AIRCRAFT ACCIDENT REPORT 1/2018

AAIB
Air Accidents Investigation Branch

Report on the accident to
Sikorsky S-92A, G-WNSR
West Franklin wellhead platform, North Sea
on 28 December 2016

AIRCRAFT ACCIDENT REPORT 1/2018

Air Accidents Investigation Branch

Report on the accident to

Sikorsky S-92A, G-WNSR

West Franklin wellhead platform, North Sea

On 28 December 2016

This report contains facts which have been determined up to the time of publication. This information is published to inform the aviation industry and the public of the general circumstances of accidents and serious incidents.

Published 22 March 2018

Printed in the United Kingdom for the Air Accidents Investigation Branch

Department for Transport
Air Accidents Investigation Branch
Farnborough House
Berkshire Copse Road
Aldershot
Hampshire GU11 2HH

March 2018

The Right Honourable Chris Grayling
Secretary of State for Transport

Dear Secretary of State

I have the honour to submit the report on the circumstances of the accident to Sikorsky S-92A, registration G-WNSR at West Franklin wellhead platform, North Sea on 28 December 2016.

Yours sincerely

Crispin Orr
Chief Inspector of Air Accidents

Intentionally left blank

Contents

Contents

Appendices

GLOSSARY OF ABBREVIATIONS USED IN THIS REPORT

AAD	Advanced Anomaly Detection
AAIB	Air Accidents Investigation Branch
AD	Airworthiness Directive
AFCS	Automatic Flight Control System
AMC	Acceptable Means of Compliance
AMM	Aircraft Maintenance Manual
ANO	Air Navigation Order
APU	Auxiliary power unit
ASB	Alert Service Bulletin
ºC, F	Celsius, Fahrenheit
º/s	degrees per second
CAA	Civil Aviation Authority
CCU	Cockpit Control Unit
CI	Condition Indicator
CSI	Controlled Service Introduction
CVFDR	Cockpit voice and flight data recorder
EASA	European Aviation Safety Agency
FAA	Federal Aviation Administration
ft	feet
GS	Ground Station
HDA	Helideck Assistant
HDWG	Heliport Design Working Group
HHMAG	Helicopter Health Monitoring Advisory Group
HLO	Helicopter Landing Officer
HMI	Human Machine Interface
hPa	hectopascal
hrs	hours (clock time as in 1200 hrs)
HUMS	Health and Usage Monitoring System
ICAO	International Civil Aviation Organization
IFR	Instrument flight rules
IMD	Integrated mechanical diagnosis
KIAS	knots indicated airspeed
kg	kilogram(s)
kHz	kilohertz
kt	knot(s)
lb	pound(s)
m	metre(s)
MB	Megabyte
MGB	Main gearbox
min	minute(s)
mm	millimetres
MOB	Main operating base
MOR	Mandatory Occurrence Report
MPFR	Multi-Purpose Flight Recorder
MR	Main rotor
nm	nautical mile(s)
NTSB	National Transportation Safety Board
OBS	On-Board System
OEM	Original equipment manufacturer
ppm	parts per million
PTFE	Polytetrafluoroethylene
PUQ	Process Utilities Quarters
RFM	Rotorcraft Flight Manual
RT	Radiotelephony
RVHMWG	Rotorcraft VHM Working Group
SAS	Stability Augmentation System
SB	Special Bulletin
SGBA	Sikorsky Ground-Based Application
SOAP	Spectrometric Oil Analysis Programme
TAN	Total acid number
TBO	Time Between Overhaul
TCH	Type Certificate Holders
TGB	Tail rotor gearbox
TR	Tail rotor
TRPCS	Tail rotor pitch change shaft
TSN	Time Since New
VFR	Visual Flight Rules
VHF	Very High Frequency
VHM	Vibration Health Monitoring

Intentionally left blank

Air Accidents Investigation Branch

Aircraft Accident Report No: 1/2018

Registered Owner and Operator:	CHC Scotia Ltd
Aircraft Type:	Sikorsky S-92A
Nationality:	British
Registration:	G-WNSR
Location of accident:	West Franklin wellhead platform, North Sea Latitude: N 56° 57’ 47” Longitude: E 001° 48’ 22”
Date & Time:	28 December 2016 at 0844 hrs (All times in this report are UTC)

Introduction

The Air Accidents Investigation Branch (AAIB) became aware of the accident during the morning of 5 January 2017. In exercise of his powers, the Chief Inspector of Air Accidents ordered an investigation into the accident to be carried out in accordance with the provisions of Regulation EU 996/2010 and the UK Civil Aviation (Investigation of Air Accidents and Incidents) Regulations 1996.

In accordance with established international arrangements, the National Transportation Safety Board (NTSB) of the USA, representing the State of Design and Manufacture of the helicopter, appointed an Accredited Representative to participate in the investigation, supported by advisers from the helicopter manufacturer and the Federal Aviation Administration (FAA). The helicopter operator, the European Aviation Safety Agency (EASA) and the UK Civil Aviation Authority (CAA) also assisted the AAIB.

The sole objective of the investigation of an accident or incident under these Regulations is the prevention of accidents and incidents. It shall not be the purpose of such an investigation to apportion blame or liability.

Summary

The helicopter was being operated from Aberdeen on a contract on behalf of an offshore oil and gas company. On 27 December 2016, during a flight on the day prior to the accident, the Health and Usage Monitoring System (HUMS) recorded vibration data which contained a series of exceedences related to the tail rotor pitch change shaft (TRPCS) bearing. Routine maintenance was carried out overnight which included a download and preliminary analysis of the HUMS data. Whilst an anomaly for tail rotor gearbox (TGB) bearing energy was detected by the maintenance engineer, the exceedences were not identified, in part, due to the way they were presented in the analysis tool; the helicopter was released to service without further investigation.

On 28 December 2016, during the first sector of the day, the HUMS recorded further exceedences but these were not scheduled to be downloaded and reviewed until the helicopter returned to Aberdeen; there was no method in place for either the flight crew or maintenance personnel to be made aware of these further exceedences until then.

During lift off on the second sector, the helicopter suffered an uncommanded right yaw through 45° and the flight crew re-landed. The helicopter was again lifted into the hover and responded normally to the controls, so the event was attributed to a wind effect and the helicopter departed en route.

The five-minute flight to the West Franklin wellhead platform was uneventful but, in the latter stages of landing, yaw control was lost completely and the helicopter yawed to the right. The crew landed the helicopter expeditiously, but heavily, on the helideck. The helicopter continued to rotate to the right and the crew closed the throttles before it came to rest near the edge of the helideck having turned through approximately 180°. There were no injuries.

The investigation determined that the TRPCS bearing had degraded and failed. As a consequence, the tail rotor pitch change servo was damaged resulting in uncommanded and uncontrolled inputs being made to the tail rotor (TR). The manner in which the servo was damaged had not been previously identified.

The investigation identified the following causal factors to the loss of yaw control:

- The TRPCS bearing failed for an undetermined reason.
- The TRPCS bearing failure precipitated damage to the tail rotor pitch control servo.

The investigation identified the following contributory factors:

- Impending failure of the TRPCS bearing was detected by HUMS but was not identified during routine maintenance due to human performance limitations and the design of the HUMS Ground Station (GS) Human Machine Interface (HMI).
- The HUMS GS software in use at the time had a previously-unidentified and undocumented anomaly in the way that data could be viewed by maintenance personnel. The method for viewing data recommended in the manufacturer's user guide was not always used by maintenance personnel.

Despite being unable to determine the exact cause of the bearing failure, the helicopter manufacturer has identified and introduced a number of changes intended to reduce the risk of a recurrence including: introducing HUMS software with enhanced diagnostic capabilities and improved user interfaces, tighter control of bearing manufacturing and assembly tolerances, consistency in lubricating grease quality and its application, and in-service temperature monitoring.

In this report, the AAIB makes two Safety Recommendations concerning the timeliness of acquiring, accessing, analysing and promulgating Vibration Health Monitoring (VHM) data, to enhance the usefulness of VHM data for the timely detection of an impending failure.

Intentionally left blank

Factual information

1.1 History of the flight

1.1.1 Background

The helicopter was being operated on a contract on behalf of an offshore oil and gas company. Regular flights are scheduled for personnel working in the offshore oil and gas industry to and from the offshore installations. Helicopters depart from Aberdeen and typically fly over water to an installation's helideck. For any given flight[1], multiple sectors may be flown between the offshore installations before the helicopter returns to Aberdeen; turnarounds on the helidecks are normally performed with the rotors running. A helicopter may carry out several such flights in a day, and accumulate total daily flight times in excess of ten hours.

The flight, AZ21N, was from Aberdeen to the Elgin-Franklin Offshore Field in the North Sea. The first sector was planned to take passengers to the Elgin Process Utilities Quarters (PUQ). The second sector was transferring personnel to the West Franklin wellhead platform, an unmanned installation, for a temporary stay. The helicopter was then due to return to the Elgin PUQ without passengers, before embarking further passengers for a return sector to Aberdeen.

1.1.2 Pre-flight maintenance

The helicopter was in a hangar during the night of 27-28 December 2016 for a scheduled maintenance programme which included a download of the HUMS data from the previous flights.

