Accident
Investigation Board
Norway

Issued November 2015

REPORT SL 2015/11

REPORT ON INCIDENT APPROX. 120 NM SOUTHWEST OF SOLA, NORWAY 4 OCTOBER 2013, WITH SIKORSKY S-92A, LN-ONW, OPERATED BY BRISTOW NORWAY AS

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

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Photos: AIBN and Trond Isaksen/OSL

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INCIDENT REPORT

Aircraft:	Sikorsky Aircraft Corporation S-92A
Nationality and registration:	Norwegian, LN-ONW
Owner:	Bristow U.S. LLC, Louisiana 70560, USA
User:	Bristow Norway AS, Sola, Norway
Crew:	Commander and first officer (uninjured)
Passengers:	12 (uninjured)
Incident site:	Along helicopter flight route KY10, approx. 120 NM southwest of Sola. (N 56° 41’ E 004° 21’)
Incident time:	Friday 4 October 2013, 1635 to 1703 hours.

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

NOTIFICATION

The Accident Investigation Board's on-duty officer received notification of the incident on Friday 4 October 2013, at 1733 hours., from the flight operations manager in Bristow Norway AS that a Sikorsky S-92, LN-ONW, had made an emergency landing on the unmanned and decommissioned Yme oil rig. The two-man crew and the 12 passengers were uninjured. The helicopter was en route from Valhall to Sola and had to make an emergency landing due to indication of low oil pressure in the main gear box.

Although the incident was not classified as a serious incident in accordance with the definitions in BSL A 1-3, the Accident Investigation Board Norway decided to initiate an investigation. In accordance with ICAO Annex 13, Aircraft Accident and Incident Investigation, the accident investigation board in the manufacturing country, the National Transportation Safety Board (NTSB) in the U.S., was notified concerning the incident.

SUMMARY

Due to poor visibility the helicopter had to abort a landing attempt on the Valhall QP (ENWV) oil rig and return to Sola. En route to Sola, the crew received multiple caution lights indicating a fault in the lubrication system for the main gear box. In addition, the oil pressure fell and the oil temperature increased. However, the emergency checklist provided insufficient decision support. As preparation for a possible serious malfunction of the main gear box, they looked for alternative landing sites. Eventually, the crew had to descend to 100 ft. in order to maintain visual contact with the sea, and speed was reduced in order to reduce the load on the gear box. After a while, the temperature in parts of the gear box increased above the limit, and the crew decided to make an emergency landing on the decommissioned and unmanned Yme oil rig. The landing on Yme was made without injuries, and all aboard were later hoisted on to a rescue helicopter.

The investigation showed that several of the cautions the crew received were false, and were caused by a minor fault in the indication system. The crew became seriously concerned about the indications. Despite uncertainty that arose, the crew handled the situation in a good manner and made operational decisions that reduced the risk of an potential accident occurring. The Accident Investigation Board Norway is of the opinion that the lubrication system for the main gear box on the S-92A is very complex and that the associated emergency checklists are both insufficient and complicated. As a result, the emergency checklists may be difficult to use in a stressful emergency situation.

The Accident Investigation Board Norway is submitting a safety recommendation to the helicopter manufacturer concerning simplification and increased user-friendliness of the emergency checklist for the helicopter's main gear box.

1. FACTUAL INFORMATION

1.1 History of the flight

1.1.1 LN-ONW, with flight number BHL305, was scheduled to fly from Stavanger Airport Sola (ENZV) to the oil rig Valhall QP (ENWV)[1]. An IFR flight plan was submitted to the air traffic services. According to the crew, the planning of the flight was routine. The weather forecast for Ekofisk indicated that visibility could be marginal (see Chapter 1.7). Accordingly, it was decided to carry additional fuel for both Stavanger Airport Sola and Haugesund Airport Karmøy (ENHD) as alternatives. There were no relevant remarks in the helicopter's log prior to departure.

1.1.2 BHL305 departed at 1441 hours., and was initially cleared directly towards the VALIX reporting point at 2,000 ft. (see Figure 1). It was agreed that the two pilots would fly one flight each. The first officer was Pilot Flying (PF) on the flight to Valhall. The helicopter followed helicopter flight route KY10. Three helicopters had departed for Ekofisk earlier, and the crew on BHL305 overheard the radio communication between them and Stavanger Air Traffic Control Centre (ATCC), sector offshore at 128.000 MHz. It became clear that visibility on Ekofisk was so poor, that the three helicopters did not see a reason to continue.

1.1.3 BHL305 arrived at the VALIX reporting point at 1608 hours. The helicopter was then transferred from the Stavanger ATCC to Ekofisk HFIS[2]. Ekofisk HFIS stated that Valhall had two to three km visibility and adequate cloud base for landing. However, the landing on Valhall had to be aborted because the crew was unable to make visual contact with the rig as they had arrived at the established minima during the approach.

1.1.4 After the aborted approach, the crew climbed to 3,000 ft. and set course back to Sola. The commander took over as Pilot Flying on the return. The return was also via the VALIX reporting point, where contact with the Stavanger ATCC was established. The return was also along the KY10 helicopter flight route.

1.1.5 At 1635 hours, just before BHL305 reached the KY10/120 reporting point, the crew became aware that two yellow cautions, MGB PUMP 1 FAIL and MGB PUMP 2 FAIL, appeared on three of the Multi-Function Displays (MFD no. 2, 3 and 5). The commander

[1]Valhall is located south of the Ekofisk field, but within the Ekofisk ADS (see figure 1)
[2] Helicopter Flight Information Service

has stated to the AIBN that he did not completely understand what had happened (see Chapter 1.6.5.2 for an detailed description of the oil system). A failure in both oil pumps for the main gear box would indicate a total loss of oil pressure, which was not the case.

1.1.6 Due to his experience as a flight simulator instructor, the commander had learned that it can often be beneficial to think a bit before taking action. However, the information he and the first officer read from the instruments did not make sense. They discussed the situation and agreed that it was worrying. The commander handed the controls to the first officer and began reading the checklists. Based on the analogue indicator on the central display, he saw the oil pressure had decreased from a normal value of approx. 58 psi to 49, while oil temperature was rising. This was considered a confirmation that something had happened to the main gear box. However, the emergency checklists did not provide an answer to what had happened, or what action to take. In retrospect, the commander has described this as highly frustrating.

1.1.7 The estimated time at the KY10/120 was 1635 hours. As BHL305 did not report position as expected, the Stavanger ATCC called the helicopter. The commander answered "*Stand by"* because he was occupied by trying to understand the situation. He then reported they had an uncertain situation with the oil pressure in the main gear box, and he requested a western course, towards Ula (ENLA) or Gyda (ENXG). The commander contacted Ula, but was notified that visibility was 300 to 400 metres, and landing there was not advisable. They then decided to set a northbound course to Sola, and informed the Stavanger ATCC of this. He stated they would descend to 1,000 feet.

1.1.8 The crew knew the distance to the unmanned Yme oil rig (ENWY) was significantly shorter, and decided to set course there. At approx. 1640 hours, the commander reported they were at radial 210, approx. 40 NM from Yme, and that they had to descend further to 500 feet. Altitude was reduced in order to gain visual contact with the sea, and to make an easier emergency landing if necessary. In order to reduce load on the main gear box, speed was first reduced to 100 kt, then later to 80 kt.

1.1.9 En route, the crew became aware of three additional yellow cautions for MGB OIL HOT, MGB OIL PRES and MGB MAN COOL. These cautions did not provide any further information to understand the situation. As long as no red warning lights showed up, and oil pressure indicated above the 47 psi minimum requirement, they decided to continue towards Yme. Accordingly, they interpreted the situation as *"Land as soon as possible"* and not *"Land immediately"*.

1.1.10 Cloud base became lower, and they had to descend to 200 ft. They then attempted to notify the Stavanger ATCC of this, but received no response. The Stavanger ATCC did not manage to establish contact with BHL305, despite several attempts to call up via radio transmitters on Ula, Sleipner, and Bjerkreim, as well as calls on the emergency frequency 121,500 MHz. Due to the uncertain situation, the supervisor notified the Norwegian Joint Rescue Coordination Centre and Bristow.

1.1.11 The crew was concerned by the rising oil temperature. Wind and wave height were estimated at 40 kt and 7 to 8 m respectively. A landing in the sea was therefore considered a last option. Sea and weather conditions were perceived to be even less suited for an emergency landing closer to shore, so continuing towards Sola was considered a poorer alternative than Yme.

1.1.12 Because the crew did not receive a response from the Stavanger ATCC, they decided to switch to the emergency frequency at 121,500 MHz. They transmitted MAYDAY and stated they were along radial 210, approx. 30 NM from Yme, and that they intended to land there due to oil pressure issues with the main gear box. BHL305 immediately established contact with flight WIF369 from Widerøe, which forwarded the information to Stavanger ATCC. Several other aircraft also received the communication. They forwarded the information to air traffic services units in Oslo (ENOS), Copenhagen (EKDK) and Scotland (EGPX) respectively, which again contacted Stavanger ATCC.

1.1.13 The crew assumed that the passengers were wondering about the exceptionally low altitude, and the commander therefore gave a briefing over the PA system[3]. In the announcement he apologised for the situation and stated they had indications of high temperature and low oil pressure in the main gear box. Passengers received information that the situation was stable, and that they had decided to divert to Yme. Furthermore, the commander stated there was no immediate risk of them going in the water, but asked the passengers to pull up the hoods and zip up their survival suits. The situation was still unclear, and should something unforeseen occur, it was not certain he would be able to provide more information.

1.1.14 Approx. 10 NM from Yme, the crew discovered an object on the weather radar, approx. 4 NM east of the oil rig. Hoping this was a larger vessel with a helideck, they set a course for the object. At a distance of 2–3 NM, they got visual contact with a cargo ship. The ship had large hatches, but because of the ship's movements in the heavy sea, the commander decided to continue towards Yme.

1.1.15 The fact that the visibility was good enough to discover the ship at a distance of 2–3 NM , gave optimism as regards landing on Yme. For safety reasons, the rig had not started operations, and was unmanned. The crew on BHL305 had passed over the rig several times before, and had observed two large objects on the helideck. However, their assessment was that they could land an S-92 despite these obstacles.

1.1.16 Approx. 2.5 minutes prior to landing on Yme, the yellow caution INPUT/ACC 1 HOT came on. The crew verified that this required action in accordance with the emergency checklist, and the commander pulled the left engine to idle. At that time the helicopter flew at an altitude of 100 ft. in order to have visual contact with the sea.

1.1.17 They made visual contact with the Yme oil rig at a distance of approx. 2 NM. Cloud base was 100–200 ft. and the wind direction was assessed as coming from 130 - 150° with a speed of 35 kt. The commander took over the controls (PF) and informed the first officer of how he would carry out the landing. Two of the first officer's tasks were to put the left throttle in forward position for normal engine power (FLY) upon the commander's signal, and to keep a look out on the left side of the helicopter during landing.

1.1.18 The helicopter deck on Yme is 187 ft. above sea level, but the commander continued to have good visual contact with the rig during the approach and landing. Power on the left engine was increased once more. When the helicopter's speed decreased, the left engine responded as expected, and without any sudden movement of the helicopter. The commander chose to approach the helideck from west in order to have the wind come in at a right forward angle. It was considered possible to land the helicopter to the right of

[3]Public announcement system for passengers.

the two objects on the deck[4], but the commander were somewhat surprised when he discovered how tall they were.

