Statens haverikommission
Swedish Accident Investigation Authority

Final report RL 2015:11e

Accident in Kungsängen on 14 July 2014 involving helicopter SE-JKJ of the model MD 600N, operated by a private individual

File no. L-0088/14

25/06/2015

SHK investigates accidents and incidents from a safety perspective. Its investigations are aimed at preventing a similar event from occurring again, or limiting the effects of such an event. The investigations do not deal with issues of guilt, blame or liability for damages.

The report is also available on SHK´s web site: www.havkom.se

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Content

General observations

The Swedish Accident Investigation Authority (Statens haverikommission – SHK) is a state authority with the task of investigating accidents and incidents with the aim of improving safety. SHK accident investigations are intended to clarify, as far as possible, the sequence of events and their causes, as well as damages and other consequences. The results of an investigation shall provide the basis for decisions aiming at preventing a similar event from occurring again, or limiting the effects of such an event. The investigation shall also provide a basis for assessment of the performance of rescue services and, when appropriate, for improvements to these rescue services.

SHK accident investigations thus aim at answering three questions: *What happened? Why did it happen? How can a similar event be avoided in the future?*

SHK does not have any supervisory role and its investigations do not deal with issues of guilt, blame or liability for damages. Therefore, accidents and incidents are neither investigated nor described in the report from any such perspective. These issues are, when appropriate, dealt with by judicial authorities or e.g. by insurance companies.

The task of SHK also does not include investigating how persons affected by an accident or incident have been cared for by hospital services, once an emergency operation has been concluded. Measures in support of such individuals by the social services, for example in the form of post crisis management, also are not the subject of the investigation.

Investigations of aviation incidents are governed mainly by Regulation (EU) No 996/2010 on the investigation and prevention of accidents and incidents in civil aviation and by the Accident Investigation Act (1990:712). The investigation is carried out in accordance with Annex 13 of the Chicago Convention.

The investigation

SHK was informed on 14/07/2014 that an accident involving one helicopter with the registration SE-JKJ had occurred in Lennartsnäs, Kungsängen in Stockholm county, the same day at 15.30 hrs.

The accident has been investigated by SHK represented by Mr Jonas Bäckstrand, Chairperson, Mr Agne Widholm, Investigator in Charge until 24 September 2014, thereafter Mr Stefan Carneros, and Mr Christer Jeleborg, Technical Investigator.

The investigation team of SHK was assisted by Mr Mats Gustavsson (Bromma Air Maintenance) as a technical expert.

Mr Jason Aguilera has participated as accredited representative on behalf of the National Transportation Safety Board, NTSB, United States. Mr Adrian Booth (The Boeing company) and Mr Jon Michael (Rolls-Royce) have participated as advisors to the NTSB.

Mr Magnus Holmén participated as advisor to the Swedish Transport Agency until 26 July 2014, thereafter Mr Jonas Gränge until 1 March 2015 and thereafter again Mr Magnus Holmén.

The following organisations have been notified: The European Aviation Safety Agency (EASA), the European Commission, the NTSB and the Swedish Transport Agency (Transportstyrelsen).

Investigation material
Interviews have been conducted with the pilot and a witness to the incident.

A technical examination of the aircraft and engine has been conducted in several stages.

Meetings with the interested parties were held on 26 March 2015 and 31 March 2015. At the meetings SHK presented the facts discovered during the investigation, available at the time.

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Aircraft:	
Registration, type	SE-JKJ, MD 600N
Model	MD 600N
Class, Airworthiness	Normal, Certificate of Airworthiness and Valid Airworthiness Review Certificate (ARC)[1]
Owner	Skärgårdsgruppen AB
Time of occurrence	14/07/2014, 15.30 hrs in daylight Note: All times are given in Swedish daylight saving time (UTC[2] + 2 hours) unless otherwise stated.
Place	Lennartsnäs/Kungsängen, Stockholm county, (position 59˚27'N 17˚44'E, 10 metres above mean sea level)
Type of flight	Private
Weather	According to SMHI's analysis: South-easterly wind 15 knots, visibility 10 kilometres or more, isolated light showers in the area, cloud 0-2/8 with base at 2 000 feet, otherwise above 3 000 feet, temperature/dew point 20/14°C, QNH[3] 1 009 hPa
Persons on board:	1
crew members including cabin crew	1
passengers	0
Injuries to persons	None
Damage to aircraft	Substantially damaged
Other damage	None
Commander:	
Age, licence	42 years, PPL(H)[4]
Total flying hours	2 100 hours, of which 100 hours on type
Flying hours previous 90 days	34 hours, of which all on type
Number of landings previous 90 days	52

[1] ARC (Airworthiness Review Certificate).
[2] UTC (Coordinated Universal Time).
[3] QNH (Barometric pressure at mean sea level).
[4] PPL(H) (Private Pilot Licence (Helicopter).

SUMMARY

A helicopter of the type MD 600N started from Frösön, Östersund, for a VFR flight to Bromma, Stockholm. Close to Kungsängen at an altitude of 1500 feet, the engine stopped and the pilot turned in an autorotation to search for suitable diversion site. In connection with the emergency landing the helicopter overturned and extensive damage occurred. The pilot was alone on board and was not injured.

There were about 30 liters of fuel remaining, which is more than the minimum amount of usable fuel. In spite of this, the engine stopped by fuel exhaustion. The engine's fuel exhaustion was caused by a non-functioning fuel transfer system. The transfer system did not work as intended due to a clogged check valve.

The check valve in the fuel transfer system had an impaired function due to contamination. Hence the remaining fuel could not be used and the engine stopped.

Contributing to the occurrence was that the type certificate holder`s extended maintenance instruction on annual checks of the fuel transfer system was not complied with and that such functional checks were therefore not performed.

The Commission also found that the helicopter had been foiled in such an extent that it must be considered as a modification and that this action was carried out by a company which was not a part of the air transport system. This is considered as a risk factor but it did not influence the course of the event.

Safety recommendations

EASA is recommended to:

- Use appropriate means to inform the sector of which forms of foiling of an aircraft that are permitted. *(RL 2015:11 R1)*

The Swedish Transport Agency is recommended to:

- Develop supervisory methods so that EASA Part M, Subpart G approval holders ensure that Aircraft Maintenance Programmes (AMP) are based on the latest data from the type certificate holders. *(RL 2015:11 R2)*

- Use appropriate means to inform the sector of which forms of foiling of an aircraft that are permitted. *(RL 2015:11 R3)*

1. FACTUAL INFORMATION

1.1 History of the flight

1.1.1 Conditions

The intention of the flight was to fly from Frösön Airport outside of Östersund to Bromma Airport in Stockholm. The pilot, who was alone on board, planned to conduct the flight under VFR[5] at a height of around 1 500 feet GND (height above ground). Before take-off from Frösön, 250 litres of fuel were uplifted so that the helicopter's tank, holding 440 litres, was full. In addition, an extra fuel reserve was being carried in a fuel can intended for diesel fuel oil, containing around 60 litres of fuel. For the flight in question, without passengers or additional load, the weight and balance were known from previous flights.

The weather data obtained by the pilot showed good visibility and steady headwind along the entire route. At Frösön, the weather in terms of wind direction and velocity was: 120 degrees/13 kts, visibility 10 km, few clouds at 1 400 feet and isolated clouds at 5 000 feet, temperature +19 degrees Celsius. A decision point was set to a position level with Gävle, where a decision would be made to continue the flight or to land for refuelling at Gävle Airport.

1.1.2 Sequence of events

When passing the decision point, the decision was made to continue with the remaining fuel, based on the indicated quantity of fuel.

During level flight at cruising speed at an altitude of around 1 500 feet with around 10 minutes' flight time remaining to Bromma, the pilot experienced a couple of “bangs” without prior fault indication or warning, followed by a warning for low rotor RPM. The helicopter was flying over water. The pilot lowered the collective lever and entered autorotation, banked to the right to fly in over land, and performed an emergency landing in tailwind on a meadow with grass roughly one metre high (cultivated pasture). The helicopter contacted the ground with forward speed and a high nose-up attitude, the rear part of the tail boom first, thereby breaking the tail boom. The helicopter then came down, the nose still high, at which point the rear part of the skid landing gear contacted the ground, the helicopter overturned, the rotor blades contacted the ground and the helicopter fuselage came to rest on its left side.

