Norwegian Safety Investigation Authority

Issued November 2023

REPORT AVIATION 2023/08

Serious aviation incident during approach to Stavanger Airport Sola on 25 September 2020 involving a Sikorsky S-92A, LN-ONQ operated by Bristow Norway AS

The Norwegian Safety Investigation Authority (NSIA) has compiled this report for the sole purpose of improving aviation safety.

The object of the NSIA's investigations is to clarify the sequence of events and causal factors, elucidate matters deemed to be important to the prevention of accidents and serious incidents, and to issue safety recommendations if relevant. It is not the NSIA's task to apportion blame or liability under criminal or civil law.

This report should not be used for purposes other than preventive aviation safety work.

Photo: Bristow Norway

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

Table of contents

Report on serious aviation incident

Table 1: Data relating to the aviation incident

Type of aircraft:	Sikorsky Aircraft Corporation S-92A
Nationality and registration:	Norwegian, LN-ONQ
Owner:	Knut Axel Ugland Holding AS
Operator:	Bristow Norway AS
Crew:	2, uninjured
Passengers:	3, uninjured
Location:	Stavanger Airport Sola, ENZV
Time of incident:	Friday 25 September 2020 from 1411 hours until touchdown at 1427 hours

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

Notification

At 1542 hours on Friday 25 September, the Norwegian Safety Investigation Authority (NSIA) was notified by Bristow Norway AS. An S-92A helicopter on its way from the West Elara oil platform to Sola had lost oil pressure on the main gearbox. The incident occurred when the helicopter was descending from 7,000 ft to 1,000 ft. The helicopter later landed safely at Sola where it was followed to parking by the airport's fire and rescue service.

Two NSIA accident investigators arrived at Sola the same evening and started a preliminary investigation.

In accordance with ICAO Annex 13 'Aircraft Accident and Incident Investigation', the National Transportation Safety Board (NTSB) in the USA, the country of manufacture, was notified of the incident. The NTSB appointed an accredited representative who led the investigation in the USA on behalf of the NSIA.

Summary

On Friday 25 September 2020, LN-ONQ, a Sikorsky S-92A helicopter, took off from the West Elara oil installation in the North Sea, bound for Stavanger Airport Sola. The helicopter was carrying a crew of two pilots and three passengers.

About an hour after departure, the MGB OIL PRESS[1] caution illuminated. This occurred at 4500 ft when the helicopter was descending from 7,000 ft to 1,000 ft. The caution indicated that the oil pressure in the main gearbox had dropped below 45 psi.[2] The oil pressure continued to drop, and soon after, the INPUT/ACC # 1 HOT caution illuminated (left engine).

The crew followed the emergency checklist and continued the descent to 500 ft while the left engine was pulled back to idle and a *MAYDAY* distress call was issued. When the oil pressure dropped further to 35 psi, the MGB BYPASS caution illuminated. This caution indicated that the oil cooler for the main gearbox had automatically disconnected. It was decided to reduce the altitude further, and the helicopter continued its descent towards 200 ft. This altitude was maintained until landing at Sola.

Sixteen minutes after the MGB OIL PRESS caution illuminated, the helicopter landed at Sola. The helicopter was followed into the parking stand by the airport's fire and rescue crews. After the helicopter was parked and the rotor had stopped, it became clear that a significant oil leak had occurred on the left side of the main gearbox.

When the left input module was disassembled, a metal stop-washer of the type MS20002-6 was found to have ended up in the main gearbox's oil system. The washer was standing on its edge in the main gearbox's scavenge return oil system, thereby reducing the oil flow in the passageway. This had led to overheating.

The NSIA believes it is likely that the washer entered the module in connection with maintenance and more precisely through the openings that are exposed when the generator is disconnected from the flange on the accessory module. The NSIA has not been able to establish when the washer entered the gearbox.

The last time the opening was available was 487.35 flight hours before the incident. The NSIA thus has reason to assume that the washer has been inside the main gearbox for at least 487.35 flight hours.

No one was injured in the incident.

As a result of the investigation, the NSIA submits a safety recommendation to the Norwegian Civil Aviation Authority.

[1] *Highlighted in yellow or red to reflect cautions and warnings, respectively, as displayed in the cockpit (applies throughout this report).*
[2] *Psi is Pounds per Square Inch, an indication of pressure. 1 bar = 14.5 psi.*

About the investigation

Purpose and method

The NSIA has classified the incident as a serious aviation incident. The purpose of this investigation has been to clarify what caused the oil pressure in the main gearbox to drop uncontrollably and lead to overheating of the oil in the gearbox.

The incident and the circumstances have been investigated and analysed in line with the NSIA's framework and analysis process for systematic safety investigations (the NSIA method[3]).

Focus and delimitation of the investigation

The investigation has mainly addressed the technical causes of the aviation incident.

The operational aspects have been looked into in less detail, but the crew's assessments have been included.

Sources of information

The following have been among the most important sources of information:

- Bristow Norway AS technical maintenance documentation and programme
- LN-ONQ flight data recorder (CVFDR)
- LN-ONQ technical log
- Reports from and interviews with the helicopter crew
- Report from Avinor Air Navigation Services, Sola
- Report from the fire and rescue service, Sola
- Report from the Armed Forces Laboratory Services (FOLAT)
- Bristow Norway AS' internal report
- NTSB Materials Lab Report 21-040, LN-ONQ
- Communication log from the air traffic service

The investigation report

The first part of the report, 'Factual information', describes the sequence of events as well as a what the NSIA has investigated and related findings.

The second part, the 'Analysis' part, contains the NSIA's assessment of the sequence of events and contributing causes based on factual information and completed investigations/examinations. Circumstances and factors found to be of little relevance to explaining and understanding the incident are not discussed in depth.

The final part of the report contains the NSIA's conclusions and safety recommendations.

[3] *See https://www.nsia.no/About-us/Methodology*

1. Factual information

1. Factual information

1.1 History of the flight

The helicopter crew had conducted a flight with LN-ONQ earlier that day. The helicopter, with call sign BHL 203, took off from Stavanger Airport Sola (ENZV) at 0732 hours with return at 1005 hours. The flight went according to plan, and the crew did not notice anything wrong with the helicopter. The flight time on the first flight was logged to 2 hours and 24 minutes.

The next flight, with call sign BHL 208, was scheduled to depart from Sola at 1140 hours. The helicopter took off at 1143 hours and flew 172 NM out to the West Elara oil rig on the Eldfisk field. The flight to the platform was completed without any problems.

They took off from the oil platform at 12:59 p.m. The return to Sola was flown at 7,000 ft. Descent from the cruising altitude of 7,000 ft towards 1,000 ft was commenced approximately 60 NM southwest of Sola (see Figure 1).

At 1411 hours, when the helicopter was at an altitude of approximately 4,500 ft, the MGB OIL PRESS[4] caution illuminated, indicating that the oil pressure in the main gearbox had dropped below 45 psi. The oil pressure continued to drop, and soon after, the INPUT/ACC # 1 HOT caution also illuminated (#1 meant the warning belonged to the left side and left engine).

The commander, who was the pilot monitoring (PM)[5], has informed the NSIA that he was halfway through the emergency checklist (ECL), when the second caution light came on, see Figure 2. In accordance with the checklist, the airspeed was reduced to safe speed with one engine inoperative. The power on the left engine was slowly reduced to idle, the APU[6] was started and a *MAYDAY* call was issued. The crew decided to continue the descent to 500 ft under visual flight conditions. When the oil pressure dropped to 35 psi, the MGB BYPASS caution illuminated, indicating that the oil cooler for the main gearbox was automatically disconnected. A further altitude reduction was decided, and the descent continued towards 200 ft. This altitude was maintained during the rest of the flight towards Sola.

---

[4] The various caution lights are indicated as shown in the helicopter with yellow colour and exact text.
[5] Pilot Flying – PF flies while Pilot Monitoring – PM monitors.
[6] The Auxiliary Power Unit (APU) is an auxiliary engine that supplies electrical, pneumatic and hydraulic power to the helicopter's systems. It does not supply power to the rotor system.

Figure 1: The flight route for the helicopter. The distance from West Elara to Sola is 172 NM. Map: Google Maps. Illustration: NSIA

