الهيئة العامة للطيران المدني
GENERAL CIVIL AVIATION AUTHORITY

United Arab Emirates

Air Accident Investigation Sector

Accident
– Final Report –

AAIS Case Nº: AIFN/0004/2017

Helicopter Controlled Ditching due to Failure of Main Gearbox Oil Cooler Fan Shaft and Associated Abnormal Noise

Operator:	Abu Dhabi Aviation
Make and Model:	AgustaWestland AW139
Nationality and Registration:	The United Arab Emirates, A6-AWN
Place of Occurrence:	Arabian Gulf, 8 nm east of Mubarraz Island, Abu Dhabi
State of Occurrence:	The United Arab Emirates
Date of Occurrence:	29 April 2017

Air Accident Investigation Sector
General Civil Aviation Authority
The United Arab Emirates

Accident Brief

AAIS Report No.:	AIFN/0004/2017
Operator:	Abu Dhabi Aviation
Aircraft Type and Registration:	AgustaWestland AW139, A6-AWN
MSN:	41213
Number and Type of Engines:	Two, PT6C-67C, Turbine engines
Date:	29 April 2017
Location:	Arabian Gulf, 8 nm east of Mubarraz Island, Abu Dhabi
Type of Flight:	Commercial, passenger
Persons On-board:	3
Injuries:	None

Investigation Objective

This Investigation is performed pursuant to the United Arab Emirates (UAE) *Federal Act 20 of 1991*, promulgating the *Civil Aviation Law*, Chapter VII – *Aircraft Accidents*, Article 48. It is in compliance with Part VI, Chapter 3, of the *Civil Aviation Regulations* of the United Arab Emirates, in conformity with *Annex 13 to the Convention on International Civil Aviation*, and in adherence to the *Air Accidents and Incidents Investigation Manual*.

The sole objective of this Investigation is to prevent aircraft accidents and incidents. It is not the intent of this activity to apportion blame or liability.

This Final Report is structured according to the format contained in *Annex 13* to serve the purpose of this Investigation. The information contained in this Report is derived from the data collected during the Investigation of the Accident.

Investigation Process

The occurrence involved an AgustaWestland AW139 passenger helicopter, registration A6-AWN, and was notified to the Air Accident Investigation Sector (AAIS) by phone call to the Duty Investigator (DI) Hotline Number +971 50 641 4667.

An Investigation team was formed in line with *Annex 13* obligations of the United Arab Emirates being the State of the Occurrence.

After the initial on-site investigation phase, the occurrence was classified as an 'Accident' due to the loss of the Aircraft after being submerged in the sea water.

The AAIS formed the investigation team and appointed an investigator-in-charge (IIC) and members from the AAIS for the different investigation areas. The AAIS notified the European

Aviation Safety Agency (EASA), being the organization responsible for the aircraft continuing airworthiness, the Italian Agenzia Nazionale per la Sicurezza del Volo (ANSV), being the civil aviation safety investigation authority of the State of the Manufacture and Design, and the Canadian Transport Safety Board (TSB), being the authority of the State of Manufacture of the engines. Accredited Representatives were assigned and assisted by Advisers from Leonardo Helicopters. In addition, the Operator assigned an Adviser to the IIC.

This Final Report is publicly available at:

http://www.gcaa.gov.ae/en/epublication/pages/investigationReport.aspx

Notes:

1 Whenever the following words are mentioned in this Report with the first letter capitalized, it shall mean:

- (Accident) – this investigated accident
- (Aircraft) – the helicopter involved in this accident
- (Commander) – the commander of the accident flight
- (Copilot) – the copilot of the accident flight
- (Investigation) – the investigation into this accident
- (Operator) – Abu Dhabi Aviation
- (Report) – this investigation Final Report.

2 Photos and figures used in the text of this Report are taken from different sources and are adjusted from the original for the sole purpose to improve clarity of the Report. Modifications to images used in this Report are limited to cropping, magnification, file compression, or enhancement of color, brightness, contrast or insertion of text boxes, arrows or lines.

3 Unless otherwise mentioned, all times in this Report are local time (UTC plus 4 hours).

Abbreviations and Definitions

AAIS	Air Accident Investigation Sector of the United Arab Emirates
AIFN	Accident/incident file number
ANSV	The Italian Agenzia Nazionale per la Sicurezza del Volo
ATPL	Air transport pilot license
BEA	The Bureau d’Enquêtes et d’Analyses pour la sécurité de l’aviation civile
°C	Degree Celsius
CMM	*Component maintenance manual*
CSMU	Crash survivable memory unit
DELT	Deployable emergency location transmitter
EASA	The European Aviation Safety Agency
ELT	Emergency location transmitter
EUROCAE	The European Organization for Civil Aviation Equipment
FAA	The Federal Aviation Administration
FCOM	*Flight crew operating manual*
ft	Feet
GCAA	General Civil Aviation Authority of the United Arab Emirates
HUMS	Health and usage monitoring system
ICAO	The International Civil Aviation Organization
IIC	Investigator-in-charge
JAR	Joint Aviation Requirements
KHz	Kilohertz
LT	Local time
METAR	Meteorological terminal aviation routine weather report
MGB	Main (rotor) gearbox
MHz	Megahertz
MPFR	Multi-purpose flight recorder
MSN	Manufacturer serial number
nm	Nautical mile(s)
OEM	Original Equipment Manufacturer
QRH	*Quick reference handbook*
RFM	*Rotorcraft flight manual*
RPM	Revolutions per minute
SEP	Safety and emergency procedures
TSO	*Technical standard order*
UAE	The United Arab Emirates
UTC	Coordinated universal time

Synopsis

On 29 April 2017, at 1205 local time of the United Arab Emirates, an AgustaWestland AW139 helicopter, registration A6-AWN, departed Abu Dhabi International Airport, with two flight crewmembers and five passengers, for Dhabi II oil rig, located 33 nautical miles (nm) off the coast of Abu Dhabi in the Arabian Gulf. Four passengers disembarked after arrival at Dhabi II at 1231 LT, and the Aircraft continued towards oil rig BUNDUQ, approximately 78 nm further north-west.

One minute into the climb after departing from Dhabi II, the flight crew received a high oil temperature warning for the main rotor gearbox (MGB) at approximately 490 feet (ft). The observed oil temperature was 109°C, when the Commander discontinued the climb and selected to descend to 500 ft. This action was taken to reduce power and the load on the MGB and was advised in the *quick reference handbook* (*QRH*). The flight crew decided to divert to the closest heliport, on Mubarras Island, 18 nm from Dhabi II.

Because the oil temperature continued to increase, the Commander decided to descend to 200 ft in preparation for a possible ditching. While descending through 210 ft, and with an oil temperature of 119°C, the flight crew heard a loud grinding noise emanating from the gearbox area. The Commander followed the instruction in the *QRH* and decided to ditch the Aircraft.

The crew activated the Aircraft flotation system prior to touchdown, and the inflated bags kept the Aircraft afloat during the evacuation of all occupants into the life raft, from where they were rescued by the coast guard. As the left aft float slowly deflated, the Aircraft started to tilt and capsize.

The Investigation identified that the causes of the deflation were a tear of the bag fabric and seam delamination. It was identified that the in-flight activation of the flotation bags was not compliant with the certification of the Aircraft's flotation system, which caused the deployed float cover to fragment. The remains of the float cover probably caused a tear to the aft left flotation bag. The Investigation also identified that many flotation bags did not pass inflation tests during regular shop visits because of seam problems.

The Investigation further identified that the MGB oil temperature increased because the MGB oil cooling fan failed due to bearing damage, which resulted in the loss of airflow through the oil cooler. As a result of the Accident, the Aircraft manufacturer issued initial instructions and additional maintenance tasks for the early detection of MGB oil cooling fan failures.

The Air Accident Investigation Sector (AAIS) issued recommendations in this Final Report for a review of the flotation bag reliability, a review of the Operator's ditching training effectiveness, a review of the reliability of the MGB oil cooling fan assemblies and the appropriate selection of the bearings for their application, the MGB oil temperature indication system, and the automatically deployable emergency locator transmitter system.

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1. Factual Information

1.1 History of the Flight

On 29 April 2017 at 1205 local time (LT) of the United Arab Emirates, an AgustaWestland AW139 Aircraft, registration A6-AWN, departed Abu Dhabi International Airport, with two flight crewmembers and five passengers, for Dhabi II oil rig, located 33 nautical miles (nm) off the coast of Abu Dhabi in the Arabian Gulf. The Aircraft was scheduled to continue to oil rig BUNDUQ, approximately 78 nm further north-west. Four passengers disembarked after arrival at Dhabi II at 1231 LT.

At 1233 LT, the Aircraft departed from Dhabi II for BUNDUQ with a selected altitude of 2,500 feet (ft). One minute into the climb, at approximately 517 feet (ft), the flight crew received a high oil temperature warning for the main gearbox (MGB). The observed oil temperature was 109°C. The Commander, who was the pilot flying, discontinued the climb at an altitude of approximately 1,200 ft and selected a descent to 500 ft to reduce the required engine power and the load on the main rotor gearbox as advised in the *quick reference handbook* (*QRH*). The *QRH* further advised to land as soon as possible if the MGB oil temperature remains high or the indication is considered invalid. The flight crew discussed the nearest available heliport and decided to divert to Mubarras Island which, at approximately 18 nm from Dhabi II, was the nearest heliport.

At 1239 LT, the flight crew observed a continuous increase in MGB oil temperature, which had reached 118°C, when the Commander decided to descend further to 200 ft in preparation for a possible ditching. While descending through 205 ft, with an MGB oil temperature of 119°C, the flight crew heard a loud grinding noise emanating from the MGB area. The Commander then decided to ditch the Aircraft.

Prior to contact with the sea, at about 120 ft, the Aircraft flotation system was activated. The Aircraft ditched at 1240 LT, 8 nm east of Mubarraz Island, Abu Dhabi, and the Commander declared a MAYDAY on the dedicated emergency frequency.

The flotation bags kept the Aircraft afloat for the evacuation of all occupants, however the left aft float deflated slowly and the Aircraft started to tilt towards that float. The flight crew pulled the emergency raft deployment handles in the flight deck, but only the left raft deployed successfully. After initial difficulties in opening the left flight deck emergency window, the flight crew evacuated the Aircraft into the life raft. The passenger successfully opened the cabin emergency window and evacuated the Aircraft into the same life raft. The Commander cut the life raft mooring line to separate before the Aircraft capsized.

The raft floated away from the Aircraft as it became apparent that the Aircraft was not remaining in the upright position.

All occupants were rescued by the coast guard and were taken to Mubarras Island, from where they were transported to the hospital in Abu Dhabi for medical checks.

1.2 Injuries to Persons

There were no injuries to the two flight crewmembers or the passenger as a result of the Accident.

1.3 Damage to Aircraft

The Aircraft was salt water damaged beyond repair when it capsized. The left passenger entry step, the rotor plate, and the fuselage were damaged during the recovery operation.

1.4 Other Damage

There was no damage to property or to the environment.

1.5 Personnel Information

Table 1 illustrates the Commander and Copilot information at the time of the Accident.

Table 1. Crew information

	Commander	Copilot
Age	58	51
Type of license	ATPL	ATPL
Valid to	19 March 2024	18 March 2025
Rating	A139, Bell 212/412	A139, B212/412, B206
Total flying time (hours)	14,875.7	17,135.1
Total on this type (hours)	1,144.7	1,185.8
Total last 90 days (hours)	124.2	115
Total on type last 90 days (hours)	76.2	70.3
Total last 7 days (hours)	25.45	0
Total on type last 7 days (hours)	5.40	0
Total last 24 hours (hours)	7.50	0
Last recurrent SEP[1] training	25 March 2017	27 December 2016
Last proficiency check	11 November 2016	27 December 2016
Last line check	30 June 2016	26 July 2016
Medical class	1	1
Valid to	11 November 2017	6 March 2018
Medical limitation	VNL[2]	VNL

1.6 Aircraft Information

The AgustaWestland AW139 is a twin-engine helicopter and is fitted with a five-blade main rotor and a four-blade tail rotor.

The tricycle landing gear is retractable, with the aft wheels retracting into external sponsons, which stow the emergency rafts.

1 SEP: Safety and emergency procedures

2 VNL: Pilot must have correction available for defective near vision and carry spare set of spectacles

The Aircraft was built to be operated by two flight crewmembers but was also designed to enable single-pilot operations under instrument flight rule conditions.

The passenger cabin accommodates 15 passengers in three seat rows.

The Aircraft was equipped with a modular glass cockpit, and was fitted with two Pratt & Whitney Canada PT6C-67C turbine engines.

1.6.1 Aircraft data

Table 2 provides general Aircraft data at the time of the Accident.

Table 2. Aircraft data

Manufacturer:		Leonardo S.p.A. Helicopters (AgustaWestland)
Model:		AW139
MSN:		41213
Date of manufacture:		14 August 2009 (date of acceptance test flight)
Nationality and registration mark:		The United Arab Emirates, A6-AWN
Certificate of airworthiness		
	Number: Issue date: Valid to:	ADA/84 23 December 2009 22 December 2017
Certificate of registration		
	Number: Issue date: Valid to:	106/09 14 December 2009 Open
Date of delivery		17 September 2009
Total hours since new		5,631
Total cycles since new		9,728
Last major inspection and date:		900 hours/1 year, 6 March 2017 at 5448 hours TSN / 9326 CSN
Total hours since last inspection:		138
Total cycles since last inspection:		402

1.6.2 Engines

The engines were not relevant to this Accident. Table 3 illustrates engine data at the time of the Accident.

Table 3. Engine data		
	No.1 engine	**No.2 engine**
Manufacturer	Pratt & Whitney Canada	
Model	PT6C-67C	PT6C-67C
Serial number	PCE-KB0439	PCE-KBE0273
Date installed	21/04/2016	21/04/2016
Time since new (hours)	2522:10	2372:45
Cycles since new	2178	1925
Time since last inspection (hours)	881:50	881:50
Cycles since last inspection	494	494

1.6.3 Aircraft ditching system

The Aircraft was equipped with an emergency ditching system, consisting of four flotation bags, which deploy automatically during ditching. The system can also be manually deployed if the automatic function does not operate as expected.

Two flotation bags were fitted on each side of the forward fuselage, below the flight deck entrance doors, while another two floats were fitted below the cargo doors at the rear.

The forward flotation bags consisted of three independent chambers and two pillow chambers, which were attached and filled by the forward and rear chamber. Each rear float consisted of four independent chambers and two pillow chambers at the forward and rear of the float. The intent of the pillow chambers is to provide sufficient space between the float and the fuselage. Each pillow was filled through a non-return valve, by pressure from the adjacent float chamber.

The flotation bags were designed to keep the Aircraft afloat for a safe evacuation of its occupants. The acceptance test during shop visit requires the bags to remain inflated, when undamaged, for 3 hours at air pressure of 1.9 psi, and for 24 hours at 1.2 psi.