In connection with the landing, the emergency floats were released via mechanical action on the release cable for these.

The aircraft received significant damage during landing. No injuries to persons arose.

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[5] VFR - Visual Flight Rules.

The accident occurred at position 59˚27’N 17˚44’E, 10 metres above mean sea level.

1.2 Injuries to persons

	Crew members	Passengers	Total on-board	Others
Fatal	-	-	0	-
Serious	-	-	0	-
Minor	-	-	0	Not applicable
None	1	-	1	Not applicable
Total	1	0	1	-

1.3 Damage to aircraft

Substantially damaged.

1.4 Other damage

None.

1.4.1 Environmental impact

A small quantity of sharp objects was spread in connection with the crash site. A very small quantity of aviation fuel was also deemed to have leaked out, most of which was gathered up in a tarpaulin in conjunction with salvage. Minor damage to the ground from salvage vehicles arose in conjunction with the salvage of the helicopter.

1.5 Personnel information

1.5.1 Commander

The commander was 42 years old and had a valid PPL(H) licence with flight operational and medical eligibility.

Flying hours				
Latest	24 hours	7 days	90 days	Total
All types	8	17	34	2100
Actual type	8	17	34	100

Number of landings actual type previous 90 days: 52.
Type rating concluded on 12 April 2013.
Latest PC[6] (proficiency check) conducted on 15 April 2014.

[6] PC (Proficiency Check).

1.6 Aircraft information

Figure 1. Foto: Niklas Holmberg.

1.6.1 General

MD 600N is a single engine helicopter driven by a gas turbine engine and is equipped with NOTAR[7], i.e. it has no tail rotor. The helicopter is normally flown by one pilot and can take up to 7 passengers. At the time of the accident, it was equipped with inflatable emergency floats. Such an installation is connected with air speed restrictions when inflated.

1.6.2 Helicopter

TC-holder	MD Helicopters Inc. (MDHI) Mesa, United States
Model	MD 600N
Serial number	RN018
Year of manufacture	1997
Gross mass, kg	Stated: Max start 1 860/current 1 304
Centre of gravity	Within limits.
Total flying time, hours	4 162
Flying time since latest inspection	60
Type of fuel uplifted before the occurrence	Jet A-1

[7] NOTAR – (No Tail Rotor) – A device for yaw control without a tail rotor.

Engine	
TC-holder	Rolls-Royce Corporation Indianapolis, United States
Type	250-C47M
Number of engines	1
Serial number	CAE-847813
Total operating time, hours	4 162
Operating time since overhaul, hours	60

Deferred remarks
None

The aircraft had a Certificate of Airworthiness and a valid ARC.

1.6.3 Description of parts or systems related to the accident

The helicopter's fuel system

The fuel tank is made from synthetic rubber and located below the floor plate in the passenger space. It consists of a left and a right half which are interlinked with connections that allow fuel to flow freely both ways between the halves. These halves are in turn divided into a front and rear part with a baffle plate extending from the bottom up to roughly half the height of the tank. The baffle plate has one-way valves which allow fuel to flow backwards in the direction of travel but not the reverse.

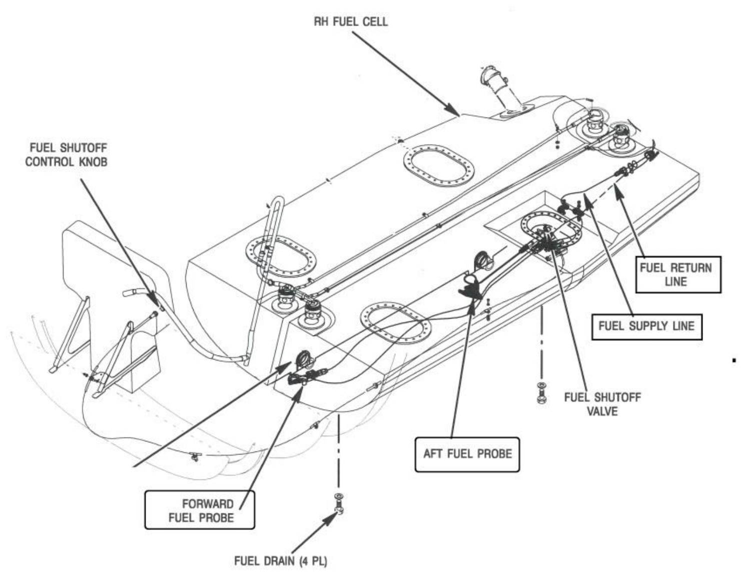

Figure 2. The fuel tank.

The tank capacity is 440 litres, of which roughly 6 litres is considered unusable. The engine is supplied from the rear left part. There are no booster pumps as the engine's fuel system sucks in the fuel required. The tank also has a shut-off valve for the fuel and a float whose purpose is to warn the pilot when the fuel level is low (about 34 litres remaining) via an indication lamp. The quantity measurement system consists primarily of an indicator and two capacitance probes, i.e. the probes have no moving parts and instead make use of the differences in capacitance in the probe when fuel or air is inside it. The probes are located in the fuel tank's front left and rear left part. There are four drainage points under the tank, which are intended for inspection and release of any occurrence of water in the tank.

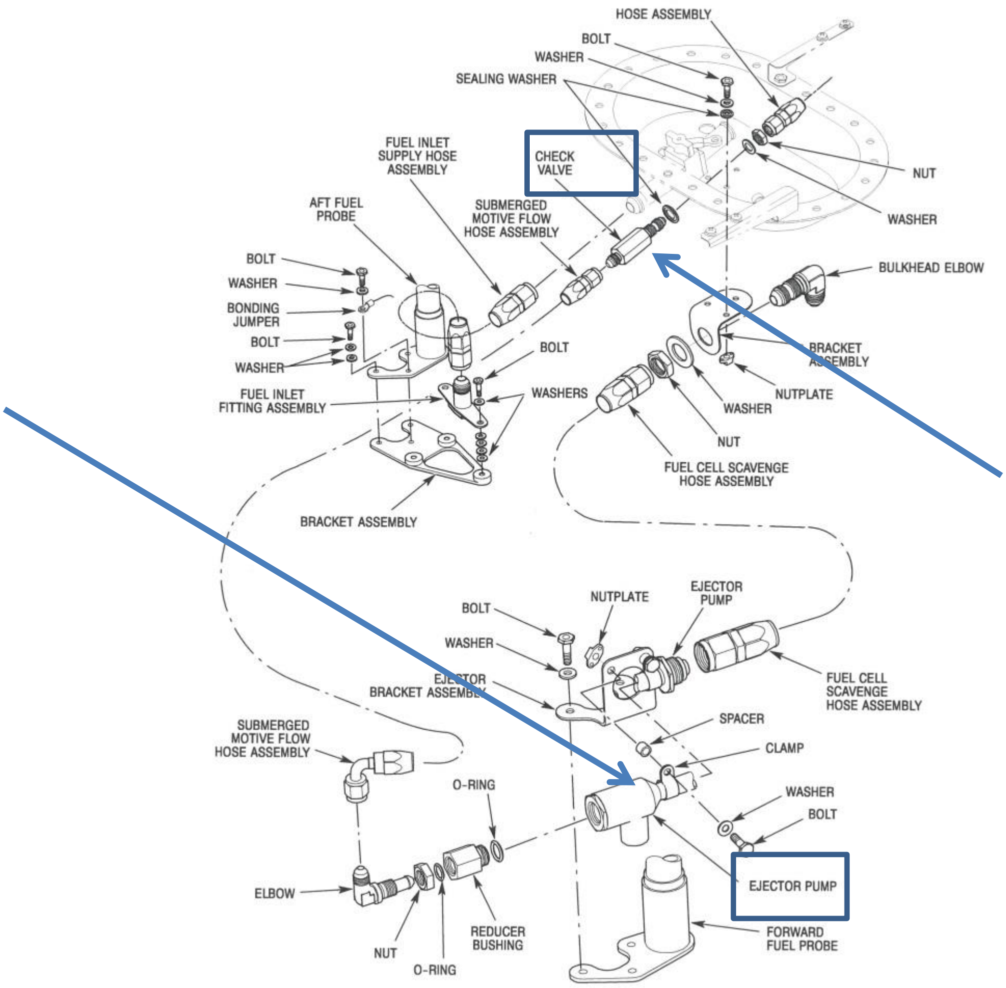

Figure 3. Fuel transfer system.

