Accident
Investigation Board
Norway

Issued September 2015

REPORT SL 2015/08

REPORT ON AVIATION ACCIDENT 24 JUNE 2014 AT HJERKINN IN DOVRE MUNICIPALITY, OPPLAND COUNTY INVOLVING AIRBUS HELICOPTERS AS 350 B3E, LN-OSY

The Accident Investigation Board has compiled this report for the sole purpose of improving flight safety. The object of any investigation is to identify faults or discrepancies which may endanger flight safety, whether or not these are causal factors in the accident, and to make safety recommendations. It is not the Board's task to apportion blame or liability. Use of this report for any other purpose than for flight safety shall be avoided.

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This report has been translated into English and published by the AIBN to facilitate access by international readers. As accurate as the translation might be, the original Norwegian text takes precedence as the report of reference.

Photos: AIBN and Trond Isaksen/OSL

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REPORT ON ACCIDENT

Aircraft:	Airbus Helicopters AS 350 B3e
Nationality and registration:	Norwegian, LN-OSY
Owner name/user:	Pegasus Helicopter AS, 2061 Gardermoen
Crew/commander:	1, seriously injured
Passengers:	4, of which 1 with minor injuries
Accident site:	In the vicinity of the Armed Forces' facility at Snøheimvegen at Hjerkinn, N62°13'52, E009°31'43
Accident time:	Tuesday, 24 June 2014, 1200 hours

All hours stated in this report are local time (UTC + 2 hours) unless otherwise indicated.

ACCIDENT NOTIFICATION

The Accident Investigation Board Norway's (AIBN's) on-duty officer received notification of the accident on Tuesday 24 June at 1200 hours from Pegasus Helicopter AS that one of their helicopters had been involved in an accident in the vicinity of Hjerkinn in Dovre municipality, and that several persons were on board. Shortly thereafter, the commander also notified the Joint Rescue Coordination Centre Southern Norway about the accident.

Two accident inspectors from AIBN responded and started investigation at the accident site the same evening. In accordance with ICAO Annex 13, "Aircraft Accident and Incident Investigation", AIBN notified the investigation authority of the manufacturing country France (Bureau d'Enquêtes et d'Analyses pour la Securité de l'Aviation civile - BEA). BEA appointed an accredited representative who, together with consultants from Airbus Helicopters and the engine producer Turbomeca, assisted in the investigation.

SUMMARY

The helicopter was chartered by the Norwegian Armed Forces for reconnaissance flights during the decommissioning of the artillery range at Hjerkinn. There were four passengers on board during the flight in question. Three of these were observers.

Immediately after take-off from the helipad, the yellow GOV light on the Caution and Warning Panel (CWP) illuminated, and a few seconds later, the engine started losing power.

The commander decided immediately to abort the flight, but had no choice but to execute a landing with forward speed. The energy in the main rotor was used to reduce the rate of descent.

When the helicopter hit the ground, it tipped forward, and came to rest on the left side with the nose in the opposite direction of the original flight direction. The pilot and passenger in the front seats were injured. The helicopter was completely destroyed.

In this accident, the sequence of events are documented by picture recordings and data from monitoring equipment installed as standard from the factory. The picture recordings made it clear to the AIBN at an early stage that the pilot had followed all procedures before lift-off. He carried out the emergency landing in the best possible manner under the prevailing conditions.

Extensive tests of the fuel system and engine with associated control systems, and data downloaded from components installed in the helicopter were analysed. These data indicated loss of engine power due to blockage of fuel supply to the engine.

It has not been possible to find a clear explanation as to what caused this blockage. The investigation has revealed that warning captions on the CWP did not illuminate, despite the loss of fuel supply.

The Accident Investigation Board Norway makes two safety recommendations with the submission of this report.

1. FACTUAL INFORMATION

1.1 History of the flight

1.1.1 The company performed reconnaissance flights for the Norwegian Armed Forces in connection with decommissioning of the artillery range at Hjerkinn. The assignment was to fly reconnaissance flights over the areas where the work was performed. The flights were carried out according to a fixed schedule, and the actual flight was the second flight of the day.

1.1.2 The first flight of the day had a duration of approximately 20-25 minutes, and was without incident. At landing, the helicopter had approximately 74 %[1] fuel, enough for the next flight.

1.1.3 The next flight was scheduled for 1200 hours, and well ahead of time, the commander walked out to remove the rotor moorings and to perform a pre-flight inspection. There were four passengers on this flight.

1.1.4 All passengers fastened their seatbelts, and a normal start was performed. The helicopter lifted to hover and rotated approximately 30 degrees right due to wind and choice of appropriate take-off path. The helicopter then accelerated. When the commander glanced at the instrument panel again, he observed the yellow GOV light on the CWP (see Figure 1). The helicopter had then moved outside the edge of the helipad.

[1]For this helicopter type, the fuel quantity is presented as a percentage of maximum capacity (540 litres).

Figure 1: First data frame from Appareo Vision 1000 showing lit yellow GOV light. Source: Pegasus Helicopter

1.1.5 The commander decided at once to abort the flight and intended to return to the helipad, but over the course of a few seconds loss of engine power occurred. He was left with no other option than to immediately perform an emergency landing without engine power in the terrain from a relatively low altitude. The helicopter had reached a speed of approximately 20 knots, and it was the intention of the commander to perform a landing with forward speed. An open spot in the terrain was selected as the landing site, but the commander quickly realised that it would not be possible to reach it. He then heard that the rotor RPM fell quickly and just before the helicopter hit the ground, the commander pulled the collective lever in an attempt to reduce the sink rate.

1.1.6 As the helicopter hit the ground, it tilted forward and came to rest on the left side, with the nose pointing in the opposite direction of the original flight path. The emergency locator transmitter started automatically. The commander climbed out through the right exit, after removing the door with the emergency release lever so that it would not block the exit for the passengers. From the outside, he assisted with the evacuation of the passengers. Battery power and the emergency locator transmitter remained on, until the commander had ensured evacuation of all passengers. The fuel tank remained intact after the collision with the ground.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatalities			
Serious	1		
Light/none		4	

The commander sustained spinal injuries and was transported to hospital in Trondheim where he stayed for 3 days.

1.3 Damage to aircraft

The aircraft was destroyed, see 1.12.2 for details.

1.4 Other damage

None.

1.5 Personnel information

1.5.1 Commander

The commander attended civil aviation training in USA in 1980. He converted to a Norwegian Commercial Pilot Licence the same year and began working as a pilot for Helilift at Fornebu. The commander has worked as a pilot in several helicopter companies, and has held multiple managerial positions until starting as general manager in Pegasus Helicopter in 2005.

1.5.1.1 The commander held a Commercial Pilot Licence for helicopter (ATPL-H). The rating for AS350 was renewed with a proficiency check (OPC/PC) on 7 April 2014.

1.5.1.2 The commander had a class 1 medical certificate, valid until 23 April 2015 with the limitation "*VML - Shall have corrective spectacles for near vision and carry a spare set of spectacles.* "

1.5.1.3 Flying hours

Flying hours	All types	Relevant type
Last 24 hours	1	1
Last 3 days	3	3
Last 30 days	11	11
Last 90 days	11	11
Total	6576	2600

1.6 Aircraft information

1.6.1 General information

1.6.1.1 AS350 B3e is a light single-turbine engine helicopter with three main rotor blades and conventional tail rotor. Significant parts of the helicopter consist of composite materials. The cabin has two doors on each side. The helicopter is equipped with dual controls. The helicopter's hydraulically powered flight control system is a single-circuit type.

1.6.2 Helicopter data

Manufacturer:	Airbus Helicopters
Type designation:	AS 350 B3e Ecureuil
Serial number:	7593
Construction year:	2014
Airworthiness Review Certificate issued:	9 May, 2014
Accumulated flying hours:	46.2 hours
Engine:	Turbomeca Arriel 2D
Serial number engine:	50261
Maximum continuous performance (MCP):	739 hp
maximum take-off power (MTOP)	860 hp
Diameter main rotor	10.69 m
Maximum mass:	2 250 kg
Mass empty (Pegasus configuration):	1 330.2 kg
Fuel:	Jet A1

The helicopter had 46.2 flight hours since delivery as new from Airbus Helicopters, and was therefore not overdue for any scheduled maintenance. There were no registered technical problems in the helicopter's log that could be related to the accident.

1.6.3 Mass and balance

	Arm	Mass (kg)	Moment
The helicopter's empty mass with equipment	3 513	1 330.2	4672.9926
Pilot	1.55	85*	131.75
Passenger in front seat	1.55	104*	161.2
Passengers in back seat	2.54	225*	571.5
Fuel	3 475	314.98[2]	1098.03
CG and total mass at the time of the	**3.22**	**2059.18**	6635.4726

*Standard mass as stated in BSL D 1-5 Section 5

The helicopter was operated within mass and balance limitations.