1.1.19 The commander landed the helicopter with approx. two meter clearance between the right main wheel and the edge of the helideck. The horizontal clearance between the objects on the deck and the main rotor was similar (see Figure 2). When the helicopter landed, the first officer read that the oil temperature on the main gear box was 152 °C. The engines and rotor were stopped in the normal manner. However, it was decided to start the helicopter's auxiliary power unit (APU) so that the helicopter could be powered without draining the battery. Simultaneously the first officer established contact with the Stavanger ATCC at 128,000 MHz, and reported that BHL305 had made a safe landing on the Yme oil rig at 1703 hours.

1.1.20 The commander entered the cabin and briefed the passengers on what had happened. The Stavanger ATCC stated that the Armed Forces' Sea King rescue helicopter was unable to depart due to weather conditions at Sola. At the same time, visibility on Yme deteriorated so it was not possible to see the sea below the oil rig. The crew and passengers accordingly started to prepare for spending the night on the rig. Stavanger ATCC was notified that they would “shut down” the helicopter for the time being, but that they would establish contact every 30 minutes in the time ahead.

1.1.21 The crew and passengers left the helicopter in order to investigate what the oil rig had to “offer” in case they had to spend the night. They kept together and found indoor shelter, various food and drinks. A little later, the commander started the helicopter's APU again and contacted Stavanger ATCC. He was informed that the rescue helicopter planned to depart Sola at 1810 hours., but that it had only fuel for 20 minutes of hoisting operations. Accordingly, LN-ONW was secured so that it could remain safe on the helideck at Yme through the night.

1.1.22 The commander again contacted Stavanger ATCC at approx. 1830 hours. Direct communication with the rescue helicopter was also established at this time[5]. The commander stated that visibility was 400–500 m and cloud base at 100–200 ft. The estimated time of arrival was stated to be 1850 hours. All were then gathered on the helideck and prepared to be hoisted two at the time.

1.1.23 Dusk had set in when the rescue helicopter arrived. There was no lighting on Yme, so the commander on LN-ONW used a powerful flashlight in order to signal their position. He assessed the hoisting operation to be highly efficient, and everyone was safely in board the rescue helicopter at approx. 1902 hours. The rescue helicopter then flew to the terminal at Sola. After landing, the commander gathered the passengers and gave a new briefing on the incident.

1.1.24 The next day, technicians were flown to Yme in order do trouble shooting. Early it became clear that the indications received by the crew could be related to the tripping of the M XMSN OIL WARN circuit breaker. This was confirmed. After a temperature switch (Main Transmission High Temperature Switch, P/N 92351-15808-101) was replaced, and the helicopter had been thoroughly checked by running the engine while on the ground, the helicopter was flown to Sola on Sunday 6 October.

[4]Maritime transponders, approx. 3.5 m high
[5]Radio call sign "Saver 50"

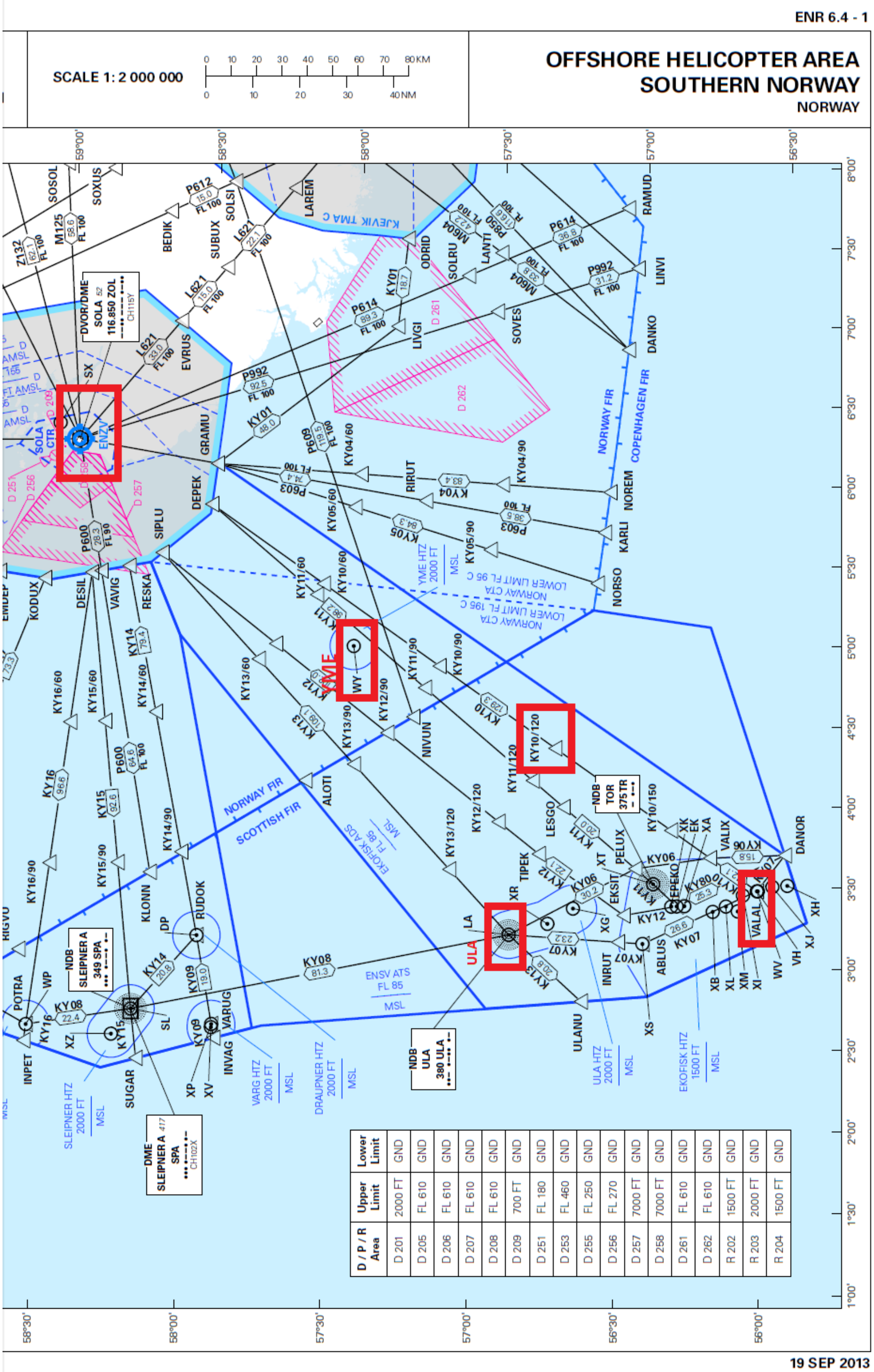

Figure 1. Extract from AIP Norway, Offshore helicopter area, Southern Norway". Stavanger Airport Sola, the oil rigs Yme, Ula and Valhall (Valal) as well as the reporting point KY10/120 framed in red.

Figure 2: The helicopter photographed on Yme 6 October, prior to being flown to Sola. Photo: Bristow Norway

1.2 Injuries to persons

Table 1: Injuries to persons

Injuries	Crew	Passengers	Others
Fatalities			
Serious			
Minor/none	2	12	

1.3 Damage to aircraft

None

1.4 Other damage

None

1.5 Personnel information

1.5.1 Commander

Male, 37 years, received civilian helicopter pilot training in the U.S. during the period 1998–1999. He was hired as first officer on Super Puma in Bristow Norway AS in 2005. The commander started piloting S-92A in 2007, and became commander for the helicopter type in 2009. For the past two years he had been *Line training captain.*

Commander had Commercial Pilot Licence (ATPL(H)) valid until 31 October 2015 and the following rights: SK92, IR(H) ME. The rights were most recently renewed on 10 May 2013 at OPC/PC. Medical certificate, without limitations, was valid until 16 May 2014.

The commander worked a shift rotation, comprising five days flying, two days off, five days flying and nine days off. The incident happened during the first flight on the last working day in a work rotation. The commander had 13 hours resting time prior to starting service.

Table 2: Flying hours commander

Flying hours	All types	Relevant type
Last 24 hours	2	2
Last 3 days	5	5
Last 30 days	51	51
Last 90 days	203	203
Total	5,340	4,340

1.5.2 First officer

Male, 33 years, received civilian helicopter pilot training in the U.S. in 2006. He was hired as first officer on S-92A in Bristow AS in 2010.

The first officer had Commercial Pilot Licence (CPL(H)) valid until 31 October 2015 and the following rights: SK92, IR(H) ME. The rights were most recently renewed on 3 May 2013 at OPC/PC. Medical certificate, without limitations, was valid until 5 October 2014.

The first officer worked a shift rotation, comprising five days flying, two days off, five days flying and nine days off. The incident happened during the first flight of the work rotation. The first officer had two weeks off prior to starting his service.

Table 3: Flying hours first officer

Flying hours	All types	Relevant type
Last 24 hours	2	2
Last 3 days	2	2
Last 30 days	47	47
Last 90 days	154	154
Total	3,065	2,065

1.6 Aircraft information

1.6.1 General

The helicopter type S-92 is a heavy transport helicopter with two turbine engines and a four-blade main rotor. The fuselage is of conventional aluminium construction, but with significant portions of composite materials. The helicopter is partially developed from S-70/UH-60 and shares many dynamic components with these. The S-92 flew for the first time in 1998 and entered service in 2004. The helicopter has 19 passenger seats and is equipped with floatation equipment certified for emergency landings at “sea state 6”[6].

[6] Wave height 4–6 m

1.6.2 Data

Manufacturer and model:	Sikorsky Aircraft Corporation S-92A
Serial number:	920090
Year of manufacture:	2008
Type certification number:	R00024BO
Airworthiness:	Airworthiness Review Certificate (ARC) valid until 25 November 2014
Engines:	2 x General Electric -8A, 2,520 hp each
Diameter main rotor:	17.17 m
Total number of flight hours:	5,021:11 hours
Total number of engine starts:	2,412
Total number of landings:	4,975

1.6.3 Mass and balance

Helicopter's maximum allowed take-off mass 12,020 kg (26,500 lb). According to the company's calculations the helicopter's mass was 12,007 kg (26 472 lb) prior to departure. With an experienced fuel consumption of 635 kg (1,400 lb) per hour, the helicopter had, after a flight of 2 hours and 22 minutes, an estimated mass of 10,505 kg (23,159 lb) when landing on Yme. The helicopter's centre of gravity was also within limits throughout the flight.

1.6.4 Type certification

1.6.4.1 Helicopter type S-92A was issued type certificate Category A[7] in accordance with Federal Aviation Regulations (FAR) Part 29, including Amendment 47, in 2002. Requirements applying to the rotor power drive lubrication systems were as follows (Part 29.927(c))1:

> *Unless such failures are extremely remote, it must be shown by test that any failure which results in loss of lubricant in any normal use lubrication system will not prevent continued safe operation, although not necessarily without damage, at a torque and rotational speed prescribed by the applicant for continued flight, for at least 30 minutes after perception by the flight crew of the lubrication system failure or loss of lubricant.*

1.6.4.2 Advisory Circular AC 29-2C, section AC 29.927, provides guidelines on how to interpret this:

> *This paragraph prescribes a test which is intended to demonstrate that in the event of a major failure of the lubrication system used on the rotor drive system,*

[7] Maximum take-off mass over 20,000 lb and 10 passenger seats or more.

no hazardous failure or malfunction will occur in the rotor drive system that will impair the capability of the crew to execute an emergency descent and landing. The lubrication system failure modes of interest usually are limited to failure of external lines, fittings, valves, coolers, etc. of pressure lubricated transmissions and/or gearboxes.