In the present configuration, this helicopter model has roughly three degrees of nose-down attitude when flying at cruising speed. It is therefore necessary, at low fuel levels, to move fuel from the front to the rear left part. This is achieved by means of a transfer system. The system is driven with excess fuel from the engine's fuel system and consists of a jet pump, a check valve and fuel lines. When the fuel is returned from the engine, fuel is sucked up from the front left tank and transferred to the rear left part.

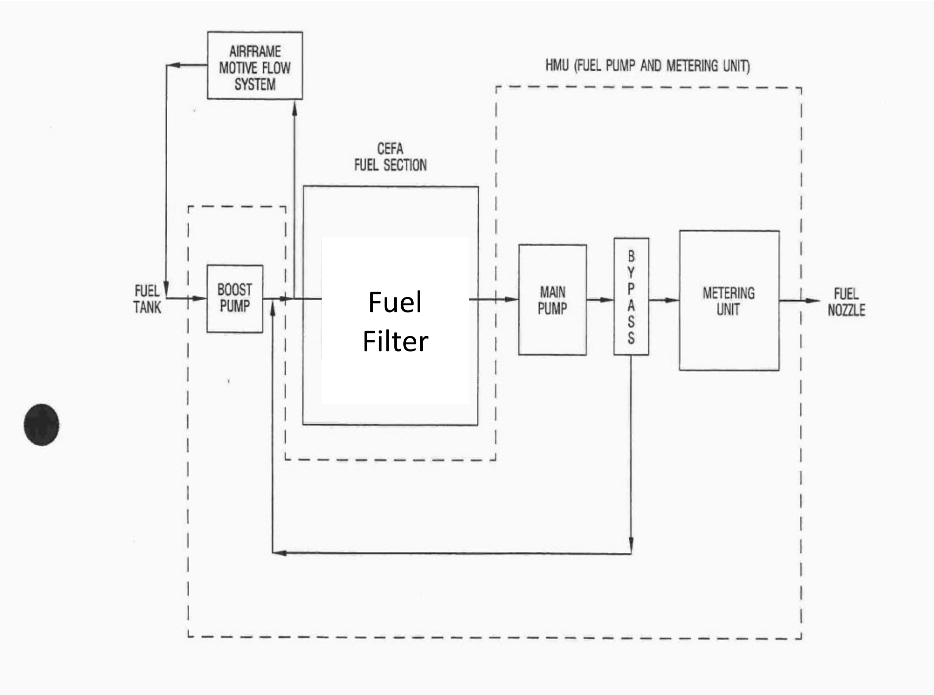

Figure 4. Motive fuel from the engine drives the transfer system.

Instrument system for engine monitoring

The system consists of three indicator modules:

- Analogue display of the engine's temperature and torque.
- Digital display of:
    - Temperature, torque, gas generator rpm and external temperature.
    - The engine's oil temperature, oil pressure, voltage and current in the DC system.

The engine temperature TOT[8] is measured with temperature probes after the second stage of the turbine in the gas generator. The engine's output torque, TRQ[9], is measured on the output axle at the engine's gearbox by means of oil pressure. The digital part contains memory functions which save information on exceedances of permitted values for these two parameters. Maximum values, duration and average values are recorded up to an individual length of 6 minutes for 238 instances.

[8] TOT – Turbine Outlet Temperature.
[9] TRQ – Torque.

Around 50 exceedances were saved by the time of the accident, though the date when these occurred was not recorded. The engine inspection revealed no damage that could be related to these exceedances, as described in Chapter 1.17.1.

These exceedances are considered not to have influenced the sequence of events during the accident.

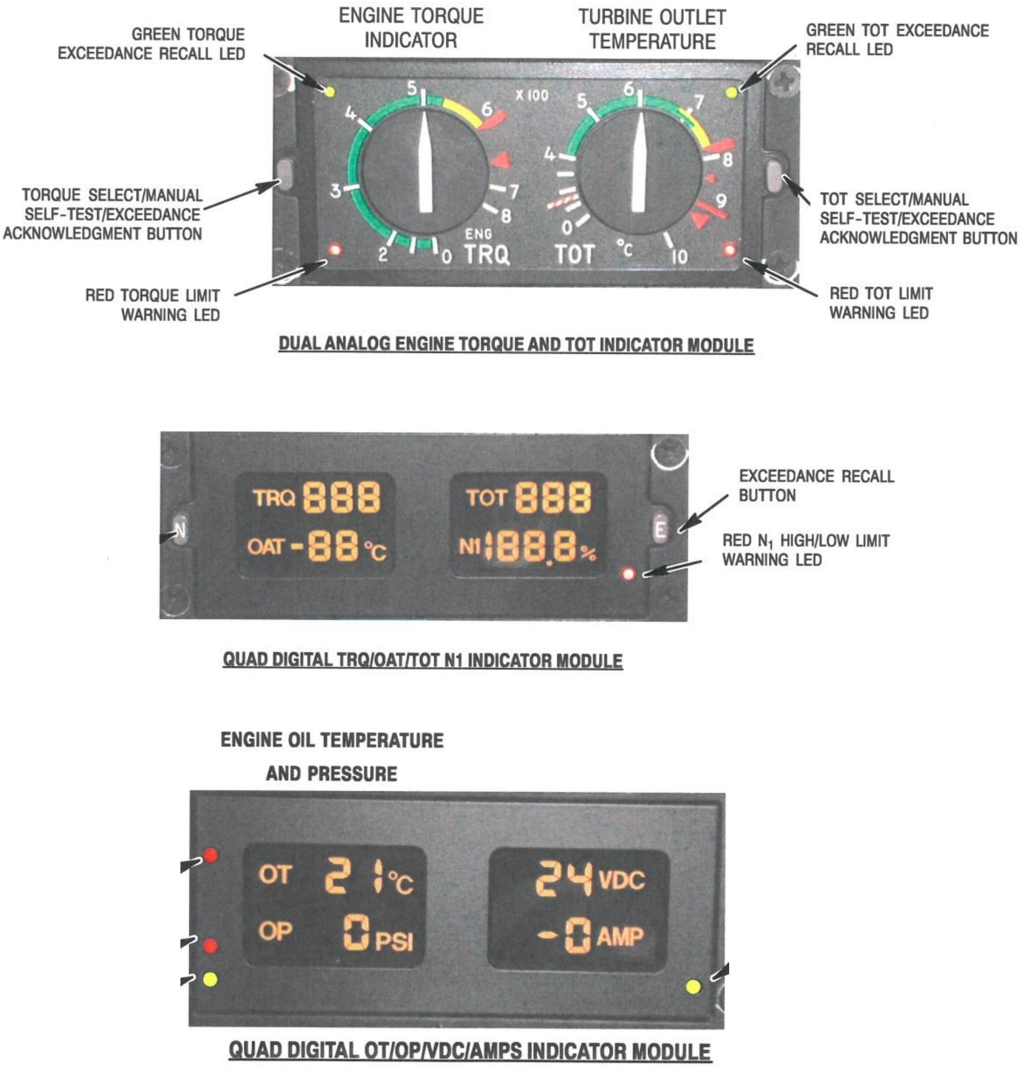

Figure 5. Indicators for engine parameters.

The aircraft engine

The Rolls-Royce 250-C47M is a turboshaft engine with a single stage radial compressor followed by a combustion chamber and two gas generator turbines, and finally two free turbines which are linked to the output axle. At 100 % rpm, the free turbines rotate at 30 650 rpm, and the geared-reduced output axle from the engine at 6 016 rpm. The fuel flow is managed by a FADEC[10] system which consists of an HMU[11] controlled by an ECU[12].

