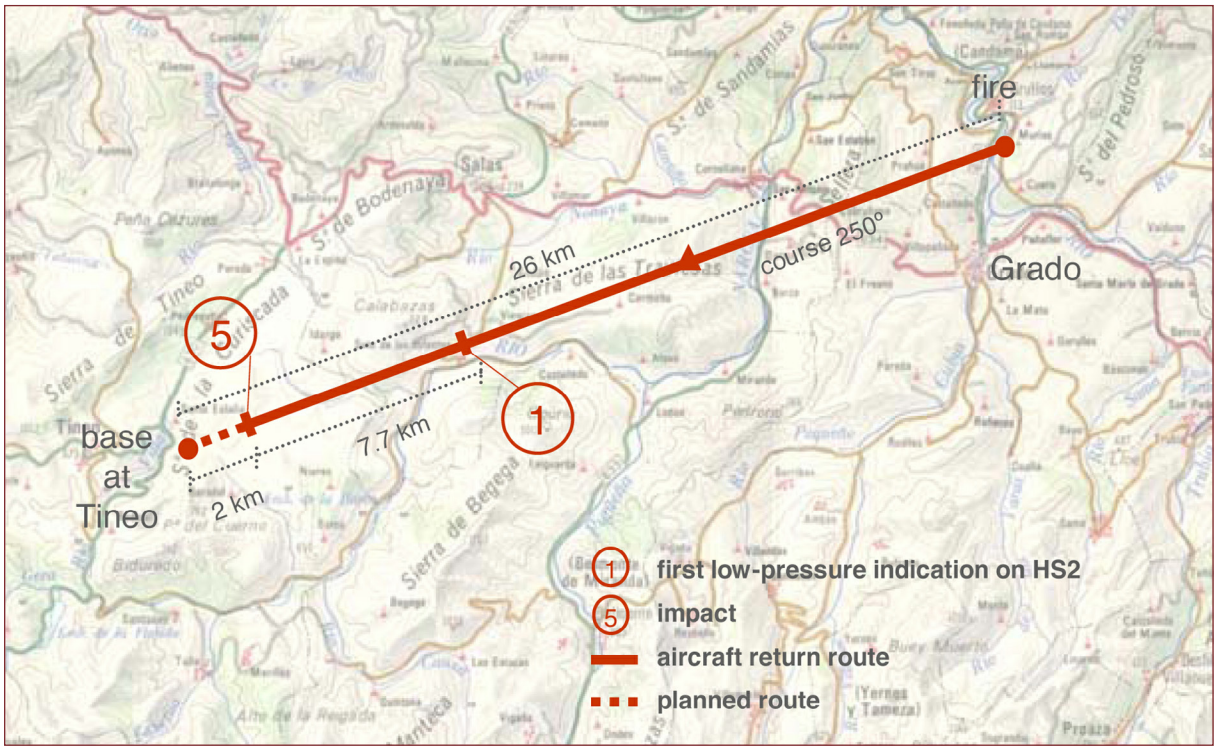


**Figure 1.** Return trajectory to the base from the fire

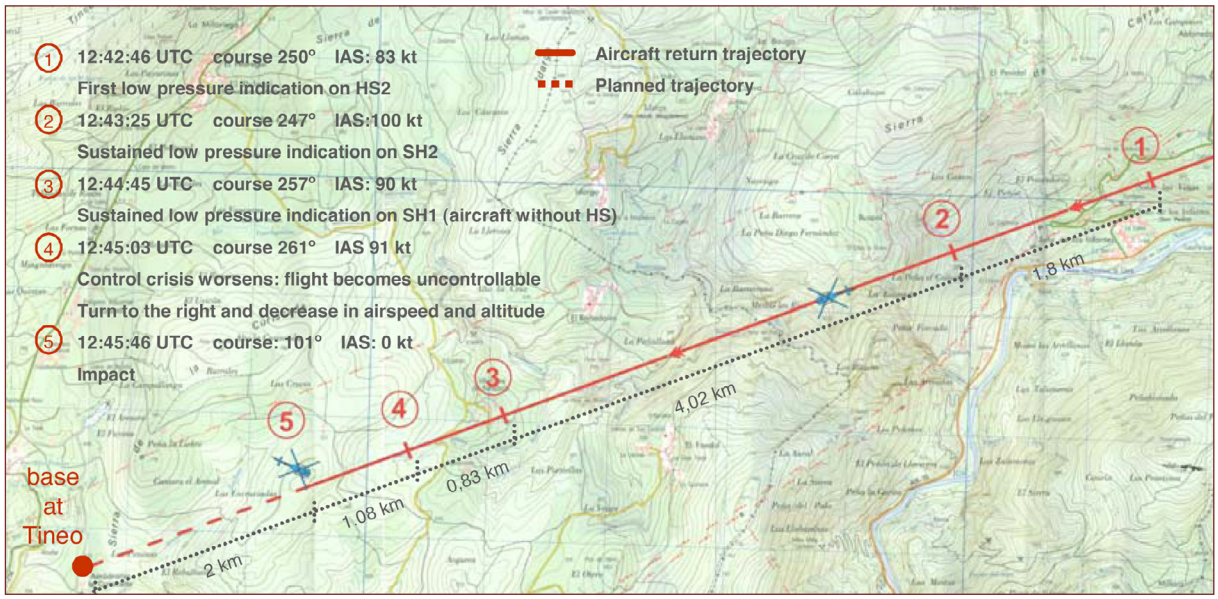


Figure 2. Trajectory during the last 3 minutes of the flight

## 1.2. Injuries to persons

The pilot and copilot were aboard at the time of the accident. The aircraft overturned and caught on fire after the impact, as a result of which the pilot suffered serious burns and cuts requiring a hospital stay of over 48 hours. The first to exit the aircraft was the copilot, who was seated on the right side and who, once outside, broke the pilot-side window and helped the pilot escape the wreckage, as the helicopter had turned over on the left (pilot) side.

## 1.3. Impact and damage to aircraft

The information provided by the FDR indicates that the pilot started losing control 43 seconds before impact at an altitude of 2,700 feet, with increasing roll and pitch movements. During that period of time the airspeed and altitude readings decreased (from 90 kt to 0 at impact) as heading changed (from 257° to 101° at impact), which is consistent with an attempted emergency landing on the part of the crew.

Three seconds before impact a ground contact signal existed for one second at an airspeed of 16 kt on a heading of 72° with a nose up, zero roll attitude. One second before impact the heading was practically unchanged but the roll had increased 20° to the right and the attitude was nose down. At the moment of impact, one final turn of 30° took place along with a change in roll to 40° left, consistent with the aircraft's final position. The maximum vertical, lateral and longitudinal accelerations recorded at the time of impact were 1.5, 0.08 and 0.03 g respectively.

Following the impact a fire broke out which completely destroyed the main fuselage and most of the tail boom. It was impossible to identify any cabin controls or any hydraulic system components of interest to the investigation. Remains from the main rotor blades were found in the vicinity of the crash site, though the majority of the wreckage was confined to within a 50-m radius of the crash site.