1.6.4 The take-off profile

The helicopter lifted to hover and turned 30 degrees to the right into the wind before accelerating. The terrain was sloping away from the helipad. The intention was to accelerate to 40 knots indicated airspeed before starting a climb. At a groundspeed of 5 knots, the yellow GOV light illuminated and at an indicated airspeed of 20 knots, the rotor RPM started to decrease due to loss of engine power. The helicopter hit the ground at a groundspeed of approximately 32 knots.

1.6.5 The helicopter's fuel system and associated warning systems

1.6.5.1 The helicopter has a fuel tank with a capacity of 540 litres. An electric pump installed at the bottom of the tank (see Figure 2) is used to pump fuel through the engine's Hydro Mechanical Unit (HMU) to avoid any air pockets in it in connection with start-up. The fuel is pumped through the engine's HMU, and returned to the tank via a return line. This pump is in use until the engine has started and has attained a gas generator (NG) speed higher than 67 %. The pilot then switches off the pump manually, and the engine's LP pump[3], which is a wing pump (see Figure 2), then lifts fuel from the tank.

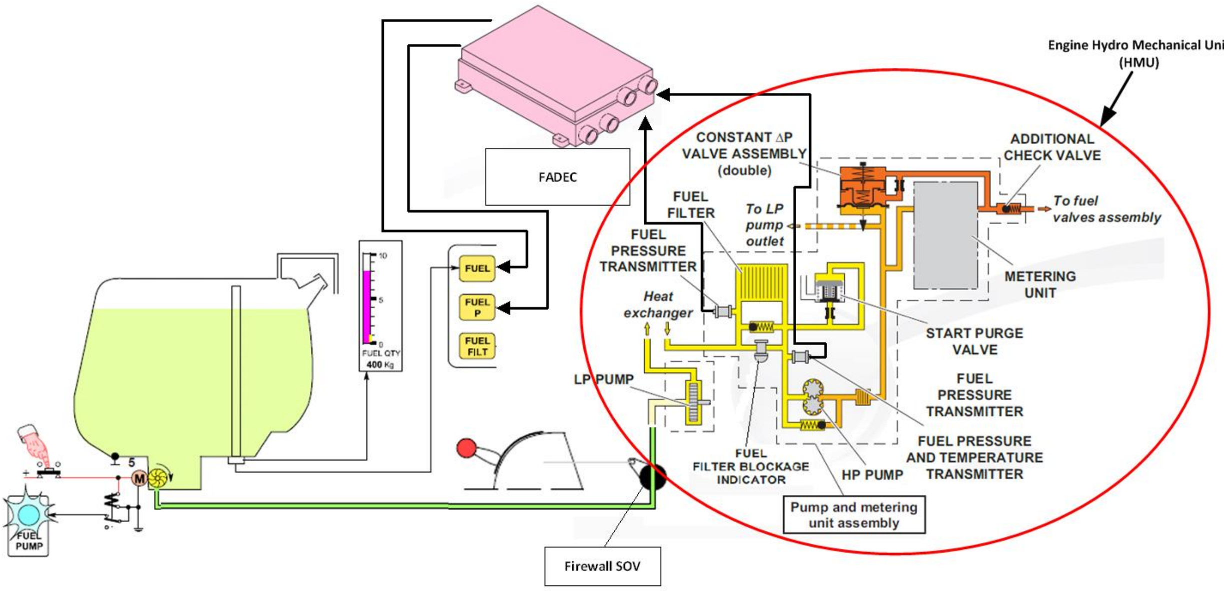

Figure 2: The helicopter's fuel system. Source: Turbomeca and Airbus Helicopters

1.6.5.2 There is a Firewall Shut Off Valve between the tank and the LP Pump, which can be operated manually in the event of a possible fire, or if there is a risk of fire.

1.6.5.3 When the fuel has passed the LP Pump, it runs through a heat exchanger that acts as an oil cooler and then on to the HMU fuel filter.

1.6.5.4 The filter in the HMU filters particles larger than 20µm. At the filter's inlet side there is a pressure sensor that measures the inlet pressure on the filter. A combined pressure and temperature sensor is installed on the filter's outlet side.

1.6.5.5 As there are pressure sensors on both the inlet and outlet side of the fuel filter, the pressure differences that occur will be an expression of the condition of the filter. If the differential pressure exceeds a certain value, it will be indicated on the warning panel (CWP) in the cockpit as the FUEL FILT warning lighting up. The CWP also has a warning light for fuel pressure (FUEL P). This will light up when the fuel pressure

[2] Calculated mass based on 74 % fuel volume.
[3] The Low-pressure Pump is an integral part of the engine's fuel regulator (HMU), and is driven mechanically by the engine's gas generator section.

registered by the pressure sensor on the inlet side of the fuel filter is below a certain value. For this engine type, the signals are transmitted from the pressure sensors to the CWP via the FADEC.

1.6.5.6 The fuel goes from the fuel filter to the HMU's HP Pump, which is a gear pump driven by the same axle as the LP Pump. From the HP Pump, the fuel goes to the hydro mechanical section of the HMU, and from there to the engine's injection wheel in the combustion chamber.

1.6.5.7 The helicopter's engine, Turbomeca Arriel 2D, is regulated by a Full Authority Digital Engine Control (FADEC). The engine's FADEC has redundancy as it is equipped with two parallel channels that monitor each other. In case of failure in one channel, transfer of control will happen automatically to the working channel. In case of failure of both channels, there is also a backup system (Engine Backup Control Auxiliary Unit – EBCAU) that will maintain the main rotor speed between 388 and 400 RPM. The EBCAU system will automatically take over if both FADEC channels fail.

1.6.5.8 A fault in the engine's control system will be presented on the CWP (see Figure 3) in three levels:

- Level 3 - "*Major failure: manual mode reversion*". Red GOV light will illuminate.
- Level 2 – *"Minor Failure: response time may be affected, but the essential control functions are ensured"*. Yellow GOV light will illuminate.
- Level 1 – *"Minor anomaly: loss of redundancy with no effect on engine performance"*. Yellow GOV light will flash when the engine stops.

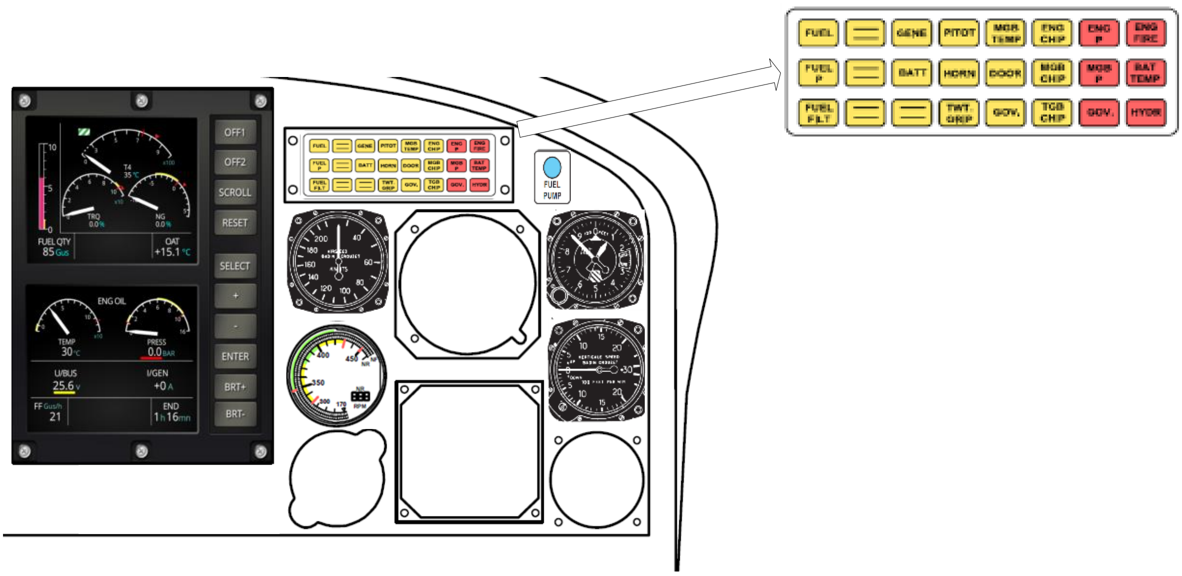

Figure 3: Caution and Warning Panel (general illustration). Source: Airbus Helicopters

1.6.5.9 In this accident, the yellow GOV light illuminated shortly after take-off. According to Airbus Helicopters' Flight Manual, this must be handled in the following manner:

WARNING PANEL	CORRECTIVE ACTIONS
GOV Minor FADEC failure	• **Permanently lighted:** Governing function degraded. 1. Collective.......................AVOID abrupt power changes. 2. IAS...............................MAINTAIN below VNE power off. **LAND AS SOON AS PRACTICABLE** On ground: do not start engine.
	• **Flashing at idle or during starting or shut down:** Governor redundancy failure, no impact on governing function. . Start-up procedure: abort, report to Maintenance Manual. . Autorotation training: cancel training, return to base.