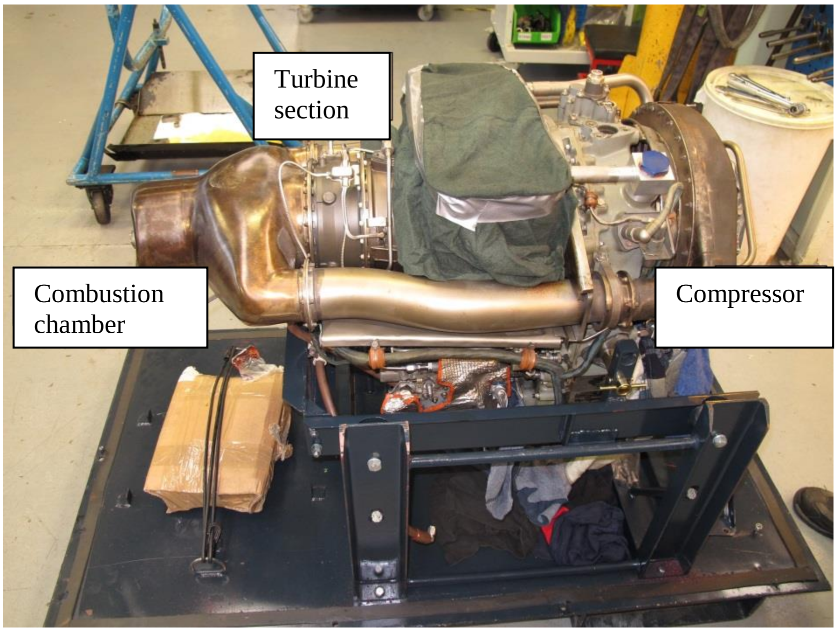

Figure 6. Rolls-Royce 250-C47M.

1.7 Meteorological information

According to SMHI's analysis: On 14 July 2014 at 15.30 hrs, the weather at Örberga, Kungsängen, (Stockholm) was as follows. South-easterly wind of around 15 knots, visibility 10 kilometres or more, isolated light showers, cloud 0-2/8 with base 2 000 feet, otherwise above 3 000 feet, temperature/dew point 20/14°C, QNH 1 009 hPa.

1.8 Navigational aids

1.8.1 Planning support

For planning of the flight and fuel calculations, the pilot used – in addition to manual calculations – the SkyDemon app for iPhone. For weight and balance, the iBal app was used.

The pilot intended to conduct the flight under Visual Flight Rules at a height of around 1,500 feet GND (height above ground). As the height above ground varied between 300 and 500 m during the first part of the flight, this corresponds to up to just over 3 000 feet above sea level (QNH). For the sake of simplicity, the calculations below have been made for the flight altitude 1 500 feet QNH. At higher altitudes, fuel consumption normally decreases.

In order to check the fuel calculations, SHK has performed calculations in the SkyDemon app. In accordance with the information provided by the pilot, the following data was used: Full fuel tanks -

[10] FADEC - Full Authority Digital Electronic Control.
[11] HMU – Hydro Mechanical Unit (the fuel control unit).
[12] ECU – Electronic Control Unit (for the HMU).

440 litres. In addition, an extra tank containing 60 litres that could be used as needed. Take-off ESNZ (at Frösön, but with the name Åre Östersund Airport) and direct to ESSB (Stockholm/Bromma) with no waypoints. Flight altitude 1 500 feet, fuel consumption during climb and level flight 150 litres/hour and for descent 75 litres/hour. Climb speed 1 500 feet/min with a speed of 80 kts. Level flight 115 kts indicated speed (IAS) and descent speed 110 kts. According to the helicopter manual, 115 kts IAS corresponds to an actual speed of 113 kts relative to the air mass. SkyDemon then gives a flight time of 2 hours and 13 minutes with zero wind and 108 litres of fuel remaining at Bromma – see below. With 440 litres in the tanks, the consumption is thus 332 litres.

	MSA	Level	TAS	TrkT	Wind	HdgM	GS	Dist	Time	Fuel	ETA	ATA
ESNZ ÅRE/ÖSTERSUND ESSB STOCKHOLM/BROMMA	3700	1500	113	157	000/00	152	113	251	133	108,0 ltr	13:13 L	
								251	2:13			

Calculations from SkyDemon. The fact that the field "Level" is red is due to the program warning that 1,500 feet relative to sea level is too low.

According to SMHI, the wind was S-SE 15 kts. If the calculations take into account a headwind of 15 kts, a flight time of 2 hours and 33 minutes is obtained, with 57 litres of fuel remaining and a consumption of 383 litres (440-57). A manual rough estimate gives 2 h 33 min x 150 litres/hour =382.5 litres.

	MSA	Level	TAS	TrkT	Wind	HdgM	GS	Dist	Time	Fuel	ETA	ATA
ESNZ ÅRE/ÖSTERSUND ESSB STOCKHOLM/BROMMA	3700	1500	113	157	157/15	152	98	251	154	56,9 ltr	13:33 L	
								251	2:33			

The distance to the crash site is somewhat shorter – 244 nautical miles (NM) – for which reason the flight time is 2 hours and 29 minutes. The remaining fuel is then 69 litres and consumption 371 litres (440-69).

	MSA	Level	TAS	TrkT	Wind	HdgM	GS	Dist	Time	Fuel	ETA	ATA
ESNZ ÅRE/ÖSTERSUND Haveriplats	3600	1500	113	157	157/15	152	98	244	149	68,7 ltr	15:29 L	
								244	2:29			

1.8.2 Navigational aids

The helicopter was equipped with a built-in GPS navigator. It has not been possible to extract any relevant data from the GPS navigator. Furthermore, the pilot used apps (applications/software) for planning and navigation on his iPhone and iPad.

The SkyDemon application can also be used for navigation, but as the iPhone has a small display, SkyDemon was less suitable for navigation during the flight itself. The pilot's iPad, which has a considerably larger screen, was of an older model and it was not possible to install SkyDemon on it. However, SkyDemon was running on the phone as a backup. The pilot thus primarily used the app Air Navigation Standard from Xample on his iPad and the built-in GPS unit as a backup.

The standard version of Air Navigation has only limited functionality and was therefore only used as an aid to navigation by means of a "moving map", which presents the aircraft's position on a map.

Below is a screenshot from SkyDemon with a route from ESNZ (Frösön) to the crash site. Note however that SkyDemon was not used for navigation during the flight.

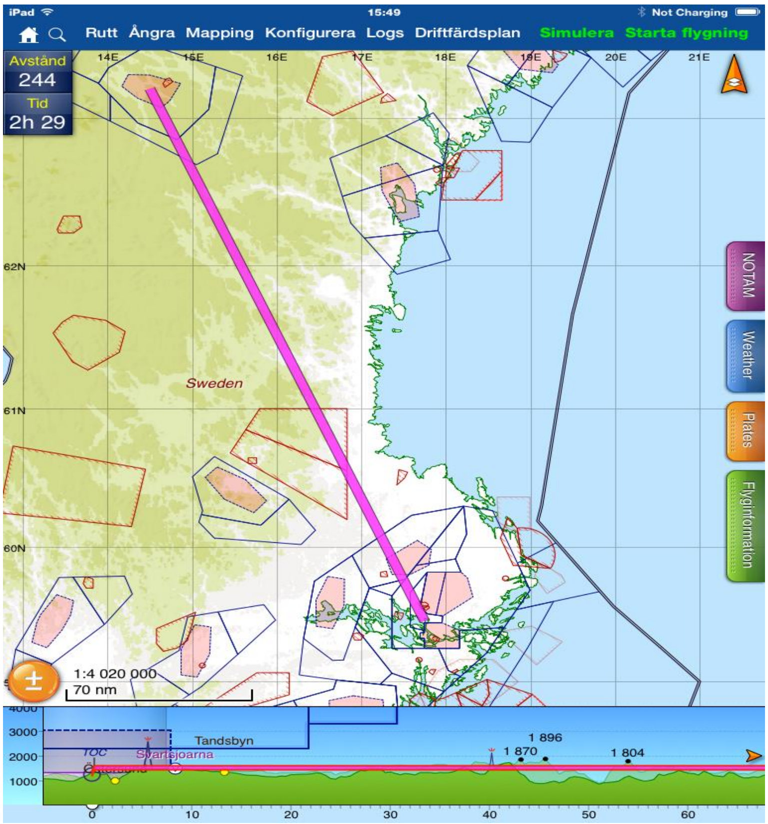

Figure 7. Screenshot from SkyDemon on the iPad. Similar screens are displayed on the iPhone version.