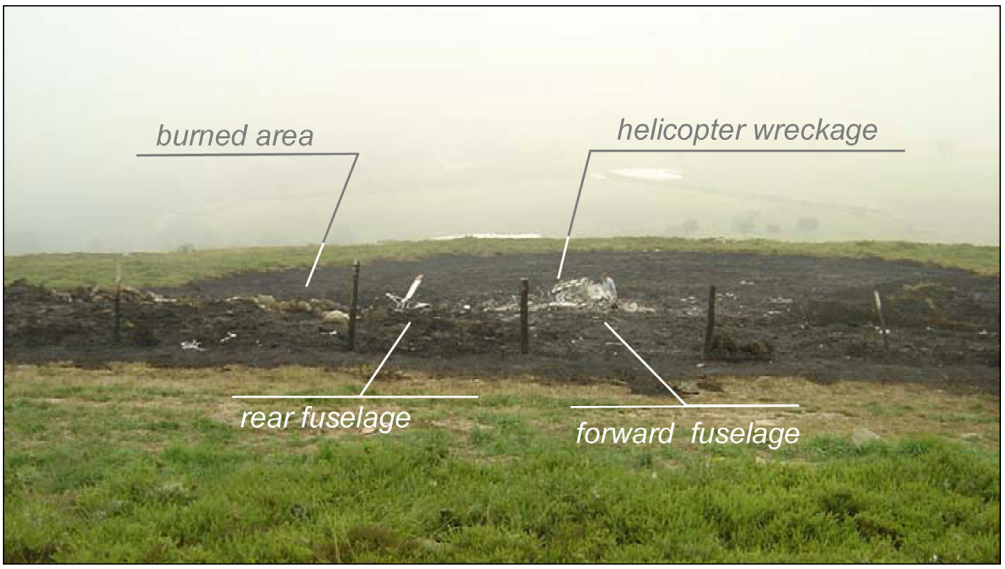


**Figure 3.** Overall view of the crash site

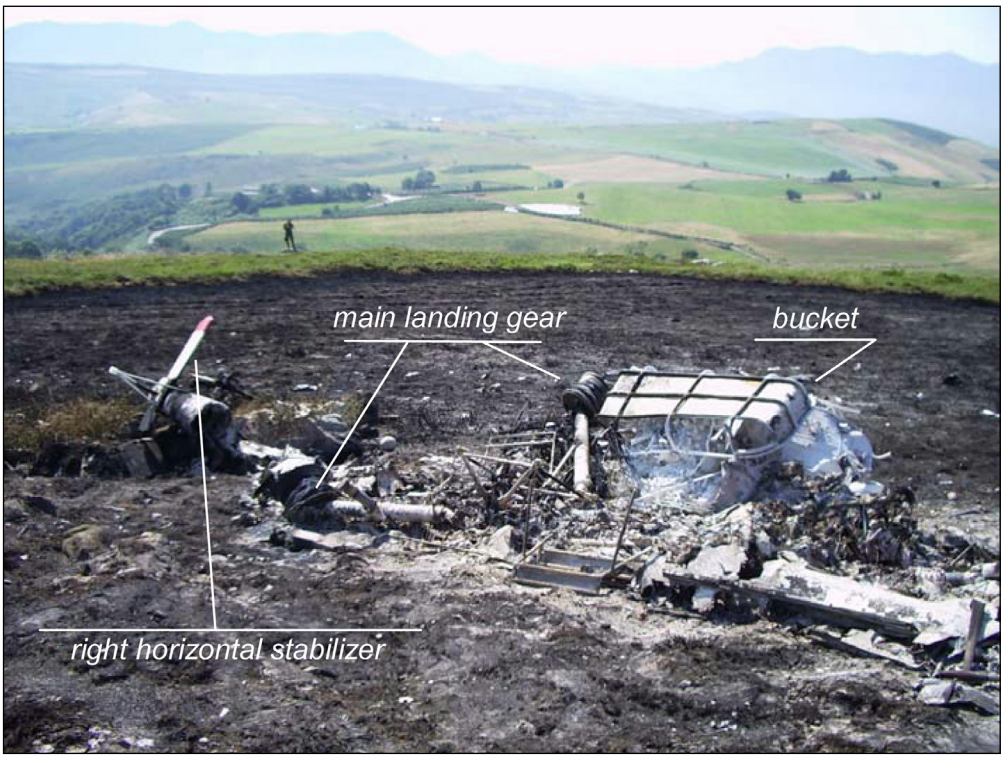


**Figure 4.** Final position of the aircraft

The crash site was 2 km away from the base at Tineo, on sloped terrain with scrubland vegetation. The area around the helicopter caught on fire.

## 1.4. Personnel information

The pilot at the controls, a Polish citizen, was 45 years old and had a commercial helicopter pilot license. According to information supplied by the operating agency, he had accumulated 5,490 hours total flying time, 2,427 of them aboard the W-3 model, 9 on the W-3A, and 104 on the W-3AS. He had flown a total of 33 hours during the previous month. On the W-3AS model helicopter, he had flown on 10 June, 4 and 5 July (the two flights made on 6 July to take helicopter SP-SUB from Poland to Madrid and from there to O'Barco), on 7 July he flew O'Barco-Tineo and, once at the base, he flew fire flights on 8, 9, 10, 11, 12 and 13 July. The pilot spoke Spanish and he was in charge of communicating with ATC and the ground coordinator.

The copilot, a Polish citizen, was 62 years old and had a commercial helicopter pilot license. He had accumulated 8,734 hours total flying time, 1,142 on the W-3 and 182 on the W-3AS, and had not flown on the W-3A. The copilot did not speak Spanish.

In the month before the accident the copilot had accumulated 20 hours flying time. He had flown 2 hours and 20 minutes on the W-3AS on 7 June, on 6 July he made the flight Madrid-O'Barco, on 7 July O'Barco-Tineo and every fire flight out of Tineo since then on 8, 9, 10, 11, 12 and 13 July.

Based on this information, the pilot and copilot had flown together as a crew a total of 18 hours 15 minutes before the accident. Of that time, 3 hours and 30 minutes had been on the ferry flight Madrid Cuatro Vientos-O'Barco-Tineo and 14 hours 45 minutes had been on fire flights out of the base at Tineo.

## 1.5. Aircraft information

The W-3AS helicopter, which had a type certificate issued by EASA on 15 March 2005, is considered a model of the W-3A type, even though it is physically adapted from the W-3 (the process for converting a W-3 into a W-3AS is specified in service bulletin BS 30-04-97 approved on 18/06/04). In August of 2005, there were a total of 23 W3AS helicopters.

In the specific case of accident helicopter SP-SUB, it was made in 1991 as a W-3. On 30 June 2005, the manufacturer, PZL-Swidnik, issued a CRS certifying the modification of the W-3 type into a W-3AS model in accordance with service bulletin BS 3004-97. The W-3, which is not certified by EASA, has two hydraulic systems which share the

same block. The FAA-certified W-3A has two completely independent hydraulic systems and two SAS systems. Lastly, the W-3AS model, certified by EASA, has two completely independent hydraulic systems but only one SAS system.

The airworthiness certificate was issued by the Polish Civil Aviation Authority and was valid from 1 July 2005 until 1 July 2006. The minimum crew complement consists of one pilot seated on the left side. The aircraft is licensed to carry up to 13 persons.

On 4 July 2005, during the vertical landing on a test flight at the manufacturer's facilities, a fracture developed in a pressure pipe in HS2 in one of the segments connecting the block with the ground service panel. According to the manufacturer, a break had developed on the final segment of pipe leading to the ground panel. A qualified mechanic replaced the pipe and the system was verified to be functioning properly, both on the ground and in flight.

On 6 July the aircraft made two ferry flights which took it from Poland to Madrid-Cuatro Vientos (with the accident pilot on board) and from Madrid-Cuatro Vientos to O'Barco (with the accident pilot and copilot on board). On 7 July the aircraft was flown to the base at Tineo. From that day on, the aircraft and crew activities were limited to fire flights as detailed below:

— On 10 July they made four flights (10:48-13:45, 14:52-15:23, 16:07-16:49, 17:08-18:22).
— On 11 July they made two flights (15:21-15:36, 15:50-17:50).
— On 12 July they made just one flight (11:38-12:58).
— On 13 July the first notification of the day informed of the fire to the north of Grado on whose return flight the accident took place.

## 1.6. Communications

### 1.6.1. *Recordings of ATC communications*

The aircraft maintained communications with Asturias TWR on a frequency of 118.15 MHz for a span of two minutes during which the crew, which had just taken off from Tineo, reported its intention to fight the fire toward which it was headed. The communications started at 11:19:55 UTC and concluded at 11:21:42 UTC.

Later, at 11:46:10 and 12:23:10 UTC, the tower controller unsuccessfully attempted to get in touch with the aircraft once again. The tower received news of the accident by means of a telephone call. According to information provided by the Asturias TWR Chief, radio coverage in that frequency in the center of Asturias is limited, preventing them from providing adequate warning and rescue services.

### 1.6.2. *CVR recordings*

The aircraft is equipped with a magnetic tape MARS-BM CVR with four audio tracks that record outside communications as well as those among the cabin crew, in addition to other sounds via a cockpit microphone. The CVR was first analyzed at ATM PP Sp.z o.o's facilities in Warsaw and later at BFU facilities. The CVR showed signs of heat damage as a result of the fire that had noticeably consumed the outer casing, leading to decreased quality in the recordings. It was through identifying the ATC communications with Asturias TWR that the conversations recorded were verified as corresponding to the accident flight.

Three of the CVR's channels correspond to the pilot's position at the left controls, the copilot's on the right and the area microphone, respectively. The fourth channel in this recorder was not used. Out of the three active channels, the area channel did not pick up any conversations. The two other channels picked up conversations in Polish between the crew, conversations in Spanish between the tower and other aircraft on the 118.15 MHz frequency, and lastly, conversations in Spanish between aircraft SPSUB, the other helicopter and the ground coordinator fighting the fire. The conversations recorded were transcribed and translated by the SCAAI (for the Polish fragments) and the CIAIAC (Spanish fragments).

The cockpit recordings started at 12:00 UTC, 42 minutes into the flight, while the aircraft was making water drops, and ended at 12:39 UTC during the return flight, 3 minutes before the first problem with HS2 appeared. Thus, the conversations recorded did not yield any additional information from the time of the accident and only referred to activities carried out in relation to the fire. Although ATC conversations made by traffic in the area were recorded, the call that Asturias TWR controller made at 12:23:10 to the aircraft could not be identified.