Figure 4: Excerpt from Airbus Helicopters' Flight Manual AS350B3e. Source: Airbus Helicopters

The Airbus Helicopters' Helicopters Flight Manual section 3 "Emergency Procedures" defines "LAND AS SOON AS PRACTICABLE" as follows:

"Emergency conditions are less urgent and in the pilot's judgement, he may proceed to the nearest airfield where he can expect appropriate assistance."

1.6.5.10 If the fuel pressure is lost, the sensor installed upstream of the fuel filter will register this, and the signal will be transmitted via FADEC to the FUEL P light on CWP. According to Airbus Helicopters' Helicopters Flight Manual, this must be handled in the following manner:

FUEL P Low fuel pressure	• **IN FLIGHT:** **1. Collective pitch .... REDUCE POWER** **2. [FUEL P] or [FUEL PUMP]* ...... ON** **LAND AS SOON AS POSSIBLE** . Low power approach and landing **WARNING** **BE PREPARED IN CASE OF AN ENGINE FLAME-OUT.**

(*) Post MOD 07-4280

Figure 5: Excerpt from Airbus Helicopters' Flight Manual AS350B3e. Source: Airbus Helicopters

The Airbus Helicopters' Helicopters Flight Manual Section 3 "Emergency Procedures" defines "LAND AS SOON AS POSSIBLE" as follows:

"Emergency conditions are urgent and require landing at the nearest landing site at which a safe landing can be made."

In this instance, the FUEL P light did not illuminate when the fuel pressure disappeared.

1.7 Meteorological information

Video recorded by witnesses in connection with the accident shows overcast, partly cloudy conditions. Below the clouds, visibility was more than 10 km. At the time of the accident, the wind was insignificant, with a temperature of an estimated 11 °C.

1.8 Aids to navigation

Not Applicable

1.9 Communication

Not Applicable

1.10 Aerodrome information

The helipad belonging to the Armed Forces is approximately 30 x 30 meter paved with asphalt. It is located so that there are no obstacles in a sector of 180 degrees covering the most prevalent wind directions. The departure path selected for the accident flight had fairly flat terrain sloping away from the helipad, with no obstacles.

1.11 Flight recorders

1.11.1 The helicopter was equipped with a Vehicle and Engine Multi-function Display (VEMD). This unit provides the commander with information about engine and system parameters during flight. It also registers system faults and parameter exceedances. Furthermore, it logs flight time and engine parameters for use during maintenance.

1.11.2 The engine is equipped with Full Authority Digital Engine Control (FADEC) as well as Engine Data Recorder (EDR). Both units register engine parameters and have storage capacity.

1.11.3 APPAREO Vision 1000

Figure 6: APPAREO Vision 1000. Image: Appareo Systems, LLC

1.11.3.1 Appareo Vision 1000 stores data on a memory stick. The data can be downloaded to a standard computer for replay. Storage frequency is 4 Hz. The series of photos taken 4 times per second show a normal start-up and system check prior to take-off. It also shows that the actions following the illumination of the yellow GOV light were adequate for the situation. The recording confirms the commander's explanation of the course of events.

Furthermore, the recording confirms that he did not touch any of the controls that could have shut off the fuel supply.

1.11.3.2 In order to utilise the stored information, all readable information from the photo file was transferred to a table. However, the resolution of the photos are so poor that it was impossible to obtain exact readings. The data is presented in a table format, and this was sent to the helicopter and engine manufacturers as supplementary information.

1.11.3.3 Figure 7 below shows an excerpt of the read data. The red line is when the helicopter hit the ground. The video shows that the yellow GOV light illuminated as explained by the commander.

Roll	Pitch	HDG	G/S	FLI	YELLOW CWP LIGHTS	RED CWP LIGHTS	A/S	BLEED VALV	IVSI/fpm
0,8100	-9,0800	286.79	4,16	7			0	OPEN	0
0,6800	-10,7800	288.80	3,907	7			0	OPEN	0
1,2100	-12,0900	290.45	3,577	7			0	OPEN	0
1,1400	-13,3800	291.74	3,713	7			0	OPEN	0
1,8900	-14,5400	292.69	3,907	7			0	OPEN	0
1,7700	-15,4900	293.44	4,607	7	STEADY GOV		0	OPEN	0
2,1300	-16,0100	293.44	5,482	7	STEADY GOV		0	OPEN	50
2,5600	-16,5000	294.25	6,492	7	STEADY GOV		5	OPEN	50
2,5100	-17,1300	295.95	7,892	7	STEADY GOV		10	OPEN	50
2,9900	-17,8800	297.72	9,175	7	STEADY GOV		12	OPEN	50
2,8800	-18,1600	299.73	10,244	7	STEADY GOV		20	OPEN	100
2,4500	-17,7600	301.97	11,877	7	STEADY GOV		21	OPEN	100
2,0100	-16,9100	304.49	13,199	7	STEADY GOV		23	OPEN	150
1,7600	-15,6000	306.91	14,559	7	STEADY GOV		25	OPEN	200
2,5500	-14,3700	309.22	15,687	6,5	STEADY GOV		26	OPEN	200
2,5200	-12,8200	311.07	16,795	6,1	STEADY GOV		29	OPEN	200
3,0900	-11,4000	312.13	17,806	6	STEADY GOV		30	OPEN	200
3,1100	-10,2100	312.52	18,758	6,1	STEADY GOV		31	OPEN	200
2,8400	-8,9000	312.44	19,633	6,1	STEADY GOV		31	OPEN	200
3,3600	-7,9300	312.14	20,41	6,2	STEADY GOV		29	OPEN	200
4,4700	-7,4300	312.13	21,032	6,5	STEADY GOV		25	OPEN	200
4,0300	-7,1800	312.74	21,654	6,8	STEADY GOV		23	OPEN	200
2,0200	-6,6200	314.05	22,315	6,9	STEADY GOV		20	OPEN	200
0,4000	-5,8100	314.50	22,84	7	STEADY GOV		19	OPEN	150
0,7300	-5,5000	316.93	23,287	7	STEADY GOV		14	OPEN	100
1,9600	-5,7300	318.23	23,715	7	STEADY GOV		11	OPEN	100
2,4000	-5,7600	319.42	24,181	7,1	STEADY GOV		10	OPEN	50
2,5200	-5,2500	320.37	24,648	7,1	STEADY GOV		9	OPEN	50
3,8100	-4,7300	321.34	25,134	7,1	STEADY GOV		8	OPEN	50
5,2000	-4,8000	322.96	25,562	7	STEADY GOV		8	OPEN	50
5,6900	-5,0700	325.65	26,164	7	STEADY GOV		7	OPEN	0
5,7400	-5,6200	329.18	26,436	6,3	STEADY GOV		7	OPEN	0
5,3300	-6,5000	333.37	27,058	5,6	STEADY GOV		6	OPEN	0
5,2800	-7,2300	337.31	27,311	5	STEADY GOV		6	OPEN	0
5,6700	-7,9900	340.59	27,797	4,2	STEADY GOV		5	OPEN	0
6,4300	-8,2200	342.78	28,147	3,9	STEADY GOV		6	OPEN	0
6,7100	-7,8500	344.23	28,672	3,4	STEADY GOV		8	OPEN	0
7,1200	-7,1900	345.13	29,177	3,1	STEADY GOV		10	OPEN	0
7,1700	-6,6800	345.76	29,624	3	STEADY GOV		12	OPEN	0
6,5100	-6,1200	346.17	29,838	3	STEADY GOV		15	OPEN	0
5,5600	-6,2400	346.44	30,285	2,9	STEADY GOV		18	OPEN	0
4,7900	-6,3200	346.72	30,635	3	STEADY GOV		19	OPEN	0
3,5700	-5,8600	347.02	30,927	3	STEADY GOV		20	OPEN	0
3,4600	-4,8400	347.43	31,024	3	STEADY GOV		20	OPEN	0
4,5400	-4,7800	347.82	31,413	3	STEADY GOV		21	OPEN	0
6,0900	-4,8100	348.33	31,607	3	STEADY GOV		20	OPEN	0
8,0600	-5,9600	348.73	31,996	3	STEADY GOV		21	OPEN	0
9,5200	-8,7100	348.87	32,365	3	STEADY GOV		22	OPEN	0
11,7300	-10,7500	349.00	32,676	3	STEADY GOV		22	OPEN	0
14,5100	-11,1200	349.46	32,909	3	STEADY GOV		23	OPEN	0
16,0300	-10,4400	350.36	33,551	3	STEADY GOV		23	OPEN	0
15,6200	-8,0600	352.03	33,94	2,9	STEADY GOV		23	OPEN	0
15,3400	-5,2800	354.05	34,114	2,9	STEADY GOV		25	OPEN	0
15,1300	-3,0200	356.14	34,289	2,8	STEADY GOV		24	OPEN	-50
15,1800	-1,3200	357.93	34,231	2,7	STEADY GOV		25	OPEN	-100
7,8000	-6,0900	358.48	34,114	2,7	STEADY GOV		23	OPEN	-150
11,8700	-28,5400	343.11	33,512	2,9	STEADY GOV		23	OPEN	-150
32,7600	-45,5200	302.36	31.724	2,9	NOT VISIBLE	NOT VISIBLE	20	OPEN	-150
106,4100	-52,9200	215.37	30,282	2,9	UNABLE TO IDENTIFY	NABLE TO IDENTIFY		OPEN	
131,2900	-12,9500	184.97	22,587	.E TO ID	UNABLE TO IDENTIFY	NABLE TO IDENTIFY		OPEN	