1.9 Rules for fuel planning

Chapter 2, Section 35 of the Swedish Civil Aviation Authority's Regulations and General Advice (LFS 2007:59) on private aviation with a helicopter states that "*When flying under VFR, fuel shall be carried in the minimum calculated quantity required for flying to the intended landing site, and thereafter for 20 minutes' flight at a speed for the best range as well as 10 per cent of the planned flight time and additionally the quantity of fuel sufficient for unforeseen events.*"

1.10 Communications

There was no radio communication or report of an emergency situation in the stage immediately before the emergency landing or in connection with this.

1.11 Aerodrome information

Not applicable.

1.12 Flight recorders

1.12.1 Flight Recorders (FDR[13], QAR[14], GPS[15])

FDR and QAR were not available and are not a requirement.

GPS was available. Flight data could not be extracted from the unit.

The software application, "the app", SkyDemon has a hidden Flight Data Recorder. I.e., during the flight, data such as the date, time, position, altitude, heading and speed are recorded once per second in a log file "gps.blackbox", which can only be decoded by the software developer. The recording function has been developed in collaboration with AAIB (the United Kingdom Air Accidents Investigation Branch). The unit with this app was inside a mobile phone, which was lost during the week after the accident. Had this information been available, accurate data from the flight could have been obtained.

However, it has been possible to confirm the equivalent data using radar data. (See Fig. 8)

[13] FDR (Flight Data Recorder).
[14] QAR (Quick Access Recorder).
[15] GPS (Global Positioning System).

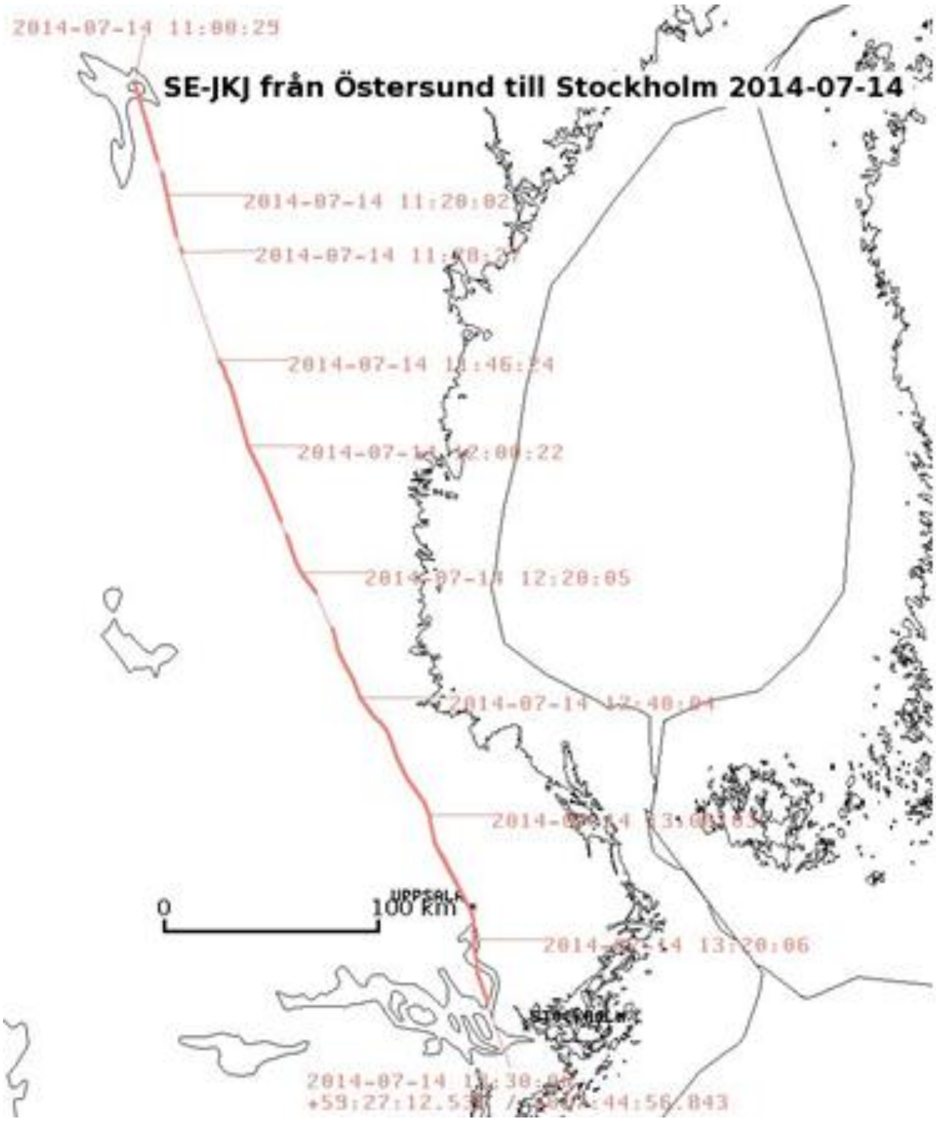

Figure 8. Radar tracks of the flight. Times given in UTC. Source: The Swedish Armed Forces.

1.12.2 Cockpit Voice Recorder (CVR)

There was no Cockpit Voice Recorder. Nor is this a requirement.

1.13 Accident site and aircraft wreckage

1.13.1 Accident site

The accident site is situated in a meadow with cultivated pasture surrounded by a forest, in a sparsely populated area. The meadow is enclosed with sheep fencing. The tail boom's lower guard hit the upper part of the fencing and cracked a post before the tail boom hit the ground and broke.

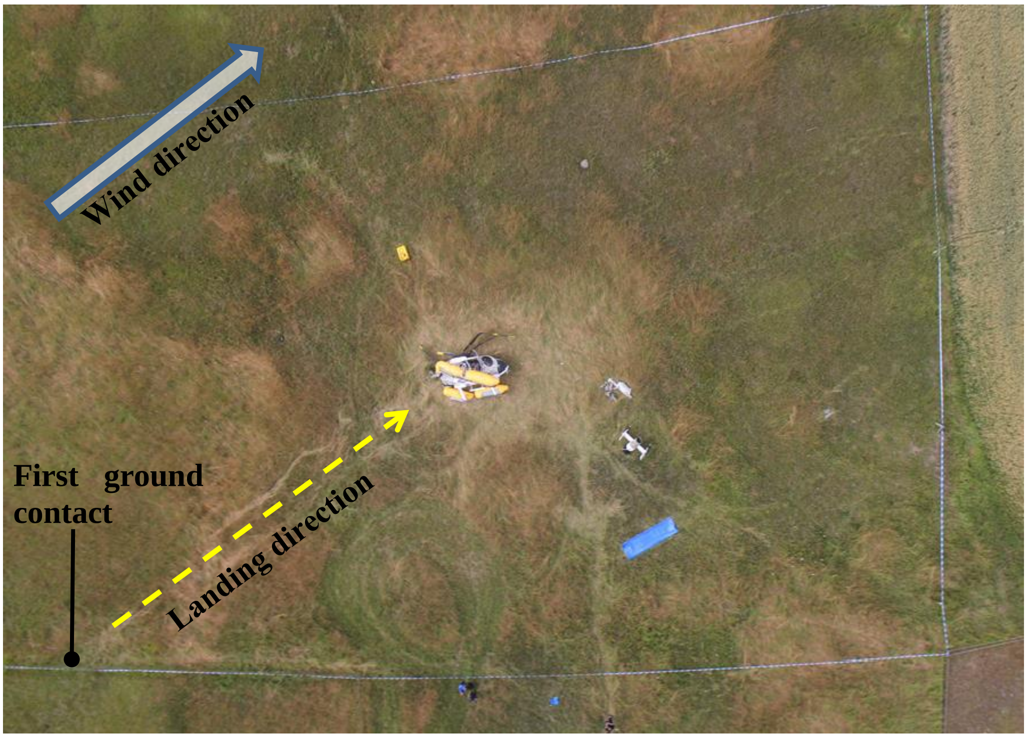

Figure 9. Accident site. Photo: Air Unit.