1.6.4.3 In 2002, Sikorsky carried out a test of the main gear box, where the oil was drained (dry run). A catastrophic failure occurred after 11 minutes. Accordingly, the requirement for 30 minutes' safe operation was not met. With reference to AC 29-2C, Sikorsky decided to install a bypass valve in the external oil cooler circuit. By closing the valve, any external oil leaks could be stopped. It was considered *extremely remote* that other leaks in the oil system could prevent a safe landing within 30 minutes. This was accepted by the certification authority, the Federal Aviation Administration (FAA).

1.6.4.4 In 2004, the helicopter type S-92A was issued EASA type certificate in accordance with Joint Aviation Requirements (JAR) 29 Change 1. Further specifications and information on limitations are available in EASA Type Certificate Data Sheet No. EASA IM.R.001.

1.6.5 The main gear box and associated warning/caution systems

1.6.5.1 *Description of the main gear box*

The main gear box (MGB) consists of five modules. These are: right and left Input Module, right and left Accessory Module, as well as the Main Gearbox Module (see Figure 3). The main task for the main gearbox is to reduce the engine speed of 21,945 rpm to the main rotor speed of 257.8 rpm. In addition, the main gearbox drives the tail rotor, two oil pumps for internal lubrication, two generators, and two hydraulic pumps. The main gearbox also constitute the attachment for the main rotor, consequently all loads from the main rotor are transferred through the gear box to the fuselage.

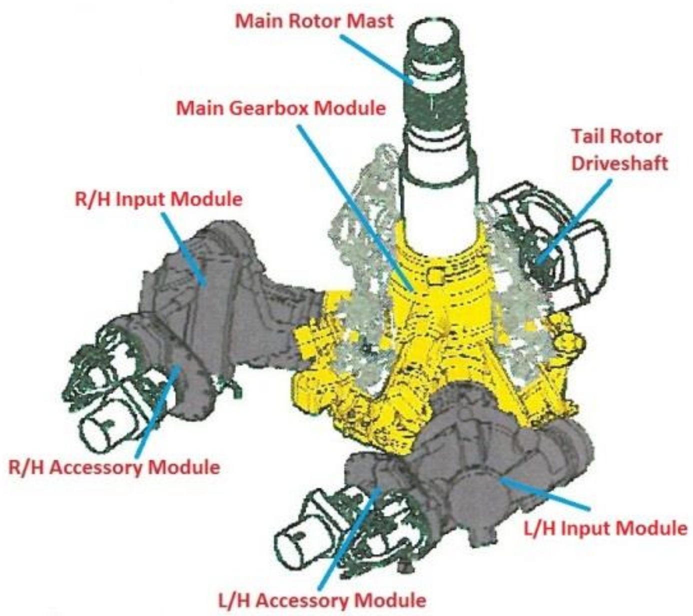

Figure 3: Overview of the main components on MGB. Source: FlightSafety

1.6.5.2 *The oil system in the main gearbox on LN-ONW (after implementation of ASB 92-63-027, see chapter 1.6.6.2)*

The main gearbox has an oil system with two combined pressure and scavenge pumps and an external oil cooler (see Figure 5). An Oil Bypass Valve can lead the oil directly from the pressure pumps to the components in the gearbox without running through the oil cooler. This function will prevent loss of gearbox oil if there is a leak in the oil cooler circuit. The valve is usually controlled automatically, but can also be controlled manually via a switch in the overhead panel in the cockpit. The switch has the following positions: AUTO, BYP and MAN COOL. An expected consequence of the oil going directly to the gearbox, bypassing the oil cooler, is an increase in the oil pressure. However, the design of the valve causes the oil pressure to drop when it is in bypass (BYP).

Normal oil pressure is approx. 58 psi. The system contain 40 litres of oil. Bristow Norway used gearbox oil with specification DOD-L-8753. The main gearbox is monitored by multiple sensors. The information is processed by the Avionic Management System (AMS) and presented using the Engine Indicating and Crew Alerting System (EICAS) on a Multi-Function Display (MFD) in the cockpit. Below is a list of sensors and associated warnings/cautions on the MFD[8]:

1. A sensor measures the oil pressure in the pressure line before the oil is distributed in the gearbox. It triggers the caution MGB OIL PRES on 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. The measured oil pressure is also presented in analogue (column) and digitally (numerical value) on the MFD.

2. The pressure switch in the left Accessory Module sense the pressure near the end of the oil distribution manifold. If the oil pressure drops below 24 psi, MGB OIL PRES will displayed on the MFD. If the oil pressure drops below 24 psi, at the same time as sensor 1 (see above) sense pressure below 35 psi, MGB OIL PRES will show on the MFD.

3. Sensor that registers the oil temperature in the pressure line before the oil is distributed in the gearbox. Triggers MGB OIL HOT on the MFD when the oil temperature exceeds 130 °C.

4. Sensor measures the oil temperature in the oil sump. The temperature is presented in analogue (column) and digitally (numerical value) on the MFD.

5. Sensors register the oil temperature in the left (1) and right (2) Input Module, respectively. If the temperature exceeds 130 °C, INPUT/ACC 1 HOT, respectively INPUT/ACC 2 HOT will show on the MFD.

6. The vacuum switches in the left (1) and right (2) Input Module, respectively, will trigger if the underpressure in the oil pump suction lines disappears. This is indicated on the MFD, with MGB PUMP 1 FAIL and MGB PUMP 2 FAIL, respectively.

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[8] Yellow text box = yellow caution light, red text box = red warning light and grey text box = the information is shown as a column or numerical value.

7. If the Oil Bypass Valve automatically go to the bypass position (BYP), the MGB BYPASS caution will be displayed on the MFD.

8. If the Oil Bypass Valve automatically go to the bypass position (BYP), and is then manually switched to the normal position with the oil cooler reconnected (MAN COOL), the caution MGB MAN COOL will displayed on the MFD.

9. The main gearbox is equipped with several Chip Detectors with Fuzz Burn. Fuzz Burn means that small metal shavings that accumulate on the plugs are burned off using electricity. If burning is unsuccessful, MGB CHIP, INPUT X CHIP or ACC X CHIP will displayed on the MFD. The system is controlled by a Chip Detector Processor.

All red lights on the MFD have audible warnings.

Much of the information in the helicopter, including most warnings/cautions, are handled by the Avionics Management System (AMS). Software for the system is regularly updated and version 7.1 was installed at the time of the incident.

The indications in Item 3, 6 and 8 are affected by a circuit breaker installed in the overhead panel in the cockpit marked M XMSN OIL WARN. If the circuit breaker trips, five yellow cautions will be shown on the MFD (see Figure 4 below).

After the incident, Sikorsky told Bristow that the main gearbox has been test run with an oil temperature of up to 225 °C, without the gearbox breaking down.

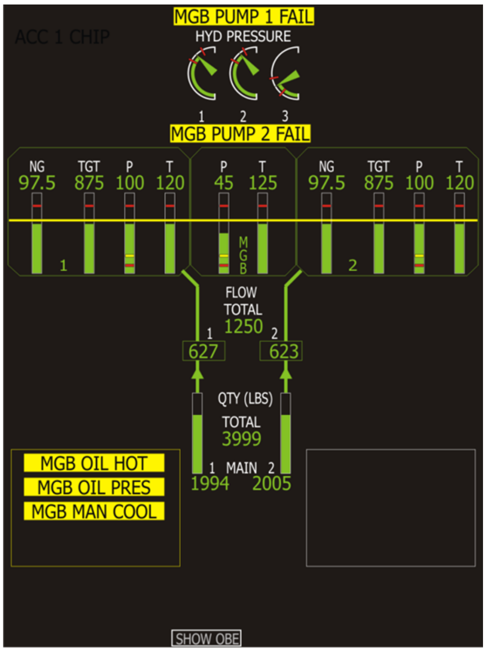

Figure 4: EICAS indications on MFD corresponding to those the crew saw in LN-ONW. Source: Sikorsky

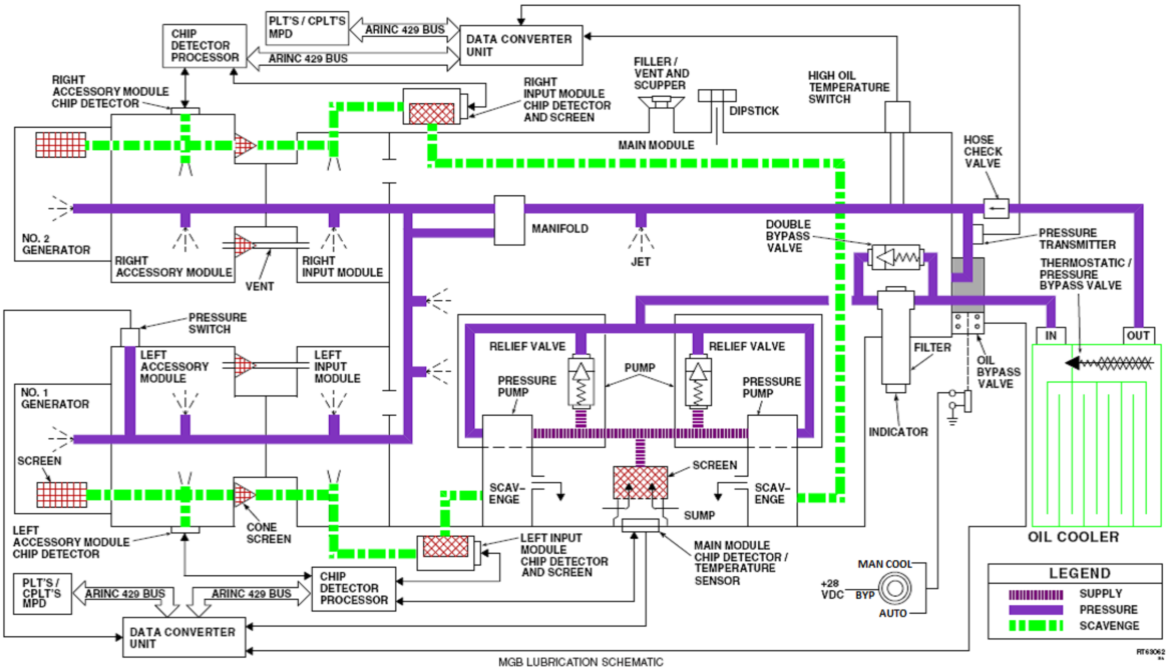

Figure 5: Simplified drawing of the oil system in MGB. Source: Sikorsky

1.6.5.3 *Emergency checklist*

The crew had the following relevant emergency checklist available in the cockpit during the flight:

Bristow Norway AS S-92A Emergency checklist

8 GEAR BOX

8.1 /8.2 MGB Oil Pressure Warning/Temperature Warnings and cautions.

Indications:

- MGB OIL OUT **AND** "GEARBOX OIL OUT" aural alert.

OR

- MGB OIL PRES **AND** "GEARBOX PRESSURE" aural alert.

OR

- MGB OIL PRES or MGB OIL HOT

Confirm:

For MGB OIL OUT warning: MGB oil pressure below 5 psi.

For MGB OIL PRES warning: MGB oil pressure below 35 psi.

For MGB OIL PRES caution: MGB oil pressure below 45 psi.

For MGB OIL HOT caution: MGB oil temperature above 130°C

Warning 1
A total loss of MGB oil pressure may result in MGB failure in less than 10 minutes. If the MGB OIL OUT warning illuminates, **LAND IMMEDIATELY**

ACTIONS:

1. **If MGB OIL OUT warning illuminates- Land Immediately**

If MGB OIL OUT warning is not illuminated.