Figure 7: Data from Appareo Vision 1000. Source: AIBN

HDG-Heading
G/S –Ground Speed
FLI – First Limit Indicator
A/S – Airspeed
IVSI – Vertical Speed indicator

1.11.4 Data stored in Vehicle and Engine Multifunction Display (VEMD)

1.11.4.1 VEMD is a multifunction instrument presenting in-flight engine and system parameters. There is also a maintenance mode with three types of data available:

- Parameter exceedances: The instrument stores data and numerical values of exceedances.
- Information about failures: The instrument generates warnings of failures, and provides a list of relevant parameters.
- Flight report: The instrument logs parameters that are relevant for time between overhauls of components in the engine and the duration of flights. Failures and parameter exceedances registered by the instrument are presented in the Flight Report.

1.11.4.2 After the transportation of the helicopter to AIBN's premises in Lillestrøm, the data stored on the VEMD was downloaded. In the Flight Report for the relevant flight, "Failure Detected" was flagged (see Figure 8). As the VEMD stores 31 flights, the 30 previous flights were checked for any failure reports or exceedances. No abnormalities were found in these.

Figure 8: Flight Report VEMD. Photo: Airbus Helicopters

1.11.4.3 It was possible through sub-menus to see that the VEMD had registered failures in the fuel pressure at both the inlet and outlet of the fuel filter (see Figure 9). This was registered simultaneously via both channels in FADEC 1 minute and 32 seconds after VEMD had started to register data for the flight (from engine start). The pressure sensors are located as indicated in Figure 10.

Figure 9: Fuel Press. failure report VEMD. Photo: Airbus Helicopters

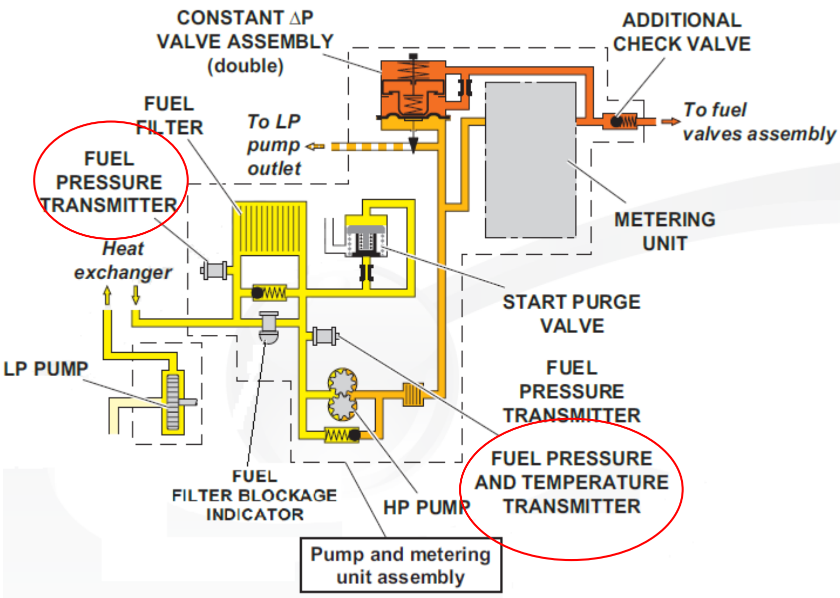

Figure 10: Excerpt from Figure 2 that shows the location of fuel pressure sensors. Source: Turbomeca

1.11.4.4 Four seconds after the VEMD reported loss of fuel pressure, a variation in the P3 sensor parameter was registered. The P3 sensor gauges air pressure at the outlet of the engine's compressor section. This was also registered in both channels in FADEC (see Figure 11).

Figure 11: P3 sensor failure VEMD. Photo: Airbus Helicopters

1.11.5 Information extracted from FADEC and EDR

1.11.5.1 Both FADEC and EDR were intact after the crash. The parts were sent to Turbomeca for further analysis. AIBN and BEA were present and monitored the work. The initial review of data stored on the units showed that these were complete for the flight. The data was compatible with the failure messages registered by VEMD.

1.11.5.2 The graph in Figure 12 is an excerpt of the data available in FADEC. It shows the course of events for the period just before the fuel pressure was lost until just after the engine started losing power. Again, both fuel pressure sensors simultaneously registered pressure drop. Due to lack of engine response, the FADEC gave increasing fuel demand signal to the HMU. Approximately four seconds after loss of fuel pressure, the P3 drift message initiated, at the same time as the "fuel demand" signal from FADEC to HMU increased.

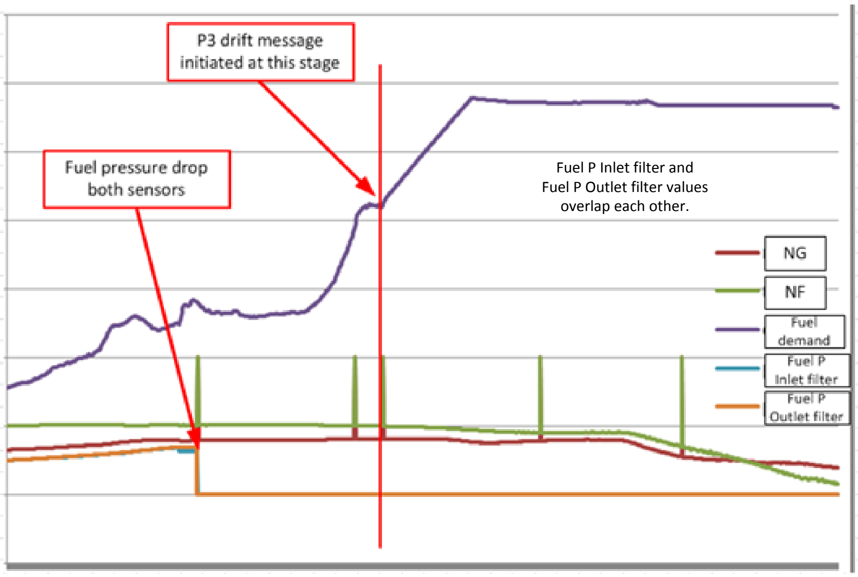

Figure 12: Graph with FADEC parameters. The five peaks on the NF and NG parameters are probably signal failures, and can be disregarded. Source: Turbomeca

1.12 Wreckage and impact information

1.12.1 The crash site

The accident occurred during take-off from the Norwegian Armed Forces' facility at Hjerkinn. The distance between the helipad and the crash site was approximately 185 metres. The terrain had a slight incline, and was partially covered in heather and birchwood. The ground was dry.

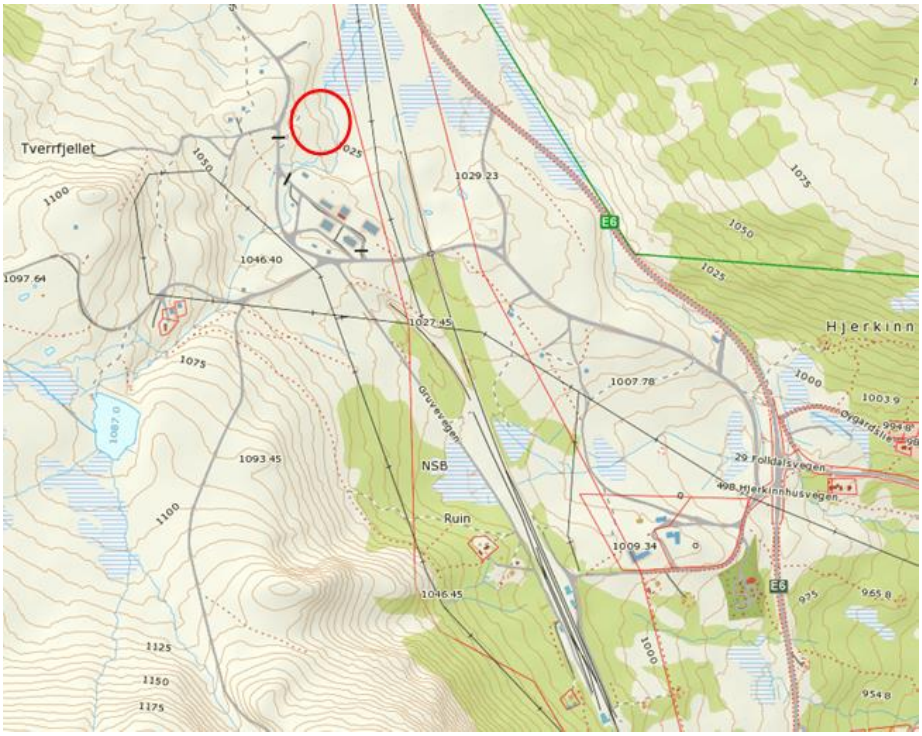

Figure 13: Overview image of crash site. Source: The Norwegian Mapping Authority , Geovekst and municipalities

Figure 14: Approximate flight path. Source: The Norwegian Mapping Authority , Geovekst and municipalities

1.12.2 The helicopter wreckage

Because the helicopter was at a low altitude when the problem occurred, it was not possible to establish an autorotation. The helicopter landed with forward speed and hit the ground with the underside of the nose of the aircraft. This caused the helicopter to tilt forward and to come to rest on the left side with the nose in the opposite direction of the original flight direction. The tail boom broke off in the rotation, and the landing gear was deformed and partly detached (Figure 15). The main rotor blades and the starflex (rotor hub) were damaged as the helicopter hit the ground, while the suspension bars attaching the main gear box to the fuselage remained intact. The helicopter cabin and cockpit got extensive damage (see Figur 16).