1.6.4 Aircraft flotation bag maintenance

The flotation bag manufacturer, AeroSekur, provided a maintenance schedule which included a 12-month detailed inspection from the installation date on the aircraft; and a 60-month overhaul dated from the manufacture date, or from the last overhaul date. Both events required the removal of the bags from the Aircraft, and were carried out in the Operator's emergency equipment workshop in accordance with the manufacturer's *component maintenance manual (CMM)*.

The detailed inspection comprised of a disassembly, check, cleaning, test, and selected approved repairs (if required) and assembly of the flotation system. Testing of the floats included a leakage test of the flotation bag, the inflate/deflate valve, swivel valve, relief valve and the system hoses and manifold.

The 60-month maintenance event included overhaul of the inflation system and the hydrostatic test of the pressure cylinder. The floats were life-limited to 15 years from the date of manufacture.

The Aircraft flotation bag maintenance records were reviewed and showed that they were within service and maintenance requirements, as shown in table 4.

Table 4. Aircraft flotation bag data

Manufacturer	AeroSekur (Italy)			
Position (S/N)	**Flotation bag manufacture date**	**Last 12-month inspection**	**Last 60-month overhaul**	**Flotation bag life limit (15 years)**
Forward left (1156)	November 2016	Not applicable	Not applicable	November 2031
Forward right (879)	March 2014	20 November 2016	Not applicable	March 2029
Rear left (232)	June 2008	11 August 2016	30 April 2014	June 2023
Rear right (212)	April 2008	20 August 2016	30 April 2014	April 2023

1.6.5 Flotation system variations and certification

The AW139 is certified with two different flotation systems: a rigid cover installation, and a textile cover installation. Both systems are interchangeable as an aircraft set (figure 1).

The textile system protects the folded float assembly in-flight with a textile cover, while the rigid cover is attached to the fuselage with shear-bolts and provide a higher degree of wind protection to the folded float assembly.

The Joint Aviation Requirements, JAR 29 Amendment 3, provide two options for the acceptance of the aircraft design for structural ditching provisions. Rotorcraft designed to the requirements of *JAR 29.563(b)(1) – Floats fixed or deployed before initial water contact*, can deploy the floats in-flight, whereas rotorcraft designed to *JAR 29.563(b)(2) – Floats deployed after initial water contact*, is fitted with a flotation system that shall only be deployed upon contact with water.

The Accident Aircraft was certificated under *JAR 29.563(b)(2),* which limits the activation of the flotation devices after ditching.

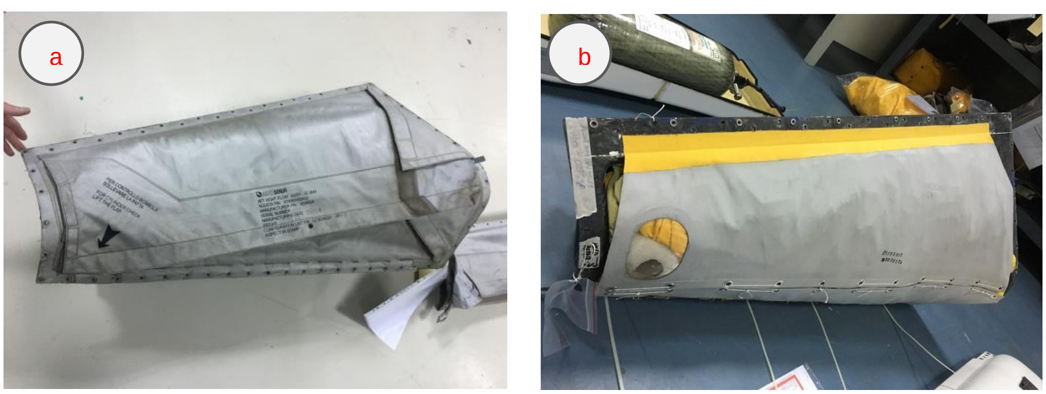

Figure 1. Textile flotation system and rigid system (rigid cover omitted)

1.6.6 Rigid flotation system covers and shear-bolt design

The rigid flotation system was fitted behind deployable composite covers at the forward and rear fuselage. The covers were fitted to the Aircraft with shear-bolts and enable the deployment of the complete cover from the fuselage to avoid damage to the flotation bags.

Certification tests have shown that damage to flotation bags is possible when covers are not deployed completely, and some of its portions remain attached to the fuselage. These fractural cover deployments were caused by the in-flight activation of the flotation bags. The in-flight activation will direct the inflation downwards rather than sideways, as designed.

1.6.7 The AW139 MGB indication system

The AW139 main rotor is powered by two PT6C-67C engines via the main gearbox (MGB).

Sensors in the MGB system provide the flight crew with indications and warnings. The system indications included the following:

- MGB - No. 1 engine input oil pressure
- MGB - No. 1 engine input bearing temperature
- MGB - No. 2 engine input oil pressure
- MGB - No. 2 engine input bearing temperature
- Main gearbox oil low
- Main gearbox oil filter
- Main gearbox oil temperature
- Main gearbox oil pressure.

Additionally, an MGB OIL PRESS warning is displayed when both MGB-engine input oil pressures are below 3.1 bar or when one of the MGB-engine input oil pressures becomes below 3.1 bar and is associated with the main gearbox oil pressure after the oil cooler also becomes below 3.1 bar.

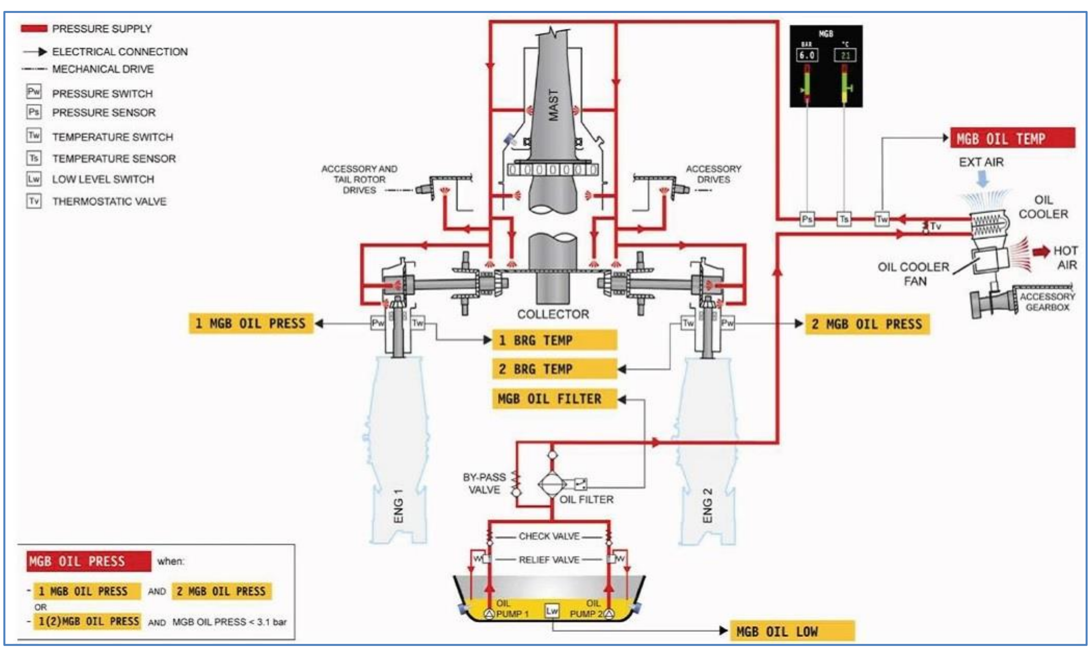

Figure 2. MGB indication system [Source: Leonardo Helicopters]

The AW139 flight crew are alerted by the warning MGB OIL TEMP when the oil temperature exceeds 109°C at the outlet of the oil cooler. At this point, the temperature indication turns to a red bar and changes from green to white numbers.

MGB OIL PRESS and MGB OIL TEMP warnings are displayed in red on the systems display and are also provided aurally to the flight crew (figure 2).

1.6.8 The AW139 MGB cooling system

The AW139 MGB oil is cooled by ambient air from the top of the open gearbox fairing, which is forced through an oil cooler by the attached oil cooling fan (figure 3).

The cooling fan is encased in a housing as an assembly and is operated at a rotating speed of approximately 16,000 rpm by a drive shaft from the accessory gearbox, which is attached to the MGB.

1.6.9 The AW139 MGB cooling fan maintenance

The fan assembly is a line-replaceable unit with a 2,400 hour overhaul life. It has been designed and manufactured by Technofan in accordance with an internal Leonardo Helicopters procurement specification.

A visual inspection of the fan assembly is scheduled at 1,200 hours in service as per *task 39-A-63-20-03-00A-310A-A* in the *aircraft maintenance manual*. The task description is: “Do a GVI [general visual inspection] to check freedom of rotation of the fan impeller (bearing roughness).”

The fan assembly is disassembled, checked, re-assembled with new parts and tested during an overhaul. An overhaul kit, part number 4611416981, provides the parts required to complete the assembly of the cooling fan. This kit includes new screws (60), washers (30, 70,120), a spring washer (130), the top bearing (80), the lower bearing (140), the fan nut (20), a retaining ring (110), the lower lipseal (100), a new fan shaft (150) and other parts to fit the fan into the cooling fan housing (figure 4).

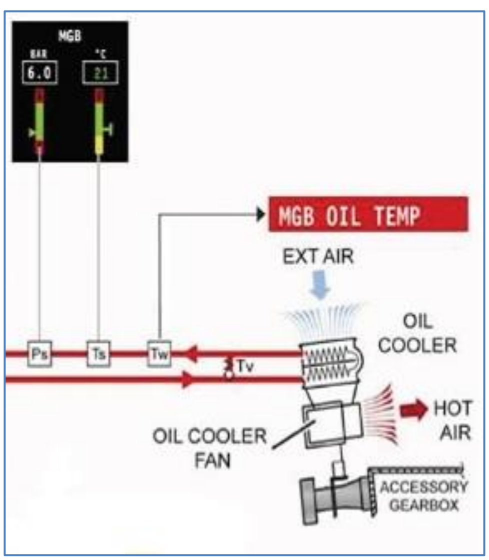

Figure 3. MGB cooling fan
[Source: Leonardo Helicopters]

The upper sealing spacer (40) is not part of this kit.

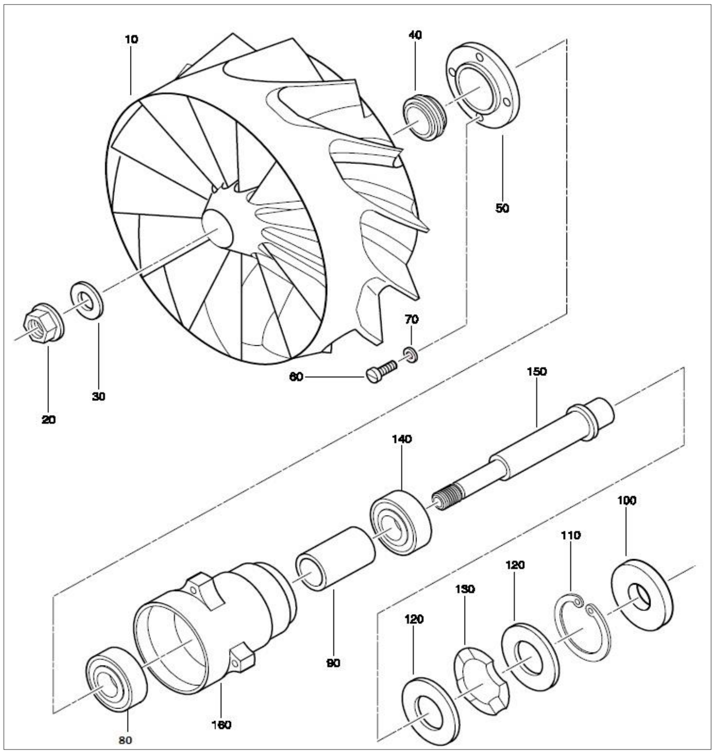

Figure 4. Cooling fan assembly overhaul parts [Source: Technofan]

The aerodynamic measurements in accordance with the *CMM 3G6320V03853*, dated 9 June 2012, nominated the fan assembly rotation speed with 16,014 ±30 rpm, and is operationally tested at between 15,984 rpm and 16,044 rpm. An acceptance test, after each overhaul, includes the same operational test which is documented on the *acceptance test report*.

A new cooling fan is issued with a shelf life of 5 years from the date of manufacture, an overhauled cooling fan is released with a shelf life of 5 years from overhaul, as stated on the Leonardo Helicopters serviceable label.

The Aircraft MGB oil cooling fan assembly was manufactured in July 2005, by Technofan in France, as part number 3G6320V03853 and serial number 0411R. It was initially installed on another aircraft from the Operator’s fleet in July 2008, and was transposed to another aircraft (for operational reasons) after accumulating 258 hours in service. After reaching 2,398 hours, it was removed for a scheduled overhaul in October 2013 and was subsequently fitted to the Accident Aircraft in January 2016. At the time of the Accident, the oil cooling fan had reached 1,016 hours since overhaul and 3,414 hours since new.

During the overhaul in 2013, the fan assembly was fitted with new bearings and a new lower lip seal as part of the overhaul kit. The top sealing spacer was not replaced. A balance test was completed satisfactorily and the fan assembly was returned to service by an *EASA Form 1 – Authorized Release Certificate*, issued on 23 October 2013.

1.6.10 The bearing manufacturer's recommendations

The cooling fan assembly bearings were manufactured by the GRW Bearing Company in Germany, as customer part number 1908003867, type 6202-2ZF W1 P5 C18/33 GPR EN G343 CP1, with the dimensions of 15mm x 32mm x 9mm; and part number 1908003702, type 6002-2RS P5 C4 GPR EN G417 CP1, with the dimensions of 15mm x 35mm x 11mm.

The manufacturer advised that the limiting speed provisions in the literature are theoretical values for initial estimations. The realistic limitations may be higher but have to be established by the user in their specific utilisation.

The theoretical limiting speeds for the upper and lower bearings were provided by the manufacturer, on request by the Investigation, to be 20,000 to 24,000 rpm and 15,000 to 16,000 rpm, respectively.

Each bearing is individually sealed and provided with a shelf life guarantee of 3 years, provided that they are stored in their original packing in a dry and clean environment with constant temperatures. Any bearings exceeding their shelf life are recommended to be discarded because a re-greasing process is uneconomical.

The packing dates of the subject bearings fitted on the Aircraft cooling fan assembly could not be determined. However, the cooling fan manufacturer advised that before the overhaul of the cooling fan, the most recent batches of bearings were received with packing dates of August 2013. The cooling fan manufacturer advised that an inspection of the shelf life, and a quick turn-around of these bearings, would ensure that no shelf-life expired bearings were fitted on the cooling fan assembly during the overhaul.