1.13.2 Aircraft wreckage

In connection with salvage, the helicopter was emptied of fuel. The quantity measured approximately 26 litres. During an in-depth technical examination at SHK's premises in Strängnäs, the remaining fuel – around 4 litres – was emptied. The remaining quantity of fuel at the time of the incident is therefore deemed to have been around 30 litres.

It can be noted that unauthorised persons had moved the tail boom and other large parts before the commission could secure the accident site.

Figure 10. The helicopter.

1.14 Medical and pathological information

The pilot had valid medical eligibility, class 2.

1.15 Fire

There was no fire.

1.16 Survival aspects

1.16.1 Rescue operation

Provisions on rescue services are found primarily in the Civil Protection Act (2003:778) and the Civil Protection Ordinance (2003:789), in the following referred to by use of the their acronyms in Swedish, LSO and FSO respectively.

According to Chapter 1, Section 2, first paragraph of LSO, the term "rescue services" denotes the rescue operations for which central government or municipalities shall be responsible in the event of accidents or imminent danger of accidents, in order to prevent and limit injury to persons and damage to property and the environment. Central government is responsible for mountain rescue services, air rescue services, sea rescue services, environmental rescue services at sea and rescue services in case of the emission of radioactive substances, as well as for searching for missing persons in certain cases. In other cases, the authorities of the municipality concerned are responsible for the rescue services (Chapter 3, Section 7, LSO).

Calls regarding the incident were received by SOS Alarm. The SOS operator informed JRCC[16] that a helicopter had performed an

[16] JRCC (Joint Rescue Coordination Centre)

emergency landing at Öråkers Gård outside of Kungsängen. The head of the rescue operation at JRCC called the helicopter pilot. Following the pilot's description of what had happened, it was decided at JRCC that municipal rescue services and police would be called to the site in order to determine whether a rescue operation was required.

Upon the rescue services' arrival at the site, it was established that the helicopter was lying on its side and that the pilot was uninjured as previously stated. There was no obvious environmental damage and no need for decontamination, for which reason the rescue operation was concluded.

The ELT[17] of type ARTEX ME 406 HM was activated during the accident.

1.16.2 Position of crew and passengers and the use of seat belts

The pilot, who was sitting in the left front seat, used a headset and a safety belt of the "four point seat belt" type. No injuries to persons arose in connection with the accident.

1.17 Tests and research

1.17.1 Engine inspection

The engine and its auxiliary devices were removed and transported to an aircraft engine workshop in the United Kingdom. The workshop had the necessary authorisations for the inspections carried out in consultation with the manufacturer and under the guidance of SHK. The gas turbine section was fully stripped down with the intention of finding signs of why the engine had stopped during the flight. The main components of the fuel control system – ECU and HMU – were also thoroughly examined. The ECU had no faults logged but had recorded a sinking engine rpm, and as the final signal, a command to the HMU to open fully in order to increase the flow of fuel. The HMU was tested in a rig and displayed correct values, which means approved functionality. Inspections of various filters in connection with the engine inspection showed some occurrence of contaminants. These were deemed not to have affected the engine's function. In summary, the report from the type certificate holder, Rolls-Royce, stated that the engine was found to be in a state with no significant remarks.

[17] ELT (Emergency Locator Transmitter).

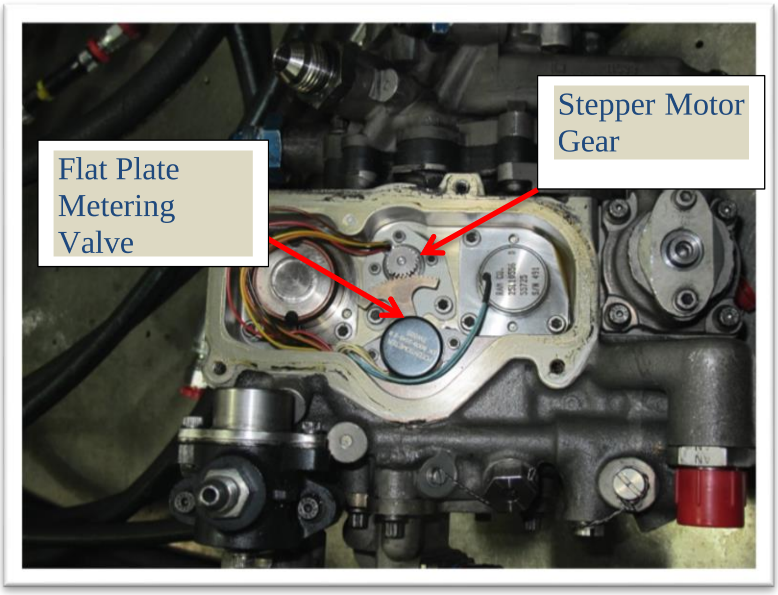

Figure 11. Shows that the position of the HMU metering valve is fully open.

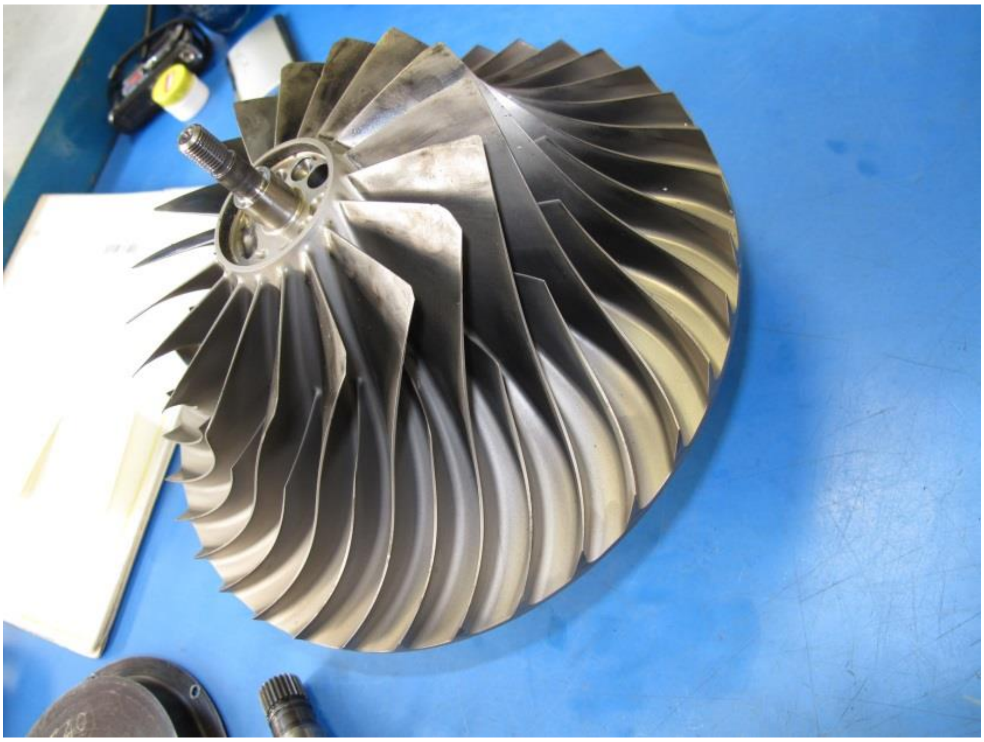

Figure 12. Radial compressor in good condition.