Figure 15: Crash site and take-off site (in the background). Photo: AIBN

Figur 16: Damages in the nose section. Photo: AIBN

1.13 Medical and pathological information

A routine blood sample was taken from the commander. No traces of alcohol, narcotic substances or drugs that could have influenced his performance of the service were found.

1.14 Fire

No fire occurred.

In this crash, the fuel tank remained intact, but due to the helicopter's position after the crash, some fuel leaked through the tank's ventilation and filler cap. The helicopter remained with battery bus switched on for a brief period after the crash. After evacuation, the aircraft commander switched off the battery power.

1.15 Survival aspects

1.15.1 Notifications and emergency services

The helicopter was equipped with an emergency locator transmitter (ELT, model Kannad 406 AF-H).

The emergency locator transmitter started automatically, and the Joint Rescue Coordination Centre was notified at 1208 hours, eight minutes after the accident.

1.15.2 Personal protection

The aircraft commander did not use a helmet during the flight.

The passenger in the left front seat hit the left frame of the windscreen and sustained a cut on the forehead. He did not wear a helmet, which is normal for passengers. None of the passengers in the rear seats were injured.

1.15.3 Seats and safety belts

The pilot and the passenger in the front seat were in seats manufactured in accordance with requirements in EASA TSO-C127a[4]. Design of the seats allows the seat structure to collapse and absorb G-loads when exposed to vertical stress above certain values. The seats have five-point seat belts.

None of the front seats were exposed to G forces that caused the energy absorbing structure to collapse. The seats, fasteners and floor structure remained intact after the accident.

The passengers in the rear seats were all secured with three-point safety belts. None of the rear seats were deformed due to G force stress.

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[4]A Technical Standard Order (TSO) is defined as: “A TSO is a minimum performance standard for specified materials, parts, and appliances used on civil aircraft.”

1.16 Tests and research

1.16.1 Running engine on test bench

1.16.1.1 The engine was removed from the helicopter and installed on a test bench at Turbomeca, Tarnos (see Figure 17) for testing. LN-OSY's FADEC was used to regulate the engine in order to achieve conditions as similar as possible to the flight where the engine stopped.

1.16.1.2 Based on stored FADEC data available from the flight, a similar profile for power settings was defined for running on the test bench.

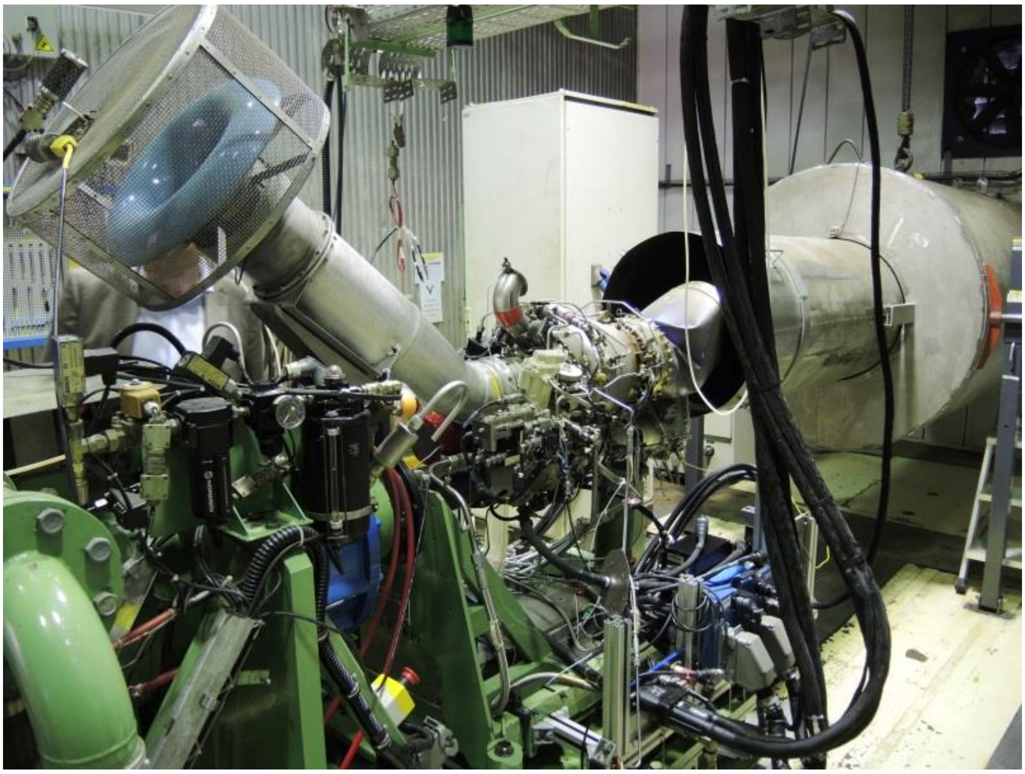

Figure 17: Engine installed on test bench. Photo: AIBN

The engine ran for 19 minutes with variations in power from ground idle to 92.7 % NG, and it functioned normally throughout the test.

1.16.2 Running of HMU on test bench

1.16.2.1 The purpose of this test was to check if the HMU functioned in accordance with the specified criteria (see Figure 18). This was done by controlling the pressure, the HMU valve position and regulated fuel volume.

All tests showed that HMU worked as it should.

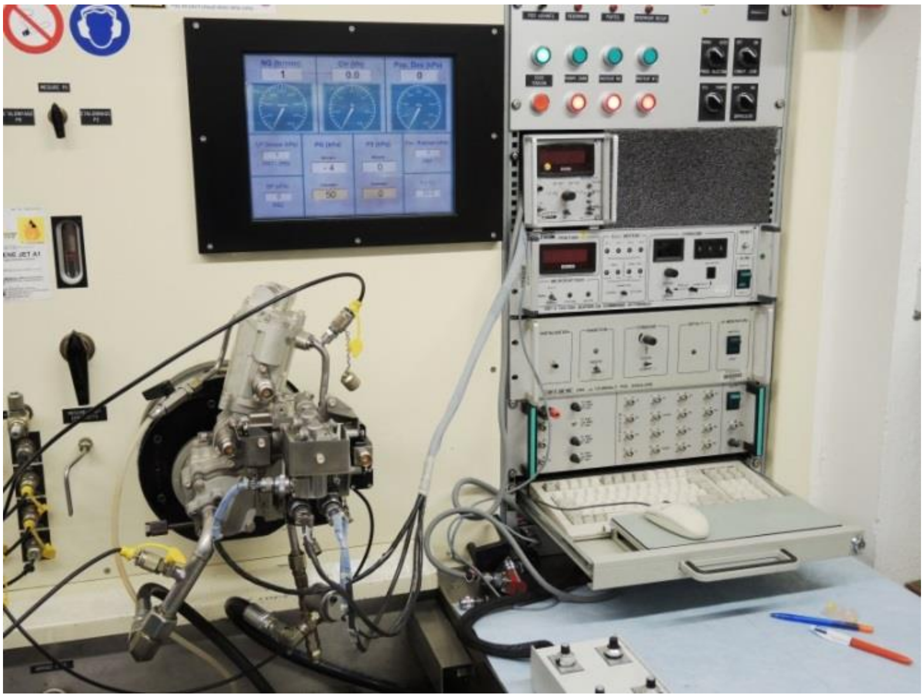

Figure 18: Test configuration HMU. Photo: AIBN

1.16.2.2 In the certification process for the Arriel 2D engine, the HMU was tested for properties with blockage of the fuel supply. This was done by installing a shut-off valve just before the fuel inlet on the HMU.

The fuel pressures stored in LN-OSY's FADEC during the accident showed a similar course of events as during the certification test.