## 1.7. Flight data recorder

The BUR-1 FDR was downloaded at ATM PP SP.z o.o's facilities in Warsaw and later at BFU's facilities. The FDR was in a bad overall condition, with evidence of an inadequate repair to a break in the tape performed prior to the accident. The analysis of the FDR covered a period of 1 hour, 32 minutes and 41 seconds that encompasses the entire duration of the accident. The impact can be identified 43 seconds before the end of the FDR readings. Data after that point have not been considered in the investigation due to their low reliability.

There are two types of parameters recorded on the FDR: analog and digital. Figures 5 and 6 show the most significant parameters dealing with the final three minutes of the flight and related to the accident. Figure 5 shows the parameters involving

the cyclic control and their transmission to the main rotor, while figure 6 shows those involving the yaw control, the collective and data related to airspeed, heading and altitude. In both figures, vertical lines delineate the instants when the problems with hydraulic pressure occurred, the impact as well as two additional reference points where significant changes were noted in the helicopter's controllability and stability.

Data correlation between ATC communications, the CVR and the FDR allowed the time when the FDR recording began to be identified as 11:13:48 UTC, while the helicopter was still on the ground at Tineo with both engines running. The aircraft stayed on the ground a further four minutes and performed, among other things, the two-second disconnection of HS1 while maintaining HS2 operating, followed by the disconnection of HS2 with HS1 maintaining system pressure. Next, both systems were restored to operation and three seconds later the SAS was connected.

At 11:17:50 UTC the aircraft took off from the field, it proceeded to the fire site at a sustained 120 kt IAS on a heading between 65° and 80° until reaching the fire site at

11:27:13 UTC. It was during that segment, at 11:19:55 UTC, that the aircraft engaged in its only conversation of the flight with Asturias TWR. The aircraft initiated a turn to the left, decreased airspeed and made the first of 16 hovering maneuvers to drop off the firefighters and start the water drops.

At 12:33:22 UTC, after more than an hour and 15 minutes working, they agreed to make one more water drop and return to Tineo to refuel. The FDR had not recorded any problems with any of the aircraft's systems, including hydraulics. At 12:36:36 UTC the aircraft informed the other helicopter of its departure after having hovered one last time, and one minute later it was already on a steady 250° heading at 80 kt.

At 12:42:46 the FDR registered a 5-second pressure drop below minimum in HS2. The fault reappeared in increasingly longer intervals (7, 7 and 11 seconds) interrupted by 1, 2 and 1 second-long recovery periods respectively until finally, at 12:43:25, 39 seconds after the initial fault, a sustained loss of pressure occurred in HS2. The aircraft, which was on a heading of 250°, had covered 1.8 km in this time. From the first fault until 52 seconds after the sustained fault (12:44:17 UTC), all flight and flight control parameters remained unchanged with respect to the previous normal flight segment.

At 12:44:17 UTC, 28 seconds before the sustained fault appeared on HS1, the parameters for the cyclic and collective controls showed the first noticeable indications of change, although the yaw control, as well as heading, altitude and airspeed remained essentially unchanged. One second before the loss of pressure in HS1 took place, the SAS went off line.

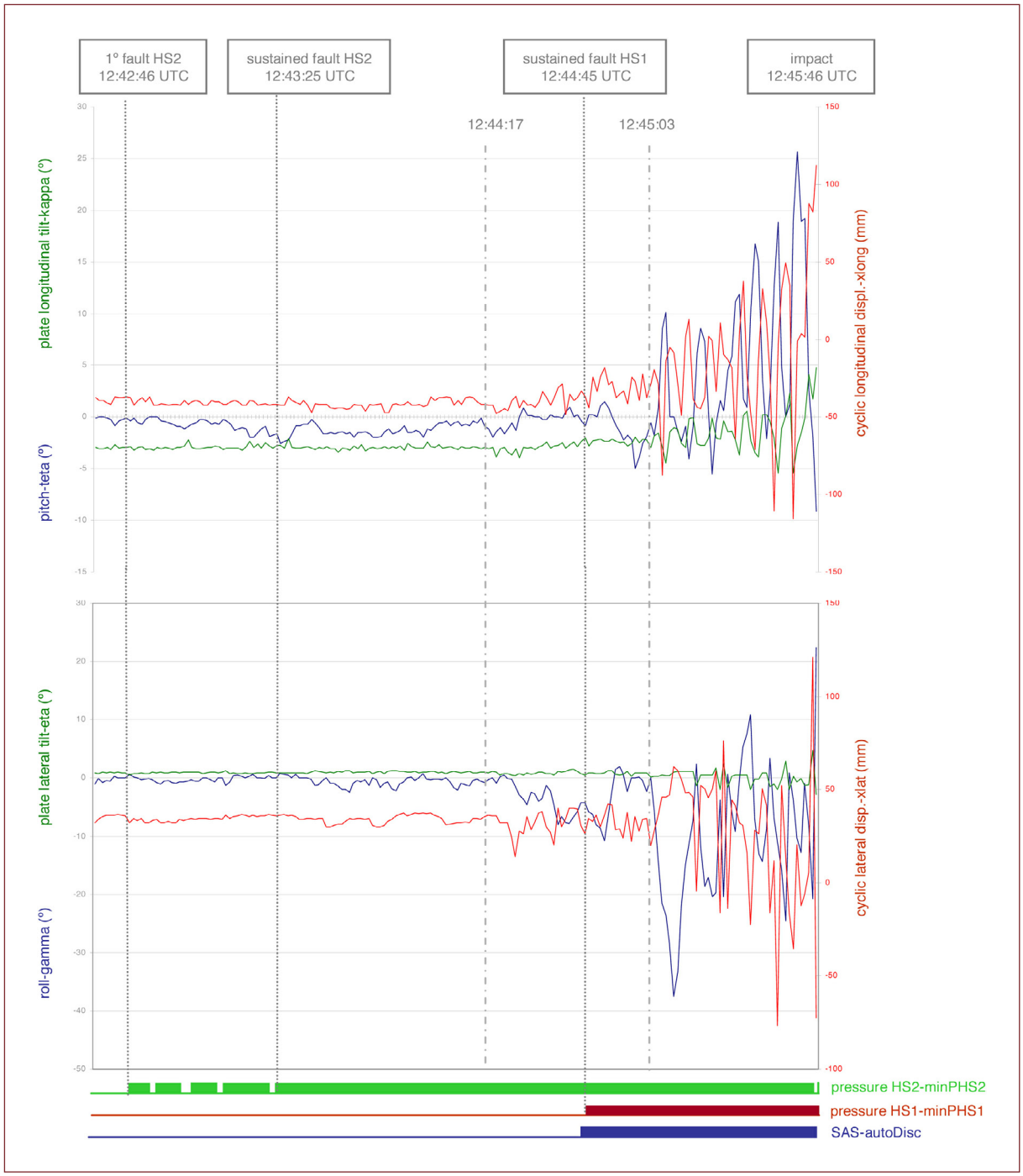


**Figure 5.** FDR parameters during the final 3 minutes of the flight associated with inputs to the cyclic control

Starting with these indications, once the aircraft had changed course to 260° and was flying at an average airspeed above 90 kt, the fault in HS1 occurred at 12:44:45 UTC, leaving the aircraft without hydraulics and 18 seconds later, at 12:45:03 UTC, all parameters indicate the control crisis deteriorated, with the appearance of temporary vertical accelerations, increasing longitudinal oscillations of the fuselage and an increasing yaw,