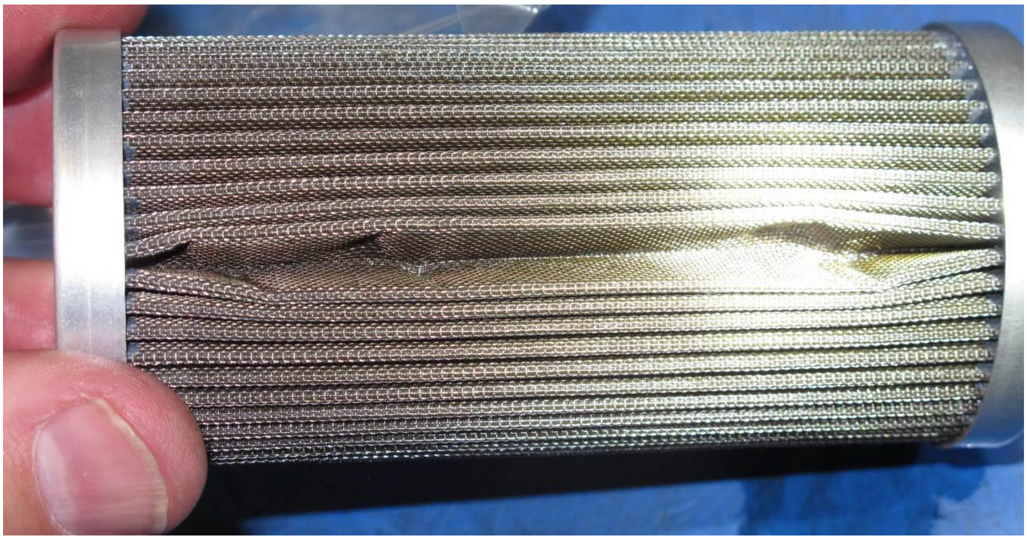

Figure 13. Fuel filter with limited quantities of foreign objects.

1.17.2 Fuel system

The Commission has appointed a separate entity to analyse fuel samples from a number of positions in the fuel system and of oil samples from the engine.

During the latest maintenance, shortly before the accident, there had been faults in the warning system for low fuel quantity, though without this having been noted in the Aircraft journey log book. The work card from the maintenance statement describes the fault, the measures taken and the functional check subsequently performed with no remark. During this work, the fuel tanks were fully emptied. During the first inspection of the helicopter at SHK's premises, it was established that the warning lamp for low fuel quantity functioned correctly.

During the Commission's investigations, the helicopter was positioned with a three-degree nose-down in the pitching plane and horizontally in the rolling plane, which corresponds to the attitude that the helicopter type has in distance flight at the speed in question, and had when the engine stop occurred. The tank was subsequently filled with the same quantity measured after the accident. The level of fluid was distributed so that the engine's supply line was lying just above the surface, which corresponds to the distribution of fuel in the tank, in the event of a faulty fuel transfer system. See also *Fuel transfer*.

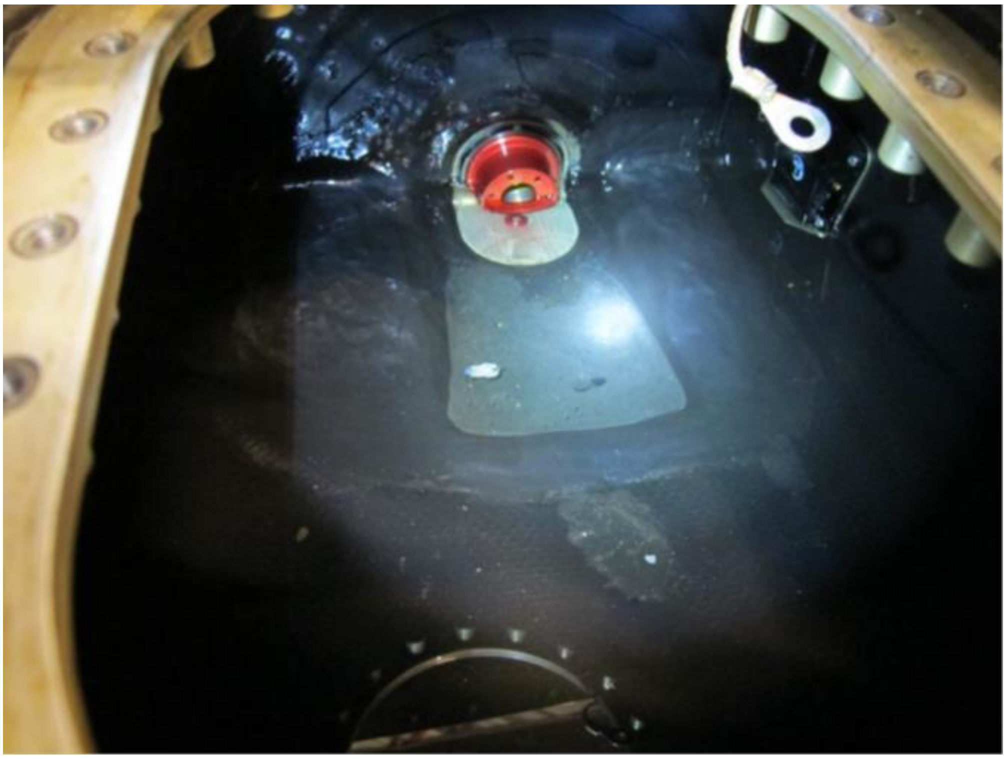
Figure 14. Fuel tank with remaining fuel and water.

Fuel transfer

Due to the design of the tank system and the fact that the helicopter often flies with a weak nose-down position, it is necessary in the event of low fuel levels, half a tank or less, to have a system for moving fuel from the front parts to the rear parts, where the engine obtains its fuel supply.

This transfer system consists of an ejector or jet pump, fuel lines and a check valve. During functional checks, the check valve was found to be clogged, which resulted in it yielding a severely restricted flow to the transfer system. A simple cleaning of the check valve provided a considerably higher flow.

Figure 15. Check valve.

1.18 Organisational and management information

The helicopter was used by a private person who had assigned monitoring of continuing airworthiness to an approved organisation, CAMO[18].

1.19 Additional information

1.19.1 Maintenance requirements

In simple terms, the provisions on airworthiness and maintenance of aircraft mean, among other things, that the type certificate holder do issue and develop maintenance data for the aircraft type. In cases where a CAMO is responsible for the aircraft's airworthiness, it shall use the current maintenance data as a basis for issuing an Aircraft Maintenance Programme (AMP), which must be adapted to the aircraft individual. This specific manual must be sent to the Swedish Transport Agency for approval. The maintenance organization engaged must follow the work orders issued by the CAMO concerned. In the present case, the Commission has established that the AMP that applied to the helicopter was not fully adapted to the aircraft individual, but was more generic designed in some respects.

The type certificate holder updated the maintenance requirements in December 2009 by introducing a requirement for an annual functional check of the aforementioned transfer system. The aim of the check is to verify the flow to the ejector pump so that the transfer of fuel can be made to the rear part of the tank.

[18] CAMO (Continuing Airworthiness Management Organisation).

No corresponding change to the current specific aircraft maintenance program (AMP) for SE-JKJ was carried out by the CAMO responsible. Furthermore, the archived maintenance records from the last three annual inspections carried out show that the functional check had never been carried out. Three different CAMOs have had responsibility for the helicopter since March 2009 when it was imported to Sweden.

1.19.2 Foiling or striping

Very large parts of the helicopter fuselage were at the time of the accident covered by a foil with patterns and advertising text. The foiling was carried out at the request of the owner on 6 November 2013 by a company without connection to the air transport system.

2. ANALYSIS

2.1 Planning conditions and implementation

2.1.1 Fuel planning

According to radar information, the first radar echo was seen at 11.00:29 at Frösön, and the last, close to the crash site, at 13.30:08, giving a flight time between the first and last echo of 2 hours, 29 minutes and 29 seconds, which corresponds well with the above calculation. According to the radar information, the helicopter made minor deviations from the track, for which reason the fuel consumption may have been somewhat higher in reality if the wind had been in accordance with the calculations, and the indicated speed somewhat higher.

According to the Swedish Civil Aviation Authority's Regulations and General Advice (LFS 2007:59 Section 35) on private aviation with a helicopter, the fuel carried should correspond to the planned fuel consumption plus 10 per cent, as well as additional fuel for 20 minutes at a speed for the best range. According to the planning tool used, and with the prevailing wind forecast, the consumption should have been 383 litres and the remaining fuel upon landing 57 litres (440-383 litres). According to the aforementioned regulations, the planned fuel consumption should in this case be supplemented with around 38+50 litres = 88 litres. The carried fuel would thus not meet the requirements laid down in the same regulations. The Commission notes that the method used to make the decision to continue to the destination without landing and refuelling, based on the indicated quantity of fuel, was not thorough enough to guarantee a sufficient fuel reserve until landing.