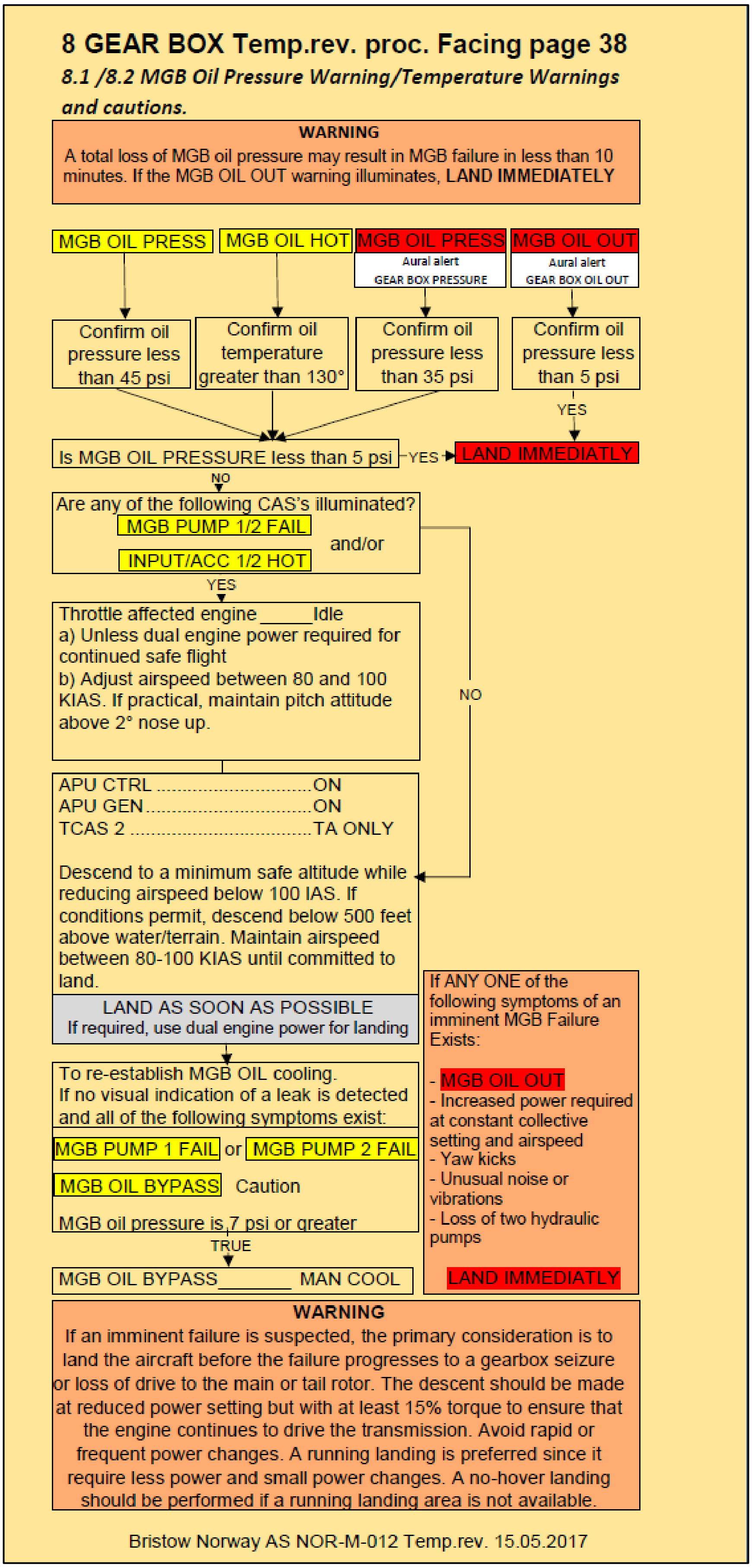

Figure 2: Emergency checklist, temp. rev. 15 May 2017. Source: Bristow Norway / NSIA

During the flight, the crew prepared for the possibility of having to land the helicopter on water if the oil pressure was lost completely. The passengers were informed and asked to prepare accordingly.

Before landing at Sola the air traffic service was updated on the situation, the landing checklist was reviewed, and the crew prepared for a 'run-on landing' to runway 11. The helicopter touched down at 1427 hours and was followed to parking by personnel from the fire and rescue service.

The passengers and crew exited the helicopter in the normal manner through the airstair door on the right-hand side of the helicopter.

Once the helicopter was parked, it was observed that oil from the area near the left engine was running down the exterior of the fuselage along the cabin (see Figure 3). The cover plates in the area were opened, and personnel from the fire and rescue service measured temperatures close to 250°C on the outside of the left main gearbox's input module. There was smoke, but no fire. A check of the oil level in the main gearbox showed that approximately 4 litres were missing.

Data from the flight recorder showed that the highest recorded oil temperature was 214°C and the lowest recorded oil pressure 28 psi.

Figure 3: LN-ONQ shortly after landing. Visible oil spill on the left side of the fuselage and open cover plates around the left engine and main gearbox. Photo: Bristow Norway / NSIA

1.2 Injuries to persons

Table 2: Personal injuries

Injuries	Crew	Passengers	Others
Fatal			
Serious			
Minor/none	2	3	

1.3 Damage to aircraft

The main gearbox had to be replaced due to overheating.

1.4 Other damage

None.

1.5 Personnel information

1.5.1 COMMANDER

The commander, 45 years old, had completed the civilian flight training and proficiency check on the Schweizer 300 and Robinson R22/R44 in the USA. He then flew Robinson R44 for NorCopter for one year before joining Norsk Helikopter AS (now Bristow Norway AS) as a first officer in January 2008. Captain's course on the Sikorsky S-92A was conducted at Bristow Norway AS in 2013.

The commander held a valid airline transport pilot licence for helicopters (ATPL(H)) with instrument rating (IR). The licence to fly S-92 helicopters was most recently renewed on 6 September 2020 and was valid until 30 September 2021. The medical certificate was valid and without restrictions.

The commander worked a rota system with five days of flying, two days off, five days of flying and nine days off. The incident occurred on the second flight on the last working day of a five-day work period before the off-duty period.

Home base was Stavanger. The commander had had 12.5 hours of rest before reporting for duty on the day of the incident. The commander has informed The NSIA that he felt rested and ready before going on duty.

Table 3: Flying experience, commander

Flying experience	All types	On type
Last 24 hours	6	6
Last 3 days	11	11
Last 30 days	20	20
Last 90 days	100	100
Total	6,300	5,500

1.5.2 FIRST OFFICER

The first officer, 26 years old, had basic training in helicopter flying from the Bristow Academy in the USA. Following the training, he was employed as an instructor in the USA on Robinson R44 and Schweizer S300. The first officer was employed by Bristow UK in May 2018 and transfer from Bristow UK to Bristow Norway AS took place in March 2020.

The first officer held a valid airline transport pilot licence for helicopters (ATPL(H)) with instrument rating (IR). The licence to fly S-92 helicopters was most recently renewed on 8 May 2020 and was valid until 31 July 2021. The medical certificate was valid and without restrictions.

The first officer worked a rota system with five days of flying, two days off, five days of flying and nine days off. The incident occurred on the second flight on the final working day of a five-day work period before starting the off-duty period.

The first officer had had 16.5 hours of rest before reporting for duty and felt rested and refreshed before starting work on the day in question.

Table 4: Flying experience, first officer

Flying experience	All types	On type
Last 24 hours	6	6
Last 3 days	10	10
Last 30 days	20	20
Last 90 days	147	147
Total	1,910	1,280

1.6 Aircraft information

1.6.1 GENERAL INFORMATION

The Sikorsky S-92A is a heavy passenger helicopter with two turbine engines, a main rotor with four rotor blades, and a tail rotor. The fuselage is mainly made of aluminium, but with substantial elements of composite materials. The first S-92 flight was conducted in 1989. After completion of development and testing, a type certificate was issued by the FAA in 2002, and subsequently for Europe by EASA in 2004. The S-92A has a cabin that seats 19 passengers and 2 pilots in the cockpit in offshore configuration. The helicopter is fitted with buoyancy equipment certified for ditching in wave heights of 4–6 metres, i.e. Sea State 6.

The S-92A was first put into service in Norway in 2007 to transport workers to and from offshore oil installations and is currently the only helicopter type in this service on the Norwegian continental shelf. As of 31 December 2019, 44 individual S-92A helicopters were registered in the Norwegian Civil Aircraft Register.

Figure 4: LN-ONQ. Photo: Bristow Norway AS / NSIA

1.6.2 DATA RELATING TO LN-ONQ

Manufacturer and model:	Sikorsky Aircraft Corporation S-92A
Serial number:	920032
Year of manufacture:	2006
Type certificate:	EASA.IM.R.001 og FAA R00024BO
Total flight time:	23,909:50 hours[7]
Flight time since previous inspection:	Approx. 715 hours[7]
Number of landings:	22,497[7]
Engines:	2 General Electric CT7-8A
Fuel:	Jet A-1
Empty mass:	7,030 kg (15,500 lbs)
Maximum take-off mass:	12,020 kg (26,500 lbs)
Never-exceed speed:	165 kt

1.6.3 WEIGHT AND BALANCE

The helicopter was within the manufacturer’s mass and balance limitations at the time of the incident.

[7] Numbers from Daily Inspection 24 September 2020.

1.6.4 DESCRIPTION OF THE MAIN GEARBOX

1.6.4.1 Structure

The main gearbox transfers power from the two engines to the main rotor and tail rotor. In addition, the engine's output rpm of 21,945 is reduced to an input rpm of 257.8 for the main rotor.[8] The main gearbox also drives the tail rotor, two 75 kVA AC generators and three hydraulic pumps. The main gearbox also forms the structure in which the rotor and thus the helicopter hangs during flight.

The main gearbox has its own oil lubrication system, which is described in section 1.6.4.2.

The main gearbox is divided into five main modules (see Figure 5).

The five main modules are:

- the right and left input modules
- the right and left accessory modules
- the main gearbox module

Each accessory module is connected to a generator and a hydraulic pump.