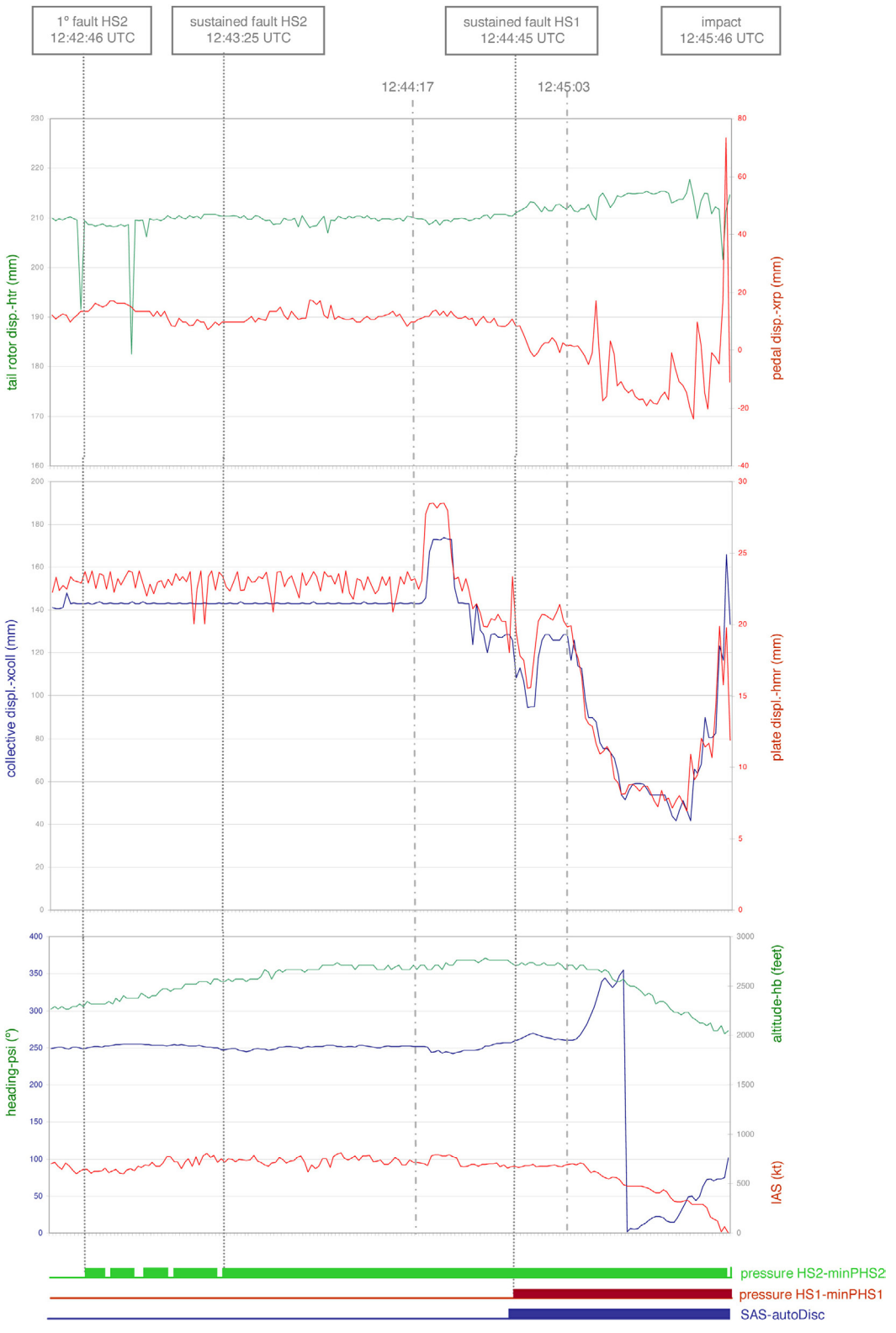


**Figure 6.** FDR parameters during the last three minutes of flight associated with inputs to the collective control and pedals and the flight profile

leading to an uncontrollable flight situation. Concurrent with the instability, there appeared the quick course change to the right and the drop in airspeed, altitude and engine power just before the impact, undoubtedly as part of the preparations for an off-field landing. Vertical accelerations of 1.5 g were registered during the impact. The aircraft covered 7.7 km from the time the first fault on HS2 was recorded until the end of the flight the aircraft.

During the entire flight, the parameters dealing with engine operation registered normal values. Likewise, the correlation between the inputs to the flight controls and the main and tail rotor movements was verified, thus discounting any problems with the transmission.

## 1.8. Hydraulic system

### 1.8.1. *Description*

The main purpose of the hydraulic system is to allow for control of the helicopter by reducing the forces required to operate the collective and cyclic controls (tilt and pitch) and the pedals (yaw). It consists of two completely independent hydraulic systems (HS1 and HS2) which allow for control via double hydraulic actuators. The system includes a single SAS system for in-flight pitch and roll control (unlike the W-3A which has two). The SAS on the W-3AS is control porwered from HS1.

Although both systems are normally in operation, there is a selector switch in the cockpit (figure 7) which allows both systems to be in operation (BOTH ON) or for one of them to be disconnected (SYST 1 OFF by flipping the switch up or SYST 2 OFF by flipping the switch down). Under normal conditions, both systems are selected, although there is sufficient hydraulic pressure to operate the actuators, and thus the helicopter controls, with just one system in operation. The same panel where the HS selector switch is located also houses two hydraulic system pressure indicators, which give information on each system's pressure, and two warning lights. The normal operating pressure is between 90-110 kg/cm$^2$. A drop in pressure to 70 kg/cm$^2$ will be reflected by the pressure gauge as well as by the warning light.

The operation of each system (Figure 8) begins as fluid is drawn from the reservoir, located in the block, by the hydraulic pump, whose motive force is supplied by the main transmission. From the pump, the pressurized fluid is sent to the block, which is designed to store fluid, direct it to the pressure lines, filter it, protect the system against over-pressure and monitor the operation. The lower part of the block houses the low pressure sensor for the system, which is associated with the warning light recorded by the FDR, the pressure transmitter that drives the manometer and the valve that disconnects the system when the cockpit switch is selected to HS1 OFF or HS2 OFF. From the block the fluid goes to the accumulator (which provides

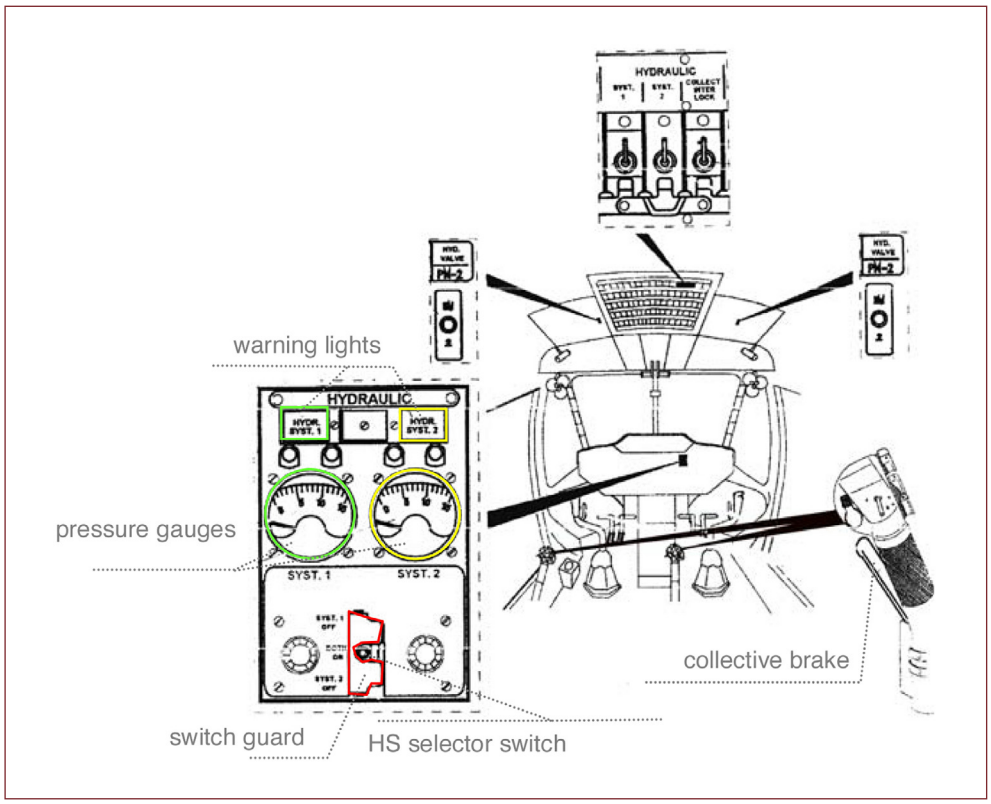


**Figure 7.** HS controls in the cockpit

additional pressure in case of sudden increase of power demand), manifold, valve block assembly and hydraulic lines connected to the roll, pitch, yaw and collective actuators. The operation of system 2 is analogous to that of system 1 with the added feature that it supplies the energy for the collective lever brake mechanism. All of these components are located in the upper part of the helicopter, atop the passenger compartment, such that a hydraulic leak in any of them would not reach the inside of the passenger cabin.

In addition to the main components described in the previous paragraph, each hydraulic system has a ground servicing circuit made up of two lines (a pressure line and a filling/suction line) which connect the lower part of the block with the ground panel located in the right rear of the main fuselage. Each ground circuit line has three pipes bundled together and arranged as follows: section I-II in figure 8 (made up of one pipe) goes from the block to the roof and section II-III in figure 8 (made up of two pipes) starts in the roof and runs along inside the passenger cabin.