1.16.3 <u>Detailed inspection of HMU</u>

1.16.3.1 HMU was dismantled and the individual components inspected for any damage or foreign objects that may explain why the fuel pressure dropped.

The low-pressure pump had a mark on one of the impeller blades. However, this may have been caused by tools when the pump was inspected initially. The high-pressure pump did not have signs of damage. The shaft driving both pumps was also intact.

Scratches were found in the HMU aluminium casing. This indicates that foreign objects had passed the low-pressure pump and continued to the engine's fuel/oil heat exchanger (see Figure 19 and Figure 20).

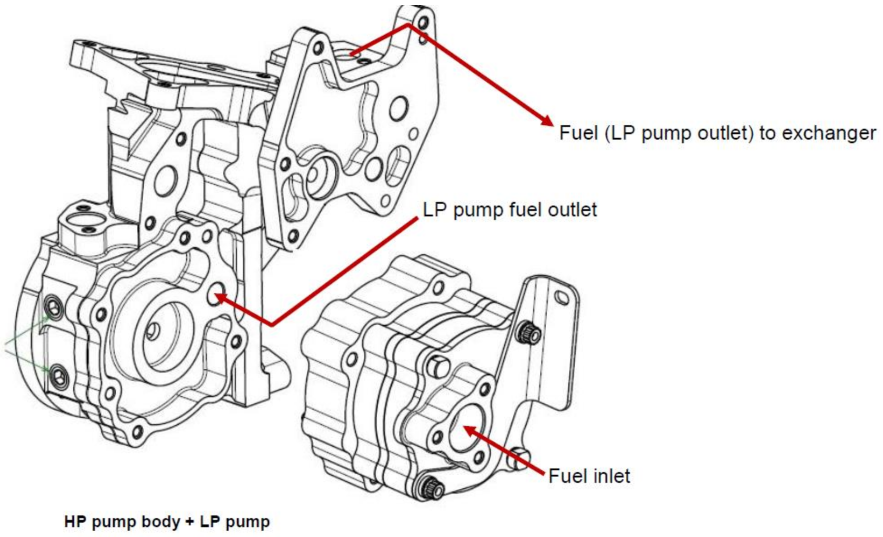

Figure 19: HMU findings. Source: Turbomeca

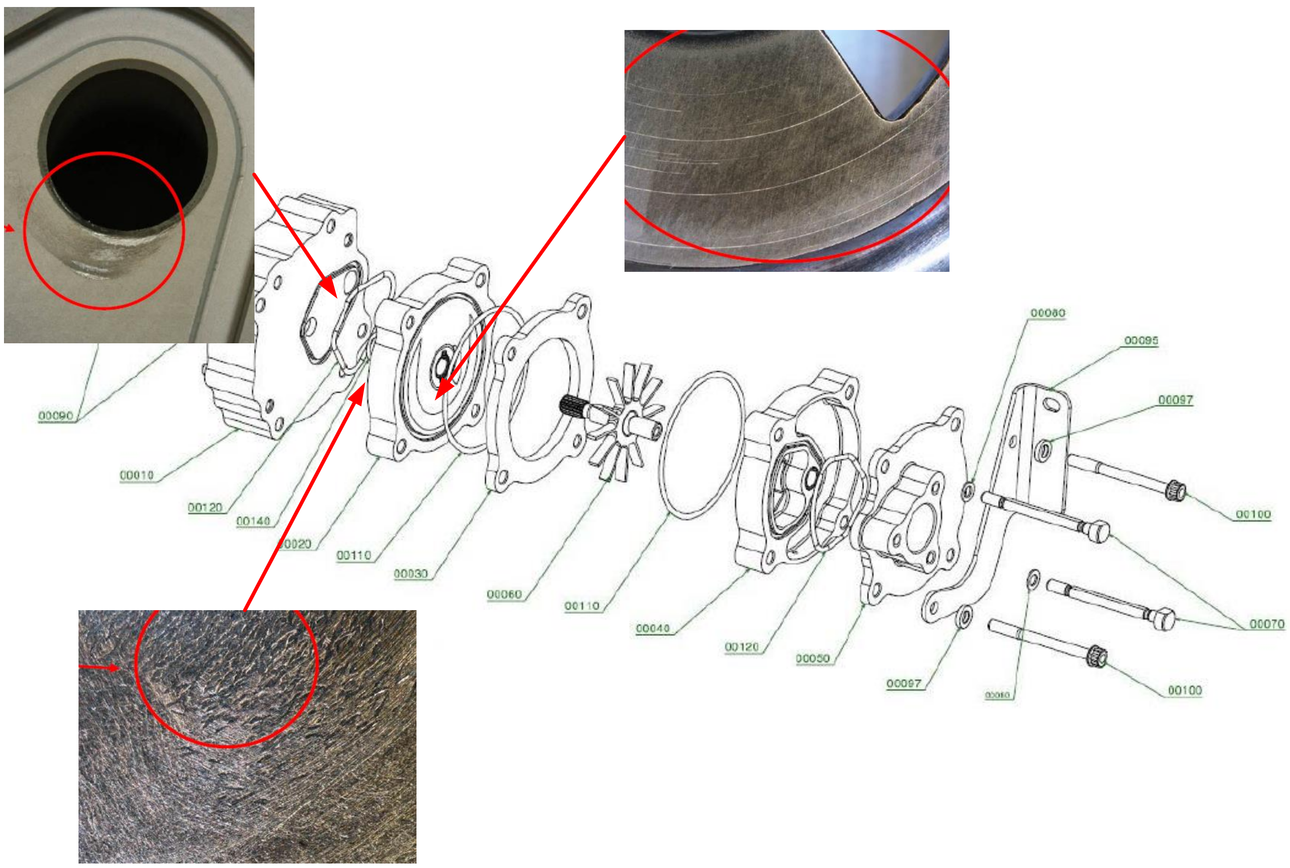

Figure 20: Photos of some of the damage with location in the HMU. Source: Turbomeca

1.16.3.2 BEA completed a more detailed analysis of the damage in an attempt to establish what may have caused it. Using a scanning electron microscope (SEM), steel deposits were discovered, and in one instance, a 30µm particle was found embedded, consisting of aluminium oxide and zirconium.

1.16.4 Examination of the fuel/oil heat exchanger

The engine's heat exchanger was dismantled after the test cell run for inspection. A mark was found in the fuel inlet port of the heat exchanger, but no foreign objects explaining the loss of fuel pressure were found inside the unit.

Figure 21: Mark in fuel inlet heat exchanger. Photo: AIBN

1.16.5 Investigation of fuel filter

1.16.5.1 The filter was examined in a test where the flow rate properties were analysed.

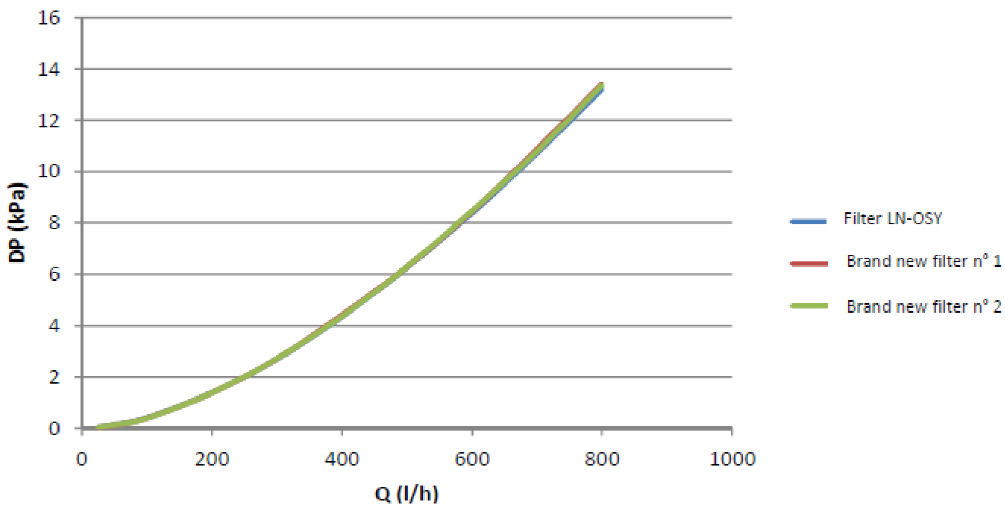

Figure 22: Test of fuel filter. Source: Turbomeca

The test showed that the filter installed on LN-OSY at the time of the accident followed the pressure drop characteristics of a new filter, and thereby did not have a larger pressure drop than a new filter.

1.16.5.2 The filter was also examined for contamination. Some foreign elements in the form of metal particles and fibres were observed. The area on the filter that was closest to the fuel flow inlet from the low-pressure pump had the largest concentration of particles. This area of the filter comprises approximately 1 % of the filter's total surface. The particles varied in size from 0.1 mm to 0.02 mm.