As part of the fuel carried was in a reserve can as baggage, it was not available to the engine and could thus not be of use without first landing the helicopter and refuelling. However, the Swedish Civil

Aviation Authority's regulations do not specify that the calculated quantity of fuel needs to be available; only that it must be carried.

2.1.2 Emergency landing

The emergency landing was initiated in a flight position with a safe height and speed above water. With the intention of reaching level ground, and avoiding an emergency landing on water despite the helicopter being fitted with emergency floats, the pilot turned approximately 180 degrees to the right. The final stage of the landing was thereby conducted with a tailwind component of around 10-15 kts. It is the Commission`s understanding that it is not possible to execute a safe conclusion to an autorotation in such a strong tailwind.

2.1.3 Recording of flight data

In a way corresponding to that of the SkyDemon app, Air Navigation Pro has functions for saving information. “Flight Recorder” saves GPS positions and altitudes in the iPad. “Flight tracking system” can send data in real time with position, altitude, speed and heading to a server on which other users can follow the flight, and it is also possible to download the information afterwards and then post it for presentation on a map such as Google Earth.

It can be noted that the cost of the planning and navigation software used is low. Such software can thus function as a cheap flight recorder, even if it is not crash-protected.

2.2 Technical and airworthiness aspects

2.2.1 Fuel system

The helicopter's fuel tank contained a certain quantity of water and other contaminants despite the fuel tank having been emptied and cleaned during maintenance work only around six weeks prior to the incident. The various fuel samples submitted contained mould spores and microorganisms. None of the contaminants found were however deemed to have affected the engine's operation.

The transfer system did not function as intended due to the clogged check valve. As the helicopter's flight position was roughly three degrees nose-down for a long time, this led to the majority of the fuel being distributed among the two front parts of the fuel tank.

2.2.2 Omitted maintenance

Since March 2009, when the helicopter was imported to Sweden, three different CAMOs have been responsible for its airworthiness. None of these have followed the extended maintenance instruction that was issued by the type certificate holder in December 2009 and that entailed a requirement to perform an annual functional check of the fuel transfer system. This means that the mandatory functional check, according to the maintenance records examined by the Commission had never been carried out.

2.2.3 Airworthiness

The circumstance that a maintenance action, which in accordance with requirements from the type certificate holder should be performed annually, had not been taken over the past three years entails that formally speaking; the helicopter was not to be considered airworthy.

2.2.4 Supervisory responsibility

The Swedish Transport Agency has oversight responsibility over Swedish CAMOs. These organisations shall work in accordance with their own procedures, which must be written so that they comply with the applicable and current parts (*Subparts*) of EASA Part M.

Responsibility for continuing airworthiness lies with the owner or the user, according to EASA Part M.A.201. However, this person may assign responsibility to a CAMO via a contract. Among other things, having responsibility for airworthiness involves ensuring necessary maintenance is carried out at the right time, by authorised personnel and in accordance with applicable maintenance data.

The Swedish Transport Agency's supervision in the present respects has, according to its staff, been confirmed to be of a spot check nature. This method has not ensured that CAMOs have functioning systems for, e.g. handling updated maintenance requirements. In light of the fact that three different CAMOs have overlooked the updated maintenance requirements from the type certificate holder, there is reason to recommend the Swedish Transport Agency to develop its oversight methods.

2.2.5 Cause of the engine stop

The accident was caused by the check valve in the fuel transfer system having reduced function due to contaminants, which meant that the remaining fuel could not be utilised and the engine therefore stopped due to fuel exhaustion.

A factor contributing to the accident was that one maintenance task, included in the TC-Holder's extended maintenance requirements, had not been carried out.

2.3 Risk factors

2.3.1 Training in emergency landing, autorotation and flying with inflated emergency floatation devices

Training in flight in autorotation was at the time of the pilots training, regulated, among other places, in the Swedish Civil Aviation Authority’s Regulations and General Advice (LFS 2008:31). Section

10 of the mentioned regulation stated that “In training for obtaining a Private Pilot Licence PPL (H), autorotation should not be fully carried out by the trainee, in accordance with what is stated in appendix 1, supplement 1 of JAR- FCL 2.125 3) h), but only be demonstrated by the flight instructor”.

The regulation was replaced on the 8 April 2013, by the Swedish Transport Agency’s Regulations and General Advice (TSFS 2013:22) regarding approved Flight Training Organisations. This regulation contains corresponding regulations for helicopter pilot training to the previous one described and it states that autorotation should not be fully carried out by the trainee. (TSFS 2013:22, Appendix 2, chapter C: Addition 1 to JAR-FCL 2.125).

Inflating emergency floats during flight and flying with inflated emergency floats affect the flight characteristics and can entail risks where there is insufficient knowledge of these. There are limitations in speeds for inflating and flying with inflated emergency floats for helicopters that carry this type of equipment. For this helicopter, the maximum speed for inflation of the emergency floats was 85 kts indicated speed, which is to be compared with a cruising speed of 115 kts. For other helicopter types, the maximum speed for inflation might be lower. A pilot who has not been drilled in releasing the emergency floats or trained in flying in autorotation with inflated emergency floats is at risk of having deficient skills in performing an emergency landing over water.

The Commission realizes that it is cost-driven to comply with JAR-FCL without the exception described by the Swedish Transport Agency, but this means an extended risk exposure. For above reasons there may be motive to review the current training requirements with the purpose of better preparing pilots for flying with inflated floats and emergency landing on water.

In connection with the accident the emergency floats were unintentionally released. It is the Commission`s opinion that these facts did not contribute to the accident.

2.3.2 Foiling or striping

Very large parts of the helicopter fuselage were at the time of the accident covered by a foil with patterns and advertising text. The foiling was carried out at the request of the owner on 6 November 2013. The type certificate holder, MD Helicopters Inc, its supervisory authority FAA[19] and the Swedish Transport Agency consider foiling of this scope to be a change to the helicopter that is termed a modification. The foiling was carried out by a company that was not a part of the air transport system. The contracted CAMO became subsequently aware that this had occurred, and the maintenance

[19] FAA – (Federal Aviation Administration) – the aviation authority in the United States.

organization noticed this during the first maintenance after the modification. It is the Commission`s understanding that the foiling did not contribute to the accident.

3. CONCLUSIONS

3.1 Findings

a) The pilot was qualified to perform the flight.
b) The helicopter had a Certificate of Airworthiness and valid ARC.
c) The annual functional check of the fuel transfer system was not implemented in the helicopter's approved maintenance programme.
d) The annual functional check of the fuel transfer system had been carried out neither by the current nor the previous owners of the helicopter in Sweden.
e) The engine incurred a lack of fuel and it stopped due to the fuel transfer system not functioning as intended.
f) The helicopter was, due to omitted maintenance, not airworthy.
g) The helicopter was, due to it having been foiled without approved data and by an unauthorised organisation, not airworthy.

3.2 Causes/Contributing Factors

The cause of the accident was lack of fuel supply to the engine, which was caused by a non-functioning fuel transfer system. This was in turn due to a prescribed maintenance action not having been stated in the helicopter's maintenance programme and therefore also not having been taken.

A factor contributing to the scope of the accident was that the emergency landing had been performed in tailwind.

4. SAFETY RECOMMENDATIONS

EASA is recommended to:

- Use appropriate means to inform the sector of which forms of foiling of an aircraft that are permitted. *(RL 2015:11 R1)*

The Swedish Transport Agency is recommended to:

- Develop oversight methods so that EASA Part M, Subpart G approval holders ensure that Air Maintenance Programmes (AMP) are based on the latest data from the type certificate holder. *(RL 2015:11 R2)*

- Use appropriate means to inform the sector of which forms of foiling of an aircraft that are permitted. *(RL 2015:11 R3)*

The Swedish Accident Investigation Authority respectfully requests to receive, **by 25/09/2015 at the latest**, information regarding measures taken in response to the safety recommendations included in this report.

On behalf of the Swedish Accident Investigation Authority,

Jonas Bäckstrand Stefan Carneros