The four lines, two from each HS, from the ground circuit inside the cabin (section II-III) follow the same path to the ground panel thanks to four clamps that fasten them to the structure. Figure 9 shows the arrangement of the ground circuit lines in another helicopter identical to the accident helicopter. Note how the path followed by section IIIII, inside the cabin, begins slightly in front of the panel that marks the end of the

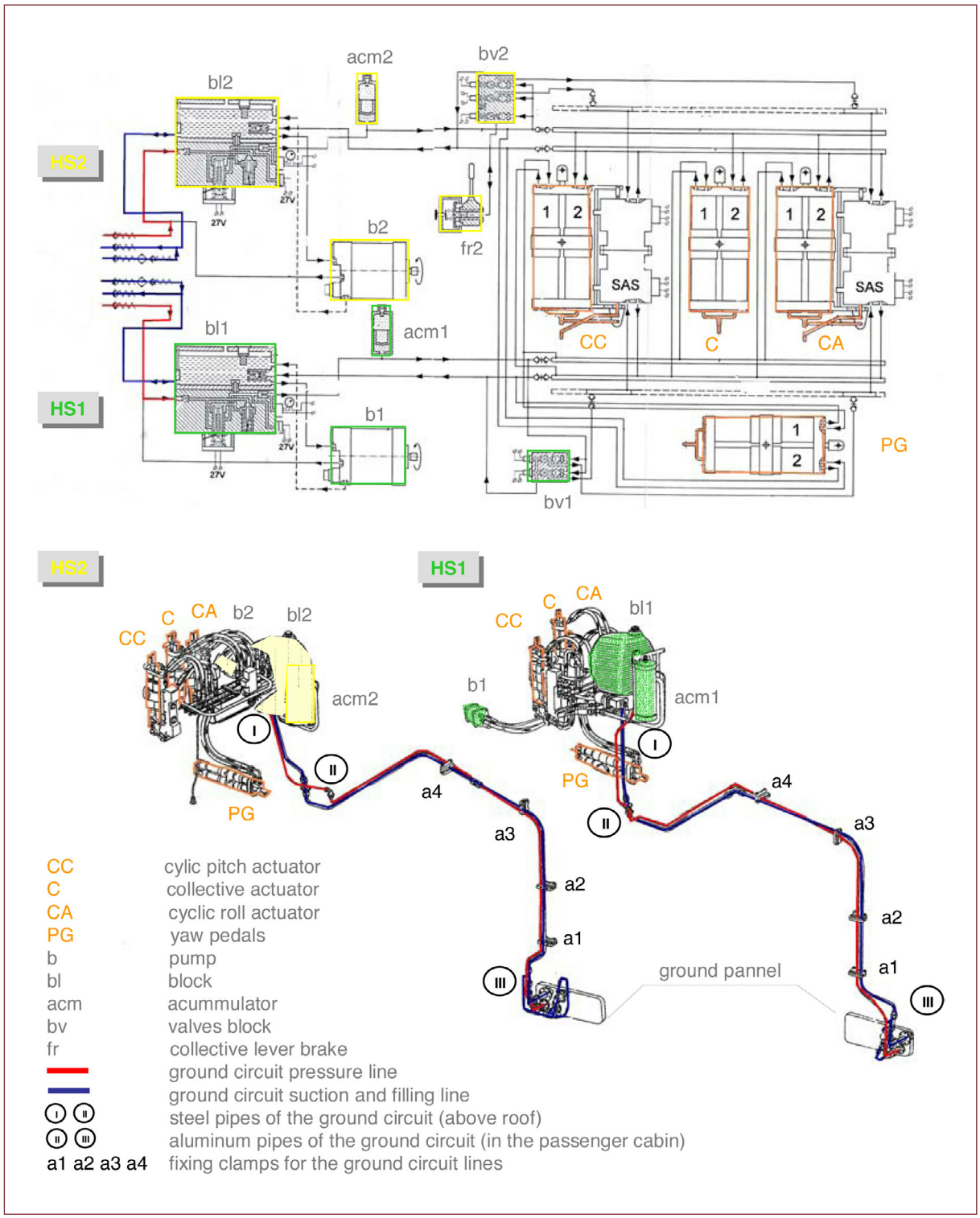


**Figure 8.** HS layout and distribution in the W-3AS

passenger cabin, penetrates it at clamp number 4, and from that point on runs behind the passenger cabin along the right side of the helicopter to the ground panel, held in place by the 3 other clamps.

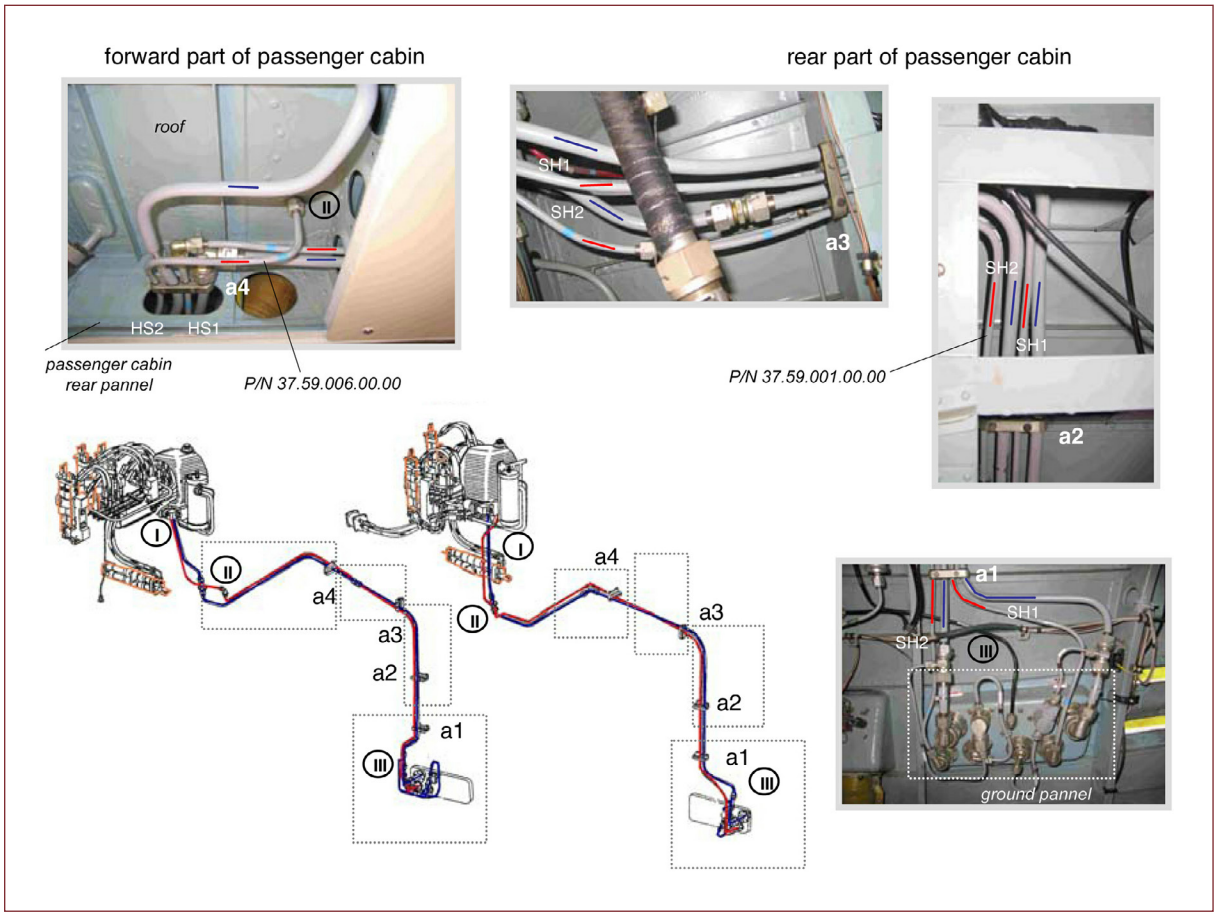


**Figure 9.** Section II-III of the ground circuit located inside the cabin

The ground circuit works as follows:

— During fill, the hydraulic fluid flows through the appropriate valves in the ground panel and from there through the filling/suction line (in the filling function) to the reservoir.
— When the system is energized from the outside, the external hydraulic pump sucks fluid from the reservoir and through the filling/suction line (in the suction function), passing through the corresponding valve on the panel. Once the external pump has supplied enough pressure, the fluid is returned to the system through the panel and the ground pressure pipe to the block, from where it is distributed to the other system components.

The materials and diameters of the ground servicing pipes vary according to the section and function, respectively (see table 1). The section of circuit in the helicopter's overhead, both for the discharge and filling/suction lines, is made of acid-resistant steel. According to the manufacturer, the reason for the different materials is that the main rotor's transmission gearbox compartment is classified as a fire risk area, and therefore all the pipes used there are made of steel. The remaining sections, which are inside the

passenger cabin and go to the ground panel, are made of aluminum alloy. As for the diameter, the discharge piping is smaller than the fill/suction line.