On the evening of 27 December 2016, G-WNSR was placed in the charge of a licensed engineer, hereinafter referred to as Engineer A. Prior to working on G-WNSR, Engineer A carried out a daily maintenance check on another helicopter which was already in the hangar. He carried out this work package between 1530 hrs and 1700 hrs. Then, at approximately 1700 hrs, he received a call from Police Scotland regarding an attempted break-in to his garage near his residence in Aberdeen. He was given permission to leave work and meet the police officer on the case at his home address. During this meeting, the police reported that Engineer A appeared upset and showed signs of distress. On return to work one hour later, he said nothing in particular about the incident and his colleagues assumed the matter had been closed.

The shift supervisor then allocated Engineer A to G-WNSR to carry out post-flight maintenance, a 50-hourly check and a HUMS download and review. He was

1 In this report the term 'a flight' is used for a series of sectors between start up and shutdown.

provided with another type rated engineer to assist him with the hangar work. Engineer A's normal routine was to carry out the HUMS download and review the HUMS data first, complete the required scheduled maintenance and then physically check that any safety critical parts of the servicing work had been carried out. Only then would he complete the electronic documentation and paperwork to release the helicopter back to service. He did this in case the HUMS data review influenced any other work required on the helicopter.

Engineer A extracted the HUMS PCMCIA data card (Data Card) from the helicopter and uploaded the card's data on to the helicopter's HUMS Ground Station (GS) situated in an office next to the shift control room. His assistant started the various other tasks on the helicopter and was not involved in the HUMS data analysis. Engineer A completed the analysis using the main diagnostics software tool and found no abnormalities. He then completed the additional diagnostic tools on the HUMS GS designed to detect abnormalities for particular components or sub-systems of the drive train. One of these was for the tail rotor gearbox (TGB) bearing energy, the graph of which did not appear normal to him in that the red horizontal line, indicating the threshold for an alert to be generated, was low down on the y-axis (Figure 9). He had never seen an exceedence before and so was used to the line being near the top with the HUMS data points below, but he was aware, from his HUMS training, that the tools automatically rescaled the axes to display all of the available data.

After a short while attempting to understand why this line was in an unusual position, he brought this to the attention of a colleague, another licensed engineer (Engineer B), who was working on another HUMS GS nearby. Thinking it was probably indicating an exceedence they attempted to zoom in on the graph to identify the magnitude of the exceedence; however, after multiple attempts they could not get the zoom function to work, making them think that the scaling could also be due to a 'software glitch'. Engineer B returned to his own task and thought no more about it. However, Engineer A was uncomfortable with the abnormality and made a mental note to draw it to the attention of his supervisor later, prior to completing the electronic documentation and release to service.

He then completed the scheduled maintenance and physical check of the servicing work on G-WNSR by which time most of that evening's work on the other helicopters was also nearing completion. At about 2345 hrs, he returned to the G-WNSR HUMS GS and completed the electronic documentation and paperwork before releasing G-WNSR back to service. He had, however, forgotten to inform his supervisor of the abnormality with the red line on HUMS related to TGB bearing energy. At about 0100 hrs on 28 December he went off shift and went home.

1.1.3 Pre-flight planning

The accident occurred on the second sector of the four-sector flight from Aberdeen to the Elgin-Franklin Offshore Field in the North Sea (Figure 1). The weather conditions were suitable for the flight and the pre-flight planning carried out at Aberdeen was routine. The flight crew reported at 0600 hrs; the helicopter commander was designated as the handling pilot for the first two sectors.

1.1.4 First sector

The first sector from Aberdeen to the Elgin PUQ was uneventful. The reported wind at the Elgin helideck prior to the approach was from 220° at 20 kt. The approach was made from the east on a track of 270°, passing close to a jack-up rig positioned temporarily to the east of the Elgin helideck. The helicopter landed on a heading of 270°. The passengers disembarked and sufficient fuel was uplifted for the remaining sectors including the return to Aberdeen.

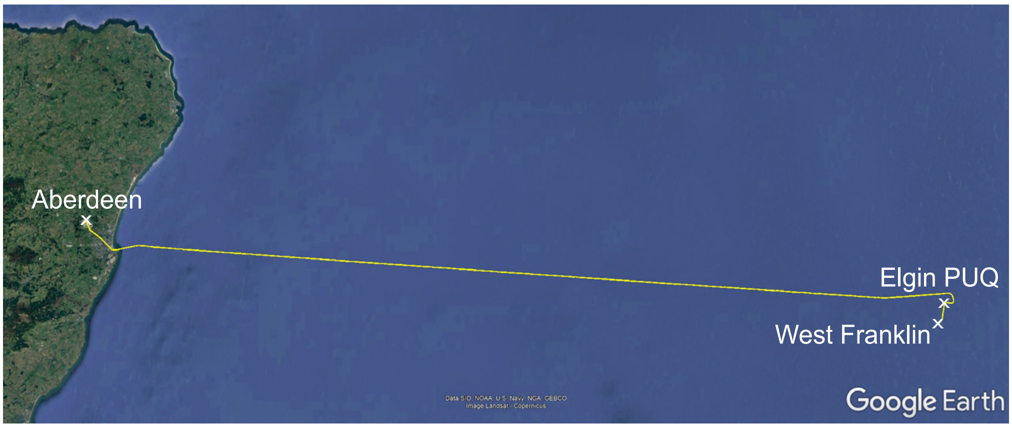


Figure 1

Flight track from Aberdeen to the Elgin PUQ and West Franklin platform

1.1.5 Accident sector

The helicopter, with nine passengers on-board, started to lift off from the Elgin PUQ helideck on a heading of 270°. As it lifted, it yawed unexpectedly to the right through 45°. The commander applied full left yaw pedal, checked the rotation and landed back onto the deck. He told the co-pilot that he used full left pedal but was turning right and both commented that "IT SHOULDN'T DO THAT." The commander lifted off again to check for the correct response to the flight controls; after lift off he applied additional left yaw pedal and the helicopter responded and turned to the left; all control responses appeared normal. The crew briefly discussed what happened and commented on the wind direction; the commander described the event as "VERY STRANGE" and "VERY VERY STRANGE" and the co-pilot concurred. They continued the departure and climbed to 500 ft on course towards the West Franklin wellhead platform, 3.3 nm to the south.

The Helicopter Landing Officer (HLO) and two Helideck Assistants (HDA) on the Elgin helideck observed the lift off, yaw and subsequent touchdown. They watched as the helicopter lifted off again and turned left, commenting that it had appeared to drift backwards with the tail coming close to the handrail on the northern edge of the helideck, before it climbed and flew away to the south.

En route the crew further discussed the event, the commander saying: "I THOUGHT THERE WAS SOMETHING WRONG WITH THE TAIL ROTOR THERE." The co-pilot confirmed with the commander that full left pedal had been used and commented "WELL IT'S A BIT STRANGE BECAUSE WITH ANYTHING THE NOSE SHOULD HAVE COME LEFT……WE'VE GOT THE WIND OFF TO THE LEFT". There was no time for further discussion and the co-pilot contacted the Elgin radio operator and checked the West Franklin helideck status; the HLO confirmed the helideck was available.

The helicopter made a normal approach and deceleration to the West Franklin and crossed over the edge of the helideck. At approximately 4 ft above the helideck, it yawed rapidly to the right, reaching a maximum rate of 30° per second. At the same time it rolled 20° to the left, at which point the left main landing gear contacted the helideck. It continued to yaw to the right on its left mainwheels and nosewheels before the right mainwheels contacted the surface. The co-pilot closed the throttles before the helicopter came to rest on a heading of 041°, having rotated through 187°. The crew shut down and secured the helicopter.

After the helicopter was made secure, the co-pilot responded to a transmission from the Elgin radio operator and confirmed that everyone on-board was okay, but that there was a TR malfunction and the helicopter was unserviceable. The crew and passengers then disembarked; there were no injuries.

1.1.6 Notification of the accident

Regulation (EU) No 996/2010 of The European Parliament and of The Council of 20 October 2010 on the Investigation and Prevention of Accidents and Incidents in Civil Aviation, Article 9, provides an obligation to notify accidents and serious incidents:

> *'Any person involved who has knowledge of the occurrence of an accident or serious incident shall notify without delay the competent safety investigation authority of the State of Occurrence thereof.'*[2]

The accident occurred on 28 December 2016; the helicopter operator raised a Mandatory Occurrence Report (MOR) and transmitted it to the UK CAA the same day. The AAIB became aware of media reports about the event during the morning of 5 January 2017. A copy of the MOR was requested from the CAA and, when it had been reviewed, a Field Investigation was initiated.

The helideck operator, although aware of the event, was not at the time aware that they also held a responsibility for reporting the accident to the AAIB. A notification process was not included in their procedures. Since the accident, the '*Helicopter Occurrence - Communication Process*' procedures for their UK operations have been revised to include a requirement to report an accident or serious incident to the AAIB.

1.2 Injuries to persons

Injuries	Crew	Passengers	Other
Fatal	0	0	0
Serious	0	0	0
Minor/None	2	9	0

1.3 Damage to helicopter

The helicopter sustained minor visible damage which consisted of a small dent, approximately 80 mm long, to the left side outer mainwheel outer rim; the main landing gear was undamaged. Despite the dent, the left side outer mainwheel tyre remained inflated. There was no other visible evidence of external damage to the helicopter. However, later examination revealed damage to the TR pitch control servo (TR servo) and TRPCS bearing.

1.4 Other damage

The helideck surface sustained minor damage to its surface consisting of tyre scuff marks and a small dent within which the aluminium surface had split (Figure 18).