2. If an INPUT/ACC 1/2 HOT and/or MGB PUMP 1/2 FAIL caution(s) also illuminate(s) **continue at item 3, if not continue at item 5:**
3. Throttle (affected engine) __________________________ IDLE unless dual engine power is required for continued safe flight.
4. Adjust airspeed between 80 and 100 KIAS. If practical, maintain pitch attitude above 2° nose up.
5. APU CTRL ....ON
6. APU GEN ....ON
7. TCAS 2 ....TA ONLY
8. Descend to a minimum safe altitude while reducing airspeed below 100 KIAS. If conditions permit, descend below 500 feet above water/terrain. Maintain airspeed between 80-100 KIAS until committed to land.

If no visual indication of a leak is detected and **ALL** of the following symptoms exist: MGB PUMP 1 FAIL or MGB PUMP 2 FAIL caution.

MGB BYPASS caution.

MGB oil pressure is 7 psi or greater.

9. MGB OIL BYP____________________________MAN COOL
10. **LAND AS SOON AS POSSIBLE**. If required, use dual engine power for landing.

CONTINUE ON NEXT PAGE

Bristow Norway AS S-92A Emergency checklist

If **ANY** of the following symptoms of an imminent gearbox failure exist:

- MGB OIL OUT warning.
- Increased power required at constant collective setting and airspeed.
- Yaw kicks.
- Unusual noise or vibrations.
- Loss of two hydraulic pumps.

Land Immediately. If required, use dual engine power for landing.

(The lower part of page 37 in the emergency checklist has been removed as it contained no text.)

Bristow Norway AS S-92A Emergency checklist

CONTINUED FROM LAST PAGE

Caution 1

High oil temperatures or loss of lubrication may result in loss of the main generators. The APU should be started so that the APU generator will be immediately available.

Caution 2

If a leak occurs in the external cooler, and the MGB OIL BYP switch is set to BYP in less than 5 seconds, the remaining oil is likely to heat up very quickly into the red zone.

Note1

The detection systems for the EICAS oil pressure gauge and the MGB OIL PRES warning are independent, so a warning with the corresponding gauge reading outside the normal range shall be taken as a valid indication.

Note 2

The decent should be made at a reduced power setting but with at least 15% torque to ensure the engines continues to drive the transmission. And use 80 KIAS for descend. Avoid rapid or frequent power changes. A running landing is preferred since it requires less power and smaller power changes. A no-hover landing should be performed if a running landing area is not available.

Note 3

High oil temperature may cause the paint on the gearbox to smoke or emit fumes which may be noticeable in the cabin or cockpit.

Note 4

A loss of MGB oil may result in the mechanical failure of a hydraulic pump drive.

Note 5

The main gearbox oil temperature sensors are "wet bulb" systems which require some presence of oil to indicate properly. When MGB oil pressure is completely lost, MGB temperature indications are not reliable.

Note 6

If the MGB OIL PRES warning illuminates as a result of a steady decline in pressure, the MGB OIL PRES caution will extinguish.

Note 7

The MGB OIL PRES caution illuminates in flight when gearbox pressure at the manifold falls below 45 psi or pressure at the "last jet" falls below 24 psi. The MGB OIL PRES warning illuminates when oil pressure at the manifold falls below 35 psi and pressure at the "last jet" falls below 24 psi. If the MGB OIL PRES warning illuminates, the MGB OIL PRES caution will not be illuminated.

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1.6.5.4 *Revised emergency checklist*

After the incident with LN-ONW, Sikorsky published a revised emergency checklist, describing the relevant situation.

8.5 MGB caution system fault/ M XMSN OIL WARN circuit breaker.

Indications:

- MGB PUMP 1 FAIL + MGB PUMP 2 FAIL + MGB OIL HOT + MGB MAN COOL + MGB OIL PRES

Confirm:

- Main gear box oil pressure above 45 psi
- Main gear box oil temperature below 130°C

Actions:

1. Check the M XMSN OIL WARN cb on the overhead DC Essential panel.
2. Reset (once) if tripped.

If cb re-trips:

3. MGB BYP switch________________________________ MAN COOL
LAND AS SOON AS POSSIBLE

If cb does not re-trip:

4. MGB BYP switch______________________________ MAN COOL

5. MGB BYP switch____________________________________ AUTO
If there are no further signs of MGB oil lubrication distress:

6. LAND AS SOON AS PRACTICAL

If MGB oil temperature exceeds 130 degrees or MGB oil pressure drops below 35 psi or any additional warning/caution lights illuminates follow the appropriate Emergency procedure.

Note 1 In flight, tripping of the M XSN OIL WARN circuit breaker will cause the bypass valve to close and the oil is now being diverted from the cooler. The **MGB BYPASS** caution **does not** illuminate.

Note 2 If the cb re-trips (after an attempt to reset) the oil needs to be manually diverted through the cooler by placing the MGB BYP switch to the MAN COOL position. There is no subsequent caution as the **MGB MAN COOL** caution would already be illuminated.

Note 3 If the cb does not re-trip (after an attempt to reset) then the **MGB BYPASS** caution will illuminate. The system needs to be returned to the non-BYPASS condition by cycling the MGB BYP switch to the MAN COOL and then to the AUTO position. The **MGB BYPASS** caution will then extinguish.

1.6.6 Main gearbox history

1.6.6.1 *Accident with Cougar Helicopters in 2009*

On 12 March 2009, an S-92 from the helicopter company Cougar Helicopters Inc. was heading towards the Hibernia oil field in Canada when it lost all its main gearbox oil. The crew attempted to return to St. Johns at Newfoundland, however, the helicopter fell uncontrolled into the sea at high speed approx. 35 nautical miles from the airport. One passenger survived, whereas 15 passengers and the two-person crew died in the accident. The accident was investigated by the Transportation Safety Board of Canada and is described in report A09A0016.

The accident occurred as a result of a failure in two of the titanium bolts that held the oil filter housing on the main gearbox in place thus causing the oil to leak out. This led to a failure in the tail rotor drive shaft when the main gearbox had flown for 11 minutes without oil. Following the accident, Sikorsky implemented changes to the maintenance procedures and subsequently replaced titanium bolts with steel bolts. In December 2009, Sikorsky published an Alert Service Bulletin ASB 92-63-022A which recommended replacing the entire oil filter housing with a new type. The modification was mandatory according to Airworthiness Directive (AD) No. 2010-10-03, published 21 June 2010 by the US Federal Aviation Administration (FAA).

Weaknesses in the emergency checklist were a contributing factor in the leak developing into a fatal accident. For example, the emergency checklist did not include what time-critical actions in connection with gearbox issues needed to be remembered (memory items). The oil cooler had to be bypassed within 5 seconds (switch to BYP) in the event of loss of oil pressure, but this was not marked as a ”memory item“. Furthermore, the crew had an insufficient understanding of the oil system's architecture, and thus made the incorrect diagnosis when the warnings/cautions were triggered.

1.6.6.2 *Modification of the main gearbox's oil system (Alert Service Bulletin ASB 92-63-027)*

On 21 January 2013, Sikorsky issued Alert Service Bulletin (ASB) number 92-63-027. It ordered modification of the main gearbox's oil system by 21 January 2014. The purpose of the modification was to automate the operation of the Oil Bypass Valve so that the crew would not have to set the switch to BYP within 5 seconds if the MGB OIL PRES warning was triggered. The modification entailed a series of changes in the system's wires, replacement of the switch on the overhead panel, additional pressure sensors and a new version of the software (AMS 7.1). The switch which previously had the positions TEST, NORM and BYP, would now have the positions AUTO, BYP and MAN COOL.

Sikorsky issued Rotorcraft Flight Supplement No. 45 in connection with the modification. The supplement consists of two parts and contains revised normal routines, emergency routines and a brief general description of the modified systems. The document contains descriptions of hypothetical failure scenarios, but contains no information about the cautions MGB PUMP 1 FAIL and MGB PUMP 2 FAIL in combination with approximately normal oil pressure. Furthermore, it was not mentioned that the circuit breaker M XMSN OIL WARN could result in automatic bypass of the oil cool circuit and more unintended cautions.

On the basis of the modification and Rotorcraft Flight Supplement no. 45, Bristow Norway published revision no. 12 of the Emergency/Abnormal Checklist.

LN-ONW was modified in accordance with ASB 92-63-027 and the Emergency/Abnormal Checklist complied with Rotorcraft Flight Supplement no. 45 when the incident occurred.

1.6.6.3 *Incident involving an S-92A in the Gulf of Mexico*

On 28 August 2013, there was an incident in the Gulf of Mexico that was similar to the incident with LN-ONW. An S-92A with serial number 920015 and registration N392PH received the same five yellow cautions on the MFD because circuit breaker M XMSN OIL WARN had tripped. Sikorsky had not yet alerted other operators of S-92A regarding this when the incident with LN-ONW took place. However, knowledge concerning the incident with N392PH helped Sikorsky to give Bristow Norway good guidance during the trouble shooting and work on understanding what happened to LN-ONW.

1.6.7 Modified Automatic Dependant Surveillance (M-ADS)

1.6.7.1 Significant parts of the helicopter traffic in the North Sea takes place outside controlled airspace in areas without radar coverage. In order to increase safety, Norwegian companies developed the M-ADS monitoring system. In simple terms, the system uses satellite communications to provide air traffic control positional information. Use of the system in the Norwegian sector of the North Sea became mandatory from 1999.

1.6.7.2 In recent years, there have been issues obtaining new and maintaining existing M-ADS systems in the helicopters. Accordingly, it has become necessary to fly with an exemption from the requirement. LN-ONW did not have a M-ADS on board during the flight in question. In this connection, Avinor[9] has stated that LN-ONW had not applied for an exemption to fly the relevant flight without M-ADS.

1.6.7.3 Automatic Dependent Surveillance – Broadcast (ADS-B) is new technology that will be gradually introduced from 2014 to increase safety. ADS-B will replace M-ADS and facilitate implementation of controlled airspace on the Norwegian Continental Shelf.

1.7 Meteorological information

1.7.1 General weather situation

1.7.1.1 Upon request from the AIBN, the Norwegian Meteorological Institute (West coast section) prepared a report. The following is quoted from this report:

> ***Weather situation at 1500 hours UTC 4 Oct. 2013:***
>
> *Low pressure 988 hPa northeast of Iceland. Cold front from approx. 67N, 00E southward to near Ekofisk and onwards to the Netherlands. Behind this a more marked cold front from the low pressure centre and southward to Scotland. On the hot air side, i.e. east of the first cold front, there was hot and humid air with extensive fog/mist. Bottom approx. 3000 feet of the atmosphere had stable layers, while it was instability higher up. A cumulonimbus area is shown on the analysis 15UTC, just southwest of Jæren. Due to this, both fog/mist was forecasted in the North Sea, with the possibility of thunder showers both on the coast and in the North Sea. In the route forecast 09-19 UTC for Sola-Ekofisk, fog and mist was forecast in the southwestern part of the route, which spread in a north-eastern direction. At the next update, valid 12-19 UTC, local fog and mist was forecast in the entire area except for the shore/coastline.*

[9] The Norwegian Air Navigation Service Provider

Regarding possible alternatives:

The area with fog/mist was moving in a northeast direction, but was not expected to reach all the way to Sola in the relevant period, which was shielded due to south-eastern wind. However, there was a forecast possibility of thunder showers at Sola, and later, towards 18 UTC somewhat lower cloud base, down to 1000 ft. When the first cold front passed Ekofisk at around 1500 hours UTC / 1700 local time, there was a modest improvement in visibility and cloud base, but still somewhat low stratus, and varying visibility. This improvement came at approximately the same time at Vallhall.
However, by 1650 UTC/1850 local time, there was no improvement in visibility and cloud base at Ula, which is located further north than Ekofisk.

Based on the available forecast, there was no reason to search further south for alternatives, though there appeared to be a certain improvement behind the first cold front. The alternative was flying back to the coast. Here, one would benefit from the southeast wind that prevented low cloud cover and poor visibility, but this improvement would likely not have come until they were near shore.