The cooling fan manufacturer, after assembly and tests with new bearings, guarantees a shelf life of 5 years.

1.6.11 The cooling fan manufacturer's bearing justification

The cooling fan manufacturer provided the Investigation with their specification sheets for the selection of the upper and lower ball bearings. While the specification sheet for the upper bearing specifies a speed limit of 20,000 rpm, the specification sheet for the lower bearing shows a speed limit of 14,000 rpm.

The cooling fan manufacturer's justified their bearing selection with:

> "Bearing manufacturer's catalog shows:
>
> - Limiting speed whenever lubricated with grease of 17 000 rpm with seal
> - Limiting speed whenever lubricated with grease of 25 000 rpm without seal.
>
> Bearing 1908003867 is manufactured with semi-sealed closure. Therefore, maximum allowable speed (above which seal might begin to be worn out) is between 17 000 and 25 000 rpm. Since contact with semi-sealed closure is very light compared to full-sealed closure, by engineering judgment, allowable speed is expected close to 25 000 rpm."[3]

The lower bearing specification sheet was originally drafted in October 1997 and twice revised, in January 1998 and in May 2003. The initial draft and the first revision were certified as

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[3] Reference: Information provided by Leonardo Helicopters 1 September 2017

drafted and verified by two independent persons. Revision two appears to have been editorial changes without an independent verification.

1.6.12 The Aircraft MGB oil temperature increase

A review of data downloaded from the flight recorder showed that the oil temperature started to increase above the normal operation temperature of approximately 86°C, 1 minute 40 seconds prior to landing on the helipad of Dhabi II. At this time, the Aircraft was in the final approach to the oil rig and the approach checklist had been completed. The Aircraft landed with an MGB oil temperature of 102°C. By the time the Aircraft left Dhabi II, 1 minute 52 seconds later, the oil temperature had increased to 103°C.

One minute 5 seconds after departing from Dhabi II, the oil temperature reached 109°C, at which point the MGB OIL TEMP warning alerted the flight crew to the temperature exceedance.

The flight crew decided to follow the *QRH* and to divert to the nearest heliport on Mubarras Island. When the new destination was entered into the flight management system, the heliport was 14.9 nm away and the MGB oil temperature had increased to 114°C.

Three minutes 56 seconds later, and when the temperature had reached 119°C, a sudden grinding noise was heard by the flight crew, and the Commander decided to ditch the Aircraft in accordance with the *QRH*.

1.6.13 Before take-off checks

The AW139 *Before Takeoff Checks* includes a check of the displayed system temperatures and pressures. The *Offshore Before Takeoff Checks* do not include check items for system temperatures and pressures. The flight crew was not heard commenting on the increased MGB oil temperature before taking off from the oil rig.

BEFORE TAKEOFF CHECKS	
Takeoff Briefing	Completed
Fuel	Check
ECL 1 & 2	Flight
AHRS	MAG/DG
ENG Mode 1 & 2	FLIGHT
Autopilots	ON
RPM	As Required
XPDR/TCAS/Wx Radar	ON/As Required
Guidance Controller	PF side
EAPS	As Required
Ts & Ps	Check
CAS	Check & Acknowledge
Parking Brake	As Required
Nose wheel	Lock

OFFSHORE BEFORE TAKEOFF CHECKS	
Doors & Passengers	Closed/Briefed
ENG Mode 1 & 2	FLIGHT
CAS	Check & Acknowledge
Autopilots	ON/ATT
Floats	ARMED
Takeoff Briefing	Completed
RPM	As Required
Clearance	If Required
Radio call	Before liftoff

Figure 5. *Before take-off checks* and *offshore before take-off checks* [Source: Operator's checklist]

1.6.14 Life raft deployment system

The Aircraft was equipped with two emergency rafts for occupants. The system consisted of one raft on each side of the Aircraft and manual inflation handles on each side of the flight deck, forward of the doors. Each handle operated the raft on its respective side. The raft containers were attached to the sponson, behind the passenger cabin doors.

The rafts are activated by removing a safety spring and pulling the handles (figure 6a) approximately 100 mm from their resting position. Each handle deployed the raft located in the adjacent sponson (figure 6b). A supplemental handle is provided at the forward stowage container for the deployment of the raft from outside the Aircraft.

The deployment handles were connected to a pull-cable, which manually activated a valve on the pressure cylinder, inflating and deploying the raft. A short and a long mooring line kept the raft attached to the Aircraft. Knives were placed on both sides of the raft, in the vicinity of the mooring lines, to cut the lines and detach the raft from the Aircraft. Labels fitted on the inside of the raft, near the cutting knives, explained the use and detachment of the mooring lines. Each raft (figure 6c) was designed for 11 occupants with an overflow capacity of 17, and was fitted with survival equipment.

Annual operational checks were conducted in accordance with Aircraft Maintenance Manual *task 25-24* to verify the correct sliding inside the sheath and to visually check the protruding cable ends to verify the integrity of the connections. These were last carried out on the Aircraft on 5 March 2017.

Figure 6. Raft deployment handle, raft sponson location and deployed raft assembly

1.6.15 Evacuation system

The AW139 evacuation system consists of six window panels for the passenger cabin and two for the flight deck (figure 7). The cabin or flight deck doors are not operated as exits during a ditched landing because their opening may damage the inflated flotation bags.

Each passenger cabin window panel can be either pushed in from the outside or pushed out from the inside once the passenger extracts a seal filler.

The flight deck emergency exit windows are either pulled inside by the flight crew, using a strap handle, which is fitted to the rear lower corner of the panel or from the outside by pushing this corner of the window panel inwards, after a seal cord had been removed (figure 8a).

Since November 2015, the annual functional check of the window emergency release devices in accordance with task *56-01 – Cockpit emergency exits*, and task *56-02 – Cabin emergency exits*, was replaced by a 4-year in-service limit for all emergency windows in accordance with *DT56-01– Cockpit emergency exits*, and *DT56-02 – Cabin emergency exits*. The in-service limit applies from the latest window installation or the last recorded functional check of each window emergency exit, whichever was more recent.

The left and right cockpit emergency window exits on the Aircraft were last functionally checked in accordance with task *56-01* on 30 December 2015 and 12 January 2016, respectively.

The cabin emergency window exits on the Aircraft were last functionally checked in accordance with task *56-02* as per the following:

- Left forward: 12 November 2012 Right forward: 15 December 2014
- Left center: 1 July 2011 Right center: 12 January 2016
- Left aft: unknown Right aft: unknown[4]

Figure 7. Cabin and flight deck emergency windows

Figure 8. Cockpit emergency window

1.6.16 Deployable emergency locator transmitter system

The AW139 is fitted with an automatic deployable emergency locator transmitter system (DELT) which is a radio aid to alert search and rescue teams and assist in locating the aircraft in distress. The system (figure 9a) consists of an emergency locator transmitter (ELT) (1), mounted on the left rear outside fuselage and held in place by the beacon release unit (4). A controller (6) (figure 9b) is fitted in the center console, providing the flight crew with a test and manual transmitting option. A system interface unit (3) and an aircraft identification unit (2) are fitted in the rear of the aircraft. A water activation switch (5) is fitted at the rear panel of the left float compartment. The Aircraft "g" switch provides input to the system interface unit, when the g-load limit is exceeded during a crash.

The ELT consists of a beacon containing the transmitter and antenna and can be automatically activated and deployed from the aircraft. It transmits on frequency 121.5 MHz for 48 hours, and simultaneously on 406.25 for 24 hours.

The system transmits and deploys should one or more of the following inputs be received in the armed system interface unit:

[4] The Operator's last functional check for the aft cabin windows could not be confirmed

- The 'g' switches senses an excess load
- The flight crew selects "Deploy" on the flight deck controller
- The water activated switch is being immersed in water
- The aircraft crash switch if fitted to the aircraft

Should the flight crew select "Transmit" on the flight deck controller, the system requires a reset for a successful manual or automatic deployment of the beacon.

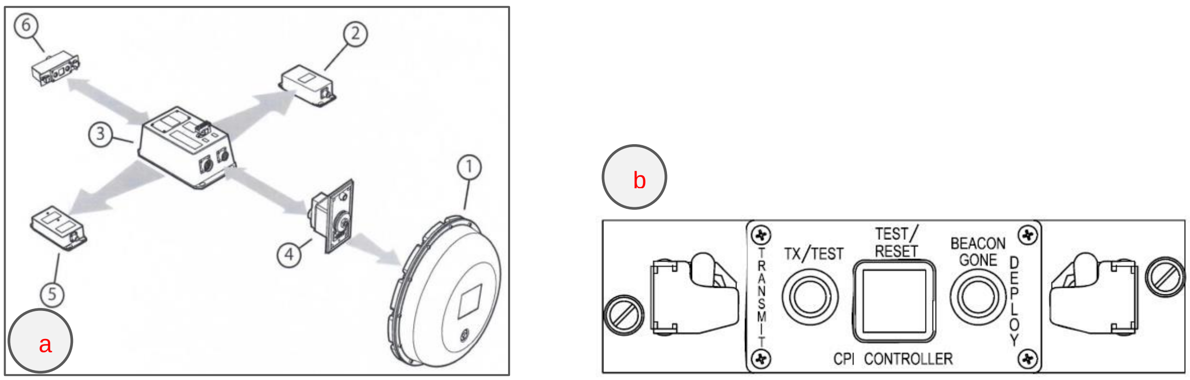


Figure 9. Deployable emergency locator transmitter system [Source: Techtest Limited]

1.6.17 Health and usage monitoring system (HUMS)

The AW139 is equipped with a HUMS to monitor the condition of the transmission gearbox and the rotor system. Parameters are stored on a data card, which can be downloaded to HUMS ground system software on a daily basis. The AW139 HUMS consists of a data acquisition unit, a cockpit display and transfer unit, a data transfer device, and a rotor blade tracking device.

Several sensors are installed to monitor the main rotor tachometer, the drive train tachometer, the tail rotor tachometer, the vertical load accelerometer, the four rotor track-and-balance accelerometers, and the eleven vibration accelerometers.

Additional aircraft data are fed to the HUMS through the modular avionics unit 1. These include aircraft identification, anti-ice on, barometric altitude, date, engine data, time, gearbox data, heading, airspeed etc.

While the HUMS records and evaluates data pertaining to the transmission and the rotor, the condition of the MGB oil cooling fan is not one of the recordable parameters.

Evaluations of the Aircraft HUMS data did not show any indications of an adverse trend of any recorded MGB data.

1.7 Meteorological Information

The National Center of Meteorology & Seismology of the United Arab Emirates provided weather reports for the day of the Accident in form of meteorological terminal aviation routine weather reports (METAR).

At the time of the Accident, between 0800 and 0900 UTC, the temperature at Abu Dhabi International Airport (the nearest airport to the location of the operation) was 39°C to 41°C, with a wind from 140 to 160 degrees, and wind speed of 7 to 8 kts. The visibility was between 7,000 to 8,000 meters with no significant clouds and no significant anticipated changes.

The prevailing meteorological conditions were not a factor in this Accident.

1.8 Aids to Navigation

Ground-based navigation aids, onboard navigation aids or visual aids of the landing site and their serviceability were not a factor in this Accident.

1.9 Communications

All inter-pilot communications were made via the intercom system.

When the Commander decided to divert to Mubarraz Island, the Copilot contacted the operations department to inform of the diversion to Mubarraz Island due to the high MGB oil temperature and with an estimated arrival time of six minutes. The operations department then contacted the Aircraft to querying about the reason for the diversion. The Commander then attempted to contact Mubarraz Island unsuccessfully.

Although the Aircraft was equipped with a headset for the passenger in the forward left hand seat, the passenger did not wear the headset and the communication was conducted verbally without the use of the intercom system.

The flight crew did not communicate with the passenger between the take-off from Dhabi II until the ditching, at which point the Copilot requested that the passenger remain seated. After the left emergency raft had deployed, the Copilot instructed the passenger to exit the Aircraft on the left side.

1.10 Aerodrome Landing Site Information

The Dhabi II oil rig was equipped with a helipad and was located at 24°30’09.49”N and 53°42’07.86”E, approximately 33 nm west of Abu Dhabi, the United Arab Emirates.

The heliport on Mubarraz Island was approximately 18 nm west of the Dhabi II rig.

1.11 Flight Recorders

The Aircraft was fitted with a multi-purpose flight recorder (MPFR), part number D51615-102, which was an integrated solid state digital cockpit voice recorder combined with a flight data recorder, manufactured by Penny & Giles Aerospace Ltd (figure 10a).

The MPFR consisted of an orange coloured steel chassis with white reflective stripes and was fitted on the left side of the rear fuselage (figure 10b). An underwater locator beacon was attached to the side of the recorder. The crash survivable memory unit (CSMU) (figure 11b) module consisted of a tungsten steel cylindrical casing with a non-volatile memory.

The Aircraft data and the cockpit voice recording are normally stored on the non-volatile memory unit. The FDR data is recorded in-flight for 25 hours at 256 words per second.

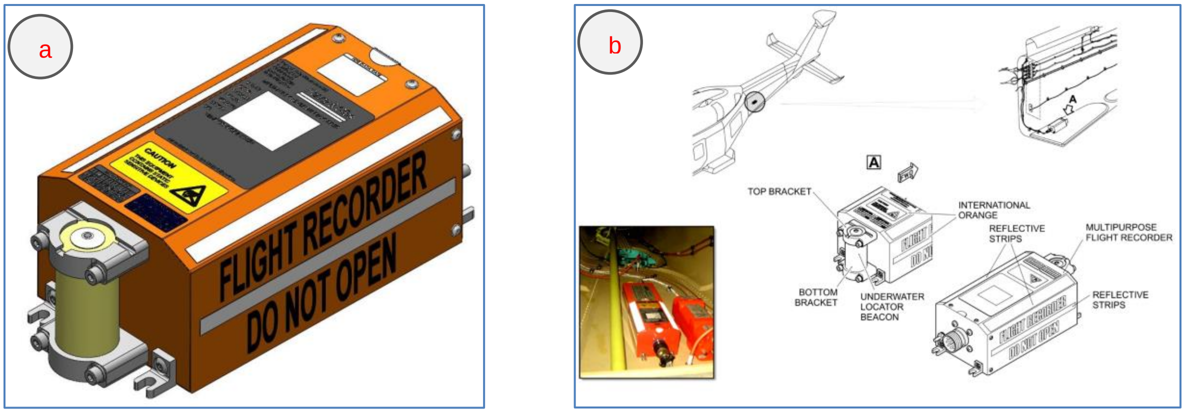


Figure 10. Multi-purpose flight recorder and location [Source: Leonardo Helicopters]

The cockpit voice recorder continuously recorded on six channels for the durations shown below:

- Channel 1 (Cabin inter-communication system) - 30 minutes
- Channel 2 (Copilot headset) - 30 minutes
- Channel 3 (Commander headset) - 30 minutes
- Channel 1-2-3 (Combined) - 120 minutes
- Channel 4 (Cockpit area microphone) - 30 minutes (high quality - full bandwidth 0-6 KHz)
- Channel 4 (Cockpit area microphone) - 120 minutes (low quality - reduced bandwidth 0-3.5 KHz).