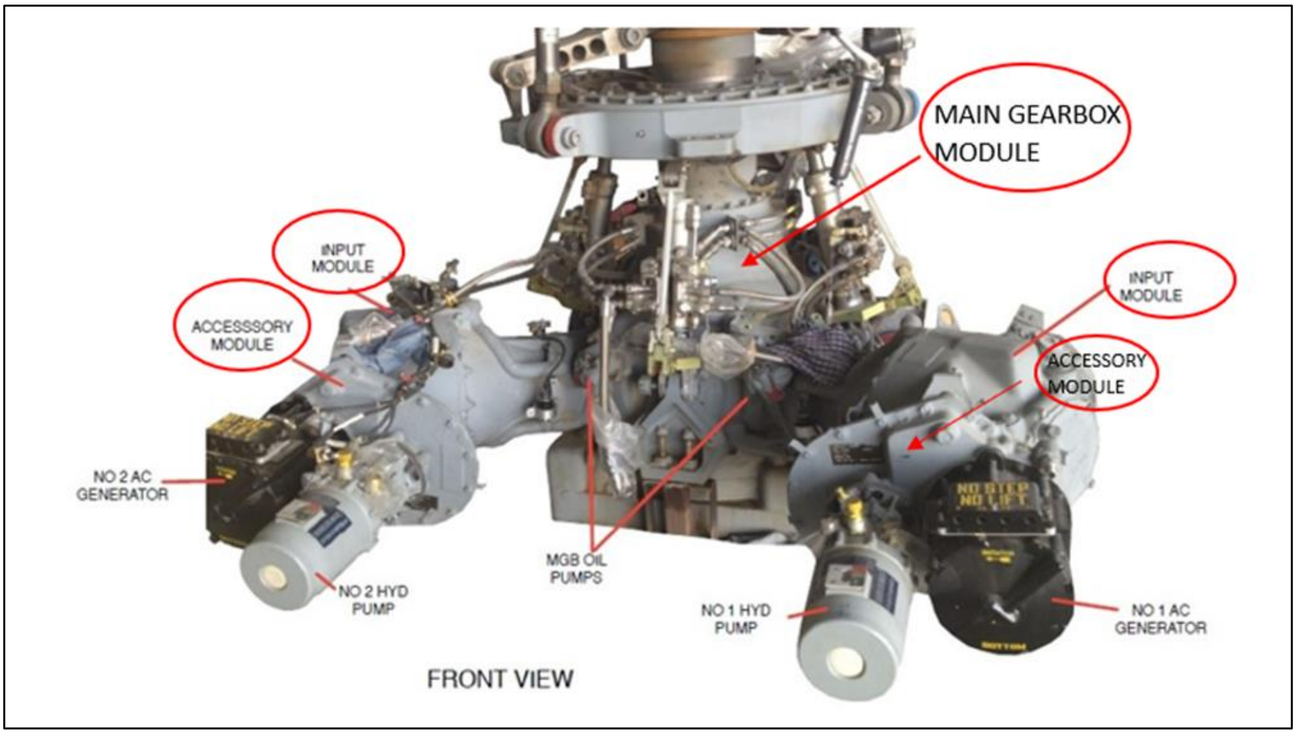

Figure 5: Front view of the main gearbox. The main rotor mast extends upwards from the main gearbox module in the middle of the photo. Photo: Sikorsky/NSIA.

[8] *Based on a main rotor rpm of 105%.*

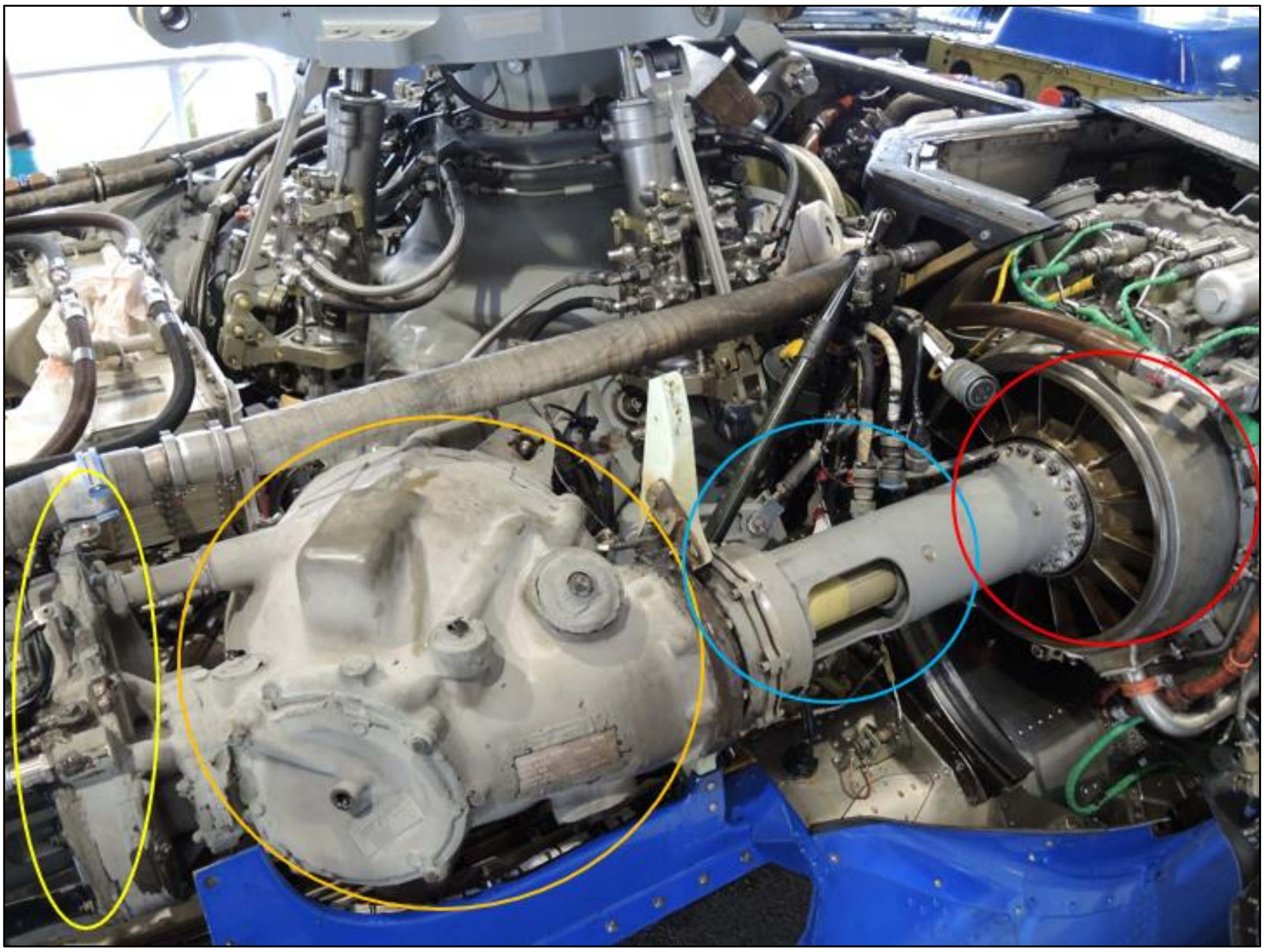

Figure 6: LN-ONQ photographed the day after the incident. Left accessory module (on the far left, yellow circle) and the left input module (in the centre, orange circle). The drive shaft (blue circle) and the front of the left engine (red circle) can be seen on the right. Photo: NSIA

1.6.4.2 Oil system

The main gearbox has a dedicated oil system with two parallel pumps and an external oil cooler. Each oil pump consists of a pressure pump and a return pump. The pressure pumps draw oil from an oil sump inside the main gearbox module and supply oil to the gearbox cogwheels and bearings through internal passageways and tubes. The return pumps draw the oil from the peripheral areas of the gearbox and return it to the oil sump. The oil system has an oil filter, sensors and magnetic chip detectors. Parts of the system are shown in Figure 7 and are explained in section 1.6.4.3. The oil system is also described in NSIA report Aviation 2022/08.

The main gearbox holds 38.9 litres (10 US gallons) of oil. The oil circulates inside the main gearbox. The only exception is the oil cooler, which is separate and connected via two hoses. If leaks occur in the external part of the oil system, the oil cooler can be isolated using an oil bypass valve. The oil will then flow directly from the pressure pumps to the gearbox components. If the oil pressure drops below 35 psi, the oil bypass valve will automatically disconnect the oil cooler. The valve can also be controlled manually from the cockpit.

The generator is connected to the main gearbox's oil system and has connections for both pressurised and return oil.

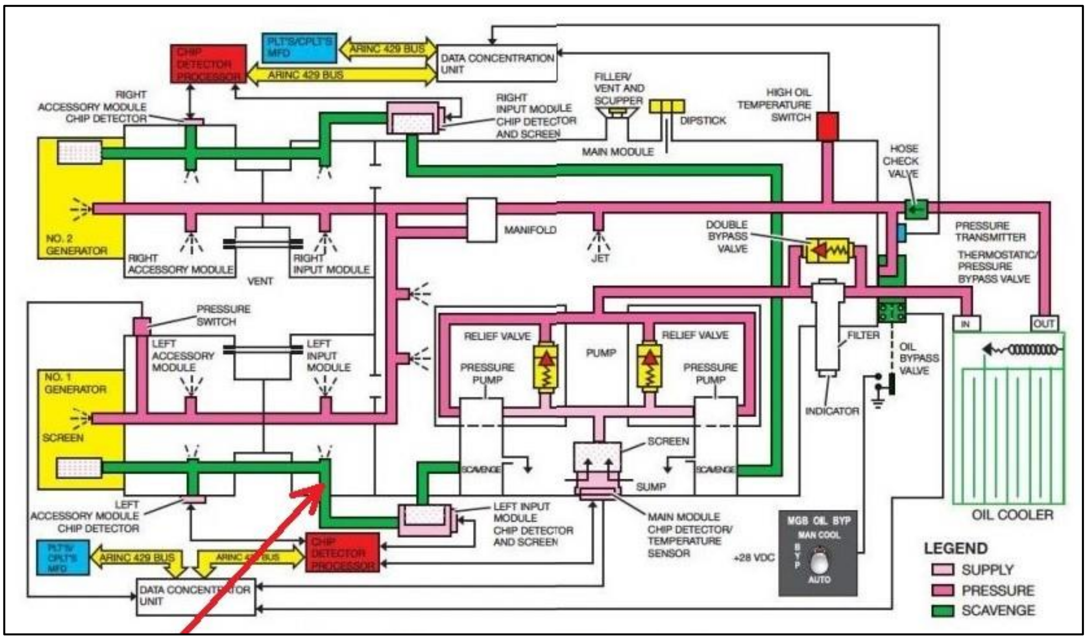

Figure 7: Schematic diagram of the oil system for the main gearbox. The place where the washer got stuck is indicated with a red arrow. Source: Sikorsky Aircraft Corporation/NSIA

1.6.4.3 Oil system warnings and cautions

The main gearbox is monitored by sensors. The information is processed by the Avionic Management System (AMS) and presented using the Engine Indicating and Crew Alerting System (EICAS) on the multi functional display (MFD) in the cockpit (see Figure 8). Below is a list of sensors and associated cautions and warnings on the MFD:[9]

Figure 8: Five multi functional displays in the cockpit of the S-92. The information to the crew regarding the main gearbox oil pressure and temperature is displayed on the MFD in the middle. Image: Brita Sandveen. Illustration: NSIA

1. An oil pressure sensor measures the pump pressure in the pressure line before the oil is distributed inside the gearbox. It displays MGB OIL PRES on the MFD when the oil pressure drops below 45 psi, MGB OIL PRES when the oil pressure drops below 35 psi and MGB OIL OUT when the oil pressure drops below 5 psi. In addition, the measured oil pressure is presented as a column and as a numerical value on the MFD.