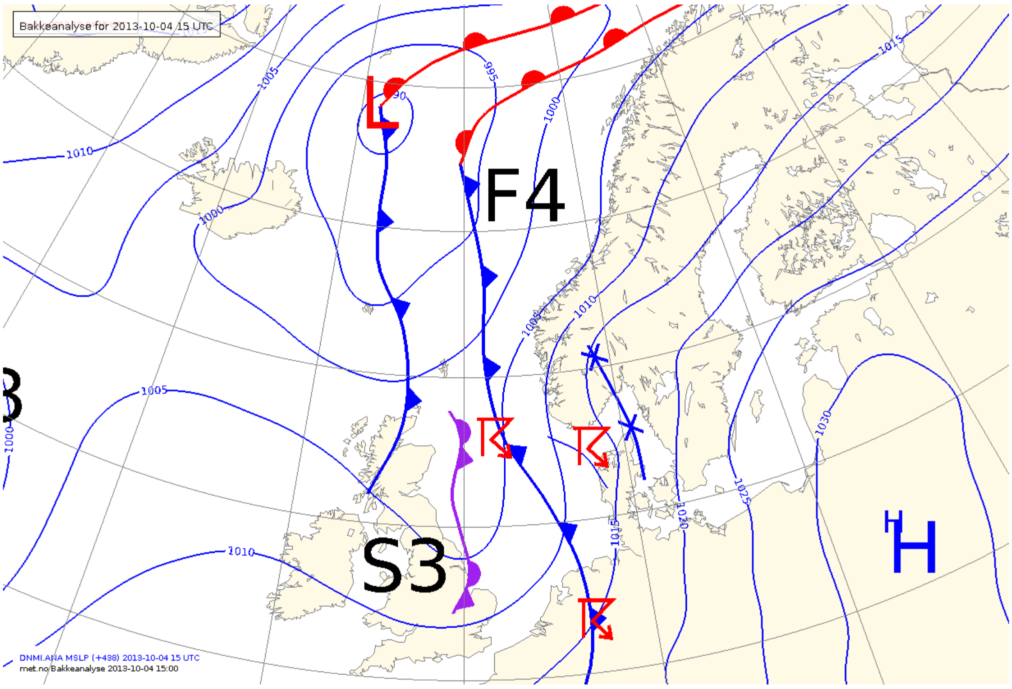


Figure 6: Surface analysis of the weather situation in Northern Europe at 1700 hours. Source: Norwegian Meteorological Institute

1.7.2 TAF (terminal aerodrome forecast)[10]

1.7.2.1 TAF Ekofisk:

ENEK 041100Z 0412/0421 15030KT 4000 BR SCT004 BKN015 TEMPO 0412/0421 2000 SHRA BR BKN004 BKN030CB PROB40 0412/0421 0300 FG VV001=

[10] Decoding of meteorological abbreviations, see: https://www.ippc.no/ippc/help_met.jsp and https://www.ippc.no/ippc/help_metabbreviations.jsp

ENEK 041400Z 0415/0424 16027KT 0300FG VV001 TEMPO 0415/0424 3000 SHRA BR BKN004 BKN030CB BECMG 0420/0423 26020KT=

1.7.2.2 TAF Sleipner:

ENSL 041100Z 0412/0418 14035KT 3000 BR BKN004 PROB40 0412/0418 0200 FG VV001=

ENSL 041400Z 0415/0418 17028KT 0100 FG VV001 PROB40 TEMPO 0415/0418 3000 TSRA BKN004 SCT015CB=

1.7.2.3 TAF Sola:

ENZV 041100Z 0412/0512 14015KT 9999 BKN050 TEMPO 0412/0424 15020G35KT SHRA PROB30 0412/0424 TSRA BKN040CB BCMG 0415/0418 BKN010 BECMG 0502/0505 26008KT TEMPO 0500/0508 3000 RADZ BR BKN005=

ENZV 041400Z 0415/0515 14012KT 9999 –SHRA FEW015 BKN030 TEMPO 0415/0424 15018G28KT SHRA PROB30 TEMPO 0415/0424 TSRA BKN014 SCAT030CB BCMG 0422/0501 BKN010 TEMPO 0500/0508 2500 RADZ BR BKN004 BECMG 0502/0505 26008KT BCMG 0507/0510 SCT015 BKN025=

1.7.3 METAR (Meteorological Aerodrome Report)

1.7.3.1 METAR Ekofisk:

ENEK 041320Z 16023KT 0800 FG VV002 14/14 Q1006 W13/S4=

ENEK 041350Z 16024KT 0500 FG VV002 14/14 Q1006 W13/S4=

ENEK 041450Z 16025KT 0500 FG VV001 14/14 Q1005 W13/S4=

ENEK 041520Z 16023KT 1500 BR BKN004 14/14 Q1005 W13/S4=

1.7.3.2 METAR Sleipner:

ENSL 041350Z 17025KT 0150 FG VV000 13/13 Q1004 W11/S5=

ENSL 041420Z 18027KT 0150 FG VV000 13/13 Q1004 W11/S5=

ENSL 041450Z 18028KT 0150 FG VV001 13/13 Q1004 W11/S5=

ENSL 041520Z 18027KT 0300 –SHRA FG VV000 13/13 Q1003 W11/S5=

1.7.3.3 METAR Sola

ENZV 041320Z 13013KT 9999 FEW015 BKN032 12/07 Q1011 TEMPO 15018G28KT=

ENZV 041350Z 13013KT 9999 BKN031 12/08 Q1010 TEMPO 15018G28KT=

ENZV 041420Z 12012KT 9999 BKN030 BKN100 12/08 Q1010 TEMPO 15018G28KT=

ENZV 041450Z 13013KT 9999 BKN028 13/08 Q1009 TEMPO 15018G28KT=

ENZV 041520Z 12010KT 9999 BKN027 13/08 Q1009 TEMPO 15018G28KT=

ENZV 041550Z 14014KT 9999 BKN024 13/08 Q1009 TEMPO 15018G28KT=

1.7.3.4 METAR Valhall:

ENVH 041320Z AUTO 16027KT 2700NDV –SHRA BR BKN004 /// 14/14 Q1006 W///S4=

ENVH 041350Z AUTO 16028KT 0450NDV –SHRA BR NCD 14/14 Q1006 W///S4=

ENVH 041420Z AUTO 17026KT 0400NDV –RA BR NCD 14/14 Q1006 W///S4=

ENVH 041450Z AUTO 18027KT 1400NDV –RA BR NCD 14/14 Q1005 W///S4=

1.7.3.5 METAR Ula:

ENLA 041320Z AUTO 16023KT 0150NDV FG NCD 14/14 Q1005 W///S4=

ENLA 041350Z AUTO 16025KT 1000NDV BR BKN003/// 13/13 Q1005 W///S4=

ENLA 041420Z AUTO 16026KT 0150NDV FG NCD 13/13 Q1004 W///S4=

ENLA 041450Z AUTO 16027KT 0150NDV FG NCD 14/14 Q1004 W///S4=

ENLA 041520Z AUTO 17027KT 0150NDV FG NCD 14/14 Q1004 W///S4=

1.7.4 Sea temperature and sea state

1.7.4.1 As follows from METAR above, observations showed that the sea state for Ekofisk, Valhall and Ula on the relevant afternoon and the evening was S4. This is classified as "Moderate", between 1.25 and 2.5 m significant wave height. There were no available observations for Yme.

1.7.4.2 Based on the weather situation, the Norwegian Meteorological Institute had assessed that the wave height near the coast may have been equal to or somewhat higher than the wave height on Valhall and Ula. All the way at shore, near Sola, it may have been somewhat lower due to the south-eastern wind direction.

1.7.4.3 As follows from METAR above, the sea temperature was measured at 13 °C at Ekofisk (W13) and 11 °C at Sleipner (W11). There were no available measurements at Valhall and Ula.

1.7.5 Observations

See Chapter 1.1 for a description of weather observations made by the flight crew.

1.8 Aids to navigation

1.8.1 The helicopter has a Flight Management System connected to the aids to navigation VOR/DME, ADF and GPS. The helicopter also has a mapping radar that is also used to locate oil installations during low altitude flights.

1.8.2 A non-directional radio beacon (NDB) was installed on the Valhall oil installation.

1.8.3 There were no available aids to navigation on the Yme oil rig.

1.9 Communications

1.9.1 During large parts of the flight, BHL305 should have maintained communication with the Stavanger Air Traffic Control Centre (ATCC), offshore sector at 128.000 MHz. Several radio transmitters/receivers have been stationed on e.g. Ula, Sleipner and Bjerkreim for the purpose of achieving good coverage on this frequency. However, there is bad coverage in a distance of 80–110 NM from Sola below 1,000 ft. Because the helicopter flew all the way down to 100 ft., it was not achieved contact between the Stavanger ATCC and BHL305 during the period between approx. 1640 and 1703 hours.

1.9.2 The transmitter/receiver for the emergency frequency 121.500 MHz only exists on shore, and the range in low altitudes is accordingly not longer than approx. 75 NM out from Sola. However, airplanes in the area detected the communication on the emergency frequency and relayed this to the air traffic control.

1.10 Aerodrome information

1.10.1 <u>Alternative airports</u>

After the crew at LN-ONW aborted the approach to Valhall, they returned towards Stavanger Airport Sola (ENZV). The airport is equipped for precision approach (Instrument Landing System – ILS) to runway 11, among others. Correspondingly, Haugesund Airport Karmøy (ENHD) had ILS for runway 14.

1.10.2 <u>Radar</u>

The radar coverage is limited in the area where the incident occurred. The Stavanger ATCC has radar coverage 90 NM out from shore for aircraft at an altitude of 2,000 ft. For aircraft flying at an altitude of 1,000 ft., the radar coverage extends 75 NM out from shore.

1.10.3 <u>Yme</u>

1.10.3.1 Yme is a permanent oil rig that was about to commence operations, but was for safety reasons evacuated on 10 July 2012. The platform is scheduled for removal in 2015.

1.10.3.2 The helicopter deck on Yme was approved for helicopter landings until the rig was evacuated. The Accident Investigation Board has been granted access to an instrument landing chart from Jeppesen published on 25 May 2012. The map contains the following relevant data regarding the helicopter deck:

- Position: N57 48.0 E00 32.0

- Elevation: 187 ft
- D-value: 21 metres
- Max Weight: 28,220 lb/12,800 kg
- Helideck heading: 353°

1.10.3.3 After the platform was evacuated, landing on the helicopter deck was prohibited. Furthermore, two maritime transponders were positioned on the helicopter deck (see Figure 2). Although these blocked parts of the deck, it was possible to land the helicopter without damaging the rotor blades. A standby vessel near the platform enforced a safety zone of 500 metres around the installation. The vessel crew did not register that the helicopter landed on the helicopter deck, and was first made aware of the incident by the rescue helicopter briefly before it arrived at Yme.

1.11 Flight recorders

1.11.1 The helicopter was equipped with a combined Cockpit Voice Recorder (CVR) and Flight Data Recorder (FDR) model Penny and Giles Multi-Purpose Flight Recorder D51615-102 with serial number (S/N) 000729-002.

1.11.2 Bristow Norway AS downloaded data from FDR and made these available to the Accident Investigation Board. The information from the FDR supports and supplements the explanations provided by the flight crew. Key parameters are presented in Appendix B.

1.11.3 Information from the voice recorder has not been available to AIBN because the helicopter was left with the power on for a period of time after the emergency landing. Information from the actual incident was accordingly recorded over.