The MPFR was certified to the requirements of EUROCAE *ED-55*, *ED-56A Amendment 1*, *ED-112*, FAA *TSO-C123a*, and *TSO-C124a*. This required the recorder to withstand water pressure equivalent to a depth of 6000 meters for 24 hours if the recording medium is unaffected by sea water, and 3 meters of sea water at a nominal temperature of 25°C for a period of 30 days.

After the MPFR was removed from the Aircraft, it was immediately placed in fresh water to avoid further oxidation damage due to the contact with sea water. The Operator's avionics facility at Abu Dhabi Airport was utilized to examine the condition of the recorder and to download the recorded data with the assistance of Aircraft manufacturer experts.

During disassembly, it was noted that water had penetrated the outer chassis and covered the electronics controls unit. A small amount of water was also found covering the CSMU inner steel cylinder that contains the data storage memory boards (figure 11a).

A total of 99.98 percent of the flight data for the previous 24 flights, including the Accident flight, was recovered and downloaded. Although a channel 1 audio file (cabin intercom system) was successfully downloaded, no conversation was recorded because the headset in the cabin had not been worn by the passenger. Channel 2 (Copilot headset) and channel 3 (Commander) recorded voice data and were both audible.

Downloading channel 4 (cockpit area microphone) files resulted in erroneous data, which could not be converted into audible data.

An annual inspection and function check of the cockpit voice recorder system is a requirement of the General Civil Aviation Authority and confirms the “Proper recording on each audio channel from area microphone (s), receiver audio, side tone, interphone, public address (if recorded) and boom microphone.” This task was conducted satisfactorily by the Operator, and was certified on 20 February 2017.

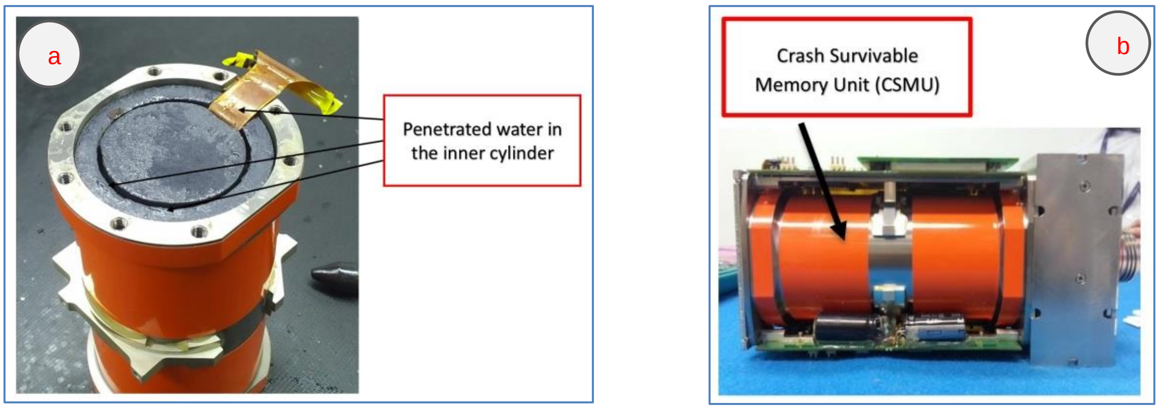


Figure 11. Evidence of moisture penetration to inner cylinder and CSMU installation

1.12 Wreckage and Impact Information

After the evacuation of the occupants, the Aircraft capsized and remained afloat at the surface (figure 12). The recovery team penetrated the floats to be able to turn the Aircraft for the recovery and the transport.

Figure 12. Aircraft recovery

1.13 Medical and Pathological Information

Post-Accident blood tests did not reveal any psychoactive materials that could have degraded the crew performance.

1.14 Fire

There was no evidence of pre-or post-impact fire.

1.15 Survival Aspects

1.15.1 Aircraft safety equipment

The Aircraft was fitted with four-point restraint harnesses for the passengers and five-point harnesses for the flight crew. Each passenger and flight crewmember was provided with a life preserver, certified in accordance with FAA *TSO-C13f*. An inspection found that the safety equipment was appropriate and serviceable at the time of the Accident.

1.15.2 The Aircraft ditching system

The Aircraft was equipped with an emergency ditching system, consisting of four flotation bags. These floats were fitted to the fuselage under protective covers and were deployed automatically during ditching. The flight crew could also manually activate the system in case the automatic function does not operate as expected during ditching. The floats were designed to keep the Aircraft afloat to enable safe evacuation of the occupants.

Figure 13. Flotation system activation switch and arming/test panel

The floats were fitted on each side of the forward fuselage, below the flight deck entrance doors, and also below the cargo doors at the rear fuselage. A control panel on the flight deck center console (figure 13b) allows for arming of the system. Once armed, the system will automatically deploy during ditching. The system can also be manually deployed by the flight crew by selecting the deployment switch on each pilot’s collective grip (figure 13a). When the floats are deployed and inflated, shear bolts release the float covers from the fuselage.

The forward floats consisted of three independent chambers and two pillow chambers, which were attached and filled by the forward and rear chamber. Each rear float consisted of four independent chambers and two pillow chambers. The pillow chambers were designed to provide sufficient space between the main floats and the Aircraft fuselage to prevent float damage. Each pillow was filled, through a non-return valve, with pressure from the adjacent float chamber.

The flight crew deployed the emergency floats during the controlled descend at 120 ft prior to contact with the water. All four flotation bags inflated fully and provided sufficient buoyancy to keep the Aircraft upright and afloat. After the evacuation of the occupants, the Commander noticed that the Aircraft started to tilt towards the aft left float.

Images showed that all the floats, except the left rear float, were intact prior to the recovery of the Aircraft, approximately six hours after ditching. Damage, identified on these floats during the shop inspection, was most likely caused by the recovery and transport of the Aircraft.

It was identified that part of the aft pillow chamber had delaminated, releasing air from the aft flotation chamber through the pillow inflation valve (figure 14a). A second area of delamination was found at a main chamber seam which was slowly releasing air (figure 14b).

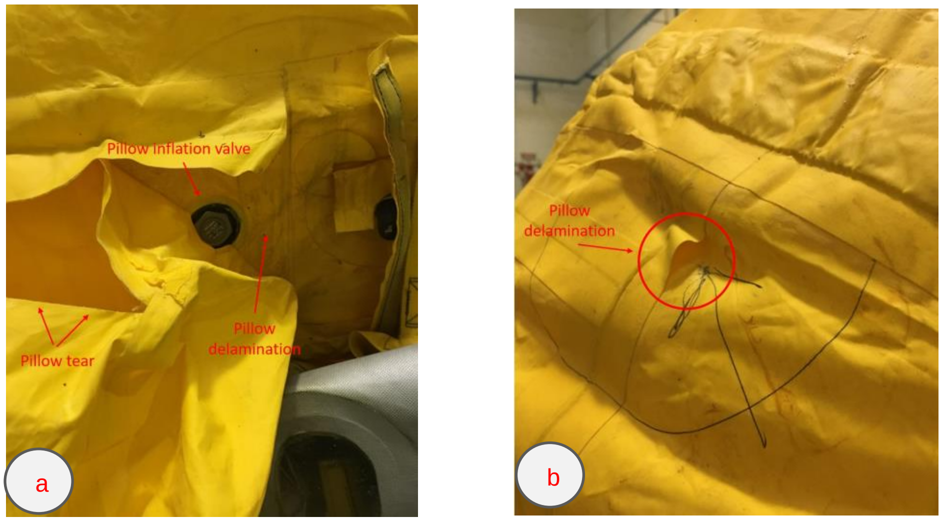


Figure 14. Left aft float damage

An inspection of the Aircraft identified that the shear-bolts (attaching the upper edge of the float covers) had not sheared causing fracture of the composite covers leaving the remains attached to the Aircraft (figures 15a and 15b).

The Aircraft manufacturer advised that this type of failure was evident during the certification process when the floats are deployed in-flight, resulting in a downward deployment instead of a sideway deployment of the flotation bags.

This failure has the potential to cause damage in form of cuts or abrasions to the main flotation bag or the pillow bag. Aircraft manuals therefore warn of in-flight deployment.

Figure 15. Left and right aft composite cover damage

1.15.3 Life raft deployment system

The Aircraft was equipped with two emergency rafts, stowed inside each of the Aircraft's left and right sponsons below the cabin doors. Manual inflation handles were located on each side of the flight deck, forward of the doors.

The rafts were activated by removing a safety clip and pulling the deployment handles approximately 100mm from their resting position. Each handle would deploy the adjacent raft. A supplemental handle, attached to the forward stowage container, allowed for the deployment of the raft from outside the Aircraft.

The handles were connected to a pull-cable system, which manually activated a valve on the pressure cylinder, inflating, and deploying the raft. A short and a long mooring line kept the raft attached to the Aircraft. Knives were placed on both sides of the raft, in the vicinity of the mooring lines, to cut the lines and detach the raft from the Aircraft. Labels were fitted on the inside of the raft, near the cutting knives, to explain the use and detachment of the mooring lines.

After the Aircraft ditched, the flight crew pulled the deployment handles. While the left raft deployed as designed, the right raft did not deploy when the Commander pulled the handle.

An operational test of the right raft deployment system confirmed operational functionality of the handle and cable mechanism. The raft was subsequently removed to conduct an inspection of the system, confirming the operational serviceability of the mechanism. A functional check of the pressure cylinder confirmed that the raft was serviceable at the time of the Accident.

An inspection of the raft deployment handles revealed that the safety clips were both released. Compared to the left handle, the right handle housing installation did not appear tightened and exhibited excessive play.

1.15.4 The Aircraft evacuation

The Aircraft emergency exits consisted of six emergency windows for the passenger cabin and two for the flight deck. Once a seal filler is extracted by a passenger, each passenger cabin window panel can be either pushed in from the outside or pushed out from the inside.

The flight deck emergency windows are opened by first pulling a seal cord to release the pressure on the window seal and then by either pulling a strap handle attached to the forward lower corner of the panel from the inside or from the outside by pushing this corner of the window inwards. The window panels are then thrown out of the opening before exiting.

The cabin and the flight deck doors cannot be used as exits during a ditched landing as they may let water into the Aircraft and could damage the emergency flotation system during opening.

The Copilot reported that when he pulled the left window panel as described in the emergency evacuation procedures, the window panel cracked in the area of the pull handle creating a hole in the panel. The Copilot was able to pull the panel inwards by using this hole as a holding point.

The two flight deck window panels were not found during the recovery of the Aircraft, whereas the cabin window was recovered.

1.15.5 Deployable emergency locator transmitter system

After the recovery of the Aircraft, the automatically deployable emergency locator transmitter (DELT) beacon was found attached to the beacon release unit on the rear Aircraft fuselage.

1.16 Tests and Research

1.16.1 The MGB oil cooling fan assembly examination

The MGB oil cooling fan assembly was removed from the Aircraft and sent to Leonardo Helicopters for a forensic examination. The component manufacturer (Technofan) disassembled the assembly in the presence of the investigator-in-charge (IIC), the Italian Agenzia Nazionale per la Sicurezza del Volo accredited representative, and representatives from Leonardo Helicopters.

It was found that the fan shaft had lateral play of 5.3mm (figure 16a) and was no longer connected to the impeller, which showed signs of rubbing with the outer shroud and was cracked in two places (figure 16b).

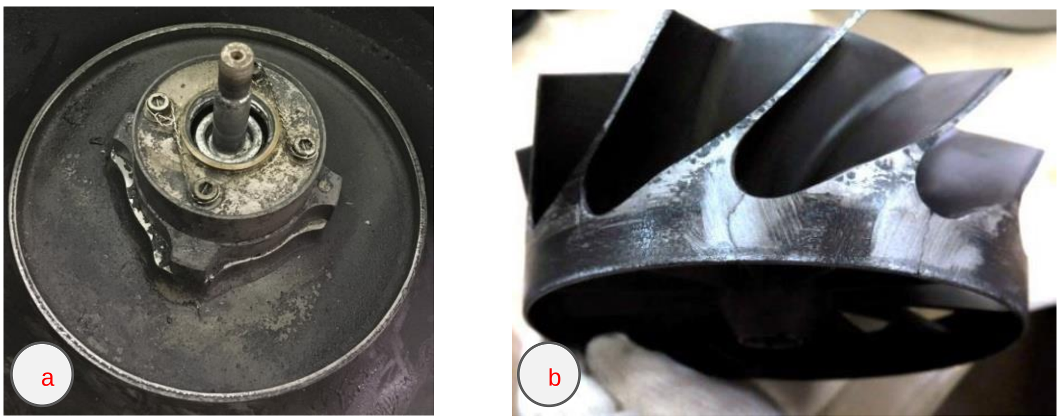


Figure 16. Fan shaft damage and cracked impeller [Source: Leonardo Helicopters]

The top bearing was completely degraded, showing signs of overheating, with the inner bearing race physically expanding its width from 11mm to 18mm (figure 17a).

The lower bearing was destroyed and its seal package found extruded from the housing by 4.8mm. Figure 17b shows the destroyed bearing balls and ball cages from the top and lower bearings.

The fan shaft thread was stripped and showed signs of extensive heating near the lower end (figure 17a).

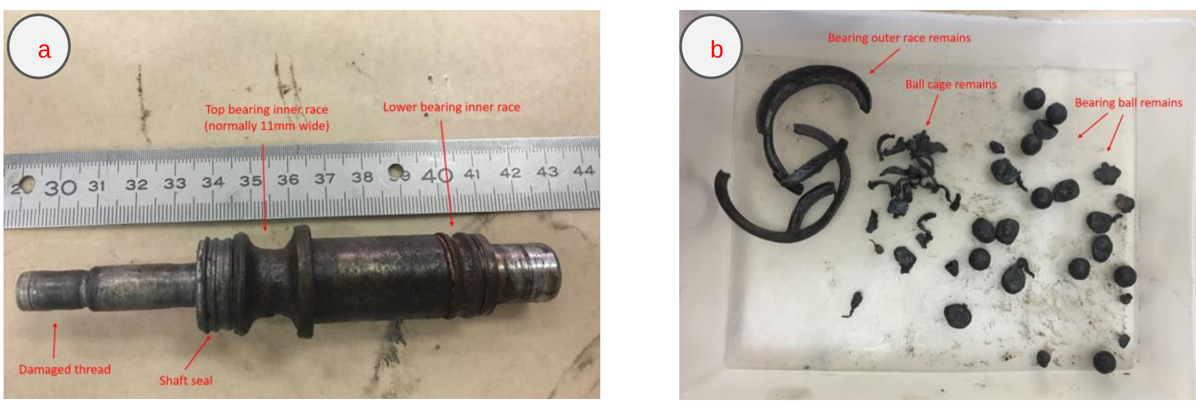


Figure 17. Cooling fan assembly shaft and bearing parts findings [Source: Leonardo Helicopters]

1.16.2 The MGB oil cooling fan drive shaft examination and analysis

The cooling fan drive shaft was recovered and forensically examined by Leonardo Helicopters in the presents of the IIC, the ANSV and representatives from Leonardo Helicopters. It was found that the shaft fractured at the nominated shear point. Both fracture surfaces showed evidence of rubbing. The splines on each end were in good condition and the lower O-ring was still present (figures 18a and 18b).