2 The competent safety investigation authority for the United Kingdom is the AAIB.

1.5 Personnel information

1.5.1 Commander

Age:	58 years
Licence:	Airline Transport Pilot's Licence (H)
Aircraft Rating:	AS332/EC225/SK92
Licence Proficiency Check:	Valid to 31 August 2017
Medical Certificate:	Valid to 13 January 2018
Flying Experience:	Total all types - 8,785 hours
	On type - 243 hours
	Last 90 days - 169 hours
	Last 28 days - 54 hours
	Last 24 hours - 3 hours
	Previous rest period 18 hours 40 mins

The commander had been employed by the operator for 11 years. He flew the AS332 and the EC 225 helicopters on North Sea operations until August 2016 when he completed a type conversion to the S-92A helicopter. He had flown to the Elgin PUQ and the West Franklin on other occasions.

1.5.2 Co-pilot

Age:	37 years
Licence:	Airline Transport Pilot's Licence (H)
Aircraft Rating:	EC135/SK92
Licence Proficiency Check:	Valid to 30 June 2017
Medical Certificate:	Valid to 24 May 2017
Flying Experience:	Total all types - 4,490 hours
	On type - 1,400 hours
	Last 90 days - 134 hours
	Last 28 days - 47 hours
	Last 24 hours - 5 hours
	Previous rest period 17 hours 05 mins

The co-pilot joined the operator in May 2014 and completed conversion training to the S-92A in June 2014. He had flown to the Elgin PUQ and the West Franklin on other occasions.

1.5.3 Flight crew interviews

1.5.3.1 Commander

The commander reported that, on departure from the Elgin helideck, he had lifted out of wind (crosswind from the left) into the hover. He commented that a wind from the left is less favourable for the S-92A and that, on lift off, the helicopter felt as though it was being buffeted, which he attributed as due possibly to the effect of being near the edge of the helideck. He felt the helicopter turning to the right, used full left pedal to correct it and then landed back on the helideck.

He reported that he had discussed with the co-pilot what happened and put it down to an effect of the buffeting wind. He lifted the helicopter back into the hover and turned to the left to face into wind; it all felt normal. He then positioned forward to the edge of the deck and departed towards the West Franklin. On approach, as the helicopter crossed over the edge of the West Franklin helideck from the north, he needed to use an increasing amount of left pedal. Then suddenly the helicopter yawed right and, even with full left pedal, he could not stop it so he ‘dived’ onto the helideck. He commented that it had felt uncontrollable immediately, and was unlike the earlier yaw event on the Elgin when he had felt he was able to maintain control.

1.5.3.2 Co-pilot

The co-pilot noted that the approach to the Elgin PUQ helideck could be tricky due to the other installations nearby, together with the position of the helideck and superstructure. He commented that the wind could roll up onto the helideck and may also come round from behind. He reported that the approach from the east and the landing were both normal. The yaw on lift off from the Elgin he perceived as being through about 20°, and which he thought may have been as a result of a misjudgement of the wind conditions.

He reported that the approach to the West Franklin had appeared normal until the helicopter yawed to the right and the commander made an exclamation and put the helicopter down. The rotation to the right continued after touchdown and he was concerned that the helicopter might fall off the helideck; he was on the outside of the turn and unable to see the edge. Therefore, he delayed closing the throttles until after he was sure they were safely on the deck. After a short delay to regain his composure, he responded to a call from the Elgin radio operator.

1.5.4 Licensed engineers

Engineer A held a valid Part 66, A and B1 licence with an S-92 type rating and authorisation certificate issued by the operator. He joined the operator in January 2015 as a helicopter maintenance engineer with previous single and multi-engine gas turbine helicopter experience. After joining, he underwent the operator's multi-point competency check which he completed and was signed off in July 2015. During his initial training, he carried out a Human Factors Refresher Course and in September 2015, he successfully completed the S-92 Integrated Mechanical Diagnostics Health and Usage Monitoring System (IMD-HUMS) course.

Following the accident, at about 1500 hrs on 28 December 2016, Engineer A was contacted by the operator's managerial staff and informed that G-WNSR had suffered a serious TR problem in-flight, as it was about to land, and was now unserviceable on a gas platform. He was asked to come in to work as soon as possible to discuss the matter. This he did and whilst on the journey to work, he realised what the problem might be and its relationship to the abnormality with the energy tool he had seen the night before. He arrived at work upset and distressed, realising his mistake, recalling that he had completely forgotten to inform his supervisor of the HUMS graph anomaly the night before as he had intended. He immediately informed the managerial staff what had happened but could offer no explanation as to why the matter had 'slipped his mind'.

Engineer B also held a Part 66, A and B1 licence with an S-92 type rating.

1.5.5 Passenger statements

The nine passengers provided statements concerning their recollection of events during the flight. Eight passengers commented on the first attempt at takeoff from the Elgin, describing variously a "snatch", "veer", "tilt", "swing", "cant", and "loss of control" before re-landing.

With the exception of a passenger who occupied the rear seat in the cabin, the passengers described the subsequent lift off and flight as normal until just before landing on the West Franklin when they noticed "rocking", a "loss of control" and a "hard" landing.

The passenger at the rear of the cabin had heard and felt a '"knock" from somewhere behind him when the helicopter was in the hover after the second lift off from the Elgin and on several occasions during the sector to the West Franklin.

1.6 Aircraft information

1.6.1 General

Manufacturer:	Sikorsky
Type:	S-92A
Aircraft Serial No:	920250
Year of manufacture:	2014
Number and type of engines:	2 General Electric Co CT7-8A turboshaft engines
Total airframe hours:	1,776 hours
Total airframe landings:	2,012 landings
Airworthiness Review Certificate:	Valid to 27 April 2017

1.6.2 Helicopter general description

The Sikorsky S-92A is a twin-engine multi-mission large utility helicopter of metal and composite construction. The helicopter's maximum certified weight is 12,020 kg. It is designed to carry up to 19 passengers and is certified for dual-pilot VFR and IFR, day and night operations. As well as passenger transport, the S-92A is designed to carry out cargo, external lift, medevac and search and rescue operations. At the time of the accident G-WNSR (Figure 2) was configured for 19 passengers.

Figure 2

G-WNSR (photograph courtesy of CHC Scotia Ltd)

1.6.3 Helicopter structure

The fuselage is aluminium monocoque construction strengthened by stringers and longerons. The upper areas of the helicopter, cowlings, fairings and cockpit nose structure are of lightweight composite construction.

1.6.4 Landing gear

The helicopter is fitted with retractable landing gear consisting of double-wheel air/oil shock absorbers. The main landing gear is installed in the sponsons each side of the fuselage just aft of the cabin area, and the castering nosewheel within a wheel bay beneath the cockpit. The main landing gear struts are fitted with a frangible panel at the top of the outer cylinder. If the vertical landing loads exceed the shock absorbing capability of the air/oil component within the strut, the inner cylinder is designed to rupture the frangible panel, absorbing additional energy in the process. The landing gear is fitted with forged aluminium alloy split-rim wheels with pneumatic tubeless tyres.

The main and nose landing gears are aluminium cross-shaped forgings with their pivot points located at the ends of the arms of the cross-piece. The cross-pieces are reinforced by bracing struts extending at a 45° angle from the top of the strut down to the end of the cross-piece at the pivot point. The cross-pieces' length is quite large in proportion to the length of the main gear struts to give the pivot points at the end of the cross-pieces a mechanical advantage when absorbing lateral landing loads.

The landing gear is extended and retracted by hydraulic actuators powered from the utility hydraulic system. The actuators also have a nitrogen charge emergency blow-down system built in.

The nosewheel is non-steerable but its design allows for a 360° caster and has a damper fitted to prevent nosewheel shimmy during taxiing. Differential braking and TR thrust are used to steer the helicopter during taxiing.

The lower castering section of the nose landing gear is fitted with tow bar linkages for ground handling.

1.6.5 Power plants and transmission

The helicopter is powered by two General Electric Co CT7-8A turboshaft engines delivering 2,520 HP connected to the main rotor gearbox (MGB) via two input modules which contain the primary reduction gearboxes and freewheel units. The TR drive shaft is in four sections supported by hanger bearings and flexible couplings. An intermediate gearbox is connected between the third and fourth section of the shaft. It reduces the shaft rpm and changes the plane of rotation. The fourth section of the shaft drives the TGB located at the top of the TR pylon. Shaft rpm is further reduced by the TGB which is canted at 20° and produces a small percentage of the lift component.

The TGB contains its own lubricating oil and is splash-lubricated by rotation of its internal components. The TRPCS bearing is lubricated on assembly by grease held in place and separated from the gearbox oil by polytetrafluoroethylene (PTFE) seals which are held in place by snap rings. The TGB oil has a 625-hour life which can be extended by 100% providing a Spectrometric Oil Analysis Programme (SOAP) sampling process is in place. The TRPCS has a 1,250-hour life at which point it is removed and returned to the original equipment manufacturer (OEM) for rework.

1.6.6 Main rotor (MR) and tail rotor (TR) assemblies

The MR system consists of four blades attached to a fully articulated MR hub. The rotor head assembly consists of a titanium hub which incorporates blade dampers, blade retention yokes, elastomeric bearings, droop stops and flap restrainers. The rotor head is also fitted with a vibration absorber which works in conjunction with an active vibration cancellation system. The MR blades are of a composite construction around a graphite and fibreglass structural spar. A Nomex honeycomb core is wrapped in a fibreglass skin. Mesh lightning protection is built-in and the leading edges are protected by titanium and nickel anti-abrasion strips.