1.11.4 The helicopter was equipped with a condition monitoring system (Health and Usage Monitoring System – HUMS), which records information. The system monitors pressure, temperature and vibrations, among other things, in the main gearbox. The information from the system supports and supplements the explanations provided by the flight crew.

1.12 Wreckage and impact information

Not applicable

1.13 Medical and pathological information

Not applicable

1.14 Fire

Not applicable

1.15 Survival aspects

1.15.1 Personal survival gear

The crew on board were wearing Viking Etso 2C503 survival suits and personal emergency beacons (HR Smith Multi-Function Human Resources Locator Beacon Type 500-27).

All passengers were wearing Hansen Protection Sea/Air 85336 survival suits, with HPL-1 emergency beacons attached.

1.15.2 Equipment on board the helicopter

The helicopter was equipped with the following relevant equipment:

- A satellite based Cloud Connect Tracking System from Honeywell made it possible for the operator to follow all of its helicopters' movements in real-time.
- Emergency beacon (HR Smith Crash Position Indicator (CPI) Type 503).
- An Emergency Flotation System with five inflatable floats installed on the helicopter. These will keep the helicopter afloat in the event of an emergency landing in the sea.
- Two rafts, each certified for 14 people, and with an emergency capacity of 21 people. Each raft has an emergency beacon (HR Smith Multi-Function Human Resources Locator Beacon Type 500-12).
- Five-point seatbelts for the crew and four-point seatbelts for passengers.

1.16 Tests and research

None

1.17 Organisational and management information

1.17.1 Bristow Norway AS is wholly owned by Bristow Helicopter Ltd which is part of the Bristow Group Inc. with headquarters in Houston, Texas, US. Bristow Group Inc. flies for the offshore industry worldwide.

1.17.2 Bristow Norway AS is authorised to conduct commercial air transport in accordance with Air Operator Certificate (AOC) No. 10 issued by the Norwegian Civil Aviation Authority.

1.17.3 At the time of the incident, the company had the following fleet:

Helicopter Type.	Number
Sikorsky S-92	15
Eurocopter EC225	2

1.17.4 At the time of the incident, Bristow Norway AS was organised as indicated below:

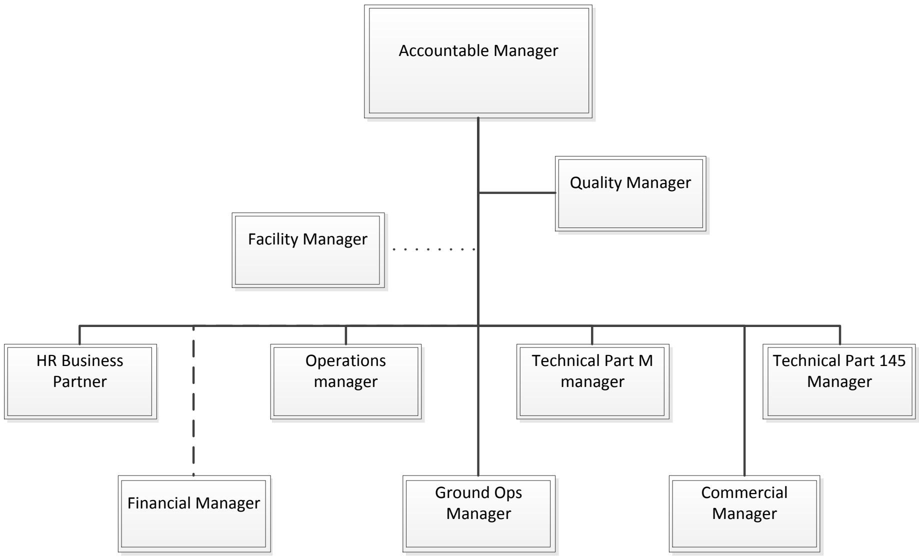


Figure 7: Organizational charts of Bristow Norway AS. Source: Bristow Norway AS

1.18 Additional information

1.18.1 Measures implemented after the incident

1.18.1.1 It was clear from an early stage what had happened to LN-ONW, and Bristow Norway informed all of its pilots. Based on information from Sikorsky (FTR No. 12113T255), Bristow Norway issued a circular (Operations Information Circular – OIC No. 0157) as early as 7 October 2013, explaining the incident. In simple terms, the following information was provided:

- An electrical short in certain components or wiring will cause the M XMSN OIL WARN circuit breaker to trip.
- If this happens, the MGB PUMP 1 FAIL, MGB PUMP 2 FAIL, MGB OIL HOT, MGB MAN COOL and MGB OIL PRES cautions will be triggered.
- The oil system's bypass valve will go to the bypass position, but the MGB BYPASS will not be enunciated and the annunciation MGB MAN COOL is misleading.
- If the bypass valve remains in the bypass position (oil does not pass through the cooler), the oil temperature will rise above the permitted limit.
- If this situation occurs, the bypass valve must be set to MAN COOL. The oil pressure should stabilise at 40–55 psi and the oil temperature should return to normal values.
- If this situation occurs, the best indication of the main gearbox's condition are the analogue and digital readings of the main gearbox's oil pressure and temperature.
- As the flight continues, the MGB indications must be continuously monitored.
- If the oil temperature exceeds 130 °C or the oil pressure drops below 35 psi, the emergency routines in the aircraft flight manual must be followed.

- A circuit breaker can be reset once. If the situation normalises after the reset, the switch for the bypass valve must be set to MAN COOL, BYP and then back to AUTO.

1.18.1.2 On the same day, 7 October 2013, Sikorsky issued All Operator Letter (AOL) No. CCS-AOL-92-13-0015 with identical content.

1.18.1.3 On 21 November 2013, Sikorsky published a temporary revision of the helicopter's Rotorcraft Flight Manual (RFM) and associated supplements (RFM Supplements – RFMS). This stipulated the routines to be followed if the circuit breaker M XMSN OIL WARN tripped.

1.18.1.4 In July 2014, Sikorsky stated that they had started the work on improving the electrical supply for the monitoring and warning system for the main gearbox. This e.g. entailed installation of an additional circuit breaker. The improvement would be incorporated in the production line for all new S-92As. Furthermore, the plan involved publishing an Alert Service Bulletin which stipulates a corresponding modification of all existing S-92As. Sikorsky plan to release this ASB in July 2016.

1.18.2 The company's internal investigation

In accordance with its own routines, Bristow Norway AS commenced an internal investigation of the incident. Among other things, the report published on 26 November 2013 contained four safety recommendations. One of these related to a dialogue with Sikorsky with regard to improving the main gearbox's oil system. The remaining three related to information and training own personnel in order to be better prepared to handle similar situations.

1.19 Useful or effective investigation techniques

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

2. ANALYSIS

2.1 General

2.1.1 The Accident Investigation Board has determined that this incident was not a serious incident in accordance with applicable definitions, thus an investigation was not required. In other words, the incident did not involve: *circumstances indicating that there was a high probability of an accident.* However, the cautions and indications presented to the crew during the flight were perceived as very serious. The severity was augmented by the crew's knowledge regarding the Cougar Helicopters accident in Canada in 2009 (see Chapter 1.6.6.1), and more recent instances of failure in main gearboxes in Super Puma helicopters. For this reason, the crew was prepared for potential problems that would make an emergency landing in the rough seas the only possible alternative. This alternative could have become dramatic.

2.1.2 The incident started with a minor technical error, which should generally not result in serious consequences. However, the error and the ensuing indications led to deeper concern, particularly because there was limited guidelines for making decision in applicable checklists. The crew accordingly had to make operative decisions in a situation where adverse weather imposed major restrictions. Exercise of good airmanship prevented the situation from escalating.

2.1.3 The Accident Investigation Board chose to investigate the incident because it involves several topics that could provide useful learning.

2.1.4 In this analysis, the Accident Investigation Board emphasised the following:

- Technical matters
- The crew's handling of the situation
- Emergency checklists

Furthermore, the Accident Investigation Board discussed matters regarding a potential emergency landing at sea and use of Yme as an emergency landing site.

2.2 Technical matters

2.2.1 The technical fault

2.2.1.1 When the fault occurred in the Main Transmission High Temperature Switch (see Item 1.1.24), the circuit breaker M XMSN OIL WARN tripped and the bypass valve automatically switched to the position that prevented the oil from going to the external oil cooler circuit. This was the only physical change in the main gearbox. The indications received by the crew were a result of the circuit breaker tripping, and were consequently not real warnings. Because the oil was no longer flowing through the oil cooler, the oil temperature gradually started to rise. This caused the caution for INPUT/ACC 1 HOT to switch on after about 30 minutes into the flight. The caution is triggered when the oil temperature in the area exceeds 130 °C. However, the main gearbox could have withstood far higher oil temperatures before a critical situation would occur. This is reflected with the fact that the emergency checklist only prescribes that the engine in question shall be set to idle. The Accident Investigation Board assumes that the helicopter could have flown all the way back to Sola without flight safety being threatened by high oil temperature.

2.2.1.2 Logically, a direct routing excluding the oil cooler circuit should lead to the oil pressure rising at the sensors in the pressure line inside the gearbox. However, due to the design of the bypass valve, the automatic switching caused the oil pressure to drop from the normal value of around 58 psi, down to 49 psi. This was above the minimum pressure of 45 psi, but the pressure drop further convinced the crew that something had happened inside the gearbox.

2.2.2 Considerations regarding the main gearbox's history

2.2.2.1 Generally, the main gear box did not fulfil the certification requirements, as it should be possible to fly for 30 minutes after the oil was drained (see Item 1.6.4.3). By placing a bypass valve in the external oil cooler circuit, the oil is prevented from leaking out via external details that were considered to be vulnerable. The risk of other oil leaks was considered minimal. On this basis, the oil was expected to remain in the gearbox, and the lubrication system was accepted.

2.2.2.2 The Cougar Helicopters accident in 2009 also showed that leaks could occur in the actual gearbox. Furthermore, it became clear that the instruments could be misread, so the crew did not fully understand the severity of the situation. A situation that could have been avoided with an emergency landing therefore had a fatal outcome.

2.2.2.3 Improvements in the main gearbox's oil system after the Cougar accident was introducing a new oil filter, automation of the bypass function to the external oil circuit, changes to the warning/caution system and changed routines/checklists (see Item 1.6.6.2).

2.2.2.4 The Accident Investigation Board believes that the main gearbox's lubrication system became even more complicated and difficult to understand afterwards. This is reflected in the emergency checklist, which is very difficult to understand with a number of conditions and comparisons using and/or (see Item 1.6.5.3). In a real emergency situation, this could cause incorrect interpretations and an unnecessarily high stress level, particularly if the indications do not correspond with the alternatives mentioned in the emergency checklist.

2.2.2.5 The indications that arose when the circuit breaker M XMSN OIL WARN tripped were not described in the emergency checklist. This could indicate that not even Sikorsky had the full overview of the consequences when ASB 92-63-027 was introduced. Modifications normally solve the problem that the modification was intended to solve. Occasionally, however, modifications can introduce undesirable effects that were not anticipated. In order to prevent such unwanted effects, the modification must undergo a critical evaluation by both the manufacturer and type approval authority. In the case in question, it appears as if both Sikorsky and the US Federal Aviation Administration (FAA) have not sufficiently assessed this during the consequence analyses and certification process.

2.2.2.6 Sikorsky became aware of the result of the M XMSN OIL WARN circuit breaker tripping in connection with the incident in the Gulf of Mexico on 28 August 2013 (see Chapter 1.6.6.3). The incident in the Gulf of Mexico took place about one month before the incident with LN-ONW, and this could have been enough time for Sikorsky to analyse potential consequences and notify other operators of this helicopter type. It can be challenging for a manufacturer to sort and analyse incidents that are reported by operators. AIBN is of the opinion that this incident illustrates the importance of quickly communicating relevant safety information to operators.