[9] Yellow text box = yellow caution, red text box = red warning, and grey text box = the information is indicated by a column or numerical value.

2. An oil pressure switch in the left accessory module (Last Jet Pressure switch) senses the pressure near the end of the oil distribution manifold. If the oil pressure drops below 24 psi, the MGB OIL PRES caution will appear on the MFD. If the oil pressure drops below 24 psi at the same time as sensor 1 (see above) detects pressure below 35 psi, the MGB OIL PRES warning will appear on the MFD.
3. A temperature switch samples the oil temperature in the pressure line before the oil is distributed inside the gearbox. If temperature exceeds 250° +/- 5°F (121° +/- 3°C), the switch supplies the caution MGB OIL HOT indication on the MFD.
4. Another sensor measures the oil temperature in the oil sump. This temperature is presented both as a column and a numerical value on the MFD.
5. Two sensors detect the oil temperature in the left (1) and right (2) input module, respectively. If the temperature in one of the modules exceeds 130°C, INPUT/ACC # 1 HOT or INPUT/ACC # 2 HOT, respectively, will appear on the MFD.
6. Two vacuum switches in the left (1) and right (2) input module, respectively, will issue a caution if the negative pressure in the oil pumps' suction lines is lost. This is indicated on the MFD as MGB PUMP 1 FAIL or MGB PUMP 2 FAIL, respectively.
7. If the oil bypass valve goes to bypass automatically, the MGB BYPASS caution will appear on the MFD.
8. If the oil bypass valve automatically switches to bypass and is subsequently set to the normal position manually with the oil cooler engaged *(MAN COOL)*, the MGB MAN COOL caution will appear on the MFD.
9. The main gearbox is equipped with a series of chip detectors with fuzz burn, which means that small metal chips that accumulate on the plugs will automatically be electrically burnt off. If burning is unsuccessful, MGB CHIP, INPUT X CHIP or ACC X CHIP will appear on the MFD. The system is controlled automatically by a chip detector processor which makes a total of six attempts before the crew receives one of the three alerts.

All red lights on the MFD have an aural alert.

1.6.5 MAINTENANCE

1.6.5.1 Overview of relevant maintenance

The helicopter has a maintenance programme based on specified intervals. In addition, necessary unscheduled maintenance is carried out on the basis of inspections and reported faults. The following points are relevant to the LN-ONQ incident:

- *Pre-departure Inspection.* Performed before each flight. The inspection prior to the aviation incident was carried out and signed for by a licensed technician at 1020 hours. The cover plates around the main gearbox were opened, but the oil level was not checked, since the gearbox must rest for 20 to 30 minutes before the level can be gauged. No defects were discovered during the inspection.
- *Pre-departure Inspection*. The first pre-departure inspection of the day was carried out and signed for by a licensed technician at 0632 hours. The cover plates around the main gearbox were opened and the oil level checked. The oil level was within the normal range. No defects were discovered during the inspection.
- *Daily Inspection*. The inspection was carried out by two licensed technicians on the evening of 24 September 2020, the night before the incident occurred. They have stated to the NSIA that they had plenty of time to carry out the inspection. The cover plates around the main gearbox were opened and the oil level checked. There was no need to top up the oil. They also

checked the pop-out indicator on the oil filter. One of the technicians signed for inspection completed at 2345 hours. At that time, LN-ONQ had a total flight time of 23,909:50 hours and a total of 22,497 landings. No defects were discovered during the inspection.

- A 50-hour inspection was carried out on 21 September 2020 when the total flight time of the helicopter was 23,883.73 hours.
- An inspection of all magnetic plugs in the main gearbox was carried out on 23 August 2020. This is an inspection that is performed every 375 flight hours. Nothing was remarked.
- Two small hair-like metal chips were found on the magnetic plug in the left accessory module on 3 August 2020. At that time, the helicopter's flight time was 23,654 hours. The finding was not subject to reporting because of its limited size.
- Metal chips were found on the magnetic plug in the left accessory module on 30 July 2020, when the helicopter's flight time was 23,652 hours. The finding was not subject to reporting because of its limited size.
- Hair-like metal chips were found on the magnetic plug in the left accessory module on 28 July 2020, when the helicopter's flight time was 23,635 hours. The finding was not subject to reporting because of its limited size.
- The left generator was removed to replace the Vespel spline on 22 May 2020, when the helicopter's flight time was 23,422.26 hours (see section 1.6.5.2).
- The 625-hour inspection, which included oil and filter changes, was carried out on 22 March 2020, when the total flight time of the helicopter was 23,199,41 hours.
- The oil in the main gearbox was changed on 3 November 2019, when the helicopter's flight time was 22,586.22 hours.
- The main gearbox module, with part number 92351-15100-050 and serial number A172-00148, was installed on 14 June 2019. At that time, the unit's run time was 5,178.52 hours, and the helicopter's flight time was 21,968:43 hours.
- The left generator was removed to replace the Vespel spline on 4 June 2019, when the helicopter's flight time was 20,398.79 hours.
- The left input module of the main gearbox, with part number 92351-15001-042 and serial number A171-00191, was installed on 25 November 2014 when the total flight time of the helicopter was 15,759:48 hours. It has not been possible to determine the run time of the component when it was installed.
- The left generator, with part number 92550-04806-101 and serial number C397-00106, was installed on 18 January 2014, when the helicopter's total flight time was 14,206.52 hours.

1.6.5.2 Replacement of Vespel splines

A Vespel spline is located between the input module and the generator (see Figure 9) and must be replaced every 3,000 flight hours. To replace the Vespel spline, the generator must be disconnected. Disconnection and reconnection of the generator must be done in accordance with Aircraft Maintenance Manual (AMM) 24-21-01-900-002.[10] During this work, eight nuts and their washers (part number MS20002-6) must be unscrewed and later refitted (see Figure 9).

When the generator is disconnected, there is a risk of foreign objects entering the accessory module. Measures to avoid this are discussed in the procedures as follows:

---

[10] *Bristow Norway used Revision No 35, issued on 24 May 2017.*

(20) Install protective caps or plugs to all open ports on accessory gearbox and 75 kVA AC generator (120).

The NSIA's investigation has shown that Bristow Norway had used sets of protective covers when working on the accessory module, but no sets were delivered when work was to be done on the input module.

1.6.5.3 Overview of consumption of standard parts and consumables

Bristow Norway keeps an overview of the consumption of standard parts, and what jobs the consumption relates to. The overview shows that washers with part number MS20002-6 were most recently used in connection with work on the generators on 15 June 2018, when a washer was removed. No list is kept of discarded consumable parts. The last time the generator was dismantled was 22 May 2020.

During the preliminary examination of LN-ONQ at Bristow Norway, the NSIA observed loose washers lying on a working table. None of the personnel present were able to account for these washers.

The oil for the main gearbox comes in metal cans containing one US quart (0.95 litres). The cans, which were placed in storage, were dedicated to specific helicopters and were marked with the helicopter's registration. However, the company did not keep an overview of the oil consumption associated with each individual helicopter.

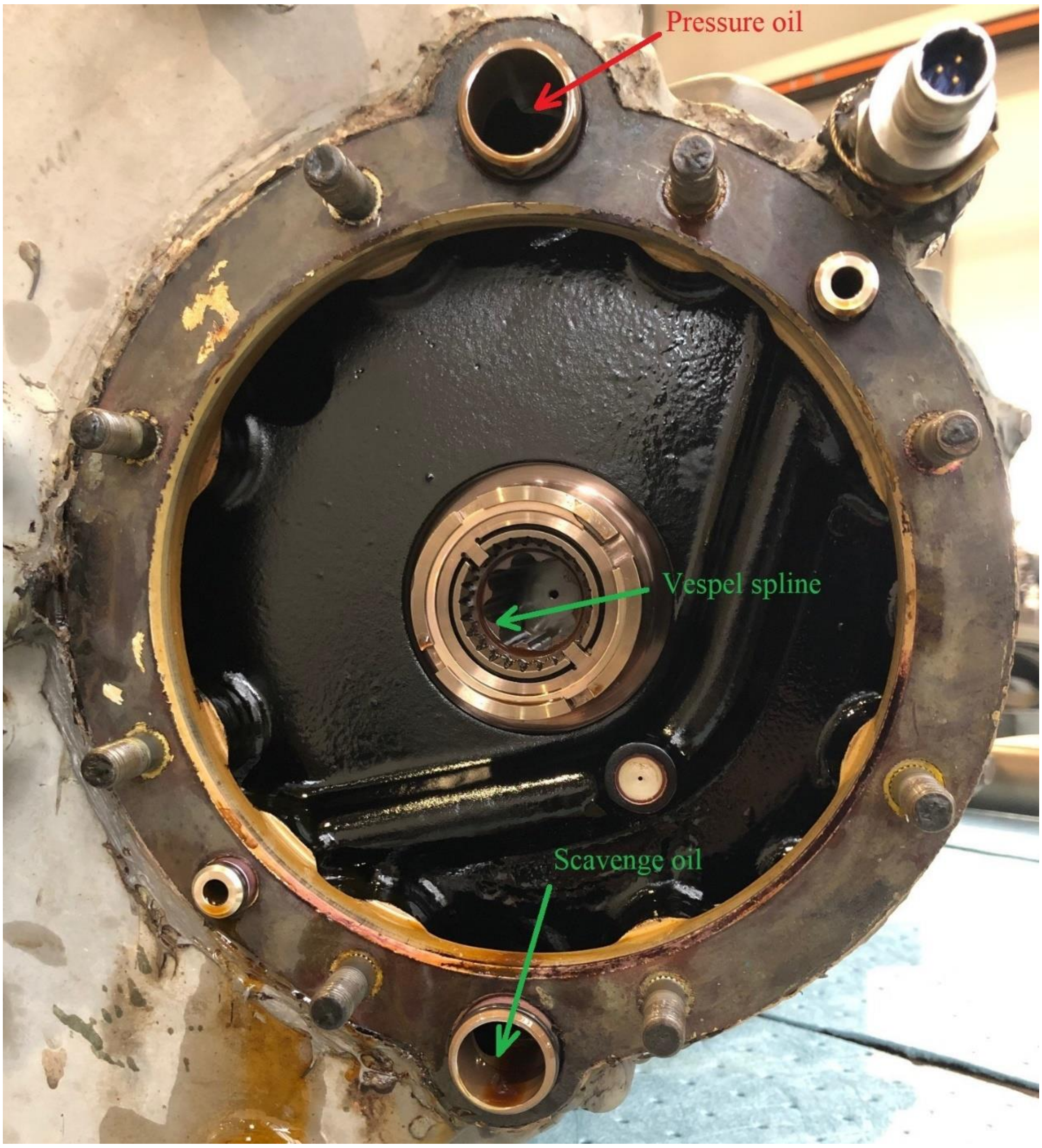

Figure 9: The flange of the accessory module where the generator was connected. The eight stud bolts holding the generator can be seen around the flange. The generator is fixed with the corresponding washer and nut on each of the stud bolts. Photo: NSIA

1.7 Weather

There was high cloud ceiling and good visibility at Sola and on Eldfisk where the oil rig West Elara was located. The crew has reported that the wind was northeasterly, with strong gusts of between 45 and 55 kt out at sea.