The TR hub consists of a titanium head fitted with four TR blades of graphite and fibreglass construction. The blade assembly includes an inboard torque tube section, an outboard aerofoil section and pitch horn. The head is fitted with a four-arm pitch change beam connected to the TRPCS that imparts pitch changes into the blades via links to the pitch horns of each blade. The hub and blades are a bearing-less fully rigid system with pitch change of the blade being accomplished by the twisting of a specially-designed graphite flexbeam within the blade enclosed within a torque tube and cuff. The flexbeam also reacts flapping and dragging loads and is supported within the torque tube and cuff by elastomeric bearings. The torque tube carries the twisting loads into the blade from the pitch horn.

1.6.7 Flying controls

The cyclic and collective flying control systems consist of a series of rods, levers and bellcranks which transmit pilot and co-pilot inputs into a mixing unit.

Outputs from the mixing unit are transmitted to the MR and TR hydraulic servos via rods and cables. The MR forward, left and right servos consist of tandem independent hydraulic actuators powered by the No 1 and No 2 hydraulic systems, and are mounted on the MGB and connected to the swashplate. The swashplate fixed and rotating star assembly transmits inputs into the MR blade pitch change rods.

Yaw outputs from the mixing unit are transmitted via cables along the top of the tail cone and into the TR pylon to the TR servo attached to the back of the TGB. The linear non-rotating inputs from the servo are transferred into the rotating TRPCS bearing assembly and from there out to the TR pitch change beam.

The yaw cable system inputs are translated into a push-pull to the valves on the TR servo by a TR quadrant. A system of opposing springs is built into the quadrant which allow a continuous and normal response to yaw pedal inputs in the event of one of the cables breaking.

In the unlikely event of both cables failing, the helicopter will not respond to yaw inputs, but a spring built into the TR servo will set a TR thrust condition which will allow trimmed flight between 30 to 150 KIAS depending on atmospheric conditions and gross weight.

1.6.8 TR servo

The TR servo is attached to the TGB and imparts linear inputs into the rotating TR four-arm pitch change beam via the TRPCS (Figure 3) within the bore of the TR crown wheel shaft.

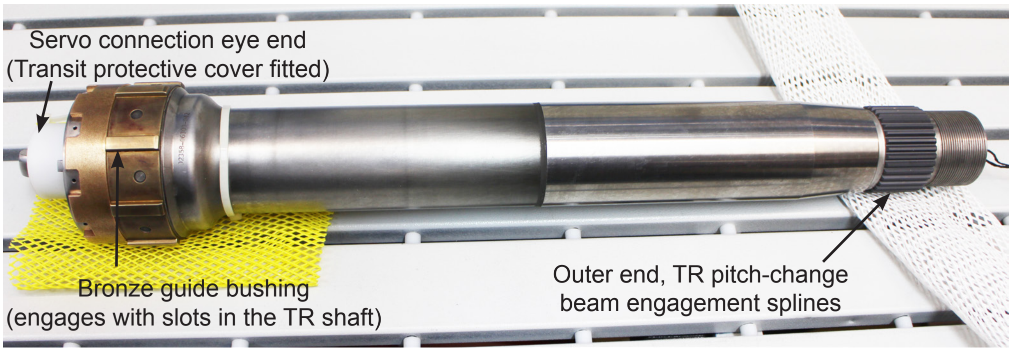


Figure 3

TRPCS

The non-rotating servo output rod is connected to the rotating portion of the TRPCS by a double row self-aligning barrel bearing. Each race of the bearing consists of a set of barrel-shaped rollers running on inner and outer races inclined outwards from each other. This allows push and pull loads to be imparted into the TRPCS. The outer races are mounted in a phosphor bronze carrier which engages in grooves cut into the crown wheel shaft to ensure that the pitch change beam rotates with the TR crown wheel shaft and stays in alignment with its corresponding blade.

The dynamic interaction between the inner and outer races and the rollers and their cages is complex. Ideally, the path the rollers follow in the races and the alignment of each roller should be geometrically perfect. However, in practice the rollers are allowed, by virtue of including some end float, to move axially and laterally within their cage and follow slightly differing paths in their races. The barrel-shaped curved surface of the roller creates differing diameters from the middle of the roller outwards towards each end. The inner and outer race surfaces are curved to match the shape of the roller which naturally causes it to follow its track. Despite this, if a roller runs slightly out of track or oscillates, micro-skidding can occur as the varying diameters present differing circumferential speeds between the roller and its race. In the worst case, constant skidding can lead to sustained heating in the roller or race, lubricant damage and eventual bearing degradation.

The TRPCS bearing location within a TGB cross-section is shown in green in Figure 4.

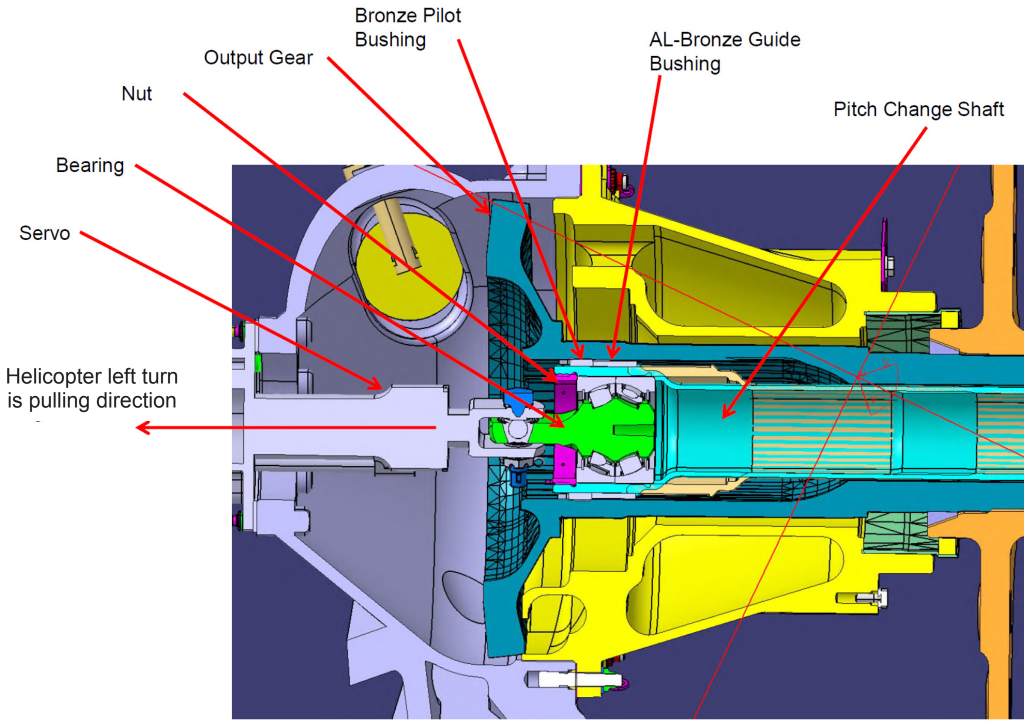


Figure 4

TGB cross-section

The TR servo consists of two pistons on the same shaft, each piston being powered independently by the No 1 and No 2 hydraulic systems. Inputs from the yaw control system act on a 'walking beam' which is mounted on a pivot on the outer end of the servo piston shaft. The walking beam is y-shaped and connected to two servo valves, one for each hydraulic system, which are operated simultaneously on movement of the walking beam. Yaw inputs cause the walking beam to pivot and, in turn, this movement opens the servo valves to allow hydraulic pressure to the servo pistons. The servo moves inwards or outwards, depending on the yaw direction required, and carries with it the walking beam pivot. On cessation of the input from the yaw system the pivot location effectively transfers to the control rod connection, leaving the piston shaft to continue to move until the servo valves are recentralised by the walking beam. Figure 5 shows the TR servo and walking beam assembly. The range of movement of the servo is approximately 3.5 inches (89 mm). The servo piston assembly is prevented from rotating by means of a tab which engages with an anti-rotation slot on the outer casing of the servo.