Table 1. Characteristics of the HS ground circuit lines in the W-3AS

| | PA2r aluminum pipes (section II-III in figure 8) | | 1H18N10TA steel pipes (section I-II in figure 8) | |
|---|---|---|---|---|
| | Pressure line | Filling and suction line | Pressure line | Filling and suction line |
| Diameter | 8 mm | 14 mm | 8 mm | 14 mm |
| Maximun working pressure in the aircraft | 100 kg/cm$^2$ | 0.15 kg/cm$^2$ | 100 kg/cm$^2$ | 0.15 kg/cm$^2$ |
| Maximun working pressure according to GOST 13977-72 standard | 150 kg/cm$^2$ | 80 kg/cm$^2$ | 480 kg/cm$^2$ | 260 kg/cm$^2$ |
| Minimun failure pressure according to GOST 13977-72 standard | 472.5 kg/cm$^2$ | 252 kg/cm$^2$ | 1,512 kg/cm$^2$ | 819 kg/cm$^2$ |

### 1.8.2. *Procedures*

The information and procedures associated with the hydraulic system as contained in sections 1, 2 and 3 of the flight manual are as follows:

#### Section 1-General

— Indicates the minimum and maximun hydraulic pressure limits of both systems as 90 and 110 kg/cm$^2$. It also specifies that they have no components in common, so that a rupture in one should not affect the other.
— Both systems must be operational before take-off. Turning off either system in flight is prohibited except in case of emergency (though the emergency is not specified in any section associated with the HS).
— It is impossible to control the aircraft with both hydraulic systems inoperable since the forces in the control systems are too large.

#### Section 2-Normal procedures

— The HS is checked in the following order before taxiing: check pressure gauges in both systems, displace controls to check for roughness or binding, disconnect HS1 and verify that its warning light comes on and that the pressure gauge drops to zero

after several displacements of controls, disconnect HS2 and verify that HS1 warning light extinguishes and that pressure returns to normal, followed by HS2's warning light illuminating and its pressure dropping to zero after cycling the controls. Adjust the friction brake on the collective to ensure the stick does not drop when released by the pilot and, lastly, place the HS selector switch in the BOTH ON position.

Section 3-Emergency procedures

— In case of a loss of pressure in HS1, its warning light would illuminate and the HS1 pressure gauge would read below 70 kg/cm$^2$. The procedure calls for:

1. Landing as soon as possible
2. If the controls are restricted, landing immediately.

— In case of a loss of pressure in HS2, its warning light would illuminate and the HS2 pressure gauge would read below 70 kg/cm$^2$. The procedure calls for:

1. Adjusting the collective control lever friction brake to allow moving it without undue effort and ensuring it does not drop since the brake is inoperative
2. Landing as soon as possible
3. If the controls are restricted, landing immediately.

— In case of a loss of pressure in one system, there may be some increase in control forces when aplying the collective to cushion landing.
— The term "land immediately" indicates the urgency of landing is paramount. The primary consideratoin is to assure the survival of occupants. occupants' survival is of the utmost concern.
— The term "land as soon as possible" indicates the need to land with no delay at the nearest suitable area at which a safe approach and landing is reasonable assured.

### 1.8.3. *Differences between the W-3, W-3A and W-3AS*

The differences in the hydraulic systems of the three SOKOL helicopters, the W-3, W3A and W-3AS are as follows:

— W-3 has two hydraulic systems that share the same block. Normal operation is always with the primary system (PRIMARY). There is an HS selector switch in the cockpit, as well as pressure gauges for each system and three warning lights above. The emergency procedures for the W-3 state that the first step for any hydraulic failure is to place the HS selector switch in SECONDARY.

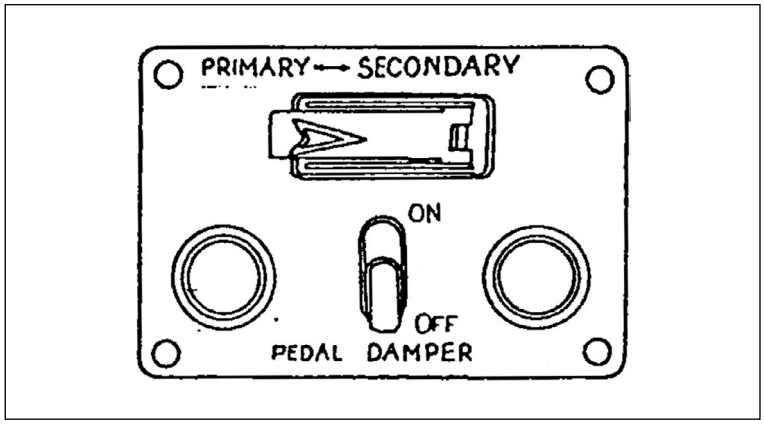


**Figure 10.** HS selector switch in the W-3 cabin

— W-3A and W-3AS have two independent hydraulic systems identical in every respect except one: the W-3A has two SAS systems, whereas the W-3AS only has one (powered from HS1). The W-3A's cockpit panel is different from that of the W3AS, which has the warning light, pressure gauge and HS selector switch situated together, whereas in the W-3A the warning light is separate from the selector switch and pressure gauge. Moreover, in the W-3AS the HS selector switch has a guard, not present in the W-3A, which must be lifted to the left to disconnect one of the systems. In the W-3AS, HS1 is disconnected by flipping the switch up while on the W-3A the switch is flipped down. As for the emergency procedures, they are the same for both models and neither mention any required actions for the hydraulic selector switch.

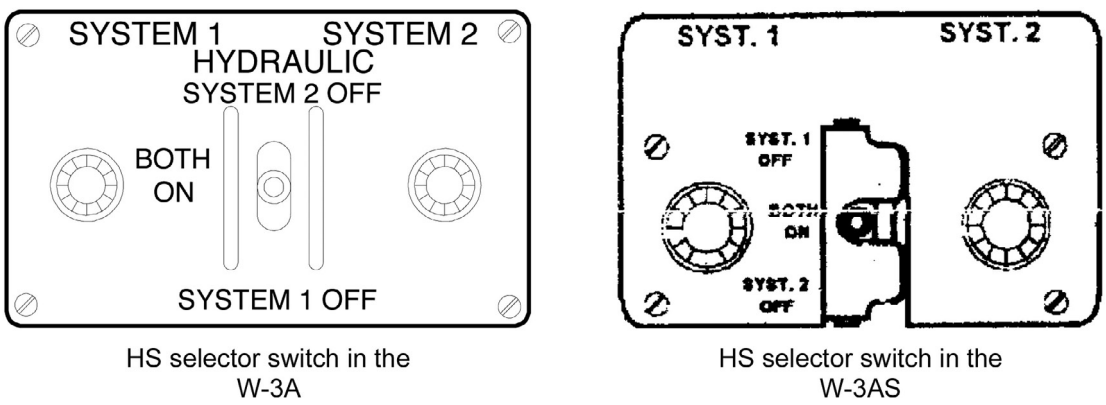


**Figure 11.** Differences between the cockpit HS selector suites in the W-3A and W-3AS

### 1.8.4. *Training*

Heliseco's training program for the W-3AS helicopter, approved by the Civil Aviation Authority of Poland, contains a practical exercise in which one of the two hydraulic sys-

tems is disconnected in flight. This program was carried out by the accident crew as part of the 23 pilots approved for this training.

### 1.8.5. *Prior occurrences of hydraulic system failures*

According to information from PZL-Swidnik, for the fleet of 23 W-3AS helicopters that had been modified from the W-3, by the end of 2005 there had been a total of 10 hydraulic system faults serious enough to render one of the two systems inoperable. Out of those 10 incidents, 6 of them (including the accident which is the subject of this report) showed a significant loss of hydraulic fluid directly related with breaks in one of the sections of HS2's ground servicing pressure piping.

In three of the 6 accidents a break occurred in pipe P/N 37.59.006.00.00 in HS2 (see figure 9). This pipe forms part of the ground circuit's pressure piping; specifically, it runs from the overhead to clamp number 4 just in front of the passenger cabin rear panel. The manufacturer determined that the failure was caused by a production defect of the pipes, and therefore new pipes were manufactured and sent to the operator.

In the other two accidents (one of them involving aircraft SP-SUB on the test flight of 04/07/05) there was a break in pipe P/N 37.59.001.00.00 in HS2 (see figure 9). This pipe forms part of the ground circuit's pressure piping and is in the last section just before the ground service panel located behind the passenger cabin between clamps 1 and 3. The manufacturer determined that the cause, in this case, was an improper installation of the pipe. In consecuence, the manufacturer initiated the elaboration process of a service bulletin (which was issued after the SP-SUB accident) and the manufacture of the needed components for its implementation. During this process, the SP-SUB accident took place.

## 1.9. Statements

### 1.9.1. *Pilot's statement*

The pilot, who was interviewed on 5 August 2005, stated that on the day of the accident he had been informed by the base engineer of a fire to the north of Grado, some 8 minutes away from the base. Before taking off they performed the hydraulic test, which gave normal readings. When they arrived at the site of the fire they dropped off the fire brigade (8 fire fighters and one technician) in a nearby field, and three of the firefighters deployed the bucket which was used for the water drops over the fire.