2.3 The flight crew's dispositions

2.3.1 Before the crew departed from Sola, they were aware that the weather conditions could prevent landing at Valhall. Therefore they brought enough fuel to return to Sola or Haugesund. Accordingly, there was nothing unusual about the flight until after they set course back to Sola.

2.3.2 When the two cautions MGB PUMP 1 FAIL and MGB PUMP 2 FAIL came on, the crew were uncertain about the meaning. If both oil pumps in the main gearbox had failed, the oil pressure would have been completely lost. It is understandable that the commander saw this as not being logical, as the instruments continued to show virtually normal oil pressure. Consulting the emergency checklist did not help, as it did not describe a combination where both lights came on simultaneously.

2.3.3 The announcements that turned on may have been an false indication. However, the fact that independent systems showed an oil pressure drop and an slow oil temperature rise, indicated that something had happened physically inside the gearbox. Based on this, the Accident Investigation Board understands why the crew did not believe that it was just an indication problem.

2.3.4 The three cautions MGB OIL HOT, MGB OIL PRES and MGB MAN COOL did not provide any further help in understanding the situation. Reading the emergency checklist was to no help in this situation either. The MGB MAN COOL caution could also have led to a misunderstanding. Before ASB 92-63-027 was introduced, the switch in the overhead panel had a position marked BYP (bypass) so one could manually disconnect the external oil circuit, including the oil cooler. The fact that the MGB MAN COOL caution was triggered, could have contributed to creating the perception that the oil cooler was still connected. If the indications provided clues that the oil cooler was disconnected (bypass), the crew could have corrected this by setting the switch in the overhead panel to MAN COOL. This would have reconnected the oil cooler, and re-established normal cooling of the main gearbox oil. This would have removed the disturbing indications with low oil pressure and slowly rising oil temperature. Neither this possibility was listed in the emergency checklists.

2.3.5 In general, the Accident Investigation Board believes it is good practice to check all available circuit breakers if something unusual occurs during flight. If time permits, such a check may be useful, regardless of the checklists' potential deficiencies and weaknesses. In this case, the crew had enough time to check the circuit breaker panels. Such a check could have revealed that the circuit breaker M XMSN OIL WARN had tripped. A reset could have normalised most of the indications and given the crew a clue that something was wrong in the indication system, but it is also possible that the circuit would have immediately tripped again due to the fault in the temperature switch (see Item 1.1.24), and that a reset would not have helped the crew much.

2.3.6 The Accident Investigation Board understands the crew's frustration. By interpreting the emergency checklist, they determined that they could continue flying because no red warnings were on. In most cases, a red light means *Land immediately*. They also made the conclusion that a reduction in flight speed would reduce the strain on the gearbox. A lower altitude would also shorten the total time needed to execute a potential emergency landing.

2.3.7 The Accident Investigation Board also understands the worry caused when the oil temperature finally became so high that the INPUT/ACC 1 HOT caution came on. Reduction of the effect from the left engine would have initially solved the problem. If INPUT/ACC 2 HOT also came on, it would have been impossible to simultaneously reduce the effect in the right engine and continue flying.

2.3.8 The crew had to evaluate which critical cautions they could accept before having to perform an emergency landing in the sea. With rough sea and wind speeds exceeding 25 kt, this was not a desirable option. The fact that they could use the helicopter deck on Yme as an emergency landing site was therefore very welcome.

2.3.9 The Accident Investigation Board would like to commend the crew for how they handled the situation. They made operative decisions that reduced the risk of an accident and they kept the air traffic control up-to-date insofar as possible.

2.4 Emergency checklists

2.4.1 Introduction

2.4.1.1 The commander worked as a simulator instructor and had an above average understanding of how the main gearbox and warnings systems were designed. Neither he nor the first officer got relevant decision support by reading the emergency checklists during the incident with LN-ONW.

2.4.1.2 The Accident Investigation Board is critical of two factors regarding the emergency checklist as it existed in October 2013 (see Item 1.6.5.3). One is that the indications received by the crew were not described in the emergency checklist. The second is that the emergency checklist relating to the main gearbox is confusing and difficult to understand. These two factors are discussed below.

2.4.2 Deficient description

The oil system and associated warning and monitoring systems on S-92A can be characterised as complex. The Accident Investigation Board understands that a checklist cannot cover all contingencies and faults. However, in this case, the fault was not improbable or surprising. A minor fault caused a circuit breaker to trip. Several other faults in the warning and monitoring system could also have caused the circuit breaker to trip. The Accident Investigation Board is of the opinion that Sikorsky should have predicted and described this in the emergency checklist[11].

2.4.3 Complicated emergency checklist

2.4.3.1 It can be challenging to describe a complicated system in an orderly fashion in an emergency checklist. The Accident Investigation Board believes that Sikorsky has not succeeded in the work on making it user-friendly while also being sufficiently exhaustive. The emergency checklist, as at October 2013, contained a series of provisos, often in combination with the expression “and/or”. This can be difficult to understand even when the checklist is read in a calm and quiet environment.

2.4.3.2 Item 8.1/8.2 *MGB Oil Pressure Warning/Temperature Warnings and cautions* is split into three sections: *Indications, Confirm* and *ACTIONS*. For the purpose of achieving a full overview of the situation and necessary measures, all three sections must be consulted. There are a number of provisos and alternatives within each section. In order to gain an overview, one must relate to three sections and the alternatives within each section. The Accident Investigation Board also believes that the checklist is not faithful to the sectioning *Indications, Confirm* and *ACTIONS* because there are five *symptoms* at the end of the *ACTIONS* section. Another example is that the *MGB OIL OUT* warning is mentioned a total of six times in the checklists. Five of these mentions relate to a positive indication, whereas the latter relates to the warning not being on (not illuminated). The emergency checklist also contains an entire page devoted to supplementary information in the form of *Cautions* and *Notes* which could increase the stress of the person attempting to understand the situation.

2.4.3.3 With training and good insight into the systems in the main gearbox, it is no doubt possible to understand the checklist in its current form. However, the Accident

[11] The applicable checklist at the time of the incident with LN-ONW.

Investigation Board believes that this is not acceptable because all pilots must be able to read and understand the checklist, including pilots that may not always have an up-to-date and exhaustive system understanding. Even more important is that it must be possible to reach and understand an emergency checklist under time pressure in a critical situation. In this context, it is relevant to reference the requirements in the Federal Aviation Regulations (FAR) Part 29 Section 29.1585:

> *(a) The parts of the manual containing operating procedures must have information concerning any normal and emergency procedures, and other information necessary for safe operation, including the applicable procedures, ………*

2.4.3.4 It is desirable for all emergency checklists for an aircraft to be structured in a uniform and recognisable manner. Rewriting the emergency checklist for *MGB Oil Pressure Warning/Temperature Warnings and cautions* can accordingly introduce other problems. One alternative could be splitting the current checklist into several separate checklists that focus on a specific theme. Another potential alternative could be leaving more of the decisions to computers in the warning/caution system so that the crew could relate to warnings in clear text, for example *Land immediately* or *Land as soon as possible*.

2.4.3.5 Regardless of the chosen approach, it will be challenging to achieve an optimal, safe and clear warning/caution system for the main gearbox on the S-92. However, it is not acceptable that it is left up to the crew to interpret ambiguous and confusing checklists in a stressful situation.

2.5 Improvements after the incident

2.5.1 After the incident Sikorsky has revised the emergency checklist regarding the circuit breaker M XMSN OIL WARN (see Item 1.6.5.4). However, the remaining emergency checklist regarding the main gearbox is still complicated. This is linked to the design of the warning/caution system and may result in unnecessary stress, confusion and incorrect interpretation. The operative management in Bristow Norway AS shares this opinion.

2.5.1.1 Following this incident, Bristow has implemented measures to prevent recurrence. The Accident Investigation Board is of the opinion that this does not solve the more fundamental challenges with a complicated warning/caution system and associated complex emergency checklists. Sikorsky should therefore conduct a full review of the main gearbox's warning/caution system and associated emergency checklists with regard to increase understanding and user-friendliness. The Accident Investigation Board issues a safety recommendation concerning the emergency checklist.

2.6 Potential emergency landing in the sea

2.6.1 The crew did not understand what happened in the main gearbox. Accordingly, they had to be prepared for a main gearbox breakdown at any time. This is one of the worst-case scenarios for a helicopter, and requires an immediate emergency landing. An emergency landing is possible when flying over land, but is far more challenging over stormy seas, for example in the North Sea.

2.6.2 Expressions such as *land immediately* or *consider an immediate landing* are rarely seen in checklists for passenger airplanes. The cause is obvious as an airplane requires built-in safety so it can make it to the nearest airport. Helicopters have a number of systems that cannot be made redundant in order to increase safety. In this context, the main gearbox is one of these critical components without redundancy. Traditionally, helicopters have mostly flown over land or near the coastline, and the mentioned vulnerability was partially offset by the possibility of immediate landings. However, in connection with longer flights over sea, this alternative is significantly more problematic. An emergency landing in the North Sea generally, and particularly during winter, is extremely risky. This applies even if the helicopter is equipped with floatation gear. High technical operational reliability in critical components is therefore absolutely essential to avoid emergency landings in the sea.

2.6.3 According to meteorological information, the wind was just under 30 kt, the air temperature was 14 °C, the sea temperature was 13 °C and the significant wave height was 1.25–2.5 metres. This is more hospitable than can be expected on a winter day in the North Sea. The crew estimated the wave height to be significant greater. This deviation may be due to margins during measurements, local variations and difficulties in assessing wave heights from a helicopter. The fact that a cargo ship moved too much in heavy sea for a safe landing, might indicate that the wave height at the actual location was significantly greater than 2.5 meters. The helicopter would most likely have been lost during a landing at sea.

2.6.4 The fact that an emergency landing in the North Sea can easily become dramatic for passengers and crew as well, was demonstrated when Super Puma LN-OBP conducted an emergency landing in the North Sea 40 NM southwest of Sola on 18 January 1996 (SL RAP 02/98). For comparison, the wave height was 3–4 metres, the wind was 25 kt, the air temperature was 4–5 °C and sea temperature was 5–6 °C. The situation became somewhat chaotic after the emergency landing in the sea. No one was seriously injured, partially because everyone was hoisted on board two rescue helicopters shortly after the emergency landing. However, the helicopter was lost.

2.6.5 LN-ONW and everyone on board was equipped with emergency beacons. Consequently, notification and locating the emergency landing site could take place relatively quickly, despite the fact that the helicopter was outside both radio and radar coverage for a while.

2.6.6 The crew on LN-ONW informed the passengers so that they were prepared if they were forced to land in the sea. The Accident Investigation Board considers this to be important to increase the possibility of survival in the event of a potential landing in the sea.

2.7 The helicopter deck on Yme

Yme was evacuated and it was not permitted to be on the oil rig. Accordingly, use of the helicopter deck was also prohibited. However, the Accident Investigation Board believes that the helicopter deck should not have been blocked by objects. Yme was conveniently located between the coast and the major oil fields to the southwest in the North Sea. All installations with helicopter decks in this area presents a better emergency landing alternative than landing in the sea. In this context, installing maritime transponders on the helicopter deck on Yme was not fully thought through. In any case, when the decision was made to place them on the helicopter deck, the positioning could have been worse, preventing a helicopter from being able to land there.