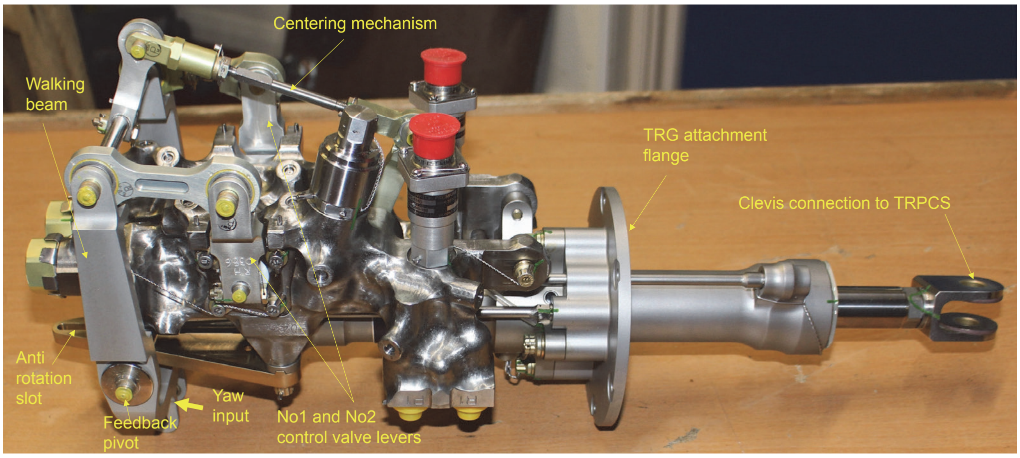


Figure 5

TR servo walking beam and valve linkages

1.6.9 Trim, Automatic Flight Control System (AFCS) and Stability Augmentation System (SAS)

The helicopter is equipped with a four-axis trim system to improve the in-flight handling qualities and allow for hands-off flying. Electromechanical trim motors are fitted to the yaw, pitch, roll and collective flying control runs above the cockpit and have full-range authority to move the control rods. During operation they are part of the outer loop control system so the pilot's flight controls move in harmony with trim inputs. In addition, SAS servos are fitted to the control runs between the trim motors and the mixer unit. There are two sets of hydraulic SAS servos for each axis and they are electrically controlled by two separate processors within the AFCS computer. The SAS servos are part of the inner loop control system so the cyclic and collective controls in the cockpit do not move during operation. In addition, boost servos are fitted to each set of SAS servos to reduce the force required to move the controls through the servo units and limit feedback.

1.6.10 Four-axis flying control interconnections

The mixing unit reduces the pilot workload by automatically compensating for collective, yaw, pitch and roll secondary effects to the various combinations of control inputs as follows:

- Collective to pitch - Compensates for MR downwash over the stabiliser and applies a forward pitch input as the collective is increased.
- Collective to yaw - Provides a proportional anti-torque control input to the TR to increase the pitch of the TR blades as the collective is raised.
- Collective to roll - Imparts a left roll input to the MR with increased collective to counter the drift tendency.
- Yaw to pitch - Compensates for the increases in the vertical TR thrust component due to its 20° in-built cant. It applies a nose-up pitch to prevent the nose-down resultant with left pedal input.

1.6.11 Maintenance history

G-WNSR was maintained, in accordance with the manufacturer's recommendations and authorised Aircraft Maintenance Manual (AMM), by the operator as a Part 145 organisation. G-WNSR's Technical Log recorded all of the recent maintenance and servicing work carried out. The relevant activity on the TR and associated components was as follows:

The TRPCS Pt No 92358-06303-042, Serial Number B063-00403, was installed in June 2016 at 1,227 airframe hours to replace the originally-fitted life-expired shaft. During this work, the output shaft seal was found to be worn and was replaced at the same time. The majority of subsequent work carried out on the TGB, TR servo and TRPCS was routine servicing and inspection.

A package of work commenced on 8 October 2016 at 1,568 airframe hours. The TGB lubricating oil sight glass was dirty, to the extent that the oil level could not be determined, so the transparency was replaced. Additionally, the inspection found the TR servo eye end, connected to the TRPCS bearing, to be worn. The TR servo assembly was replaced to rectify the problem. A borescope inspection was carried out eight flying hours after installation and there was no recorded abnormality.

On the evening of 27 December, post-flight inspections and a routine 50-hourly check were carried out on G-WNSR (paragraph 1.1.2 refers).

1.6.11.1 TRPCS history

TRPCS Serial Number B063-00403 was originally fitted new to S-92A Serial Number 920241 (G-WNSL) on 9 April 2014. It was removed for overhaul on 6 December 2015 having accrued 1,231.43 hours Time Since New (TSN) of its 1,250-hour overhaul life. It was overhauled by the manufacturer and released to service on 21 April 2016. It was fitted to G-WNSR on 25 June 2016 at 1,227 airframe hours.

The TRPCS had a routine 250-hour inspection at 1,571.83 airframe hours and at the time of the accident had accrued 548 hours Time Since Overhaul (TSO), a total of 1,779.45 hours TSN.

1.6.11.2 Oil sampling history

The lubricating oil in the TGB of G-WNSR was subject to SOAP, although this was not required by the helicopter manufacturer. The TRPCS bearing is pre-greased and not washed by the TGB lubricating oil unless the bearing seals are damaged. Therefore SOAP would not be expected to detect a defect within the bearing.

Although a SOAP report contains a lot of detailed information, the operator was using only the oil viscosity, total acid number (TAN) and water content results, in accordance with the procedure set out in AMM Task 65-22-00-200-001. This was to ensure the oil condition did not compromise the authorised extension of the oil in-service life from 625 hours to 1,250 hours.

The SOAP results were produced on a printout chart detailing the constituents of the oil and the metallic content in parts per million (ppm). There were four samples taken since the TRPCS, Serial Number B063-00403, was fitted. The first of these was a routine sample taken on 27 June 2016 at 1,232.40 airframe hours, about five hours after the TRPCS had been fitted. This sample was normal other than the copper content had triggered an Advanced Warning[3], annotated red, on the printout with a figure of 5.3 ppm.

3 The ‘trigger’ thresholds are based on a comparison of the various constituent levels recorded in the data set against this gearbox’s previous figures and those of the other gearboxes in the fleet.

The second sample was taken at 1,568 airframe hours on 8 October 2016. The copper had returned to below-threshold levels at 0.7 ppm, but this time the silver content had risen and triggered an Advanced Warning with 3.2 ppm. In addition, the magnesium content had also risen and triggered an Early Warning, annotated amber, at 3.0 ppm.

The third sample was taken on 18 October 2016. Although the flying hours at the time the sample was taken are not recorded, it appears to coincide with a TGB oil change and the level sight glass replacement two days earlier. The results of this sample showed the silver content had dropped to normal, but the copper content had risen again to trigger an Advanced Warning at 6.0 ppm. The magnesium content had risen further to 6.8 ppm and also triggered an Early Warning, annotated amber.

The fourth sample was taken after the accident and triggered Advanced Warnings for the majority of the metallic constituents with iron, copper, silver and silicon at very high levels. For example, the iron content had risen approximately 20 times its normal level and silver approximately 40 times its normal level.

The first three sample results for oil viscosity, TAN and water content showed the oil to be within the limits set out in the AMM, however the fourth sample taken after the accident showed that whilst the oil viscosity and TAN remained in limits the water content had risen out of limits.

1.6.12 Emergency procedures

TR malfunctions and associated emergency procedures are referenced in the manufacturer's Rotorcraft Flight Manual (RFM). Symptoms of an '*uncommanded sharp right yaw*' or '*yaw/spin*', not responsive to pedal inputs, are described for two malfunctions: '*LOSS OF TAIL ROTOR THRUST IN FORWARD FLIGHT*' and '*LOSS OF TAIL ROTOR THRUST IN A HOVER*'. The actions required in a hover are to hold level, move the throttles to the STOP position and use collective pitch to cushion the landing. Symptoms described for '*TAIL ROTOR CONTROL SYSTEM MALFUNCTIONS*' are: binding or restricted pedal movement or little or no response to inputs, and procedures are provided to manage the failure as a fixed pitch condition. A failure mode resulting in a complete loss of control of the TR, as experienced during the landing on the West Franklin, is not addressed.

The operator's Emergency Checklist provided emergency procedures related to the TR. There were no references to '*uncommanded sharp right yaw*' but there were references to '*uncontrolled yaw*' entitled: '*TAIL ROTOR DRIVE FAILURE*' *and* '*TAIL ROTOR CONTROL FAILURE IN HOVER*'. Both failures required an immediate landing; the '*TAIL ROTOR DRIVE FAILURE*' actions equated to the RFM actions for '*LOSS OF TAIL ROTOR THRUST IN A HOVER*'.

In June 2017, the operator published revised titles, symptoms and procedures related to TR malfunctions in its Emergency Checklist. The titles and symptoms now more closely reflect those in the RFM. The associated procedures differ from those in the RFM and reflect the operator's preferences for its specific operations in the offshore environment.

The pertinent RFM and Emergency Checklist extracts are shown in Appendix A.

1.7 Meteorological information

The meteorological observation from the Elgin PUQ before G-WNSR landed on the Elgin was: surface wind from 220° at 20 kt, visibility 10 km or greater, broken cloud at 2,200 ft, temperature 8°C, dewpoint 3°C and pressure 1038 hPa. No lightning activity was recorded in the area.

An Emergency Response and Rescue Vessel was on station for the landing on the West Franklin and reported the following weather conditions: wind from 250° at 20 kt to 25 kt, sea 2.5 m, sky overcast and visibility 10 nm.

1.8 Aids to navigation

Not applicable.

1.9 Communications

The Elgin PUQ helideck was manned and had radiotelephony (RT) communications which were recorded.

The West Franklin helideck was not manned and operations there were overseen by the Elgin radio operator via a video link and RT communication.

1.10 Aerodrome information

The Elgin installation is a manned platform designed to receive and process hydrocarbons from the West Franklin and Elgin wellheads before it is piped ashore. The West Franklin gas platform is an unmanned wellhead natural gas extraction facility in the Elgin field oil and gas area of the North Sea, situated 125 nm east of Aberdeen. The West Franklin platform stands in 93 m of water and is 3.3 nm away from the Elgin PUQ platform. At the time of the accident, there were two jack-up rigs positioned alongside the Elgin Wellhead Platforms: the Galaxy 1 and Prospector 5, detailed in Temporary Limitations Notice 15-2016.