Later, they agreed with the technician to return to base to refuel before replacing the other helicopter on station. Four or five minutes into the return trip to Tineo, the HS2

warning light came on. He looked at the pressure gauge and saw that the pressure had dropped to zero and the warning light was steady. He looked behind him, saw large quantities of hydraulic fluid flowing out quickly and with considerable force in the rear part of the passenger cabin, and informed the copilot. Up until that point he had been at the controls, except for when he turned around to look behind him, when he handed the control over to the copilot. They adjusted the collective friction to neutral. The airspeed was around 90 kt.

After a few minutes the same thing happened with HS1: first the warning light came on and then the pressure gauge dropped to zero over a span of 10-20 seconds. Both pilots tried flying but they had to exert substantial pressure on the controls and the helicopter was swaying from side to side.

They touched down on a field, breaking the blades against some rocks, and the helicopter fell onto its left side, where the pilot was. After shutting down the engines and as the copilot was exiting by the right door, a fire broke out in the rear of the cabin near the right door.

They were within sight of the base when the first fault occurred. They did not do anything when HS1 failed, they just kept flying. They did not perform any checklists because there was not enough time. He also stated that they did not touch the HS selector switch in flight as it was prohibited, and can only be manipulated on the ground.

The pilot was aware of the problem that had taken place during the test flight of 4 July 2005. In his opinion, a flight with only HS1 in operation was problematic since the cyclic was very stiff under those conditions.

### 1.9.2. *Copilot's statement*

The information given to the CIAIAC during the field investigation by the copilot indicates that they received notice of the fire at 13:10 local time and that after having carried out other procedures, they checked the hydraulic system as part of the preflight check. Everything was in order. The hydraulic fluid level was 1 cm below the maximum.

They transported 9 firefighters to the fire, dropped them off, picked up water and made water drops. When they were some 5 km away from the base, where they were going to refuel, at some 300 m above the ground and going at 100 kt, the SH2 warning light began to flash until it finally stayed on. At that moment the captain saw hydraulic fluid "gushing" in the rear of the cabin and they noticed the pressure in both systems had dropped to zero. The controls were stiff and difficult to operate, so they attempted to land on a knoll. The three wheels touched down at low speed. They flipped onto the left side and a fire broke out. They unfastened their safety belts and he exited via his

door, the one on the right. He broke the window on the captain's side and helped him escape.

### 1.9.3. *Statement from the pilot at the controls on the test flight of 04/07/05*

As he was about to land during a test flight at the factory on 4 July 1005, some 2 meters above the ground, there was a fault in HS2 which left the collective stick without friction. There was hydraulic fluid visible in the fuselage, behind the right door near the ground panel.

### 1.9.4. *Eyewitness statement*

A witness claimed to have seen the helicopter swaying from side to side. It was going slowly and tried to land uphill from where it finally landed. It touched down, turned over and he saw how the blades were ejected. He saw the rotor functioning normally.

## 1.10. Safety measures adopted by the manufacturer

As a result of the accident, the manufacturer issued a mandatory bulletin BO-37-05176 in English and Polish, with which all W-3AS aircraft had to comply before making their next flight. In addition, Heliseco, as the owner, on the day following the accident prohibited any more operations involving the W-3AS helicopters in its fleet until they were in full compliance with bulletin BO-37-05-176. This bulletin, based on the pilot's statement that he saw hydraulic fluid in the cabin, identified the section of the ground circuit that runs under the helicopter's overhead as the most likely cause of the problem and directed the following temporary corrective actions:

— Disconnect the three hydraulic pipes from both hydraulic systems to the ground circuit's pressure piping, sealing the corresponding connections in the block and the pressure valve manifold to which the pipes were connected.
— Identify each of the 6 pipes in each helicopter and send them to PZL-Swidnik for subsequent testing and checks.

As a result of the accident and of previous events known to the manufacturer, PZL-Swidnik set up a working group to look into the causes of the hydraulic problems on the SOKOL helicopters. It reached the following conclusions. First, the tests performed on the damaged pipes, both from previous accidents as well as those sent in as a result of BO-37-05-176, did not reveal any flaws in the materials or their durability, but rather that the breaks and loss of fluids were due to incorrect bends in the pipes introduced during installation. The manufacturer further concluded that, for the most part, the problems with failures of the HS had taken place on W-3 helicopters which had been

modified in accordance with BS-30-04-97 and converted into W-3AS. As a result, PZL is reviewing and verifying the standards and reference models involving hydraulic piping as well as the relevant training for technical personnel.

As for the design of the ground circuit, the necessary modifications are being implemented to install a check valve both in the block as well as in the ground panel where the circuit's pressure line comes in.

# 2. ANALYSIS

## 2.1. Analysis of the flight

Aircraft SP-SUB had been operating for 1 hour and 29 minutes. At 12:42:46 UTC (3 minutes before impact) while on the return trip to the base at Tineo to refuel, at level flight, the aircraft experienced the first fault in HS2, which would become sustained 39 seconds later. One minute and 20 seconds after that, the sustained failure of HS1 occurred. The aircraft was able to fly for a further 61 seconds before impact without an available hydraulic system.

The 18 seconds following the complete failure of the HS indicate that the flight was still controllable, no doubt as a result of the accumulator (which for a limited time of 10-20 seconds can permit flying under emergency conditions). In the remaining 43 seconds before impact, however, the helicopter transitioned into unstable flight, with oscillations and increased pitching and tilting as well as vertical accelerations.

The flight profile during the 2 minutes and 17 seconds in which the problems with HS1 and HS2 became evident was not modified in that airspeed, altitude and heading were maintained, which suggests the crew's intention to get to the base and solve the problem there. The aircraft's uncontrollability during the last 43 seconds, however, made an off field landing imperative. This drove the crew to reduce altitude, airspeed and engine power in the last seconds before impact.

## 2.2. Preflight checks

The preflight procedures described in the flight manual include disconnecting each hydraulic system in turn and checking the cockpit indications for pressure and warning lights after moving the controls several times to check them for possible irregularities. The data recorded by the FDR regarding the performance of this preflight check indicates that each system was disconnected for 2 seconds, considered to be insufficient to be able to check the movement of the controls and the other actions outlined in the manual. It would only have allowed for a check of each system's low pressure warning lights.

The fact that the aircraft was flying for over 90 minutes before any problems appeared indicates that even if a thorough preflight check had been performed, it would not have indicated any anomalies. Still, it is important to emphasize the need to carry out the procedures detailed in the manuals in their entirety.

## 2.3. Emergency management

The flight manual directs the crew to land as soon as possible in the event of a failure in either of the two hydraulic systems. This implies landing without delay in the nearest

available area where a safe approach and landing can be effected. In the case of aircraft SP-SUB, the landing was delayed for the 3 minutes that elapsed between the initial problem indication with the hydraulic system pressure until impact. In that time the aircraft traveled approximately 7.7 km, in the course of which, despite the rough terrain in the area, three locations have been identified where a safe landing could have been carried out. The first possible location for a landing was Soto de los Infantes which, according to estimates, the aircraft should have been flying over when the first fault with HS2 occurred. Further ahead, to the right of the return path, was Buspol, approximately one kilometer distant from where the sustained fault in HS2 took place. Lastly, one kilometer further along in the trajectory was El Rañadoiro.

It is likely that their proximity to the base, the possibility of flying with one hydraulic system and the problems involved with rescue and repair when landing off field in an area like Asturias, led the crew to decide to continue flying to the base and not carry out the procedures detailed in the flight manual.

## 2.4. ATC communications

The intermittent ATC communications recorded by the CVR near Grado indicate a possible gap in the radio coverage provided by Asturias TWR on the 118.5 MHz frequency.

According to information supplied by the tower itself, said problem does indeed exist and is technical in nature, complicating and, in many cases, preventing them from providing the proper alert services. In fact, the unanswered calls made by the TWR to the aircraft at 11:46:10 and 12:23:10 were not received by the aircraft although the CVR did record conversations that took place after this last communication.

## 2.5. Problems with the operation of the hydraulic system

Due to the fire which broke out after impact and which completely consumed most of the piping located in the main gear box compartment, atop the overhead, and the ground circuits of both systems, no checks could be made of the hydraulic system installation in aircraft SP-SUB.

### 2.5.1. *Failure of hydraulic system number 2*

The installation and piping run of the hydraulic system indicate that the only event that would explain a loss of hydraulic fluid in the area of the passenger cabin as described by the pilot in his statement is a break in the ground circuit's first section, which is beneath the overhead just before clamp 4 (figure 9). The intermittent pressure fault in HS2, which over the course of 39 seconds became sustained, as shown by the FDR, is

consistent with a loss of hydraulic fluid associated with a pipe break. In addition, this pipe must have been on the pressure line, which operates at 100 kg/cm2 (as opposed with the filling/suction line which is under a pressure of 0.15 kg/cm2), which matches the pilot's description that the hydraulic fluid was pouring out with considerable force and in large quantities.