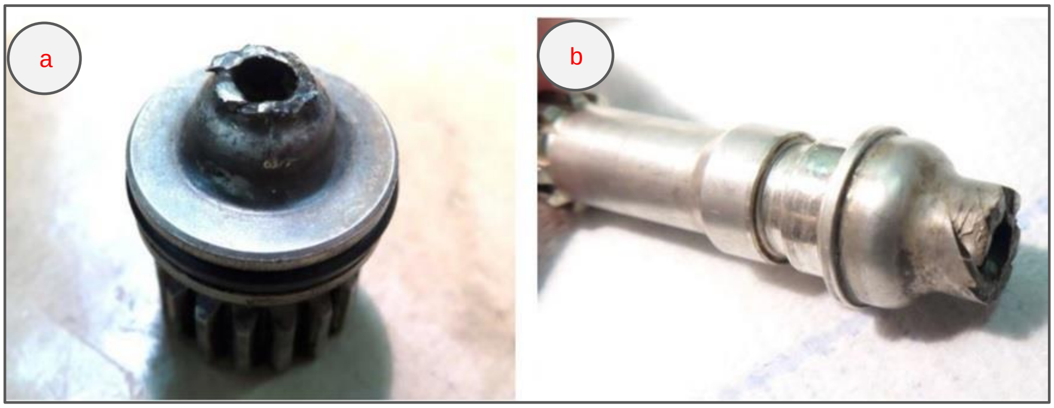


Figure 18. Cooling fan drive shaft damage [Source: Leonardo Helicopters]

1.16.3 Emergency raft deployment test

The function of the right hand emergency raft deployment system was tested to ascertain the serviceability during the Accident. Due to the removal of the raft assembly from the sponson stowage for safety reasons, the Investigation requested a functional check of the Aircraft installation in accordance with the scheduled maintenance task. No discrepancy was found and the Aircraft release mechanism installation was confirmed as serviceable.

The raft assembly was then opened and the internal release mechanism inspected. No fault with the release cable installation between the sponson connection and the pressure cylinder was found.

The Investigation subsequently conducted a functional check of the pressure cylinder release valve after the raft hoses were disconnected. This check confirmed full serviceability of the raft pressure cylinder release valve.

1.16.4 DELT system analysis

The DELT system, comprising of the ELT beacon, the flight deck control panel, the water activated switch, the Aircraft configuration unit, the system interface unit, and the beacon release unit, were removed and sent to the system manufacturer for inspection, read-out of any non-volatile memory, and an assessment of a possible failure mode.

The Aircraft wiring was inspected for any damage that could have contributed to the failure of the beacon to deploy but did not reveal any discrepancies.

Tests of the system components indicated that at the time of the Accident the DELT G-sensor did not activate due to the soft ditching, and that the cockpit switch was not manually activated. The inspection of the water-activated switch identified that although some evidence of salt water was present, the switch was not sufficiently submerged to fill up the switch cavity and allow electrical current between the contacts to send a signal to the beacon release unit.

1.16.5 Cockpit voice recorder area microphone channel failure

The flight deck area recording files were provided to the recorder manufacturer for an analysis and attempt to recover the erroneous data. This was unsuccessful. The Investigation concluded that the crash protected memory unit suffered a failure which caused the recorded data of the flight deck area microphone to be corrupted.

1.17 Organizational and Management Information

1.17.1 *Rotorcraft flight manual* and *quick reference handbook*

The *rotorcraft flight manual* (*RFM*) and the *quick reference handbook (QRH)* provide the following emergency landing guidance:

> "Throughout this Section, three terms are used to indicate the degree of urgency with which a landing must be effected. In cases where extremely hazardous landing conditions exist such as dense bush, heavy seas or mountainous terrain, the final decision as to the urgency of landing must be made by the pilot.
>
> 1. **Land immediately:** Land at once, even if for example this means ditching or landing in trees. The consequences of continued flight are likely to be more hazardous than those of landing at a site normally considered unsuitable.
> 2. **Land as soon as possible:** Do not continue flight for longer than is necessary to achieve a safe and unhurried landing at the nearest site.
> 3. **Land as soon as practicable:** Land at the nearest aviation location or, if there is none reasonably close, at a safe landing site selected for subsequent convenience."

1.17.2 The *QRH*, MGB oil temperature

The AW139 *rotorcraft flight manual* (*RFM*) and the *quick reference handbook (QRH)* provide the following guidance:

> **"Transmission System Failures**
>
> In general a single failure indication dictates that the helicopter **Land as soon as practicable** while a double failure dictates **Land as soon as possible**. If multiple failure indication, including abnormal noise and/or vibration are present **LAND IMMEDIATELY**."

Figure 19 shows the *QRH* instructions for an MGB high oil temperature indication.

1.17.3 The *QRH*, *Landing/Ditching* procedure

The AW13 *QRH Landing/Ditching* procedure provided the instructions for ditching in four steps in the *Engine Failure Shut Down* sections (figure 20). These four steps include the following:

1. Collective/Cyclic control
2. Cyclic
3. Approach/Touchdown

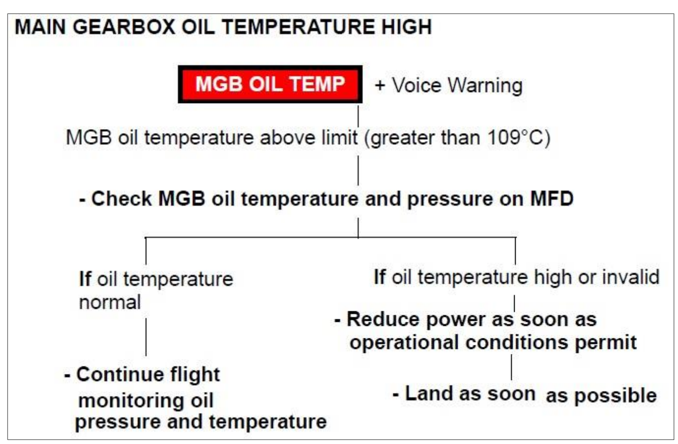


Figure 19. *QRH* MGB OIL TEMP instruction extract
[Source: Leonardo Helicopters]

4. Landing/Ditching, which states:

4. Landing/Ditching — After touchdown, centralize cyclic and simultaneously reduce collective to MPOG.
Apply brakes as required for ground landing or initiate the Ditching Procedure described in Supplement 9.

Figure 20. *QRH* landing/ditching instruction extract [Source: Leonardo Helicopters]

Supplement 9 referred to a 22-page supplement to the *RFM*, covered in section 5 – *Optional Equipment Supplements*. Supplement 9 – *Ditching Configurations*, began on page 1067 of the *RFM* and contains sections on ditching regulations, limitations, normal procedures, emergency procedures and performance data.

Page S9-6, Section 1 – *Limitations*, provided the following statement under *Miscellaneous Limitations, Flotation System*:

> "The Emergency Flotation system shall only be used for ditching. Flotation bags shall not be inflated in flight."

Section 3 – *Emergency and Malfunction Procedures*, on page S9-11 displayed two warnings, including the following:

WARNING

Do not deploy flotation bags in flight. Bags will automatically deploy on water touchdown.

Figure 21. Warning in AW139 *RFM* - 4D Supplement 9 – *Ditching Configuration* [Source: Leonardo Helicopters]

The *RFM* Supplement described, in 20 steps, the ditching procedures from pre-ditching checks to the evacuation. Step 13 provides the following step:

> "Check inflated, if not lift guard and press FLOAT override pushbutton on either Pilot or Copilot collective grip."

1.17.4 Operator's flotation system description

The Operator's *operations manual*, Part B-1, dated 1 January 2014, describes the flotation system as a standard installation to keep the aircraft floating upright in sea conditions up to sea state 5, which is defined as waves up to 12 to 18 feet. It describes that the flotation system is designed to automatically activate upon ditching, and when two of the four system sensors detect contact with the sea. The *manual* provides an alternative method to activate the system by either pilot selects the guarded FLOAT switch on the collective hand grip.

Section 11 of the *operations manual* provides procedures for the preparation of an aircraft ditching. It states:

> "Landing into wind, on top or back of a wave is preferable. Floats should be inflated prior to water entry; full inflation should take less than 5 seconds."

1.17.5 Operator's ditching training

The Operator's annual safety and emergency procedures (SEP) training covered procedures for a non-controlled ditching event associated with a double engine failure. This training was conducted either in the aircraft or the simulator, or by instructor briefing only.

Following the Accident, the Operator revised the practical SEP training mode and subsequently this training was mostly conducted in the simulator. In addition, a power-on ditching scenario was included.

All pilots were required to complete an annual online training course on the theory of AW139 SEP training. This training had been developed and provided to the Operator when the AW139 type entered the fleet. Slide 7.22 of the online training exhibited *limitations*. Included on this slide was a *limitation* that "Flotation bags shall not be inflated in flight."

Slide 7.30 provided information on manual emergency float inflation. It stated "After water Landing – Lift Guard on either Collective, Press Button."

Additionally, slide 7.32 exhibited a warning stating "Do not deploy flotation bags in flight. Bags will automatically deploy on water touch down." A discussion of the reasons for this limitation was not provided in the online training. The online course concluded with a questionnaire consisting of randomly selected questions, including questions related to SEP procedures.

1.18 Additional Information

1.18.1 Flotation system failures

The Operator advised that a high number of flotation bags in their OEM's-approved safety equipment workshop, located in the Operator's maintenance facility, had failed the 12-monthly detailed inspection. The failure was attributed to leakages at seams, valve flanges, and cracked relief valve flanges.

In the period between July 2015 and June 2017, 36 flotation bags failed in the leakage test during a scheduled shop visit, including 28 flotation bags with multiple damages. While 29 bags failed because of seam leakages due to dis-bonding, 23 bags failed because of cracked relief valve flanges, 11 displayed swivel valve leaks, and 8 bags were found with leaked flanges of the inflate-deflate valve.

1.18.2 The AW139 engine and MGB indications comparison

The engine oil indications and the MGB oil indications are displayed on a similarly designed graphic (figure 22). While the MGB oil temperature and oil pressure indications have a yellow range for the minimum values, they are not designed to display a yellow range for values before the maximum levels are reached. The MGB oil temperature indication changes from a standard green number to a white number in a red box, accompanied by the MGB temperature

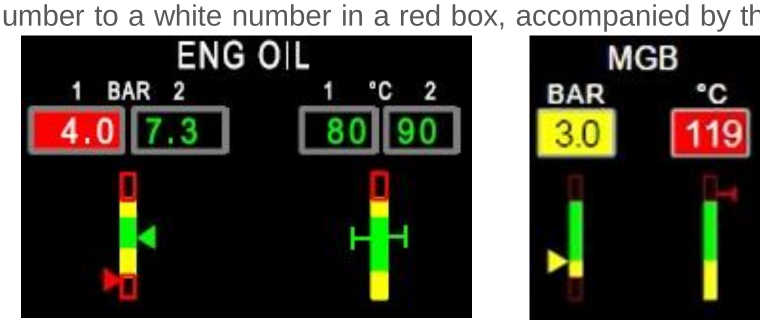


Figure 22. Engine and MGB indications [Source: Leonardo Helicopters]

alert to the pilot. When a yellow range is reached, the value changes from a green standard number to a black number displayed in a yellow box, to attract the attention of the pilot.

The engine oil indications provide a yellow range at the lower and top level, prior to reaching critical values, to attract the attention of the pilots.

1.18.3 AW139 MGB cooling fan shop visit statistics

The cooling fan manufacturer provided the Investigation with shop visit statistics over a time period from 2015 to March 2017. It shows that 74.2 percent of the cooling fans were returned for a scheduled overhaul and 23.3 percent required a repair. Of the returned assemblies, 2.5 percent were tested on request of the owner with no fault found.

The reasons for the repair requests were stated as noisy bearings (25 percent), drive shaft failures (25 percent), rough bearings (18 percent), damaged impellers (14 percent), foreign object damages (11 percent) and seal damages (7 percent).

The manufacturer provided additional cooling fan failure statistics from other aircraft types which were reviewed but considered not relevant to this Investigation.

1.18.4 Historic DELT system failure and modification

The Aircraft manufacturer provided information about reported DELT operation on the AW139 fleet. Prior to the Accident, one report was received by the manufacturer, where the aircraft impacted water at high speed in 2010, which resulted in a separation of the beacon without activation. A second report was received, where an aircraft impacted water at very high speed in 2011 without the deployment of the beacon. This Accident is the third report where the beacon did not deploy from the fuselage after contact with water.

Two reports were provided where the beacon deployed and transmitted as designed after a controlled ditching in 2010 and hard landing in 2011, while another reported occurrence from 2015 is currently under investigation by the manufacturer.

An investigation by the Aircraft manufacturer found that a manually selected TRANSMIT on the cockpit selector panel by the flight crew caused the automatic deployment of the beacon to be inhibited when the aircraft ditched, unless the system had been subsequently reset by selecting the TEST/RESET button.

A mandatory modification to the system was published as *Bollettino Tecnico 139-431*, issued on 10 November 2015 by Leonardo Helicopters, which rectified this problem by introducing a modified system interface unit.

1.18.5 Cockpit window failure reports

The Aircraft manufacturer advised that only one cockpit emergency window failure was reported during a scheduled functional check in 2011. The cause of the failure was not determined.

1.18.6 Final Report consultation submissions

The States supporting the investigation were provided with the opportunity to provide significant and substantiated comments to the draft Final Report in accordance with *Civil Aviation Regulation* Part VI, Chapter 3, Section 7.2 Consultation. After review and consultation, these comments were appended to this Final Report.

The Bureau d’Enquêtes et d’Analyses pour la sécurité de l’aviation civile (BEA) advised that after a review of the draft Final Report provided on 22 February 2018, the BEA did not wish to append any comments.

The Agenzia Nazionale per la Sicurezza del Volo (ANSV), provided submissions from their technical advisors and the European Aviation Safety Agency (EASA), which were appended in appendices 7 and 8 of this Report.

1.19 Useful or Effective Investigation Techniques

Flight recorder data and information stored in specific cockpit voice recorder channels was downloaded and, in association with the Aircraft manufacturer, converted into an aural-visual simulation, which was helpful in the analysis of the flight crew actions during the Accident sequence.