1.10.1 Elgin PUQ helideck

The Elgin PUQ is a jack-up rig of steel construction, standing in 93 m of water and is situated 128 nm east of Aberdeen. It is connected to the Elgin wellhead platform by a 90 m long bridge. It is fitted with a Category 'F' (fixed) aluminium helideck supported on an aluminium frame designed for helicopter operations with aircraft up to maximum all up weight of 15 tonnes. The helideck is 51 m above the water and is circular in shape marked out to give a landing spot 'D' (MR diameter) value of 22.8 m. It is fitted with safety netting and has a helicopter refuelling and power supply capability. Its Helicopter Landing Area Certificate was valid on 28 December 2016 and was renewed on 9 January 2017 in accordance with CAP 437. There are notes on the certificate which draw attention to possible turbulence from the turbine exhaust and exhaust stack and to the presence of various fixtures and fittings around the edge of the helideck. It also makes note of a parking area extending from the south-east sector of the helideck on which shuttle aircraft or containers may be situated. The Helideck Landing Area Certificate, Helideck Information Plate and Temporary Limitations Notice 15-2016 are shown in Appendix B.

1.10.2 West Franklin helideck

The platform is predominantly of steel construction and is fitted with an aluminium helideck supported on an aluminium frame designed for helicopter operations with aircraft up to maximum all up weight of 12.8 tonnes. The helideck is 43 m above the water, octagonal in shape and is marked out to give a landing spot 'D' value of 21 m. It is fitted with safety netting around its edges. The landing spot is marked out with a flush lighting system built into the helideck surface. The aluminium surface of the helideck also has parallel rows of serrated ridges attached which are approximately 2 mm high to provide a non-slip surface over the helideck. The flight deck is certified in accordance with CAP 437 with a valid Helicopter Landing Area Certificate issued on 14 November 2016. The helideck is fitted with a remotely controlled firefighting capability. The platform is fitted with a crane designed for heavy maintenance operations and has reach to the flight deck when required. Although unmanned, the platform is fitted with shelter, communications and provisions for use in the event of personnel having to remain on the platform for prolonged periods, ie overnight. The Helideck Landing Area Certificate and Helideck Information Plate are shown in Appendix C.

1.11 Recorded information

1.11.1 Introduction

G-WNSR was equipped with a Curtiss-Wright (Penny & Giles) Multi-Purpose Flight Recorder (MPFR), which recorded over 45 hours of data and 2 hours of audio, covering the period up to and including the accident. The audio recordings include the commander and co-pilot's communications, radio transmissions, passenger announcements and audio from the cockpit area microphone. G-WNSR was also equipped with a HUMS to meet the EASA VHM regulatory requirements. The HUMS data provided snapshots of the health of components in the helicopter's drive train for the period up to and including the accident flight. CCTV recordings from both helidecks were also reviewed to corroborate witness evidence.

1.11.2 Flight data

The MPFR data indicated that G-WNSR lifted off from Aberdeen at 0722 hrs and touched down on the Elgin PUQ at 0820 hrs. It stayed on the Elgin with rotors running before lifting off briefly into the hover (yaw event) at 0842:50 hrs and departed en route about 30 seconds later for the five-minute flight to the West Franklin platform, where it touched down at 0848 hrs.

1.11.2.1 Elgin PUQ yaw event and lift off

Figure 6 is a plot of the salient flight data parameters for the Elgin yaw event and lift off for the transit to West Franklin, starting with the helicopter on the helideck. In summary, the data indicates the following:

UTC (hh:mm:ss)	Event
08:42:47	Left pedal input made (helicopter on helideck – heading 270°).
08:42:49	Helicopter lifts off, rolls left and yaws right.
08:42:52	Full left pedal input, helicopter yawing 10°/s to the right.
08:42:53	Peak yaw rate of 12.5°/s recorded.
08:42:55	Collective reduced (then helicopter back on helideck – heading now 315° having yawed right 45°).
08:43:08.5	Collective lever starts to raise.
08:43:18	Helicopter lifts to hover and starts to yaw left.
08:43:20.5	Helicopter departs (for transit to West Franklin).

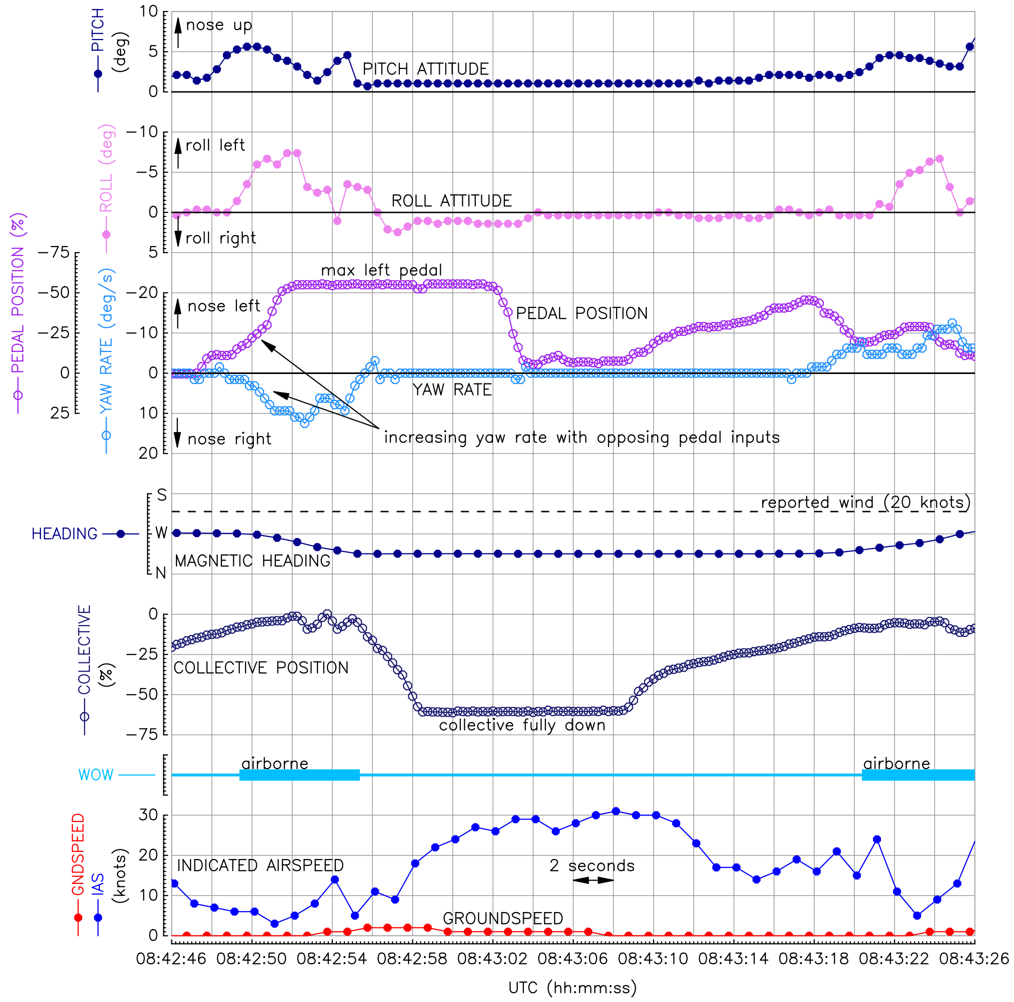


Figure 6

Salient parameters during the Elgin yaw event and lift off for transit to the West Franklin

1.11.2.2 West Franklin landing

Figure 7 is a plot of the salient flight data parameters for the landing on the West Franklin platform starting with the helicopter manoeuvring over the helideck just prior to touchdown. Note that the flight recorder does not record data associated with the use or status of the landing gear wheel brakes. In summary, the data indicates the following:

UTC (hh:mm:ss)	Event
08:47:44	Yaw rate nominally zero with left pedal held at half pedal.
08:47:47	Left pedal input reduced and helicopter starts to yaw left.
08:47:49	Half left pedal input made but helicopter starts veering to the right and rolling to the left – helicopter heading 214°.
08:47:50	Max right yaw rate of 30°/s recorded before reducing as max left pedal inputs made.
08:47:50.2	Helicopter touches down (on left landing gear) rolled 13° to left – maximum left roll of 20° recorded less than half a second later.
08:47:52	Helicopter touches down on right landing gear - yaw rate about 20°/s with max left pedal inputs still being made.
08:47:55	Left pedal inputs reduce.
08:47:57	Pedals are nominally zero - right yaw rate reduces.
08:47:58	Rotor speed starts to reduce.
08:48:01.5	End of recorded data – helicopter final heading of 041° having rotated through 187° since loss of yaw control.