It is believed, then, that the faults witnessed and confirmed by the pilot indicative of low pressure in HS2 were likely the result of a loss of fluid due to a rupture in pipe P/N 37.59.006.00.00, which extends from the overhead to the rear of the panel that demarcates the limits of the passenger cabin (figure 9). More data in support of this possibility are the similar problems previously recorded and provided by PZL-Swidnik which indicate that it is in this line in HS2 where all the hydraulic failures ever recorded on the W-3AS have taken place. From among all the faults, breaks in the HS2 ground circuit pressure line account for over 50%. Specifically, there is a history of breaks in the same pipe that is thought to have fractured in the case of SP-SUB.

Regarding this subject, until the accident involving aircraft SP-SUB, the manufacturer did not take any corrective actions despite similar, previous breaks, the last of which even took place in its own facilities.

### 2.5.2. *Failure of the hydraulic system number 1*

From the time of the initial and then the sustained failure of HS2 until the failure of HS1, 119 and 80 seconds elapsed, respectively. Unlike the failure of HS2, the failure of HS1 was not gradual; rather, the indication was instantaneous.

The lack of remains following the fire has made it impossible to confirm the cause of the failure of HS1, though the following possibilities exist: the failure of a component in HS1 or an action taken on the hydraulic system selector switch in the cockpit.

HS1 and HS2 are completely independent in their operation since they do not share any components, which makes it possible to fly with just one system. That is why it is considered unlikely that the pipe rupture in HS2 was followed by another rupture in HS1, which would have given similar indications to those associated with HS2 and not an instantaneous, permanent drop in pressure. Although functionally the two systems are completely independent, the physical layouts of the ground circuits follow the same path inside the passenger cabin through the four clamps. Another possibility is that some problem or a displacement of one of the clamps caused the rupture in the pipes in HS1 and HS2, though that does not explain the different indications shown by the two systems.

The way in which the fault occurred in HS1 is consistent with a manipulation of the HS selector switch in the cockpit. Although the emergency procedures for the W-3A and W-3AS do not include any guidance to that effect, the W-3 model does include as the

first step to be taken during in-flight emergencies with the hydraulic system to actuate the HS selector switch, changing from the primary to the secondary system. The crew's background on SOKOL helicopters showed that it was on the W-3 model where they had accumulated most of their hours (2427 and 1142 for the pilot and copilot respectively) versus the 182 and 104 hours on the W-3AS, respectively.

Supposing a deliberate action was taken in the cockpit with the HS selector switch for the purpose of isolating the damaged hydraulic system, as is done during emergencies on the W-3, an added element of confusion is introduced by the fact that the position of the switch which disconnects HS2 on the W-3A, on the W-3AS disconnects HS1. Furthermore, the normal procedures in the W-3AS manual leave open the possibility of disconnecting one system in case of an emergency (without specifying the emergency). Regarding this possibility, it must be pointed out that while this action cannot be carried out that quickly (it involves moving the switch guard and then positioning the switch), it was carried out relatively late (80 seconds after the sustained failure of HS2) and, moreover, given that the aircraft was in the air a further 61 seconds, there was time to correct the action and return the switch to the BOTH position. It must be reiterated that both pilots were emphatic in their statements about not having touched the cockpit HS selector switch at any time.

Additionally, since the CVR was not able to provide any information, as it did not record the last minutes of the flight, no additional data exists about the crew's conversation in the cockpit during the emergency which might confirm one of the hypotheses postulated to explain the failure of HS1.

## 2.6. Design of the hydraulic system

According to the information provided by the manuals, the ground circuit with which each hydraulic system is equipped is used during maintenance tasks and has no bearing on the helicopter's normal operation. In spite of that, the ground circuit is not isolated and is therefore subjected to the same pressure as the rest of the system.

Because of this, and considering the history of faults which have occurred in this pressurized section of the HS2 circuit since the inception of the W-3AS model, it seems appropriate to rethink, on one hand, the real need for a ground circuit that causes so many problems without performing any in-flight functions and, on the other, should the circuit be retained, the pressing need to isolate this part of the system.

According to information provided by the manufacturer, PZL-Swidnik, the actions being taken are in line with keeping the ground circuit but installing valves to isolate it, and verifying the specifications for these lines as well as the training of the technical personnel involved in its installation.

# 3. CONCLUSION

## 3.1. Findings

— The crew's experience on the W-3AS consisted of 104 hours for the pilot and 182 hours for the copilot, in comparison with their experience on the W-3 (2,427 hours for the pilot and 1,142 hours for the copilot).
— The experience of the pilot and copilot working together as a crew was 18 hours and 15 minutes.
— The aircraft was built in 1991 as a W-3 and was modified on 30 June 2005 into a W3AS in accordance with BS 30-04-97 at the manufacturer's facilities and by its personnel.
— On 4 July 2005, during a test flight at the manufacturer's facilities, the aircraft had a problem in HS2 caused by a break in the ground circuit piping.
— The emergency procedure after a failure of a hydraulic system in the W-3 directs the use of the cockpit hydraulic selector switch.
— The emergency procedure following a failure of a hydraulic system aboard the W-3A and W-3AS models does not require taking any action with the cockpit selector switch.
— Normal procedures for the W-3A and W-3AS models prohibit disconnecting either of the two hydraulic systems in flight except for an emergency. Said emergency is not described in any of the aircraft's manuals.
— Actuating the hydraulic selector switch in the W-3A cockpit disconnects the opposite system than in the W-3AS.
— The CVR did not register the conversations in the cockpit during the accident since it ended three minutes before the emergency took place.
— The FDR registered data from the start of the flight until impact. It was, however, improperly maintained.
— 1 hour and 32 minutes into the flight, low pressure indications started coming in on HS2, and 39 seconds later the indications were sustained.
— 1 minute and 59 seconds after HS2 indicated a problem, a sustained low pressure reading came in for HS1.
— The aircraft flew for 3 minutes from the first sign of a problem until impact, 61 of those seconds without hydraulics.

## 3.2. Causes

Aircraft SP-SUB impacted the terrain due to the crew's inability to control the helicopter as a result of losing both hydraulic systems.

The pilot's statement, the fault mechanism registered by the FDR and prior history on other W-3AS models indicate that the failure of HS2 (which occurred first) was most likely the result of a rupture in the ground circuit pressure piping located under the passenger cabin overhead, P/N 37.59.006.00.00.

The reason for the failure of HS1 following the loss of HS2 has not been determined.

## 4. SAFETY RECOMMENDATIONS

**REC 01/07.** Keeping in mind the coverage problems noted on the CVR recordings and the information reported by the Tower Chief at Asturias, it is recommended that AENA review the low altitude radio coverage for the 118.5 MHz frequency in the Asturias TWR area of responsibility.

**REC 02/07.** Considering that the pre-flight checks for SP-SUB were not completed and that the response to the emergency involved an attempt to reach the base, forgetting that there are emergencies in which a landing cannot be delayed, it is recommended that the operator, HELISECO, remind pilots of the importance of strictly applying the procedures set forth in the aircraft manuals.

**REC 03/07.** Since no corrective or preventive actions were issued following the series of faults in the HS2 ground circuit which had taken place before the accident, including one at PZL's own facilities, it is recommended that EASA review the manufacturer's system for analyzing in-service faults so as to ensure they are adequately analyzed and that urgent actions are taken when appropriate.

**REC 04/07.** Given the history of faults in the ground circuit and this component's use only and exclusively in maintenance tasks, it is recommended that the manufacturer, PZL, study the design of the W-3AS hydraulic system ground circuits to evaluate the possibility of removing them or improving their current design.

**REC 05/07.** Given the differences found in the procedures to be followed in case of an emergency with the hydraulic system, as well as with the cockpit designs of the different SOKOL model helicopters, it is recommended that the manufacturer, PZL:

— Revise the normal and emergency procedures in the W-3A and W-3AS manuals so as to ensure consistency between the actions to be taken in case of a hydraulic system emergency.
— Provide operators with adequate training guidelines designed to increase and maintain pilot awareness concerning:

- The differences between the emergency procedures for a hydraulic failure in the W-3 as opposed to the W-3A and W-3AS models.
- The differences in the design between the hydraulic selector switch in the W-3A cockpit as opposed to the W-3AS.

**REC 06/07.** Due to the bad conditions in which the FDR was found, and the absence of any recording of the three last minutes of the flight in the CVR, and therefore of the emergency, which impeded completing and verifying certain aspects of the accident investigation, it is recommended that the Civil Aviation Authority of Poland, along with operators of SOKOL helicopters, models W-3, W-3A, and W-3AS, ensure the adequate state of the FDR and CVR in these types of helicopters.