At Sola, the wind was also from a northeasterly direction, but much lighter, with a wind speed of 6 kt. The following ATIS was available to the crew prior to landing at Sola:

> *Information Y at 1150, ILS36 and LOC X11 in use, helicopters landing RWY29, Transition Level 85, Winds 030/6, Visibility 10km+, Rain, FEW020, BKN047, Temp 11C, DP 8C, QNH1002 NOSIG.*

METAR and TAF information for Sola and Eldfisk, respectively:

> *METAR ENZV 250820Z 36008KT 9999 FEW010 SCT170 10/08 Q1001 NOSIG=*

TAF ENZV 2506/2606 VRB05KT 9999 FEW020 BKN070 BECMG 2507/2509 02010KT TEMPO 2603/2606 02015G25KT=

METAR ENLE 250820Z 01037KT 9999 -RA SCT025 BKN060 11/06 Q0996W15/S5=

TAF ENLE 250800Z 2509/2518 03040KT 9999 -RA SCT015 BKN025 TEMPO 2509/2518 3000 RA BKN012 BECMG

2512/2514 01050KT=

1.8 Aids to navigation

Not applicable.

1.9 Communications

There was two-way radio contact between the crew at LN-ONQ and relevant units of the air traffic service.

1.10 Aerodrome information

Stavanger Airport Sola (ENZV, 58°52'36"N 5°38'16"E) has two runways 11/29, length 2,299 meters and 18/36, length 2,706 meters. The airport's height above sea level is 8.8 meters.

1.11 Flight recorders

LN-ONQ was equipped with a multifunctional flight recorder (Curtiss-Wright Combined Voice and Flight Data Recorder – CVFDR), part number D51615-142-090, serial number AD9905-002; see Figure 10.

Bristow Norway removed and secured the CVFDR on the same day as the incident occurred. Data from the recorder were subsequently downloaded and delivered to the NSIA. Both the audio recordings and the data were of good quality and were useful for the investigation.

Figure 10: CVFDR from LN-ONQ. Photo: NSIA

1.12 Initial examination of the helicopter

On the same evening as the incident occurred, the helicopter was parked in the hangar of Bristow Norway and cordoned off. The NSIA continued the preliminary examinations the following morning in cooperation with licensed technicians from Bristow Norway. The following findings were made:

- Dark gearbox oil had run down the fuselage along the exterior of the cabin on the left side. Some of this oil had also run to the rear part of the fuselage and the tail boom.
- Most of the oil had leaked from the area where the shaft from the left engine was attached to the left input module.
- Gauging of the oil level in the main gearbox showed that approximately four litres were missing out of a total of 38.9.
- The pop-out indicator on the main gearbox oil filter had popped out, indicating that the oil filter was becoming clogged.
- Some oil spill was detected in the area behind the main gearbox.
- The temperature in the left input module had been so high that some plugs of sealing compound had come loose or been deformed.
- All the chip detectors in the main gearbox's oil system were examined without any significant amount of metal particles being found.
- The two oil pumps were removed, and the drive shafts were examined. The oil was darker in colour than normal, but other than that, nothing out of the ordinary was observed.
- The main gearbox's oil filter was opened and examined, and grey-brown oil was found inside the filter element. The technicians considered this to be abnormal, as the oil usually flows through the filter element and back to the gearbox (see Figure 11). No visible particle contamination was found in the two filter elements that together make up the filter.

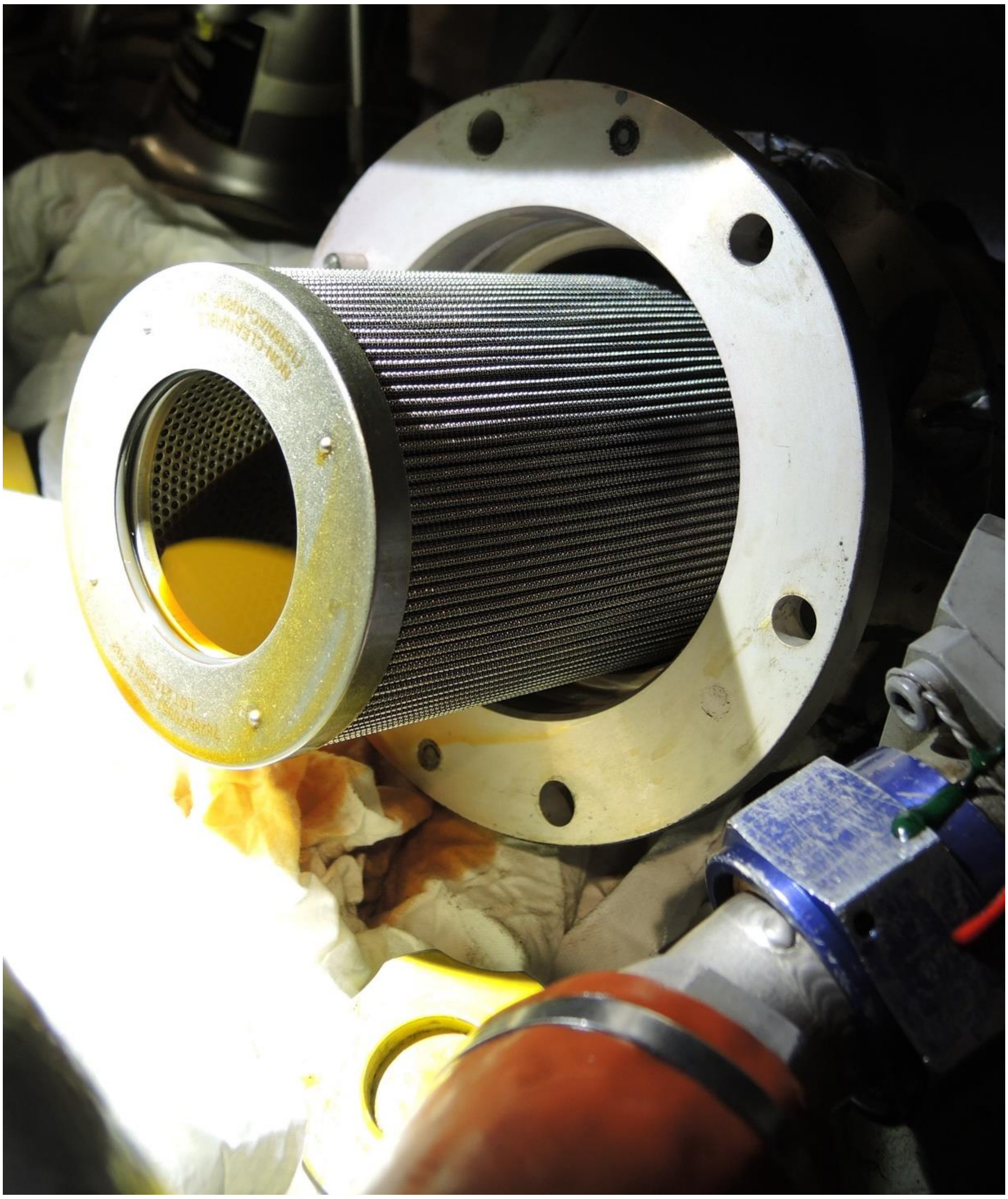

Figure 11: The oil filter after the filter housing had been removed. Brown oil can be seen inside the filter element. Photo: NSIA

After the preliminary examinations had been completed at Bristow Norway, it was decided to send the main gearbox to Sikorsky Aircraft Corporation (SAC) in Trumbull, Connecticut, USA. The main gearbox as a whole was taken out, followed by the hydraulic pumps, generators and drive shafts between the engines and the main gearbox. Each input module was disconnected from the main gearbox module as a unit, without removing the accessory module. The main gearbox module, including the input modules, accessory modules and shafts, as well as two oil samples, were packed in two sealed boxes and sent to SAC.

The oil filter and oil samples from the main gearbox were sent to the Norwegian Armed Forces Laboratory Services (FOLAT) at Kjeller for further examination.

The results of the examinations in the USA and at Kjeller are discussed in section 1.16 below.

1.13 Medical and pathological information

Not applicable.

1.14 Fire

Smoke was generated, but no fire.

1.15 Survival aspects

Personnel from the airport's fire and rescue service were on standby and in position at the runway when the helicopter landed. They followed the helicopter to the parking stand and started their work to ensure that there was no fire or that a fire did occur. This was done in collaboration with the helicopter operator's technical department.

1.16 Tests and research

1.16.1 EXAMINATION OF THE MAIN GEARBOX AT SIKORSKY AIRCRAFT CORPORATION – METAL WASHER FOUND IN RETURN OIL CHANNEL

Due to the Covid 19 pandemic, personnel from the Norwegian Safety Investigation Authority could not travel to the USA to lead the investigations there. In accordance with ICAO Annex 13, the US accident investigation board, the NTSB, was therefore asked to lead the investigation in the USA on behalf of the NSIA, which the NTSB accepted.