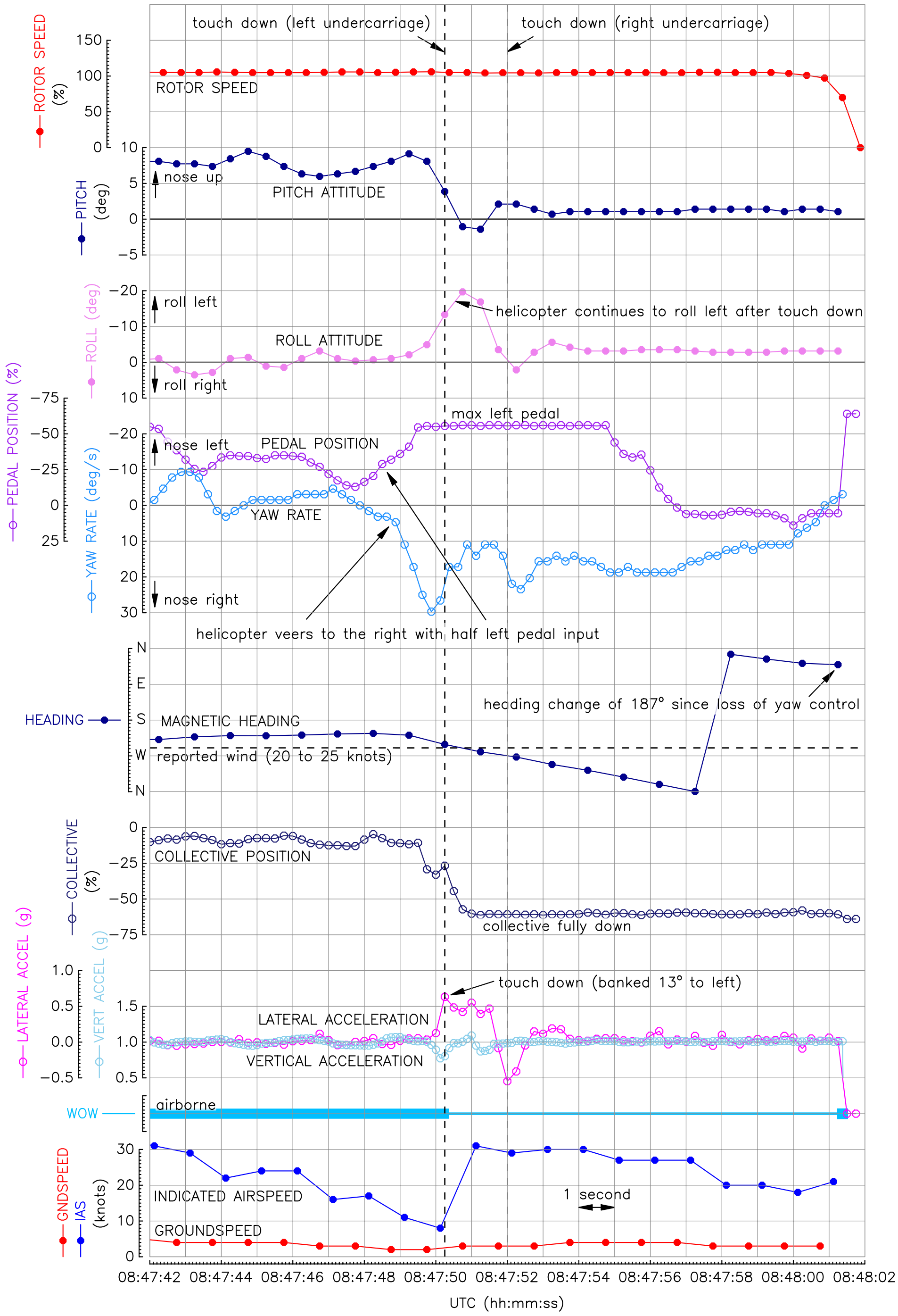


Figure 7

Recorded flight data for the West Franklin landing

1.11.3 Helicopter Vibration Health Monitoring

Helicopters, unlike fixed wing aircraft, fly by virtue of a mechanical system rather than a structure. As such, the mechanism has a number of single load paths that form the rotor and transmission system, that make them potentially more vulnerable to catastrophic failures. VHM was introduced nearly 30 years ago to provide an automatic means of monitoring the health of these mechanical components.

A HUMS is the application of VHM in an operational context providing data for trend analysis and condition-based maintenance.

1.11.3.1 VHM regulatory requirements

On 1 June 1999, the CAA issued Additional Airworthiness Directive 001-05-99 that made the installation and use of VHM mandatory for UK registered helicopters issued with a Certificate of Airworthiness in the transport category and having a maximum approved seating configuration of more than nine. The acceptable means of compliance with 001-05-99 was originally specified in Civil Aviation Publication (CAP) 693; however, this did not give detailed guidance for VHM system design in order to achieve effective health monitoring. The CAA replaced 001-05-99, a design regulation, with a requirement in the Air Navigation Order (ANO), thus making the requirement for VHM an operational requirement. Accordingly, this moved the responsibility for compliance with VHM regulations from the Type Certificate Holders (TCH) to the operators. CAP 753 '*Helicopter Vibration Health Monitoring*', introduced in September 2010, became the acceptable means of compliance with the new operational requirement.

Following their formation in 2003, the EASA reviewed the requirements for VHM. They concluded that the National Aviation Authorities should, where necessary, introduce national VHM requirements for 'demanding' operations, such as those operations in the North Sea.

More recently and presently only applicable to new VHM system designs, the publication of EASA CS-29 (Certification Specifications for Large Rotorcraft) Amendment 3 dated December 2012, introduced CS 29.1465 Vibration Health Monitoring into the regulation. The requirement was developed by an EASA/FAA/Industry Rotorcraft VHM Working Group (RVHMWG) picking up on work that had been started by the Helicopter Health Monitoring Advisory Group (HHMAG). The requirement is, however, unique to CS-29 and does not feature in the FAA's equivalent regulations for large rotorcraft, FAR-29.

EASA issued a Notification of a Proposal to issue a Certification Memorandum (CM-S-012) on 9 November 2017 that will require operators to verify that VHM system performance is compliant with an appropriate standard, where required for SPA.HOFO.155 (Helicopter Offshore Operations).

For the S-92A the VHM requirements are met by the use of HUMS.

1.11.3.2 VHM alert threshold philosophy

Gradual wear and degradation of the helicopter's principal mechanical systems is detected through Condition Indicators (CIs) which are calculated from data from vibration sensors on critical areas such as the rotors, engines, gearboxes and drive shafts.

VHM requires the design organisation to set threshold values for each CI above which an alert is generated. Whilst the thresholds need to be set above the normal vibration levels, if they are set too low then the rate of false alarms can result in an unacceptable maintenance burden. It is normal for the HUMS manufacturer or TCH to review and, if necessary, revise the threshold levels, and introduce new alerts, as a result of knowledge gained from statistical analysis of vibration levels across the fleet.

The guidance to operators given in CAP 753 states that the period between the successful download and assessment of any primary VHM indicator, used for monitoring the engine and rotor drive system components, should not exceed 25 flying hours. This interval is reduced to ten flying hours for components or indicators that require 'close monitoring' where, for example, an indicator value has exceeded a 'maintenance action' threshold or shows signs which warrant increased attention. As previously stated, ten flying hours is not atypical of a complete day's flying for North Sea helicopter operations.

The Acceptable Means of Compliance (AMC) to CS 29.1465 states in paragraph n. (Performance Criteria) that:

> *'(1) Signal Acquisition*
>
> *The applicant for VHM system certification should specify the rate of acquisition of data sets for defect diagnostics in consistent flight regimes.*
>
> *As a target, the total data set acquired in a flight should be sufficient for complete and reliable diagnostics to be produced for every flight above a defined duration in stabilised conditions. As a minimum, at least the data set for all components should be*

> *automatically obtained on each flight of greater than 30 minutes in stabilised conditions without the need for in-flight pilot action. For operations which do not contain periods of stabilised operation of greater than 30 minutes, alternative procedures need to be incorporated to ensure that the total data set is recorded within a specified number of flying hours related to the minimum adequate frequency of data collection determined under AMC 29.1465(e)(2), and in any case no longer than 25 flying hours.*
>
> *Where subsystem performance is critical or relied upon to achieve the quoted defect probability of detection or False Alert rate, such as sensor accuracy, dynamic range or bandwidth, then this should be quoted.'*

Specifically, the AMC to 29.1465(e)(2) states in bullet (ii) that:

> *'The data acquired from the vibration should be automatically gathered in specifically defined regimes at an appropriate rate and quantity for VHM signal processing to produce robust data for defect detection.'*

The AMC to CS 29.1465 paragraph n. then continues:

> *'(2) Data transfer and Storage Capability*
>
> *The VHM defect status data should be capable of being downloaded during rotors running turnarounds.*
>
> *All the data sets acquired should be stored until successfully transferred to the Ground-Based System. The storage capacity should not be less than 25 flying hours.*
>
> *The applicant should describe the maximum interval between data downloads for which the system memory capacity is not exceeded.*
>
> *In the event that a complete data set is not recorded, the data transfer process should be capable of downloading a partial data set to the Ground-Based System. In such a case, the ground station should alert maintenance personnel of a missing maintenance log or that the data set provided is incomplete.*

> *(3) VHM Alert generation and fault detection performance*
>
> *The Alert and Alarm generation processing should be designed to achieve a claimed probability of detection that is acceptable to the Agency for each component defect being monitored. Processing to isolate False Alerts and False Alarms should not result in an unacceptable workload. Also this processing should not compromise the verification and validating evidence of claimed defect detection performance. This workload should be assessed prior to completion of the Controlled Service Introduction (CSI) phase.'*

In the note to Section g of the AMC to CS 29.1465, it also states that:

> *'The fixed or learnt thresholds for each individual health monitoring indicator may have a limited capability to detect incipient failures in a timely manner. This is because the process for threshold setting is sometimes a compromise between increasing sensitivity and incurring a higher risk of false alarms, or reducing sensitivity, which will delay the point at which a rising indicator value will trigger an alert. In-service experience has shown that MGB component fatigue failures can propagate from initiation to failure in a relatively short period of time, thus the use of fixed thresholds alone may not provide a timely indication of impending failure. One characteristic that can often provide an earlier indication of anomalous behaviour is the rate of change of a health monitoring indicator, and automatic trend detection software has been developed and shown to be effective. Another method, commonly referred to as Advanced Anomaly Detection (AAD) combines numerous indicators into multi-dimensional parameters, whereby simultaneous changes of multiple indicators can provide increased confidence of the anomalous behaviour at an earlier point in the failure process.'*

CAA Paper '*2011/01 Intelligent Management of Helicopter Vibration Health Monitoring Data'* defines Advanced Anomaly Detection (AAD) as an approach that detects abnormalities in rotor drive system components by comparison of multiple downloaded health monitoring parameters with prepared multi-parameter models of normality for these components. It also provides diagnostic information on the monitoring parameters causing abnormal indications. The multi-parameter models of normality represent the statistical dependencies between monitoring parameters and are based on experience across multiple aircraft within a fleet. The approach incorporates methods to ensure that any unknown abnormalities within this experience do not prevent the detection of similar abnormalities. Models are to be periodically refined based on increasing fleet experience.