2. Analysis

2.1 The Main Gearbox (MGB)

2.1.1 The oil cooling malfunction

The examination of the disassembled oil cooling fan identified that it is most likely that the top bearing started to degrade and overheat, resulting in an expansion which led to a reduction in the clearance gap between the impeller and the fan housing, until contact between the impellor and the housing occurred . This resulted in an increasing tightening load on the fan shaft nut and a sudden over-torque, which sheared the thread and allowed the nut to separate from the shaft.

It is likely that this was the point where fan rotation stopped and airflow through the oil cooler ceased, resulting in a gradual increase in the MGB oil temperature. The overheated top bearing degraded further and expanded from its original 11mm width to approximately 18mm, as shown in section 1.17.2 figure 19. This resulted in an expansion force towards the lower end of the shaft, allowing the lower bearing/seal package protruding the housing.

The complete fragmentation of the top bearing created radial play of the fan shaft, allowing the fan to contact the housing and producing the grinding noise heard by the flight crew. This radial play also overloaded the drive shaft until it fractured at the designated shear point.

2.1.2 The oil cooling fan bearing design

The fan manufacturer's 1997 bearing specification sheet lists a speed limit of 14,000 rpm for the lower fan bearing, while the fan operational speed is 16,000 rpm. The fan manufacturer justifies the selection of the bearing by referencing speed limits of 17,000 rpm, according to the bearing catalogue, which has since been revised as shown in appendix 6. The bearing manufacturer explained that the limiting speeds provided in their literature are theoretical values and should have required in-situ verification by the user.

Of all fan assemblies received by the manufacturer, 23.3 percent required a repair prior to an overhaul and 43 percent of these assemblies were removed from service due to bearing problems.

The Investigation believes that the fan manufacturer's initial selection of the fan assembly bearings was based on assumed limiting speeds below the actual fan operating speeds, and that the failure rate indicates that the selected bearings are not appropriate for the required life, anticipated load, or rotational speed limit.

2.1.3 The oil cooling fan overhaul procedures

During the overhaul of the fan assembly, all parts, comprising the overhaul kit were replaced. This included the fan shaft, both bearings, the lower seal and other hardware. The upper sealing spacer is not part of the overhaul kit and is only replaced when required.

Considering the importance of excluding dust and debris from the bearing housing, the Investigation recommends the inclusion of the sealing spacer in the overhaul kit.

The critical parts of the fan assembly are the bearings, which are removed from their sealed package and fitted during the assembly of new fans and during their regular overhaul. The bearing types contain seal plates to protect the bearings from dust and to contain the lubricant. New and overhauled fan assemblies are issued by the fan manufacturer with a 5-year shelf life. However, the bearing manufacturer provided a 3-year shelf life for the bearings, only provided they are kept in their original packing and are stored in dry, moderate temperature conditions.

The Investigation could not determine whether the storage and transport conditions of the fan assembly between the overhaul and the installation, had contributed to the bearing failure. However, the Investigation believes that uncontrolled transport and storage conditions may have a direct effect on the internal bearing lubricant.

The Investigation recommends that the fan manufacturer address the storage and transport conditions and their effect on the shelf life of the new and overhauled fan assemblies.

2.1.4 The Aircraft MGB oil temperature indication system

The Aircraft's MGB oil temperature system is one of the critical MGB monitoring systems, referenced in the *QRH*, and is designed to warn the pilots if the oil system overheats. However, it does not provide an alert system to indicate the oil temperature increase rate as a prediction of potential overheating. Other aircraft indicating systems, such as the engine oil temperature indicating system, provide the pilots with visual graduated green, amber and red indications to provide a timely alert.

The Aircraft's MGB oil temperature started to rise approximately 1 minute 40 seconds prior to landing on the Dhabi II oil platform. When the Aircraft departed the oil rig, the oil temperature exceeded 103°C which is very significantly above the nominated 86°C operating temperature. Had the crew been alerted by the system, or checked the MGB oil temperature in addition to the *Offshore Before-Takeoff Checks*, prior to takeoff, they could have identified the oil cooling system malfunction and reacted accordingly.

2.2 The Diching and Emergency

2.2.1 Flight crew handling of the emergency

Both flight crewmembers were experienced and familiar with the Aircraft and its systems. Communication during the flight was normal and compatible with a relaxed cockpit environment. The MGB oil temperature started to rise when both crewmembers were focused on flying the approach and landing on the oil rig. This most likely explains why the high oil temperature went unnoticed and was also not identified during the subsequent takeoff two minutes later, when the *Offshore Before Takeoff Checks* were completed.

In the final moments prior to ditching, the crew made decisions based on the procedures described in the *quick reference handbook (QRH)* and the Operator's *procedures manual* when they diverted to the nearest heliport, and when the Commander decided to descend to a lower altitude to reduce power and reduce the load on the gearbox.

The repeated attempts to communicate with Mubarraz Island, and the ongoing communication with the Operator's operations department at a critical time, distracted the flight crew from troubleshooting the problem. The normal MGB oil pressure, and the lack of abnormal vibration were not considered by the flight crew to help them gain a better understanding of the situation.

The international accidents literature contains details of historical helicopter accidents where an in-flight main gearbox failure has led to catastrophic consequences. The flight crew stated that their knowledge of such accidents had encouraged them to discuss the possibility of ditching before the Aircraft descended to 200 ft altitude. The sudden abnormal grinding noise that was heard from the vicinity of the main gearbox area triggered the crew response to ditch the Aircraft.

Had a warning been presented in the *QRH*, the crew may have been provided with a memory trigger to avoid in-flight activation of the flotation system.

Because of the increasing workload, and the rapid decision to ditch the Aircraft, the crew did not brief the passenger. In addition, the passenger was not wearing the headset during the crew conversation, so he was not aware of the situation and was not provided with critical evacuation instructions until after the Aircraft had ditched.

2.2.2 The Aircraft manufacturer's ditching procedures

The intent of the *QRH* is to provide the flight crew with procedures that can be implemented in time-critical situations, during emergencies or during system malfunctions.

The *Landing/Ditching* procedure was contained in the *Engine Failure Shutdown* section of the emergency procedures. It described, in four steps, the handling of the Aircraft. The last step after touchdown provides information to initiate the *Ditching Procedure* in Supplement 9 of the *rotorcraft flight manual (RFM)*, and includes 20 steps from pre-ditching checks to the evacuation. (Refer appendices 2 to 5)

The 4-step *Landing/Ditching* procedure in the *QRH* did not provide additional information and does not display any warnings regarding the use of the flotation system in flight, as provided in the flight crew operating manual (*FCOM)*. (Refer appendix 1)

The Investigation believes that the *QRH* did not provide the flight crew with sufficient information to follow the critical steps necessary for a successful ditching in a time-critical situation. A warning in the *QRH* that the in-flight deployment of the flotation system may result in damaged flotation bags, could have led the flight crew to use the automatic deployment system during ditching. The reference to Supplement 9 of the *RFM* is only considered adequate for situations where sufficient time allows the flight crew to plan for ditching.

2.2.3 The Operator's ditching training and procedures

The Operator provided annual practical safety and emergency procedure (SEP) training, which was conducted in the aircraft, a simulator or by way of a briefing. Additionally, annual theoretical online training on AW139 safety and emergency procedure was provided to the crew. That training featured warnings that flotation bags should not be deployed in-flight. The Commander had completed the latest SEP training in March 2017, a month prior to the Accident.

The Investigation could not confirm in the recordings of the cockpit voice recorder that the flight crew had discussed in-flight deployment of the flotation bags. The crew deviated from the ditching training provided to them and from the published ditching procedures. Had the training contained a practical session on ditching, any crew deviation from procedures could have been identified by the training instructor, and corrective training action could have been taken.

Although the Operator revised the practical SEP training syllabus after the Accident and now mainly conducts this training in the simulator, it is recommended that the Operator review the effectiveness of the training to help ensure that flight crewmembers adhere to trained procedures in an emergency situation.

2.2.4 The Aircraft flotation system reliability

The failed aft left flotation bag displayed a tear in the vicinity of the composite cover remains, and delamination of seams near the pillow inflation valve and of the main chamber. The tear was most likely caused by the in-flight activation of the flotation system, when the float cover fragmented due to the inflation of the flotation bag.

The seam delamination on the flotation bag was probably caused by the rapid inflation of the flotation bag to operational pressure. This is supported by the Operator's flotation bag reliability data, which indicated that a high number of flotation bags had failed the annual inflation test because of multiple defects, including seam delamination. This issue was known to the flotation bag manufacturer and was addressed by reducing the inflation test pressure. However, this action did not significantly reduce the failure rate. The Investigation believes that the action of the flotation bag manufacturer did not address the root cause of the failures, and therefore the Investigation recommends that the manufacturer analyze the failure cause and take appropriate rectification action.

2.2.5 Life raft operation

The flight crew activated the life raft handles, which were located near the cockpit doors. The Copilot did not experience any problems with the inflation of the raft, but the Commander's raft did not deploy. Post-Accident testing of the raft system could not determine the cause of the failure to deploy, however, the activation handle housing was found loose and with significant play. It is therefore possible that while it appeared that the activation handle had been fully extracted, excessive play prevented the complete handle extraction and so prevented activation of the inflation valve and the deployment of the raft.

2.2.6 The deployable emergency locator transmitter (DELT) system

According to the flight crew's description, the Aircraft ditched at a low rate of descent, which did not reach the level necessary to activate the DELT G-sensor. The manual deployment switch was not activated by the crew, leaving the water activated switch as the sole mechanism to achieve activation and deployment of the DELT.

The lack of saltwater evidence in the water activated switch cavity suggests that it had not been sufficiently submerged during the ditching, or that water was prevented from entering the switch for other reasons. It is possible that the inflation of the floats prior to ditching and the subsequent tilting of the Aircraft, prevented filling of the water activated switch and the activation of the DELT.

It is recommended that the Aircraft manufacturer, in association with EASA, review the DELT system's activation design, particularly the location of the water activated switch, in order to ensure that the system functions as per the certification requirements.

2.3 The Flight Recorder

The multi-purpose flight recorder (MPFR) was exposed to normal physical forces and normal operational temperatures during the Accident.

When the flotation bag failed after ditching, the Aircraft capsized and the MPFR was submerged in the sea water at a depth of 3 to 4 meters for approximately 6 hours.

Disassembly of the MPFR by a specialist from the Aircraft manufacturer, revealed that water had penetrated the crash survivable memory unit, probably through the ribbon cable cut-out, and had reached the inner steel cylinder, which contains the data storage memory boards.

The Investigation could not determine whether this water ingress was the cause of the corrupted data in the cockpit area microphone recording.

3. Conclusions

3.1 General

From the evidence available, the following findings, causes and contributing factors were made with respect to this Accident. These shall not be read as apportioning blame or liability to any particular organisation or individual.

To serve the objective of this Investigation, the following sections are included:

- **Findings.** Statements of all significant conditions, events or circumstances in this Accident. The findings are significant steps in this Accident sequence but they are not always causal or indicate deficiencies.
- **Causes.** Actions, omissions, events, conditions, or a combination thereof, which led to this Accident.
- **Contributing factors.** Actions, omissions, events, conditions, or a combination thereof, which, if eliminated, avoided or absent, would have reduced the probability of the Accident occurring, or mitigated the severity of the consequences of the Accident. The identification of contributing factors does not imply the assignment of fault or the determination of administrative, civil or criminal liability.

3.2 Findings

3.2.1 Findings relevant to the Aircraft

(a) The Aircraft was certified, equipped, and maintained in accordance with the existing requirements of the *Civil Aviation Regulations* of the United Arab Emirates.

(b) The Aircraft records indicated that it was airworthy when dispatched for the flight.

(c) At the time of the Accident, the MGB oil cooling fan had accumulated 1,016 hours since overhaul and 3,414 hours since new.

(d) The MGB oil cooling fan was subject to an overhaul interval of 2,400 hours and an inspection after 1,200 hours in service.

(e) 23.3 percent of all oil cooling fans were received by the fan manufacturer because of repair requirements. Of these, 43 percent exhibited bearing damage.

(f) The fan manufacturer's lower bearing specification sheet nominates a limiting speed of 14,000 rpm, while the operating speed of the fan is approximately 16,000 rpm.

(g) The fan manufacturer issued a 5-year shelf life for new and overhauled assemblies.

(h) The bearing manufacturer issued a 3-year shelf life for bearings in their original, sealed packaging.

(i) Reliability data from the Operator indicated a high failure rate of flotation bags during scheduled inspections.

3.2.2 Findings relevant to the flight crew

(a) The flight crewmembers were licensed and qualified for the flight in accordance with the existing requirements of the *Civil Aviation Regulations* of the United Arab Emirates.

(b) The flight crew diverted to Mubarraz Island, two minutes after the MGB oil temperature warning illuminated.

(c) The crew activated the flotation system in-flight, seven seconds after an abnormal grinding noise was heard.

3.2.3 Findings relevant to the ditching and emergency

(a) Approximately one minute 40 seconds prior to landing on the Dhabi II rig, the MGB oil cooling fan failed and the oil temperature started to rise.

(b) The helicopter landed on the Dhabi II rig with an MGB oil temperature of 102°C and took-off one minute and 52 seconds later with an MGB oil temperature of 103°C.

(c) The elevated MGB oil temperature was not noticed by the crew.

(d) The MGB oil temperature warning illuminated one minute and five seconds after take-off from Dhabi II, when the temperature had reached 109°C.

(e) A grinding noise was heard from the MGB area three minutes and 56 seconds after diverting to Mubarraz Island.

(f) The in-flight deployment of the flotation system by the Commander caused the float covers to separate fragmented from the fuselage.

(g) The left aft flotation bag was found with tear damage, which had allowed air to escape.

(h) Air also escaped from the left aft flotation bag due to seam delamination.

(i) The left emergency raft deployed as intended after activation by the Copilot.

(j) The right raft handle was pulled but did not deploy the right emergency raft.

(k) The deployment handle was later found to exhibit excessive radial play.

(l) The left cockpit emergency window failed when the Copilot pulled the strap handle.

(m) The automatically deployable ELT failed to activate and deploy from the fuselage.

(n) The water activated switch of the automatically deployable ELT system did not sufficiently fill with water to activate.

(o) The multi-purpose flight recorder (MPFR) showed signs of water penetration of the crash survivable memory unit.

(p) The downloaded cockpit area microphone recording was corrupted and could not be converted to an audible file.

3.3 Causes

The Air Accident Investigation Sector (AAIS) determines that the cause of the Accident was the complete submergence of the Aircraft in the sea water, causing damage beyond repair.

The Aircraft could not remain afloat upright after the controlled ditching and submerged in the sea water, because the left aft flotation bag deflated.