The examination of the gearbox took place between 20 and 22 October 2020. In addition to the accredited representative from the NTSB, representatives from the Federal Aviation Administration (FAA) and personnel from Sikorsky Aircraft Corporation (SAC) participated in the work. Based on the investigation, the NTSB prepared a report (NTSB report no. CEN20WA418).

The relevant sections from the report are reproduced below:

- The left input module and the accessory module were visually examined before they were disassembled. The exterior paint was dull and had cracks. The sealing compound around the oil nozzles was partially deformed or missing. Visible parts of the inside were discoloured with a brownish colour and contained dark oil but were otherwise normal. The shafts could be freely rotated without anything abnormal being noticed.
- The unit was then examined internally with a borescope (peephole inspection). That was when a washer was observed in the input module's scavenge oil passageway. The position of the washer is illustrated in Figure 12. No other foreign objects were found inside the parts that could be accessed with a borescope.
- The input module was disconnected from the accessory module and disassembled. Colour changes compatible with the influence of high temperatures were found on details inside the input module.
- The engine shaft's input pinion was disconnected from the input module. Measurements of clearances in the oil seal around the input pinion showed that these were outside the tolerance limits. As a consequence, it was possible for oil to leak past the seal.
- Disassembly of the input module provided access to the washer, which was located approximately 76 mm inside the passageway (see Figure 13). The washer was removed and examined further. This is discussed in section 1.16.2 below.
- Some non-magnetic material found inside the left input module and the accessory module was further analysed and found to be remnants of sealant/gaskets.

- The left accessory module was disassembled. The internal components could be freely rotated without anything mechanically abnormal being noticed. Colour changes compatible with the influence of high temperatures were found on details inside the accessory module.
- The right input module and the accessory module were disassembled and examined. The colour changes on the interior were less noticeable than on the left side. No other notable anomalies were found.
- The main module was disassembled, and some colour changes were observed. It was also observed that blisters had formed in the primer on the main rotor mast in an area near the swash plate. It is not clear whether this was related to high temperatures in the main gearbox. No other notable anomalies were found.
- The magnetic plugs and temperature sensors in the main module were tested and showed normal function. The magnetic plugs in the accessory module could not be tested due to lack of test equipment.

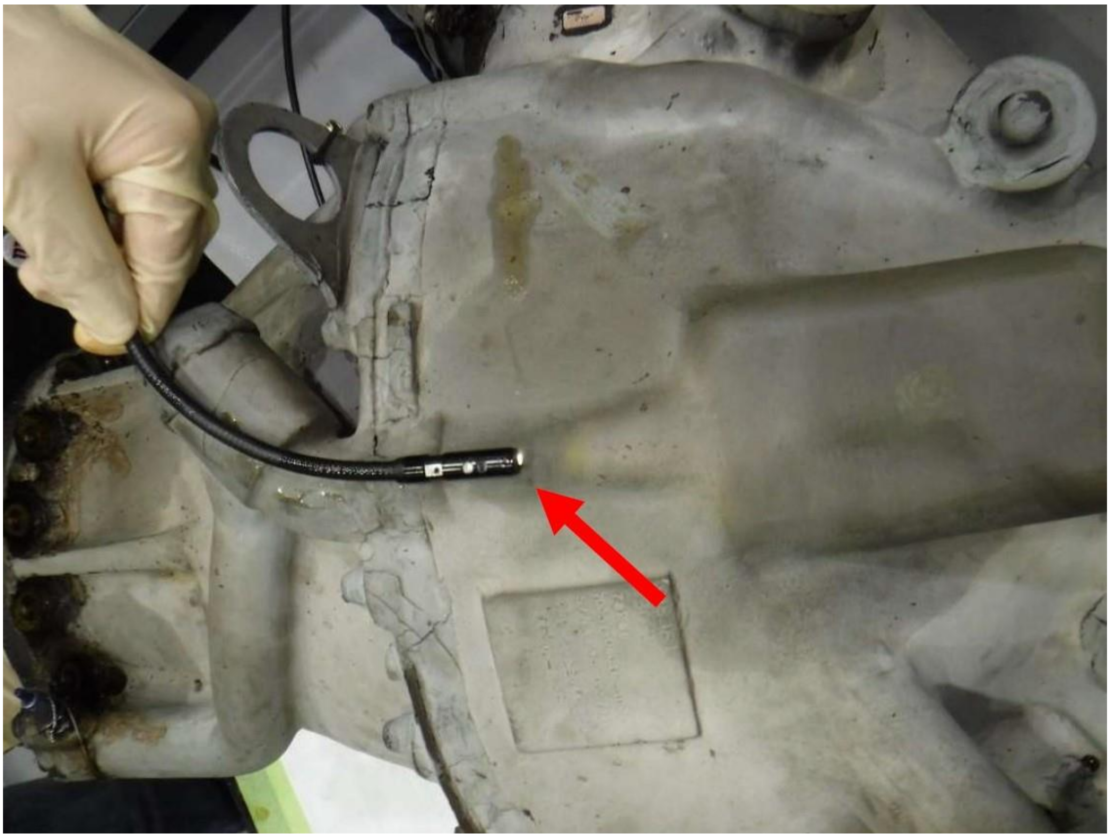

Figure 12: Left input module seen from below. The connection for the main gearbox module can be seen on the left side of the photo. The end of the borescope (the flexible inspection equipment) is laid over the passageway that was followed into the washer. The red arrow indicates where the washer was found. Photo: NTSB/NSIA

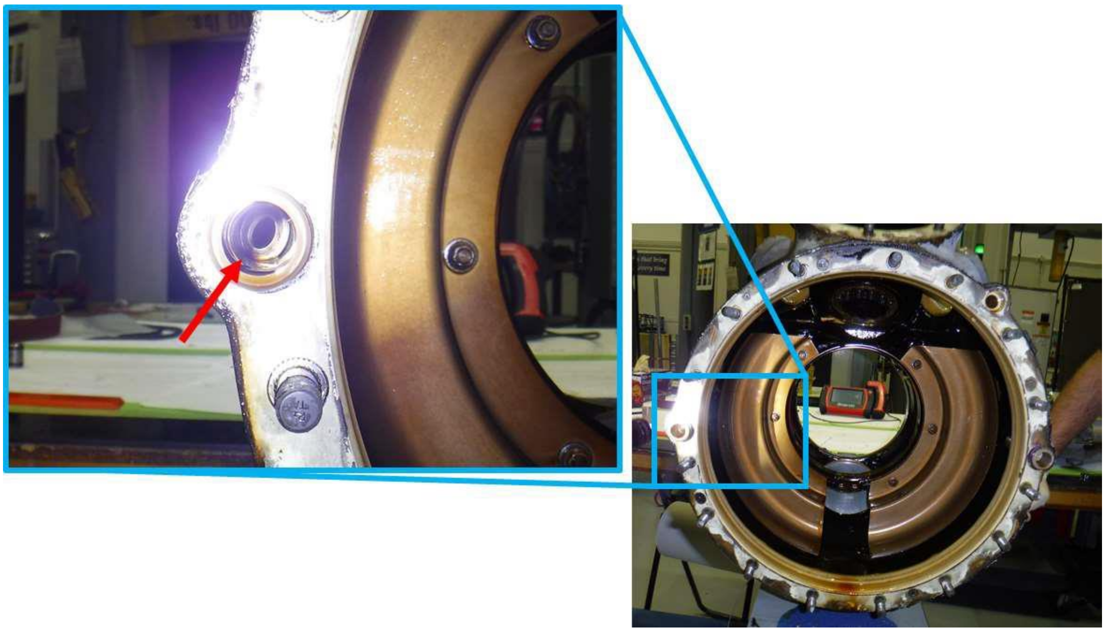

Figure 13: The washer as it was found in the scavenge oil passageway after the input module had been disassembled. The unit is photographed lying on its side. When the module is installed in the helicopter, the passageway is at the lower end of the unit.
Photo: NTSB/NSIA

1.16.2 EXAMINATIONS CARRIED OUT BY THE NTSB

1.16.2.1 Examination of washer

The washer had the following dimensions:

- Outer diameter: 17.22 mm
- Inner diameter: 10.90 mm
- Thickness: 3.40 mm

Based on measurements and knowledge of washers used on the gearbox, the washer was assumed to be of type MS20002-6. The washer found in the main gearbox was compared with a reference specimen (see Figure 14 and Figure 15). A test conducted with an X-ray fluorescence spectroscopy (XRF) alloy analyser showed that both washers were essentially made of iron (Fe) with a surface of cadmium (Cd). The reference washer had a higher content of iron, which could indicate that some of the surface coating on the washer found in the return oil passageway had been worn away. Circular grooves and missing cadmium indicated that the washer had previously been mounted.