3. CONCLUSIONS

3.1 Findings

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

b) The aircraft's mass and balance were within the permitted limits at the time of the incident.

c) The crew members had valid licences and privileges to fly the aircraft.

d) The main gearbox's oil system and associated warning/caution system are very complicated.

e) A minor technical error in the main gearbox resulted in the crew receiving multiple false indications.

f) The emergency checklist for the main gearbox's oil system was incomplete and did not provide decision support in the relevant situation.

g) The cautions received by the crew gave reasons for serious concern and an emergency landing in the sea was considered a possible option.

h) Upon return to Sola, low clouds forced the helicopter to descend to an altitude of 100 ft. in order to maintain visual contact with the sea.

i) The crew decided to divert to the decommissioned oil rig Yme.

j) The helicopter did not have radio and radar coverage for a portion of the flight.

k) The crew kept the passengers up-to-date concerning the situation along the way and prepared them for an emergency landing in the sea.

l) In the final 2.5 minutes before the emergency landing on Yme, the INPUT/ACC 1 HOT caution came on. In accordance with the emergency checklist, the crew let the left engine at idle until more power was needed during landing.

m) The helicopter deck on Yme was partially blocked by maritime transponders.

n) No damage/injuries occurred during the emergency landing on Yme.

o) Everyone on board was hoisted on board a rescue helicopter two hours after the helicopter completed the emergency landing.

p) An emergency landing in the North Sea during winter is very risky, even if everyone on board is wearing survival suits and the helicopter is equipped with floatation gear.

q) A similar fault occurred in an S-92A helicopter in the Gulf of Mexico on 23 August 2013. Information regarding this incident may have helped with understanding the LN-ONW incident. However, Sikorsky had not communicated information about the incident in Mexico to other operators.

r) After the incident, Sikorsky initiated a process to improve the warning/caution system on the helicopter.

4. SAFETY RECOMMENDATIONS

The Accident Investigation Board Norway (AIBN) issues the following safety recommendation:

Safety recommendation SL No. 2015/11T

On 4 October 2013, LN-ONW made an emergency landing on the evacuated Yme oil rig. A minor technical fault in the main gearbox resulted in indications which the crew perceived to be serious. The Accident Investigation Board is of the opinion that the emergency checklist for the main gearbox on the S-92A was complicated and difficult to understand, particularly in a stressful emergency situation. This view is supported by the operating company Bristow Norway AS. After this incident, Sikorsky has revised the relevant parts of the emergency checklist, and started a redesign process to improve the warning/caution system on the main gearbox. The Accident Investigation Board Norway is however of the opinion that further improvements is needed, and therefore recommends that Sikorsky revise the emergency checklist with the aim of further simplification and increased user-friendliness.

The Accident Investigation Board Norway

Lillestrøm, 18 November 2015

APPENDICES

Appendix A: Abbreviations

Appendix B: Selected parameters from FDR

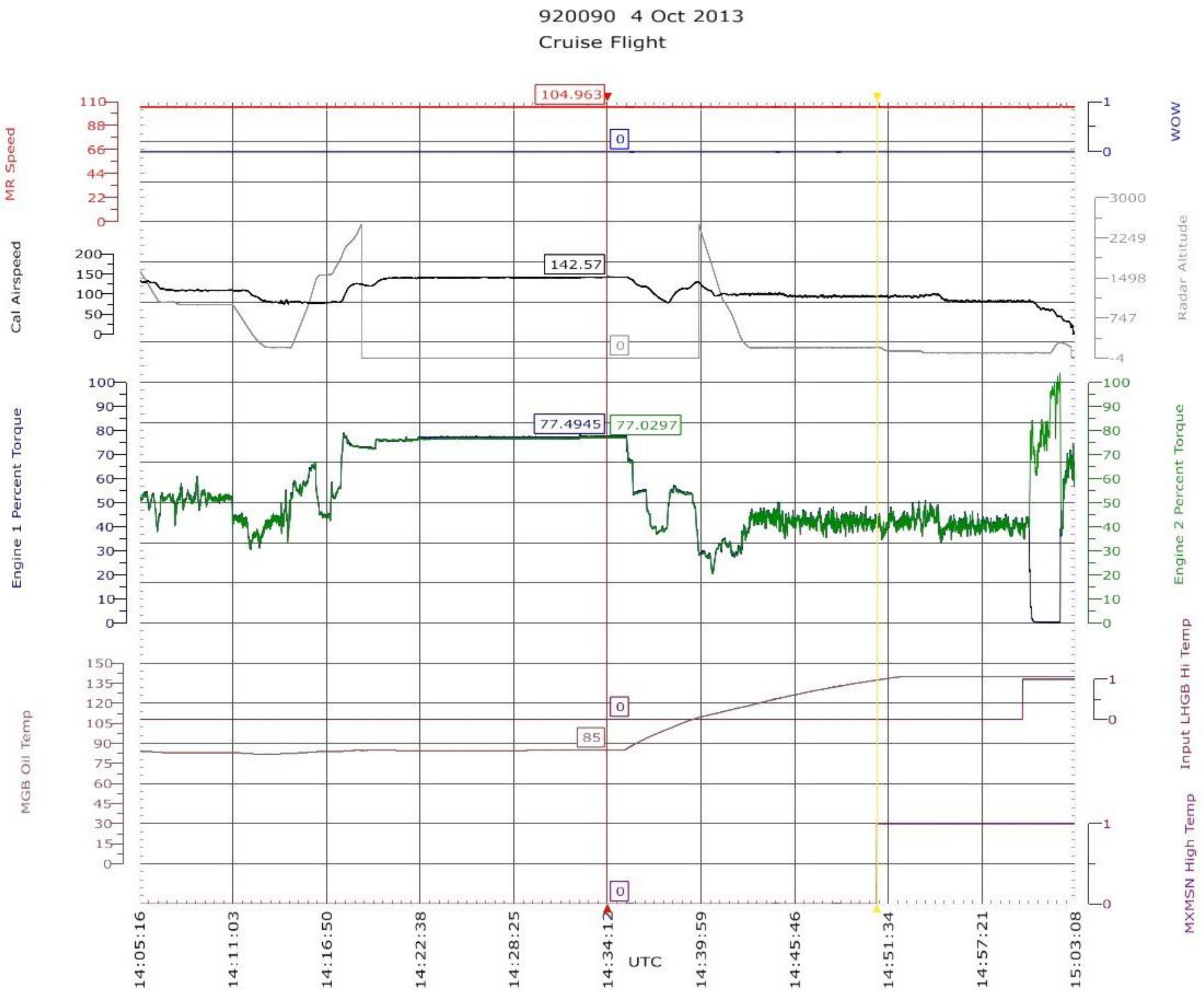
APPENDIX A - ABBREVIATIONS

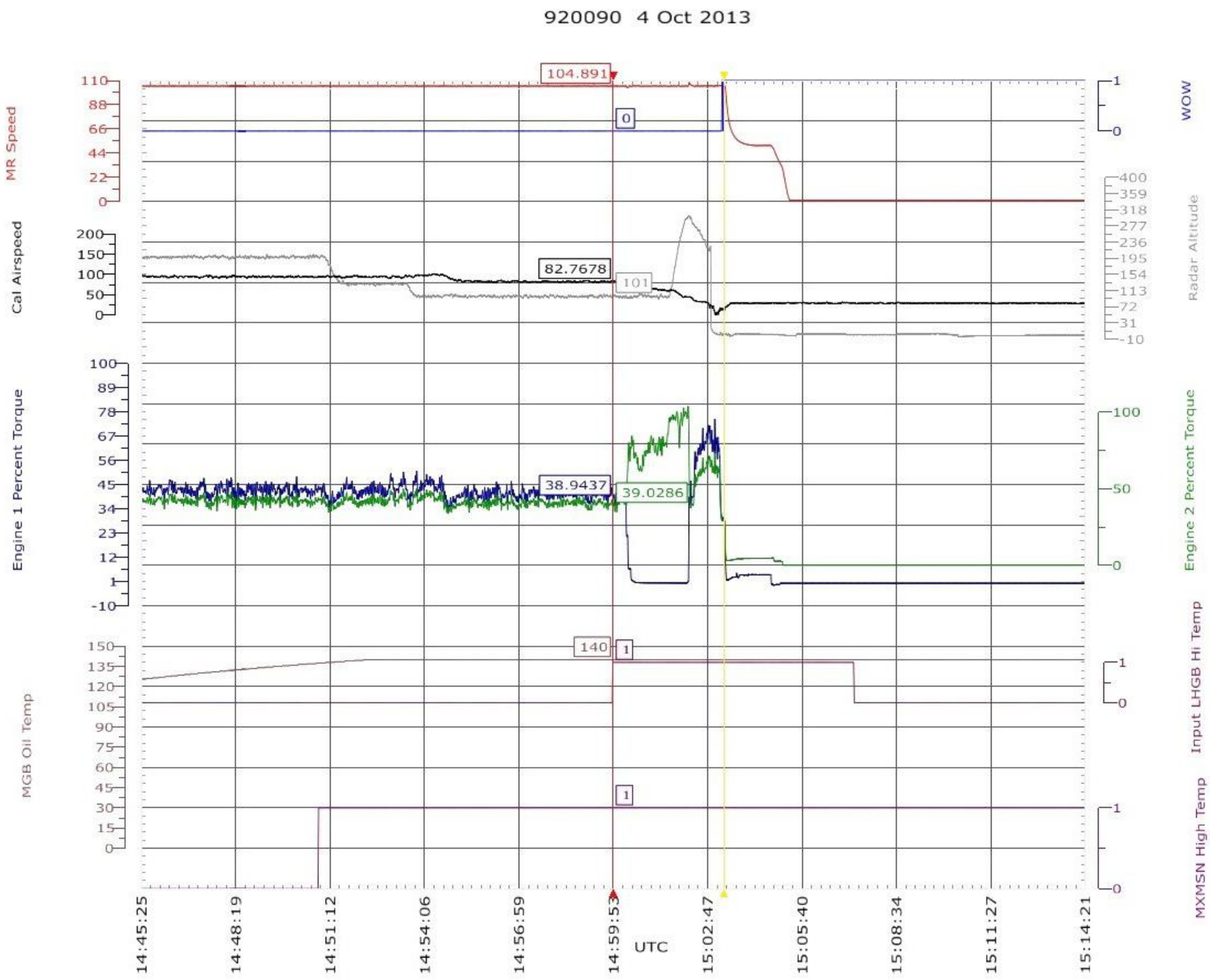
AC	Advisory Circular
ACC	Accessory – support system
ADF	Automatic Direction Finder
APU	Auxiliary Power Unit
ASB	Alert Service Bulletin
ATCC	Air Traffic Control Centre
ATPL(H)	Air Transport Pilot Licence, Helicopter
BYP	Bypass
CPL(H)	Commercial Pilot Licence Helicopter
DME	Distance Measuring Equipment
E	East (Eastern longitude)
EASA	European Aviation Safety Agency
EICAS	Engine Indicating and Crew Alerting System
FAA	US Federal Aviation Administration
FDR	Flight Data Recorder
ft.	foot (feet) – (0.305 m)
GPS	Global Positioning System
HFIS	Helicopter Flight Information Service
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
IR(H)	Instrument Rating for Helicopter
KIAS	Knots indicated airspeed
lb	pound(s) (0.454 kg)
M-ADS	Modified Automatic Dependent Surveillance
MAN	Manual
ME	Multi Engine

MFD	Multi-Function Display
MGB	Main Gear Box
MHz	megahertz
N	North (North latitude)
NM	nautical mile(s) (1,852 m)
OPC	Operator Proficiency Check
P/N	Part Number
PC	Proficiency Check
UTC	Coordinated Universal Time
VOR	VHF Omnidirectional Radio Range
XMSN	Transmission – normally used relating to power transmission on helicopters

Appendix B

Representation of a few selected parameters from the helicopter's FDR.

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