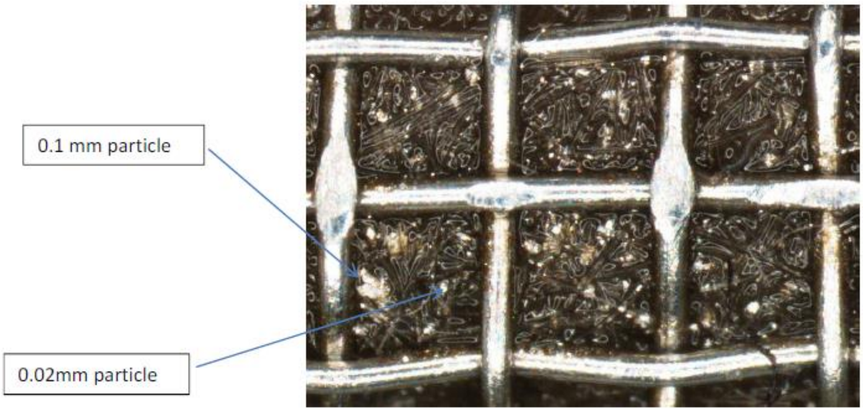

Figure 23: Fuel filter, particles at the filter inlet. Image: Turbomeca

The rest of the filter's surface (99 % of the filter's surface) was clean.

1.16.6 <u>Reference test</u>

1.16.6.1 Turbomeca carried out a test on another Arriel 2D engine with a representative from AIBN present. The purpose was to observe the fuel pressure variations in the HMU, as well as relevant engine parameters when the supply is blocked on the inlet side of the HMU. The test was performed with a power setting similar to the power setting at the time of the accident. (Gas generator RPM=90 %, fuel flow=180 l/h). Blocking of fuel was done by using a solenoid-operated stop valve on the supply hose to the HMU.

1.16.6.2 The test showed that the pressure sensors up- and downstream of the fuel filter went to minimum value approximately 2 seconds after the fuel supply was blocked. The engine's power generator RPM decreased approximately six seconds after the pressure sensors indicated minimum value. The result of this test corresponds with the test of the engine from LN-OSY, and the certification test of the Arriel 2D engine.

1.16.6.3 Some differences were observed between registered parameters from the accident and running of the reference engine in the test bench. Turbomeca assumes this is explained by the differences in how the engine is installed in the helicopter, compared with how the reference engine was installed in the test bench. Pipes and hoses on the test bench have different volumes than those installed on the helicopter. The fuel volumes available after closing the supply in the test bench are thereby different from the installation in the helicopter. Additionally, the exact location of the blockage of fuel flow in the accident engine's fuel system is unknown. Thereby, the remaining amount of fuel available for combustion during the accident was not necessarily the same as in the reference test.

1.16.7 <u>Sampling of fuel for quality control.</u>

Samples were taken from the tanking facility the helicopter used, as well as the helicopter's fuel tank.

The analysis of the fuel samples was performed by the laboratory services of the Norwegian Armed Forces. The analysis showed that the fuel from the tanking facility and the helicopter was of the correct quality. The fuel sample from the helicopter's fuel tank contained traces of plant fibres.

Both samples contained minor amounts of water. (Tanking facility: 34ppm/Helicopter tank: 35 ppm). The water content was considered as normal.

1.16.8 Test of the helicopter's fuel system

1.16.8.1 After the helicopter had arrived at AIBN's premises, the fuel system was checked by switching on the pump installed in the fuel tank. The purpose of this was to pressurise the fuel system to check for any leaks, which were not observed.

1.16.8.2 The system was also checked by establishing underpressure. The purpose of this was to see if air entered the fuel through hose and plumbing connections while travelling from the tank to the engine, and if hoses in the fuel supply had de-laminated, thereby blocking fuel at underpressure.

Under normal operations, the fuel pump in the helicopter's fuel tank does not run, it is the low-pressure pump in the engine's HMU that draws the fuel from the tank. In order to simulate this, a test set-up was prepared with a pump simulating the HMU low-pressure pump, an adjustable flow meter and a pressure indicator (Figure 24). The pump was placed at the same height as the HMU inlet in relation to the helicopter's fuel tank, and the tank was filled with the same amount of fuel as the helicopter had prior to take-off. The purpose of this was to achieve the correct under pressure conditions. A transparent hose was used between the pressure indicator and pump to visually check if the fuel system sucked in air due to under pressure in the liquid column between the level in the fuel tank and the pump. A hose returned fuel to the helicopter's tank. The flowmeter was adjusted to the engine's consumption at take-off.

No air was observed in the transparent hose during the test.

If there had been such a leak, it could have caused a temporary loss of fuel pressure, with subsequent loss of engine power.

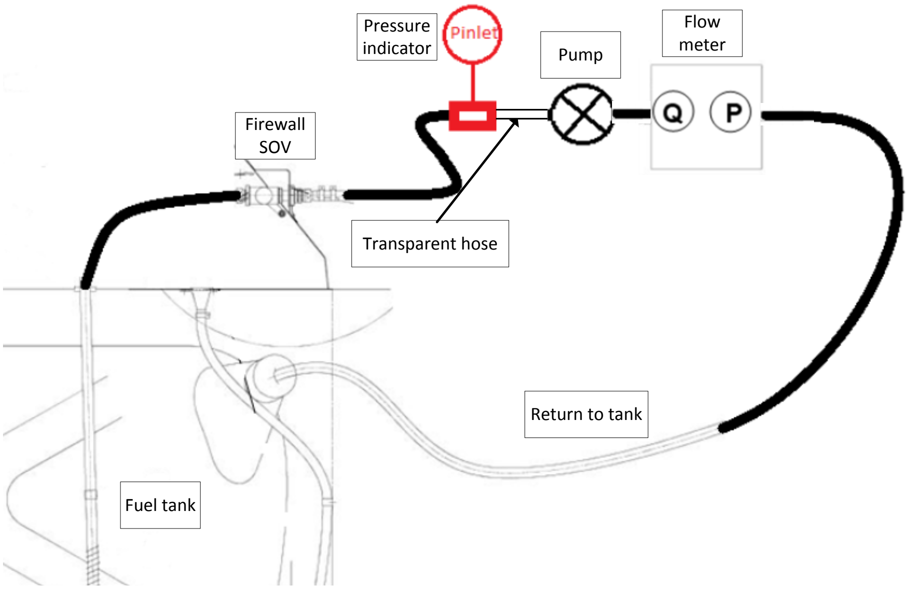

Figure 24: Chart for test of the helicopter's fuel system. Source: Airbus Helicopters/Processed by AIBN

The performed test showed no leaks or other conditions that could explain loss of engine power. Moreover, the complete examination of the airframe fuel system components and plumbing after dismantling did not exhibit any damages, or evidence of foreign objects ingestion causing blockage.

1.17 Organisational and management information

1.17.1 Pegasus Helicopter AS

Pegasus Helicopter has a norwegian Air Operator certificate (AOC) No N-060 for the following types of operations: A1-Passenger, A2-Cargo.

The company has its main base at Oslo Airport (ENGM). Secondary bases for operations are at Skien airport, Geitryggen (ENSN) and Sola Airport (ENZV).

Further organisational investigations have not been carried out in connection with this accident.

1.18 Additional information

1.18.1 A registration unit (APPAREO Vision 1000), which records GPS data, sound and video, was installed on LN-OSY. This is a new concept for this helicopter class, and installation of such equipment is not required from the certification authority. Heavier helicopters have had flight and voice recorder requirements for many years. AIBN believes such equipment is a valuable contribution in order to analyse what happened during incidents and accidents. In addition, the companies can use the data for training and incident review purposes.

1.18.2 AIBN considers recordings from APPAREO Vision 1000 and similar systems to be data in accordance with Section 12-10 of the Aviation Act and EU regulation 996/2010 relating to "*…investigation and prevention of accidents in civil aviation…*" This means that the material shall be handled in the same way as data from ordinary flight recorders and voice recorders, and is thus legally protected against insight from others.

1.18.3 It is also important to emphasise that the opportunity such equipment provides for analysing flights in retrospect establishes requirements for how such information is used by the companies. Section 12-11 of the Aviation Act describes this, and reference is made to Section 12-31 of the act that prohibits sanctions from the employer based on data from recording systems.

1.18.4 Analyses of data from this equipment after the accident involving LN-OSY showed that the quality of video and audio could have been better. The video had low resolution, and this made it difficult to make out the helicopter's instruments. The audio recording was of such a quality that the only audible sounds were normal noise from the main gearbox and loud noises from the impact with the ground.

1.19 Useful or effective investigation techniques

No methods qualifying for special mention have been used in this investigation.

2. ANALYSIS

2.1 Introduction

2.1.1 Fairly soon in the investigation, findings were made that indicated that the loss of engine power was caused by technical issues. The results of extensive and detailed examinations have led to AIBN concluding that loss of fuel supply to the engine HMU is the most likely cause of the loss of engine power on LN-OSY. In this analysis, the AIBN will discuss the loss of fuel supply in further detail.