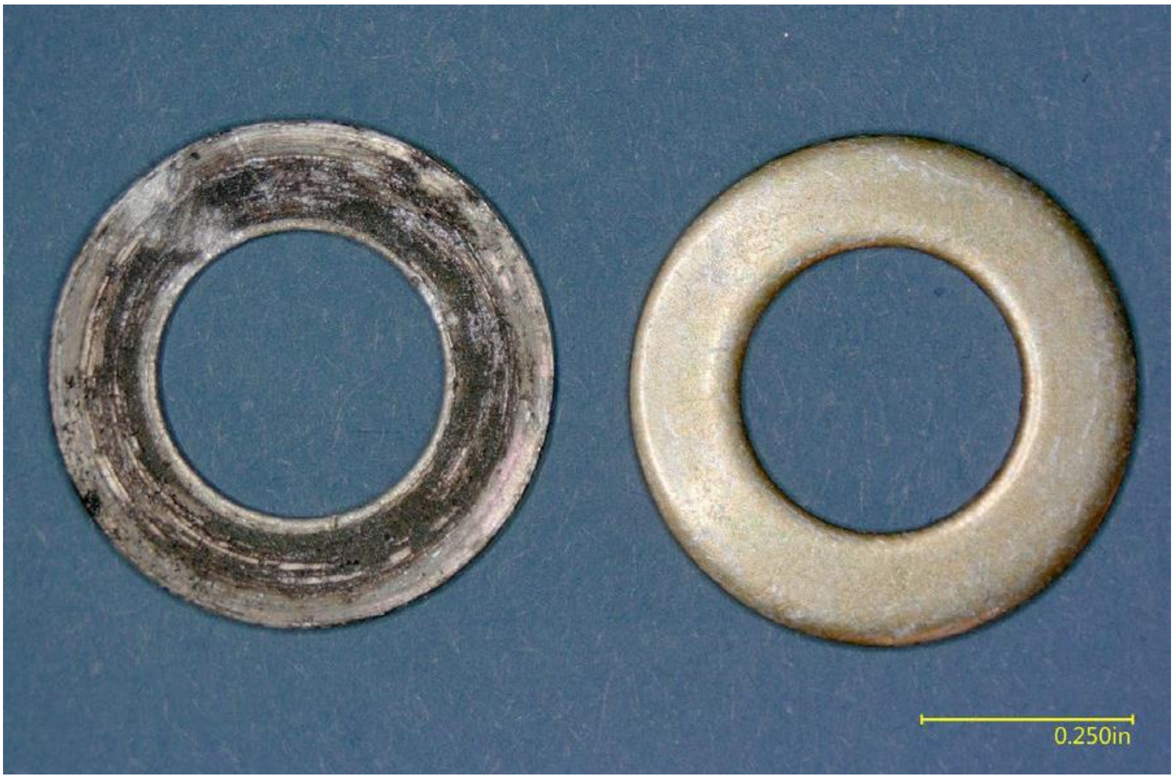

Figure 14: The washer found in the main gearbox on the left, and the reference washer on the right. Photo: NTSB/NSIA

Figure 15: Detail photo of the washer found in the main gearbox. Circular grooves and missing cadmium indicate that the disc has previously been mounted. Photo: NTSB/NSIA

1.16.2.2 Oil samples

Oil from the main gearbox was analysed in relation to the specification DOD-PRF-85734 (new oil). The analysis showed that it was within the requirements for new oil, with the exception of a higher acid contents (2.28 mg KOH/g). The higher acid level was considered a negligible exceedance of the threshold value in the specification for new and unused oil.

1.16.3 EXAMINATIONS CONDUCTED BY THE NORWEGIAN ARMED FORCES LABORATORY SERVICE (FOLAT)

The oil filter and oil samples from the main gearbox were sent together with a reference oil sample to the Norwegian Armed Forces Laboratory Service at Kjeller for further examination. The technical report from FOLAT showed that the oil in the main gearbox oil filter had a substantially higher content of particles than the reference sample (see Figure 11). It was concluded that the particles were not metal particles resulting from wear, but rather soot particles (oxidation). The report concludes that oxidation of the oil is normally the result of high temperatures.

1.17 Organisational and management information

Bristow Norway started operations in 1993, then under the name Norsk Helikopter. After various acquisitions, the Bristow group became sole owners of the company in 2009.

At the time of the incident, Bristow Norway had 427 employees. The company operated 25 Sikorsky S-92A helicopters, and its administration and operational base was at Stavanger Airport Sola. The helicopter operator is now an established supplier of helicopter services to the oil companies on the Norwegian continental shelf.

Bristow Norway has its own Part-145[11] maintenance organisation that carries out maintenance on the company's helicopters.

1.18 Additional information

The helicopter operator conducted an internal investigation and has, in the period following the aviation incident, introduced measures with special attention to foreign object debris (FOD).

The following measures were emphasized in the report:

- *FOD prevention – Establish instruction for consistent practices to covering exposed areas during maintenance. Suitable means of covers and fasteners to be used. Update applicable maintenance instructions (AMM etc.) subsequently to ensure compliance with use of FOD prevention means, covers etc.*
- *FOD prevention – Establish FOD policy and program suitable to the maintenance operation Part-145.*
- *Hazard register – Review and update any related hazard register Part-145.*
- *Hazard register – Review and update any related hazard register Flight Operation Manual.*
- *Make a summary of this report distributed to all applicable BN personnel for information and lesson learned.*
- *Use this event during OPC/PC for information and lesson learned.*

1.19 Useful or effective investigation techniques

The NSIA has not used any investigation methods warranting special mention in this investigation.

[11] *Approved maintenance organization in accordance with EU regulation 1321/2014 Annex II.*

2. Analysis

2. Analysis

2.1 Introduction

Early in the investigation, it became clear that the incident was related to a technical fault in the main gearbox. The main part of the analysis therefore deals with the main gearbox and the maintenance that had been carried out.

2.2 Sequence of events

At some point, a metal washer of the type MS20002-6 has entered the left accessory module. The washer has then moved with the flow of oil through the scavenge oil passageway until it wedged or turned sideways in the left input module so that the passageway was substantially narrowed. This must have happened shortly before the oil temperature in the left input module began to rise. Where the washer got stuck, the size of the passageway was 2.328 cm^2. The passage through the hole in the washer was approximately 0.933 cm^2, and if the washer was positioned sideways in the oil flow and sealed well against the duct, the cross-section of the oil flow would have been reduced by approximately 60%.

A reduction in the capacity of the scavenge oil passageway will result in a rising oil level in the accessory module and the input module. The supply of new oil from the pressure pump will be relatively constant, and the oil level will gradually rise until the oil floods over and into the main gearbox module. This will lead to the following:

- The high oil level in the accessory module and input module would cause the oil to be whipped into foam. Oil foam contains large amounts of air and will have a significantly reduced ability to conduct away heat.
- An oil pump will pump less oil when parts of the oil flow contain air. As the amount of foam throughout the system increases, the capacity of all the oil pumps will decrease.

Overall, these two effects reduced oil pressure and increased oil temperature. When the oil pressure dropped below 45 psi, the crew received the MGB OIL PRESS caution. As the temperature increased locally, INPUT/ACC # 1 HOT illuminated. When the oil pressure dropped below 35 psi, the oil cooler was automatically bypassed, which aggravated the problem.

The high temperature in the left accessory module and input module eventually caused the oil seal around the input pinion to fail, resulting in an oil leak in the area between the input module and the left engine. The fact that the oil temperature has been very high locally is underlined by the finding of soot particles in the oil and the oil filter. Furthermore, the temperature in the input module must have been so high that some plugs of sealing compound came loose or were deformed. In addition, the exterior paint had cracked.

The oil filter pop-out indicator was activated and visible which means that the filter had reduced oil flow. The NSIA believes that this may be due to the filter became clogged by the oxidation (coking) of the oil in the main gearbox.

2.3 How the washer entered the input module

The NSIA considers that the washer entered the gearbox in connection with maintenance, not during production. This is supported by the fact that the washer was not new. It had traces showing that it had previously been installed, where is unknown.

On 28 and 30 July and 3 August 2020, some minor metal chips were found on the magnetic plugs in the left accessory module. All these findings were within the limitations of the Aircraft Maintenance Manual and consequently not reportable to the helicopter manufacturer. Following the finding on 28 July, the magnetic plugs in the left and right accessory module were also cross-swapped to identify any faults in the magnetic plugs' burn-off system. The NSIA sees no connection between these findings and the incident involving the washer in the oil passageway.

The NSIA is able to conclude that it is not possible that the washer could have entered the relevant passageway by moving from the main module. If a washer of the type MS20002-6 had accidentally entered the main module, filtering screens would have prohibited its possibility to enter the oil passageway in which it was discovered. The NSIA believes it must have entered via the openings that became exposed when the generator was disconnected from the flange of the accessory module (see Figure 16).

It is not possible to ascertain when the washer entered the accessory module. The maintenance documentation shows that the generator had most recently been disconnected on 22 May 2020 (see section 1.6.5.1), i.e. 487:35 flight hours before the incident occurred. The washer may have entered the accessory module in connection with the work that was done at the time. However, it cannot be ruled out that the washer entered the accessory module at an earlier time. Regardless of when the washer entered, it is difficult to explain why it remained in a 'harmless' position for a long time before it changed position so that it limited the flow of oil. One possible explanation, however, is that it for a period stuck to the magnet on the left accessory module chip detector. The washer is too big to come out with the chip detector during inspection. The design and size of the washer means it will not short-circuit the chip detector and thus warn about contamination.

Lists of parts removed from Bristow's parts store show that several washers with part number MS20002-6 were removed from storage for use on LN-ONQ in the period from April 2015 to June 2019. The list of parts removed was linked to a single individual helicopter, and in several cases also specific maintenance tasks on the helicopter. The NSIA and Bristow Norway's own internal report have not been able to relate any of the parts removed to accessory module no. 1 in the relevant time period, thus the NSIA has not been able to determine how the washer ended up in the module.

During the initial investigation of LN-ONQ at Bristow Norway, the NSIA observed small loose metal washers lying on a work table. None of the employees who were present could explain where the washers belonged. The NSIA believes that it is important to reduce the risk of FOD as much as possible, and that it was possible at the time in question to have better control over the relevant small parts.

The NSIA considers that if it had been observed that a washer had accidentally fallen into the module, the necessary measures would have been initiated. The risk of FOD is always present when working on aircraft and self-checking when disassembling and assembling components is particularly important on critical systems.

A washer with part number MS20002-6 falls into the EASA category "Standard Parts[12]". Maintenance organizations are required to have a system for traceability of components, standard parts and raw material back to the manufacturer of the parts. Documentation received from Bristow Norway shows that they have a traceability system when parts are removed from storage. At the same time, Bristow Norway's parts-list shows that some of the parts are only linked to the helicopter itself and not the specific maintenance work. The NSIA recommends that Bristow

[12] Regulation 7 May 2015 no. 488 Regulation on continuous airworthiness etc. (The maintenance regulation) defines requirements for documentation and traceability for standard parts through Commission Regulation (EU) No. 1321/2014, Annex 1 point M.A 501. (AMC1 M.A.501(a)(4) point (b)).