3.4 Contributing Factors to the Accident

The Air Accident Investigation Sector determines the following to be contributing factors to the Accident:

(a) The manual deployment of the flotation system in-flight resulted in a fragmented separation of the float covers and caused a tear to the flotation bag fabric.

(b) The left aft flotation bag seams delaminated during the inflation, allowing air to escape and the flotation bag to deflate.

4. Safety Recommendations

4.1 General

The safety recommendations listed in this Report are proposed according to paragraph 6.8 of *Annex 13 to the Convention on International Civil Aviation*, and are based on the conclusions listed in part 3 of this Report; the Air Accident Investigation Sector (AAIS) expects that all safety issues identified by this Investigation are addressed by the receiving States and organizations.

4.2 Safety Actions Taken

4.2.1 The Operator

The Accident and the initial inspection prompted the Operator to conduct an AW139 fleet inspection for visible damage on other MGB oil cooling fan assemblies. This inspection included eight aircraft and was completed on 7 May 2017. The scope of the inspection was associated with the 1,200 hour inspection in accordance with maintenance program task *39-A-63-20-03-00A-310A-A – General Visual Inspection of MGB Oil Cooling Fan for freedom of rotation of the fan impeller*.

No further cooling fan defects or degradation of the fan bearings were detected. Independently of the inspection result, the Operator decided to reduce the inspection interval in their approved maintenance program from 1,200 hours to 600 hours.

The Operator also initiated a review of flotation bag failures during scheduled overhaul and service and provided the Investigation with the relevant data.

The Operator introduced an over-water emergency scenario, conducted in the simulator, involving a power-on ditching and a check of all the required practical safety and emergency procedures. The Investigation could not determine whether or not this safety action is effective and will prevent future deviations from the published ditching procedures.

4.2.2 Leonardo Helicopters

Leonardo Helicopters issued *Service Bulletin SB 319-490* on 7 August 2017, calling up a visual inspection of un-installed cooling fans for evidence of fan shroud rubbing, a roughness check of the bearings, and application of a slip mark on the fan shaft nut. Cooling fans which are installed on aircraft also require carrying out a clearance check between the fan blades and the fan shroud.

Additionally, a new maintenance task (63-47) was introduced to carry out an operational check for the clearance between the fan blades and the fan shroud. This check also includes a visual inspection for any signs of shroud rubbing and is scheduled every 600 hours.

The requirements for the Maintenance Manual task 39-A-63-20-03-00A-310A-A were amended to include cleaning of the MGB oil cooler and fan, and inspection of the fan shaft nut's slip mark, and were introduced by Service Bulletin SB 319-490. The interval for this task remained at 1,200 hours.

Leonardo Helicopters revised the *quick reference handbook* to provide a new emergency procedure and additional notes for a high MGB OIL TEMP indication.

4.3 Final Report Safety Recommendations

The survivability of all persons on-board a helicopter during overwater operation depends on the application of appropriate emergency procedures and the reliability of the emergency equipment. The helicopter flotation system is designed to keep the helicopter upright long enough to allow all occupants to evacuate safely. Damaged or unreliable emergency equipment may significantly reduce the time available for all occupants to evacuate.

Therefore, the Investigation recommends that:

4.3.1 The Leonardo Helicopter Division

SR01/2019

Review the ditching instructions published in the *quick reference handbook* (*QRH*) to include necessary information and explanatory warnings for a successful ditching in a time-critical situation.

4.3.2 The General Civil Aviation Authority of the United Arab Emirates

SR02/2019

Ensure that the Operator review the effectiveness of their ditching procedure training to ensure that flight crewmembers apply appropriate procedures in an emergency situation.

4.3.3 The European Aviation Safety Agency (EASA)

SR03/2019

Ensure that Leonardo Helicopters, in association with the cooling fan manufacturer (Technofan), review the reliability of the MGB oil cooling fan assemblies, and the appropriate selection of the bearings for their application.

SR04/2019

Ensure that Leonardo Helicopters review and assess the in-service reliability and service life limits of AW139 flotation bags to determine whether the flotation bag maintenance program is adequate.

SR05/2019

Ensure that Leonardo Helicopters review the design of the automatically deployable emergency locater transmitter (DELT) system, particularly the position of the water activated switch, to ensure that the system functions in a similar ditching scenario.

SR06/2019

Ensure that Leonardo Helicopters review the main gearbox (MGB) oil temperature warning system with the aim of introducing a cautionary temperature range to alert the flight crew that the MGB oil temperature is rising toward a critical level.

This Final Report is issued by:
The Air Accident Investigation Sector
General Civil Aviation Authority
The United Arab Emirates
e-mail: aai@gcaa.gov.ae

5. Appendices

Appendix 1. AW139 *Flight Crew Operating Manual (FCOM)* - Page 1-70

MISCELLANEOUS LIMITATIONS

FLOTATION SYSTEM

The Emergency Flotation system shall only be used for ditching.

Flotation bags shall not be inflated in flight.

FLOTATION GAS BOTTLE PRESSURE

The flotation gas bottle pressure limitation is related to ambient temperature.

See Figure 1-39 for pressure limits P/N 3G9560F00111/113 (Aero Sekur)

See Figure 1-40 for pressure limits P/N 3G9560F00212 (Aerazur)

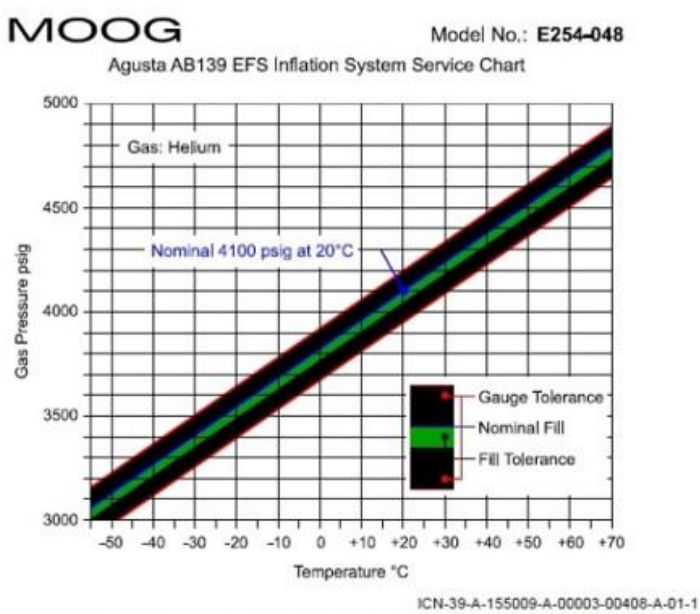


Figure 1-39 Flotation Gas Bottle Pressure Limits P/N 3G9560F00113 (Aero Sekur)

Appendix 2. AW139 *Quick Reference Handbook* - Page 18A

AW139 AW139-QRH

LANDING/DITCHING PROCEDURE

1. Collective/ Cyclic control — Rotate nose down in 1 second to an attitude of no more than -20° while decreasing collective to maintain NR at 100%.

Note

The nose down rotation should be commensurate with hover height. An engine failure at low height will not allow a large pitch attitude change prior to water/ground impact. Engine failures at higher hover heights will permit greater pitch attitude change to gain aispeed energy that is subsequently used during the flare.

2. Cyclic — At 50 ft AGL rotate nose up as necessary (maximum 20°) to decelerate.

3. Approach/ Touchdown — Continue deceleration to attain landing attitude (level or 5° nose up) prior to touchdown or ditching at the slowest forward speed possible. Use collective to cushion touchdown.

4. Landing/Ditching — After touchdown, centralize cyclic and simultaneously reduce collective to MPOG.
Apply brakes as required for ground landing or initiate the Ditching Procedure described in Supplement 9.

CAUTION

If the undercarriage is not extended the Rotor Brake will not function. In this case use the collective to slow the rotor, being aware the aircraft may yaw left.

ENG FAIL
SHT DWN

Rev. 4 Emerg-Malfunc Page 18A

Appendix 3. AW139 *Rotorcraft Flight Manual* Supplement 9 - Page S9-12

DITCHING PROCEDURES - AEO

1. Pre-ditching checks — Warn crew and passengers to prepare for ditching.
2. OFF/ARMED switch (FLOATS EMER panel) — Confirm ARMED. FLOAT ARM caution displayed on CAS.
3. Landing Gear — Confirm UP.

CAUTION

If the landing gear cannot be retracted, ditching with minimum forward speed is recommended.

4. Lights — At night, switch ON emergency lights and landing light.
5. Landing direction — If possible orientate the aircraft for an approach into the prevailing wind.
6. Brief — Cabin crew and occupants.
7. Radar altimeter — Verify working.
8. Windscreen wipers — Select FAST.
9. Distress procedure — Broadcast Mayday.
10. Initial point — During the approach, reduce airspeed gradually to arrive at a position 200 ft (60 m) above touchdown point with a rate of descent of no more than 500 fpm. Initiate a deceleration to achieve 30 kts at 50 ft (15 m). At 50 ft (15 m) rotate nose up to approximately 20° to decelerate.

Appendix 4. AW139 *Rotorcraft Flight Manual* Supplement 9 - Page S9-13

11. Approach and hover	— Continue the deceleration and descent to hover.
12. Touchdown	— Enter water cushioning touchdown with collective in a level or slightly nose up attitude (5°). Avoid rearward movement of the helicopter.
13. Flotation bags	— Check inflated, if not lift guard and press FLOAT override pushbutton on either Pilot or Copilot collective grip.
14. Collective	— Lower collective.
15. Emergency exits	— As soon as possible inform crew and passengers to jettison the emergency exits in cockpit and cabin.
16. Engines	— Shut down using **ENGINE SHUTDOWN IN EMERGENCY** procedure in Basic RFM page 3-35.
17. Collective	— If required gently raise collective to slow rotor.

CAUTION

Collective application will cause the helicopter to yaw left.

When rotors stationary

18. GEN 1 & 2 and BATT MASTER switches — OFF (using gang-bar).

Note

Item 19, below, is only applicable if Life Raft installed (P/N 4G2560F00711/00811/01011/01012)

Appendix 5. AW139 *Rotorcraft Flight Manual* Supplement 9 - Page S9-14

19. Life Raft deployment handles — Pull Pilot and Copilot deployment handles and confirm life rafts deploy. If life rafts do not deploy, locate through sliding doors emergency exits, flap marked 'LIFE RAFT HANDLE PULL TO INFLATE' on life raft container. Open flap and pull handle to manually inflate rafts.

20. Evacuation — Evacuate the aircraft, with life preservers.

DITCHING PROCEDURES - OEI

In the event of a ditching being required following a single engine failure the approach and ditching should be carried out as follows:

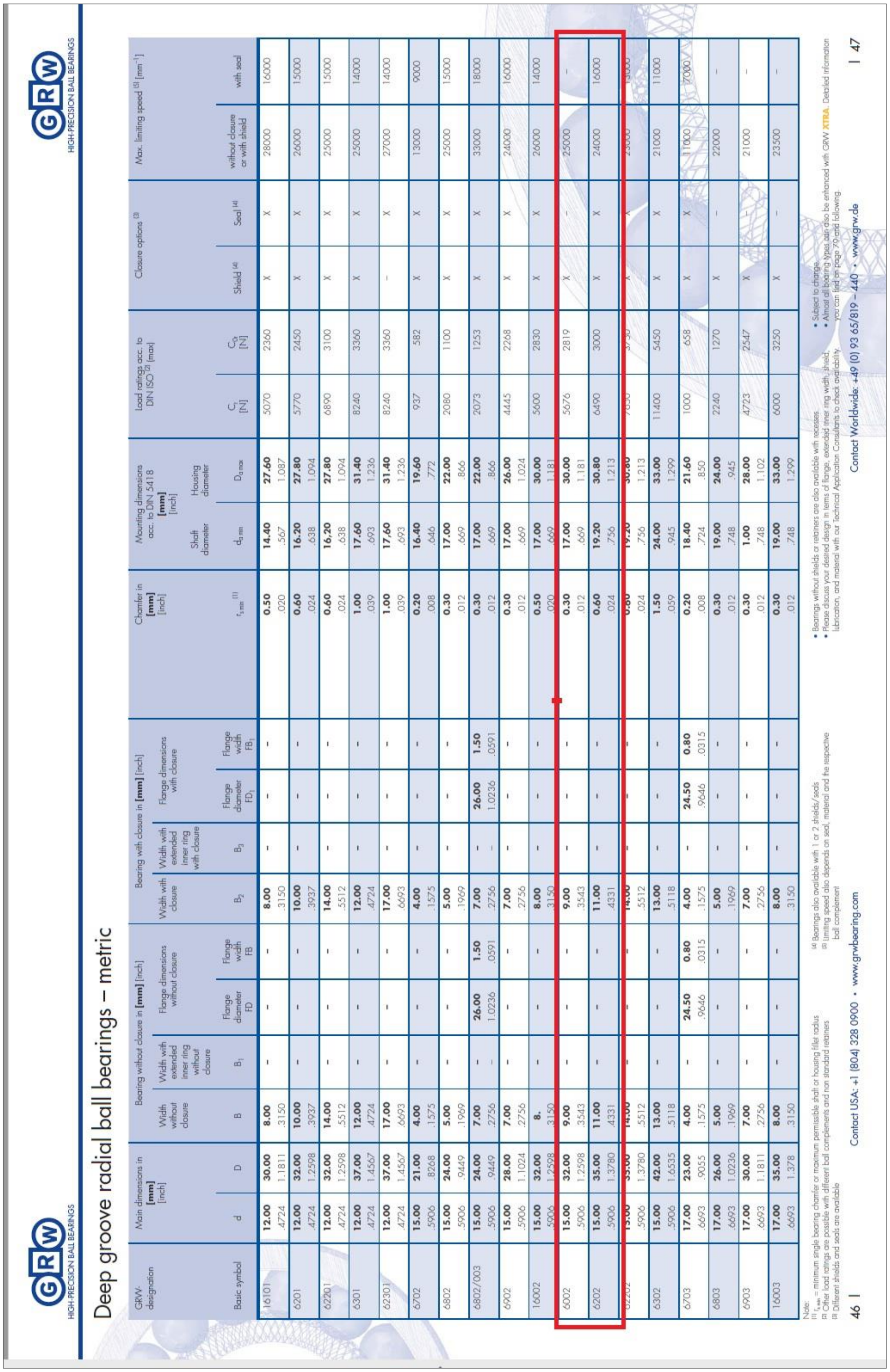
1. Speed — Reduce speed (recommended 80 KIAS.
2. OFF/ARMED switch (FLOATS EMER panel) — Confirm ARMED. FLOAT ARM caution displayed on CAS.
3. Landing Gear — Confirm UP.

CAUTION

If the landing gear cannot be retracted, ditching with minimum forward speed is recommended.

4. Lights — At night switch ON emergency lights and landing light.
5. Landing direction — If possible orientate the aircraft for an approach into the prevailing wind.
6. Brief — Cabin crew and occupants.