2.2 Accident analysis

The departure was performed by lifting the helicopter to hover in ground effect[5], and the intention was to accelerate horizontally to approximately 40 knots indicated airspeed and the start a climbout to planned altitude. The loss of engine power happened at an indicated airspeed of approximately 20 knots. Since the helicopter still was in translational lift[6], the power requirement was high. The helicopter was still at a speed and altitude that limited the possibility of establishing an autorotation, which could have resulted in a controlled emergency landing.

The only option for the aircraft commander was to establish the helicopter in the best possible attitude and use the remaining inertial energy in the main rotor to reduce vertical speed towards the ground. The photo series recorded in the monitoring unit installed on

[5] Ground effect is normally considered to have effect until the helicopter has reached an altitude above the ground that is equal to 50 % of the main rotor diameter. For the Airbus AS 350B3 this is approximately 5,35m.

[6] At an airspeed of 10-15 kts, the efficiency of the main rotor starts to improve because of increasing supply of “undisturbed air” (translational lift).

this helicopter does not reveal any actions by the aircraft commander that may explain the loss of engine power.

2.3 Loss of engine power

Loss of fuel pressure was the most likely cause of the engine's loss of power. The pressure sensors on each side of the HMU fuel filter registered the pressure drop simultaneously. When the engine did not respond to the fuel demand signal from the FADEC, the yellow GOV light on the CWP lit. Five seconds after the pressure break, the engine no longer had the expected performance due to lack of fuel, and the FADEC generated a P3 drift signal, which was saved as a fault message in the VEMD.

This course of events is confirmed by analysis of data from VEMD, FADEC and EDR. Additionally, when testing a reference engine installed on a test bench, it shows a similar behaviour as regards how long time it takes from the pressure drop until the engine becomes unresponsive.

The coinciding results of tests and analyses indicate that the fuel flow from the helicopter's fuel tank to the HMU was blocked somewhere before the pressure sensors on the upstream side of the HMU fuel filter. AIBN has not found evidence in the form of foreign objects in such quantities that they confirm these indications.

The discovery of plant fibres in the fuel in the helicopter's tank and markings/deposits in the aluminium casing of the HMU do not themselves provide a basis to conclude that there has been a complete blockage of the fuel supply.

Based on the examinations carried out in connection with the accident, it is most likely that the engine's FADEC and HMU have performed correctly, and there is therefore no basis to say that malfunction of these, caused loss of engine power.

2.4 Caution and Warning Panel

The loss of fuel pressure preceded the yellow GOV light coming on. According to the helicopter's emergency checklist, the helicopter must be landed “AS SOON AS PRACTICABLE” when this light comes on.

This wording is clarified by the checklist: “*Emergency conditions are less urgent and in the pilot’s judgement, he may proceed to the nearest airfield where he can expect appropriate assistance*”.

AIBN believes that the warning presented to the aircraft commander in this case did not provide the correct information as regards the severity of the occurred failure.

Based on the information given to the pilot on the CWP, he could, according to the emergency checklist, have continued the flight as described above.

Correct information could have provided the aircraft commander with an opportunity to respond quicker and thereby potentially landed the helicopter in a more controlled manner.

Two safety recommendations are issued concerning amendment of the logic for failure warning on CWP for AS 350 B3e Ecureuil and other helicopter types in the Airbus Helicopter family with similar warning logic.

2.5 The survival aspect

This accident occurred at low speed and there was no significant deformation of the helicopter cabin. All seats and seat belts attachments were intact. None of the persons were injured in such a manner that they lost consciousness or were unable to evacuate the wreckage on their own. No fire occurred.

The aircraft commander did not use a helmet. Had he lost consciousness, it could have had consequences for the evacuation of the passengers. AIB's have issued Safety recommendations on the use of helmets repeatedly. (Examples: SHT report SL/2007-13 and BEA report f-ce090527)

Ideally, the battery switch should have been set to off position immediately after the helicopter came to rest to reduce the risk of fire.

The front seat design in LN-OSY was in accordance with EASA TSO-C127a, which provides significantly better protection than previous versions that were of a much simpler design.

The cabin seats in LN-OSY were equipped with three-point safety belts. This provides significantly better protection for passengers than two-point hip belts that was standard for older versions of the helicopter.

The emergency locator transmitter activation was as intended when the helicopter hit the ground.

3. CONCLUSION

This accident happened due to loss of engine power in a critical phase of the flight, immediately after take-off, at low speed and at low altitude. The cause was most likely blockage of the fuel supply. Despite extensive examinations and tests, AIBN has been unable to determine a cause for the blockage.

3.1 Investigation results

3.1.1 General

a) The aircraft registration was in accordance with the regulations and had a valid airworthiness certificate.

b) The aircraft's mass and the location of its centre of gravity were within the permitted limits at the time of the incident.

c) The commander had valid certificates and rating for the helicopter type.

3.1.2 Technical findings

a) Findings indicate that the accident probably occurred due to blockage of the fuel supply to the engine with subsequent loss of engine power.

b) The fuel used from the tanking facility on the ground was of correct quality. Water content was within acceptable limitation.

c) The fuel in the helicopter's tank was of correct quality. Findings of a few fibres assumed to be from plants do not provide a basis for concluding that contamination of the fuel caused the crash. Water content was within acceptable limitation.

d) Malfunction of the engine’s electronic and hydromechanic control systems has not been found.

e) Nicks from foreign objects were found in the low-pressure pump housing and channels in the HMU. These nicks are not of such a nature that they would explain the fuel supply blockage.

f) The monitoring unit installed in the helicopter (Appareo Vision 1000) showed no incorrect actions by the aircraft commander during start-up and take-off. Additionally, the equipment provided AIBN with the opportunity to read the aircraft's instruments for large parts of the flight.

g) The warning light that lit after the fuel pressure drop did not give the aircraft commander sufficient information to make decisions that may have reduced the risk of a crash. Correct information would have provided the aircraft commander with a few more seconds to reduce speed, and perform a more controlled emergency landing.

3.1.3 Survival aspects

The commander did not use helmet. This increases the risk of incapacitation during a ground impact, and thereby compromising his ability to assist passengers during an evacuation.

4. SAFETY RECOMMENDATIONS

The Accident Investigation Board Norway (AIBN) makes the following safety recommendations:[7]

Safety reccomendation SL no 2015/07T

The loss of engine power was presented to the pilot on CWP with yellow GOV light. According to the helicopter’s emergency checklist, the action to be taken is: “LAND AS SOON AS PRACTICABLE”. AIBN is of the opinion that this does not reflect the need for immediate reaction from the pilot in the event of a fuel pressure break and subsequent loss of engine power.

The Accident Investigation Board Norway therefore recommends that Turbomeca consider changes to the AS 350 B3e warning system and other helicopter types in the Airbus family with similar warning logic, so that the pilot receives the correct information in relation to the severity of the occurred failure. (A similar safety recommendation is also issued to Airbus Helicopters.)

Safety recommendation SL no 2015/08T

The loss of engine power was presented to the pilot on CWP with yellow GOV light. According to the helicopter's emergency checklist, the action to be taken is: “LAND AS SOON AS PRACTICABLE”. AIBN is of the opinion that this does not reflect the need for immediate reaction from the pilot in the event of a fuel pressure break and subsequent loss of engine power.

The Accident Investigation Board Norway therefore recommends that Airbus Helicopters consider changes to the AS 350 B3e warning system and other helicopter types in the Airbus family with similar warning logic, so that the pilot receives the correct information in relation to the severity of the occurred failure. (A similar safety recommendation is also issued to Turbomeca.)

The Accident Investigation Board Norway

Lillestrøm, 16 September 2015

[7] The Ministry of Transport and Communications ensures that safety recommendations are presented to the aviation authorities and/or other relevant ministries for assessment and follow-up, cf. Section 17 of the Regulations relating to public investigation of air traffic accidents and incidents in civil aviation.

APPENDIX

Appendix A: Relevant abbreviations

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AIBN	Accident Investigation Board Norway
ATPL-H	Air Transport Pilot's Licence - Helicopter
BEA	Bureau d’Enquêtes et d’Analyses pour la Securité de l’Aviation civile
CPL-H	Commercial Pilot Licence - Helicopter
CWP	Caution and Warning Panel
E	East
EASA	European Aviation Safety Agency
EBCAU	Engine Backup Control Auxiliary Unit
EDR	Engine Data Recorder
ELT	Emergency Locator Transmitter
FADEC	Full Authority Digital Engine Control
GA	General Aviation
GPS	Global Positioning System
HMU	Hydro Mechanical Unit
ICAO	International Civil Aviation Organisation
IFR	Instrument Flight Rules
N	North
NF	Free turbine RPM
NG	Gas Generator RPM
OPC	Operators Proficiency Check
PC	Proficiency Check
ppm	Parts per million
RPM	Revolutions per minute
TSO	Technical Standard Order
UTC	Universal Time Coordinated
VEMD	Vehicle and Engine Multi-function Display
VFR	Visual Flight Rules