Norway in all cases link the removal of parts (all categories) to specific documented maintenance work.

Following the incident, the helicopter operator has introduced several FOD preventive measures to avoid similar incidents in the future, including the establishment of a FOD policy and program adapted to the maintenance organization as well as the establishment of instructions for consistent practice to cover exposed areas during maintenance in addition to the education and training of personnel.

A helicopter gearbox is a safety-critical component, and any possibility of contamination must be taken very seriously. In general, there is little margin for nonconformities in helicopters. A tidy workplace and a full overview of tools and parts are therefore of the outmost importance. The NSIA believes Bristow Norway can make improvements in this area. This report can be a useful aid in this work. The NSIA submits a safety recommendation to the Norwegian Civil Aviation Authority (CAA-N) related to this.

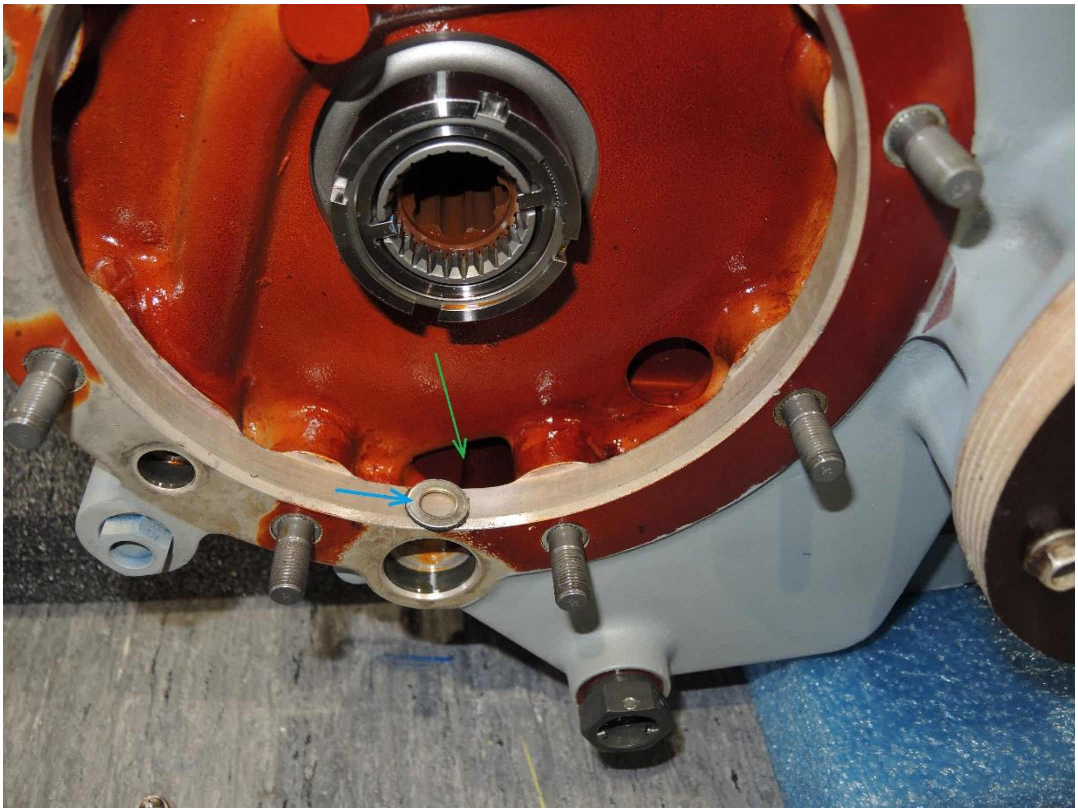

Figure 16: The flange of the accessory module. The blue arrow points to a washer of the MS20002-6 type, and the green arrow points to an opening through which the washer could fall into the accessory module. Photo: NSIA

The helicopter operator apparently had arranged for a system to control oil for the helicopters. The oil cans (1 litre) were individually marked with the helicopter's registration letters. Despite this, it was not possible to find out when and how much oil was refilled on the individual helicopter. The NSIA recommends that the helicopter operator record ongoing oil consumption for the helicopter's transmissions for each individual helicopter.

The NSIA has not made its own calculations of how long the flight could have continued before catastrophic faults had occurred in the main gearbox.

2.4 Operational aspects

The crew followed the procedure in Emergency Check List (ECL) *Item 8 GEAR BOX Temp*. rev. dated 15 May 2017 Proc. 8.1 and 8.2 *MGB Oil Pressure Warning / Temperature Warnings and Cautions.* The lowest recorded oil pressure and the highest recorded oil temperature were 28 psi and 214°C, respectively. With the oil pressure above 5 psi, and rising oil temperature, the pilots set the relevant engine to idle and reduced the airspeed as recommended by ECL. They then started the APU[13] and reduced the altitude to the recommended 500 ft, and later to 200 ft. At the same time, they asked the passengers to prepare for a possible ditching. This means that the passengers must prepare before landing on the sea by pulling the hood over their heads, closing the zip, establishing an emergency breathing system and take a crash position. A landing at sea, however, entails an increased risk of loss of life as the helicopter can overturn, fill with water and complicate an evacuation of passengers and crew.

The following warnings will require the helicopter to be landed immediately, including at sea:

- MGB OIL OUT warning, or
- MGB OIL PRESS caution, MGB OIL HOT caution and MGB OIL PRESS warning with aural alert and an oil pressure below 5 psi.

However, none of these situations occurred and the crew chose to land at the nearest safe landing site.

The first MGB OIL PRESS caution appeared at 1411 hours, and the helicopter landed at Sola at 1427 hours. In theory, the crew could have reduced the flight time by a few minutes by heading directly for land and preparing to land in the western part of Jæren. A landing at Jæren could not have been carried out as a run-on landing. Consequently, it would have been necessary to re-accelerate the engine they had set to idle before landing, and the load on the gearbox would have been greater. They would also not have had the fire and rescue service available during landing. The NSIA is therefore of the opinion that the crew made good judgement calls during the decision-making process in the minutes before landing at Sola.

The fact that the crew followed the checklist and reduced the power on the left engine to idle had little or no effect on the temperature increase in the main gearbox. All the dynamic components in the main gearbox continued to rotate at the same speed, despite the engine idling. The only thing that could have reduced the heat development in the main gearbox would have been an overall reduction of the power output from both engines.

[13] *The auxiliary power unit (APU) is a gas turbine capable of delivering electrical, pneumatic and hydraulic power to the helicopter systems, but not power to the rotor system.*

3. Conclusion

3. Conclusion

3.1 Main conclusion

The heat development and oil leakage in the main gearbox occurred as a result of a metal washer that had entered a scavenge oil passageway in the left input module and become jammed. This caused a substantial narrowing of the passageway. The NSIA believes it is likely that the washer entered the module in connection with maintenance and via the openings that are exposed when the generator is disconnected from the flange on the accessory module. The NSIA has not been able to establish when the washer entered the gearbox. The last maintenance where the washer may have entered was 487:35 flight hours before the incident. The NSIA therefore considers that the washer has been in the main gearbox for at least that long. The investigation has shown that Bristow has a potential for improvement in keeping track of consumables.

3.2 Investigation results

A. The aircraft was registered in accordance with the applicable regulations and held a valid airworthiness certificate.

B. The helicopter was equipped with a combined voice and flight data recorder (CVFDR), which made it possible to determine the exact sequence of events.

C. The crew held valid certificates and licences to perform the relevant service on board.

D. The weather was not a factor contributing to the serious aviation incident.

E. The helicopter operator conducted an internal investigation and has, in the period following the aviation incident, introduced measures with special attention to foreign object debris (FOD) to enhance safety.

F. The first indication the crew received that something was wrong was when the MGB OIL PRESS caution illuminated southwest of Sola during the descent from 7,000 ft towards 1,000 ft.

G. The helicopter landed on *RWY* 11 and was followed to parking by fire and rescue personnel.

H. The crew followed the procedure in the emergency checklist for loss of oil pressure in the main gearbox.

I. The crew issued a distress call (*MAYDAY*).

J. Data from the flight recorder showed that the highest recorded oil temperature was 214°C and the lowest recorded oil pressure 28 psi.

K. Based on a review of the relevant maintenance documentation, the helicopter was maintained according to current requirements.

L. The examination of the main gearbox and associated components was carried out at Sikorsky Aircraft Corporation and conducted by the NTSB on behalf of the NSIA.

M. The examination led to the discovery of a metal washer of type MS20002-6 in the scavenge return oil passageway in the left input module.

4. Safety recommendations

5. Safety recommendations

Safety recommendation no. 2023/05T

On 25 September 2020, a Sikorsky S-92A helicopter made an emergency landing at Stavanger Airport, Sola after a loss of oil pressure and overheating of the main gearbox. A metal washer had entered the gearbox and reduced the oil flow in the return oil passageway. A helicopter gearbox is a safety-critical component and any possibility of foreign objects entering the gearbox must be avoided.

The NSIA advises the Norwegian Civil Aviation Authority (CAA-N) to follow up the helicopter operators' procedures and routines related to FOD, and FOD related to gearbox maintenance in particular.

Norwegian Safety Investigation Authority
Lillestrøm, 2 November 2023

Abbreviations

Abbreviations

ACC	Accessory Gearbox
AMM	Aircraft Maintenance Manual
APU	Auxiliary Power Unit
ATPL(H)	Airline Transport Pilot License (Helicopter)
ATIS	Automatic Terminal Information Service
BKN	Broken
BN	Bristow Norway
EASA	European Union Aviation Safety Agency
FAA	Federal Aviation Administration
FOD	Foreign Object Debris
INPUT	Input module
MFD	Multi-Function Display
MGB	Main Gearbox
NOSIG	No Significant Change
NSIA	Norwegian Safety Investigation Authority
NTSB	National Transport Safety Board
LOC	Localiser
PF	Pilot Flying
PM	Pilot Monitoring