Appendix 6. Bearing Catalogue Information



GRW HIGH-PRECISION BALL BEARINGS

Deep groove radial ball bearings – metric

GRW-designation	Main dimensions in [mm] [inch]		Bearing without closure in [mm] [inch]				Bearing with closure in [mm] [inch]				Chamfer in [mm] [inch]	Mounting dimensions acc. to DIN 5418 [mm] [inch]		Load ratings acc. to DIN ISO [2] (max)		Closure options [3]		Max. limiting speed [5] [min⁻¹]	
			Width without closure	Width with extended inner ring without closure	Flange dimensions without closure		Width with closure	Width with extended inner ring with closure	Flange dimensions with closure			Shaft diameter	Housing diameter						
Basic symbol	d	D	B	B_1	Flange diameter FD	Flange width FB	B_2	B_3	Flange diameter FD_1	Flange width FB_1	$r_{s\,min}$ [1]	$d_{a\,min}$	$D_{a\,max}$	C_r [N]	C_{0r} [N]	Shield [4]	Seal [4]	without closure or with shield	with seal
16101	12.00 .4724	30.00 1.1811	8.00 .3150	–	–	–	8.00 .3150	–	–	–	0.50 .020	14.40 .567	27.60 1.087	5070	2360	X	X	28000	16000
6201	12.00 .4724	32.00 1.2598	10.00 .3937	–	–	–	10.00 .3937	–	–	–	0.60 .024	16.20 .638	27.80 1.094	5770	2450	X	X	26000	15000
62201	12.00 .4724	32.00 1.2598	14.00 .5512	–	–	–	14.00 .5512	–	–	–	0.60 .024	16,20 .638	27.80 1.094	6890	3100	X	X	25000	15000
6301	12.00 .4724	37.00 1.4567	12.00 .4724	–	–	–	12.00 .4724	–	–	–	1.00 .039	17.60 .693	31.40 1.236	8240	3360	X	X	25000	14000
62301	12.00 .4724	37.00 1.4567	17.00 .6693	–	–	–	17.00 .6693	–	–	–	1.00 .039	17,60 .693	31.40 1.236	8240	3360	–	X	27000	14000
6702	15.00 .5906	21.00 .8268	4.00 .1575	–	–	–	4.00 .1575	–	–	–	0.20 .008	16.40 .646	19.60 .772	937	582	X	X	13000	9000
6802	15.00 .5906	24.00 .9449	5.00 .1969	–	–	–	5.00 .1969	–	–	–	0.30 .012	17.00 .669	22.00 .866	2080	1100	X	X	25000	15000
6802/003	15.00 .5906	24.00 .9449	7.00 .2756	– –	26.00 1.0236	1.50 .0591	7.00 .2756	– –	26.00 1.0236	1.50 .0591	0.30 .012	17.00 .669	22.00 .866	2073	1253	X	X	33000	18000
6902	15.00 .5906	28.00 1.1024	7.00 .2756	–	–	–	7.00 .2756	–	–	–	0.30 .012	17.00 .669	26.00 1.024	4445	2268	X	X	24000	16000
16002	15.00 .5906	32.00 1.2598	8. .3150	–	–	–	8.00 .3150	–	–	–	0.50 .020	17.00 .669	30.00 1.181	5600	2830	X	X	26000	14000
6002	15.00 .5906	32.00 1.2598	9.00 .3543	–	–	–	9.00 .3543	–	–	–	0.30 .012	17.00 .669	30.00 1.181	5676	2819	X	–	25000	–
6202	15.00 .5906	35.00 1.3780	11.00 .4331	–	–	–	11.00 .4331	–	–	–	0.60 .024	19.20 .756	30.80 1.213	6490	3000	X	X	24000	16000
62202	15.00 .5906	35.00 1.3780	14.00 .5512	–	–	–	14.00 .5512	–	–	–	[illegible] .024	19.20 .756	30.80 1.213	7650	3750	X	X	23000	13000
6302	15.00 .5906	42.00 1.6535	13.00 .5118	–	–	–	13.00 .5118	–	–	–	1.50 .059	24.00 .945	33.00 1.299	11400	5450	X	X	21000	11000
6703	17.00 .6693	23.00 .9055	4.00 .1575	–	24.50 .9646	0.80 .0315	4.00 .1575	–	24.50 .9646	0.80 .0315	0.20 .008	18.40 .724	21.60 .850	1000	658	X	X	11000	7000
6803	17.00 .6693	26.00 1.0236	5.00 .1969	–	–	–	5.00 .1969	–	–	–	0.30 .012	19.00 .748	24.00 .945	2240	1270	X	–	22000	–
6903	17.00 .6693	30.00 1.1811	7.00 .2756	–	–	–	7.00 .2756	–	–	–	0.30 .012	1.00 .748	28.00 1.102	4723	2547	X	–	21000	–
16003	17.00 .6693	35.00 1.378	8.00 .3150	–	–	–	8.00 .3150	–	–	–	0.30 .012	19.00 .748	33.00 1.299	6000	3250	X	–	23500	–

Note:
[1] $r_{s\,min}$ = minimum single bearing chamfer or maximum permissible shaft or housing fillet radius
[2] Other load ratings are possible with different ball complements and non standard retainers
[3] Different shields and seals are available
[4] Bearings also available with 1 or 2 shields/seals
[5] Limiting speed also depends on seal, material and the respective ball complement

- Bearings without shields or retainers are also available with recesses.
- Please discuss your desired design in terms of flange, extended inner ring width, shield, lubrication, and material with our Technical Application Consultants to check availability.
- Subject to change.
- Almost all bearing types can also be enhanced with GRW XTRA. Detailed information you can find on page 79 and following.

46 | Contact USA: +1 (804) 328 0900 • www.grwbearing.com

Contact Worldwide: +49 (0) 93 65/819 – 440 • www.grw.de | 47

Appendix 7. Agenzia Nazionale per la Sicurezza del Volo (ANSV) Comments to the Final Report

Comment to paragraph 1.1 History of the Flight:

> "The Flotation bags kept the Aircraft afloat for the evacuation of all occupants; however the left aft float deflated slowly…"

The EFS (Emergency Flotation System) is designed and installed to allow safe egress of H/C [helicopter] occupants in case of ditching in accordance with the certification requirements (e.g. not to maintain the H/C floating as long as needed to completely recover the H/C). The system therefore performed as required as it maintained the H/C floating, without capsizing, thus guaranteeing safe egress of all occupants.

The following certification requirements have been fulfilled, at H/C certification, with the maximum number of passengers: JAR 29.803 (e): "A combination of analysis and tests may be used to show that the rotorcraft is capable of being evacuated within 90 seconds."

Comment to paragraph 2.1.4 The Aircraft MGB oil temperature indication system:

> "The Aircraft's MGB oil temperature started to rise approximately 1 minute 40 seconds prior to landing on the Dhabi II oil platform. When the Aircraft left the oil rig, the oil temperature exceeded 103°C which is far above the nominated 86°C operating temperature. Had the crew been alerted by the system, or checked the MGB oil temperature additional to the Offshore Before-Take-off Checks, prior to take-off, they may have identified the oil cooling system malfunction and reacted accordingly"

The current green arc upper limit has been defined to be adequate to cover all normal flight conditions across the certified OAT envelope, including high power flight conditions with minimal upper deck cooling. Operating the aircraft at the highest green arc limit is therefore considered a normal flight condition as opposed to a cautionary range that defines a condition where pilot action or time limits is expected. The Updated RFM procedure represents an adequate measure to provide the relevant information to the crew regarding the expected oil temperature behavior in case of OCF failure. At the same time it minimizes the potential consequences resulting from an increasing MGB Oil Temp. Additionally the RFM already requires the MFD PWR PLANT being selected on MFD and all parameters being checked to be within normal operating limits before take-off.

Comment to paragraph 2.2.6 The deployable emergency locator transmitter (DELT) system:

> "It is recommended that the Aircraft manufacturer considers this finding for a review of the DELT system's activation design and procedure, to ensure that the DELT system functions as per the certification requirements."

The ADELT is developed and certified by ADELT OEM (ETSO EASA.210.1160) and installed on the H/C in accordance with applicable Installation Manual.

Following the event, ADLT OEM declared that a full set of tests was performed on the items returned for investigation.

ADLT OEM stated, at the beginning, that the Cockpit controller was not activated by the pilot and that the helicopter ditched at a lower g-level to activate the beacon on impact. According to ADLT OEM information, the memory read back suggested that the water switch filled with water and tried to activate the beacon but failed.

ADLT OEM then suggested that potential lack of electrical power may have resulted in the inability to deploy the beacon. However, the A6-AWN was operated for a significant time prior to the ditching. Both the SIU battery and the high power capacitor responsible for providing the energy to the electro-mechanical release mechanism, and which are part of the ADELT, should have been charged at the time of ditching. According to the ADELT design specifications the built-in SIU battery has a rated capacity of 2 hours, while the beacon release unit should maintain the capability to deploy the CPI for 15 minutes after a complete SIU power down. When the 15 minutes expires, the system will completely disarm. Therefore powering down the A/C would not have had any significant effect on the capability of the CPI to be deployed unless there was a malfunction internal to the ADELT system.

The Final Report finally suggests that the water sensor was not completely submerged, possibly because the floats were inflated prior to contact with the water, thus preventing the filling of the water activated switch cavity.

Based on the above information from ADELT OEM, and the implementation of a[n] float inflation procedure not per RFM, which possibly prevented the complete filling of the switch cavity, as recognized within the final report, the recommendation to review the ADELT reliability and system activation design, part of ETSO EASA.210.1160, should be either assigned to ADELT OEM or disregarded.

Comment to paragraph 4.3.2 The European Aviation Safety Agency (EASA), to:

> "Ensure that Leonardo Helicopters review the main gearbox (MGB) oil temperature warning system with the aim to assess if the flight crew can be alerted in time, when a trend is identified, that the MGB oil temperature is elevating to a critical degree."

The current green arc upper limit has been defined to be adequate to cover all normal flight conditions across the certified OAT envelope, including high power flight conditions with minimal upper deck cooling. Operating the aircraft at the highest green arc limit is therefore considered a normal flight condition as opposed to a cautionary range that defines a condition where pilot action or time limits is expected. The Updated RFM procedure represents an adequate measure to provide the relevant information to the crew regarding the expected oil temperature behavior in case of OCF failure. At the same time it minimizes the potential consequences resulting from an increasing MGB Oil Temp. Additionally the RFM already requires the MFD PWR PLANT being selected on MFD and all parameters being checked to be within normal operating limits before take-off.

Comment to paragraph 4.3.2 The European Aviation Safety Agency (EASA), to:

> "Ensure that Leonardo Helicopters collect fleet data and review the reliability of the automatically deployable emergency locater transmitter (DELT) system, to ensure that the system functions as designed"

The ADELT is developed and certified by ADELT OEM (ETSO EASA.210.1160) and installed on the H/C in accordance with applicable Installation Manual.

Following the event, ADLT OEM declared that a full set of tests was performed on the items returned for investigation.

ADLT OEM stated, at the beginning, that the Cockpit controller was not activated by the pilot and that the helicopter ditched at a lower g-level to activate the beacon on impact. According to ADLT OEM information, the memory read back suggested that the water switch filled with water and tried to activate the beacon but failed.

ADLT OEM then suggested that potential lack of electrical power may have resulted in the inability to deploy the beacon. However, the A6-AWN was operated for a significant time prior to the ditching. Both the SIU battery and the high power capacitor responsible for providing the energy to the electro-mechanical release mechanism, and which are part of the ADELT, should have been charged at the time of ditching. According to the ADELT design specifications the built-in SIU battery has a rated capacity of 2 hours, while the beacon release unit should maintain the capability to deploy the CPI for 15 minutes after a complete SIU power down. When the 15 minutes expires, the system will completely disarm. Therefore powering down the A/C would not have had any significant effect on the capability of the CPI to be deployed unless there was a malfunction internal to the ADELT system.

The Final Report finally suggests that the water sensor was not completely submerged, possibly because the floats were inflated prior to contact with the water, thus preventing the filling of the water activated switch cavity.

Based on the above information from ADELT OEM, and the implementation of a[n] float inflation procedure not per RFM, which possibly prevented the complete filling of the switch cavity, as recognized within the final report, the recommendation to review the ADELT reliability and system activation design, part of ETSO EASA.210.1160, should be either assigned to ADELT OEM or disregarded.

Appendix 8. European Aviation Safety Agency (EASA) Comments to the Final Report

Comment to paragraph 4.3.2 The European Aviation Safety Agency (EASA), to:

> "UNAR-2018-XX3: Ensure that Leonardo Helicopters review the main gearbox (MGB) oil temperature warning system with the aim to introduce a cautionary temperature range to alert the flight crew that the MGB oil temperature is elevating to a critical degree."

Comment: For information, EASA approved an improved RFM procedure supported by analysis and evidences from in-service which allows to fly the helicopter even in case of illumination of the MGB OIL TEMP warning light and require to land as soon as possible only when the MBG OIL Temperature exceeds 150 degree. Furthermore EASA is in the process of reducing the overhaul interval of the MGB cooling fan in order to increase its reliability.

Based on the above the Agency suggests to reconsider the need to issue this SR.

Comment to paragraph 1.6.16 Deployable emergency locator transmitter system

In paragraph 1.6.16, it is said that "Should the flight crew select "Transmit" on the flight deck controller, the system requires a reset for a successful manual or automatic deployment of the beacon." This is further detailed in 1.18.4 where it is said that "An investigation by the Aircraft manufacturer found that a manually selected TRANSMIT on the cockpit selector panel by the flight crew resulted in the beacon inhibition to automatically deploy when the aircraft ditched, unless the system had been subsequently reset by selecting the TEST/RESET button.

A mandatory modification to the system was published as Bollettino Tecnico 139-431, issued on 10 November 2015 by Leonardo Helicopters, which rectified this problem by introducing a modified system interface unit."

It should be added that this issue was known since 2013 and that the Agency published on 17 January 2014 the Airworthiness Directive AD No.: 2014-0019<tel:2014-0019> to address it. This AD has then been superseded by AD No.: 2014-0095<tel:2014-0095> dated 23 April 2014, which has been further revised in Revision 1 on 12 May 2014.

Regarding UNAR-2018-XX2, the performance of deployable ELTs (ELT(DT)) has been recorded in CAA UK CAP 1144 report. This resulted in further EASA actions, such as the release on 12 December 2016 of EASA CM-AS-008<https://www.easa.europa.eu/document-library/product-certification-consultations/easa-cm-008#group-easa-downloads> on Installation of ELTs and the Agency involvement in the EUROCAE Working Group 98 which will result in the publication of EUROCAE ED-62B "Minimum Operational Performance Specification For Aircraft Emergency Locator Transmitters 406 MHz And 121.5 MHz (Optional 243 MHz)" and further update of ETSO-C126b on ELT.