The use of alert thresholds for individual CIs or the anomalous behaviour based on multiple CIs are all attempts to generate warnings as early as possible. However, other factors affect the timeliness of these warnings: how often a sensor is sampled during a flight, how long it takes to process data, how frequently the data is downloaded, how soon it is checked for exceedences and any delay in passing on exceedence information to the relevant people for it be acted upon.

A 2012 CAA paper '*2012/01 Application of AAD to Tail Rotor HUMS Data*', which reported on a study to demonstrate the application of AAD methods developed and successfully applied to HUMS transmission data (CAA paper 2011/01), recognised the importance of timeliness when new techniques such as AAD were able to detect a failure with little warning. It concluded that:

> *'Using AAD it is possible to detect tail rotor defects in Vibration Health Monitoring (VHM) data, but warnings are unlikely to be much in advance of the end of the flight preceding the 'failure' flight. On-board, post-flight indications would therefore be required for such a scheme to be effective.'*

1.11.4 HUMS configuration on the S-92A

On the S-92A the HUMS forms part of the commercially available IMD-HUMS[4] that provides the following functions:

- Built-In Tests (BITs)
- Mechanical Diagnostics
- Usage Monitoring
- Exceedence / Event / Alert-Monitoring
- Engine Vibration Monitoring
- Rotor Track and Balance
- Engine Shaft Balancing

The IMD-HUMS consists of two distinct sub-systems: the On-Board System (OBS) and the Ground Station (GS). At the time of the accident, the operator was using the IMD software on its GSs. The helicopter manufacturer had released new GS software, called the Sikorsky Ground-Based Application (SGBA), in May 2015 and this was being evaluated by the operator; however,

4 IMD-HUMS was developed by the Goodrich Corporation (and the US Navy), and selected by the Sikorsky Aircraft Corporation in 2001 to be fitted as standard equipment on the S-92.

the maintenance manual revision to support the software was yet to be released. The differences in functionality between the IMD and SGBA software are discussed later in this report.

The OBS collects and records aircraft information on a per-flight basis. Data is then transferred from the OBS to the GS using a Data Card. The GS is then used to analyse the collected data and to maintain a detailed operational history of the helicopter. The percentage of the Data Card used is continuously displayed on the HUMS page of the helicopter's Multi-Function Display, and when less than 2 MB of free space remains (equivalent to about 12 minutes of data), an exceedence is generated, prompting the crew to replace the Data Card. This is the only exceedence that the HUMS will display during flight.

1.11.4.1 Mechanical diagnostics

The S-92A HUMS User Guide states that the goal of the mechanical diagnostics function is to enable a transition from time-based maintenance to condition-based maintenance by acquiring vibration data from dynamic components and other monitored systems. The system is designed to collect data snapshots automatically on the ground, in the hover and in the cruise, without any aircrew input, during all flights for specified gearbox and flight regime combinations (provided the helicopter remains within the flight regime for the duration of each acquisition). It also includes a manual mode that enables pilot-initiated data collection which is either 'prompted' (where the pilot, in conjunction with OBS prompts, explicitly selects the gearbox group of interest and then enters, and maintains, the desired flight condition and initiates data capture - if the flight condition is not maintained, the OBS will abort the acquisition), or 'forced' (where the pilot again initiates an acquisition; however, in contrast to the prompted mode, the OBS completes the data acquisition regardless of the flight regime).

Data from the TR sensor is captured automatically during cruise flight (and > 60 kt) where the helicopter needs to be maintained in a steady state condition for a minimum of ten seconds. The processing of this data takes about 1.5 minutes to complete before the system captures and processes data from other sensors. A full rotation of data capture and processing, when in the cruise, takes about eight minutes and is therefore suitable for trend analysis and detection of the gradual wear and degradation of components over time but not for capturing transient events.

1.11.4.2 Ground station software mechanical diagnostics

The mechanical diagnostics functions of the IMD GS software (used by the operator at the time of the accident) provide a means for viewing data collected from individual drive train sensors and to provide a colour-coded health indicator to provide an indication of change in the drive train components and provide assistance for troubleshooting if a significant change occurs. The green 'normal' range is based on *a priori* measurements of known, healthy components; the yellow 'warning' range denotes components that exhibit mechanical diagnostic characteristics that differ from the known, healthy components, and the red 'alarm' range denotes anomalous components that have markedly different mechanical diagnostic characteristics. Within each range, the absolute value of the health indicator is secondary to the trend of the health indicator.

The IMD GS software has summary 'debrief' pages that list each flight for the selected helicopter for which HUMS data has been uploaded onto the GS. By selecting each flight, line by line, exceedences for the selected flight are then displayed which can then be viewed in detail in time-history strip charts by selecting the exceedence.

The GS also includes diagnostic tools in addition to those in the main IMD GS software, in the form of standalone tools, run separately on the GS, to analyse and/or detect (1) TR blade pivot bearing retainer disbonding, (2) TGB bearing energy, and (3) main gearbox cracks. These diagnostic tools are selected via the standalone IMD-HUMS ToolBar (Figure 8), which requires the HUMS raw data files already installed on the GS to be uploaded into the ToolBar to be processed. The resulting CI time-history charts are then individually inspected for exceedences – these are not automatically displayed as an alert.

Figure 8

IMD-HUMS ToolBar

1.11.4.3 TGB bearing energy analysis software

The TGB bearing energy analysis software is a standalone tool accessed via the IMD-HUMS ToolBar. It is intended to help assess the condition of the TGB's two input and output bearings as well as the TRPCS bearing assembly. This tool was developed and introduced in 2007 following degradation of a bearing believed to be due to foreign object debris. The software uses data recorded by the HUMS from the existing TGB accelerometers and provides additional means of monitoring the condition of the TGB through changes in its vibration signature. The diagnostic tool responds to any defect in the TGB that manifests itself in the 15-20 kHz frequency range.

The TGB bearing energy CI is generated by computing the average 15-20 kHz energy for the selected helicopter since its last maintenance date. This date is important since removing/replacing the TGB, the pitch change shaft assembly, or the TGB accelerometer can change the absolute value of the CI. The 15-20 kHz energy is then normalized by the calculated helicopter-specific mean. This normalized energy is referred to as the CI ratio.

The CI ratio is then plotted as a trend history with reference to a baseline for the helicopter that is nominally 1.0. The baseline data consists of 200 points that provides a baseline characteristic that is unique for that helicopter and from which an alert limit threshold is generated (if the 200 points have not been acquired no limit threshold will be calculated and the tool displays 'Insufficient Data' on the trend history). In order to speed up the acquisition of the initial baseline data, pilots can manually initiate data acquisition. The limit threshold for the CI ratio is 1.75 of the baseline; however, for users of the SGBA GS software prior to the accident, the threshold was raised from 1.75 to 2.5 following a review in 2015 of the tool and process improvements to remove a high number of false alerts[5]. In January 2017, following the accident to G-WNSR, the threshold was reduced to 1.75 for SGBA users, and hence in line with the IMD GS software; manufacturer's Temporary Revision No 45-03 dated 10 January 2017 refers (Appendix D).

1.11.5 Operator's internal HUMS procedures

1.11.5.1 Operator's HUMS download procedure

At the time of the accident, the procedure was for the Data Card to be removed and downloaded every time the helicopter returned to a main operating base (MOB) for the HUMS data to be reviewed before the helicopter's release to service. The operator also limited the time between download (and review) to a maximum of five flying hours. If planned operations were such the flying time could exceed five hours, the crew would carry a card reader to enable them to download the data themselves and then forward the data to the MOB for review. If the helicopter was planned for a detachment or shutdown offshore, its GS laptop would be taken offshore too.

At the MOB it was the responsibility of a licensed engineer, signing for the flight, to transfer the data onto the GS and make a preliminary analysis of the data to look for trends and establish if any alerts had been generated. Had any alerts been generated, the engineer would inform the operator's base in Norway who were, at the time, responsible for the operator's S-92A HUMS global support. HUMS technical support was continuously available to the engineering staff through the HUMS Support team.

5 These false alerts had been caused by a now-resolved manufacturing process issue.

At the end of each day, the HUMS data was automatically sent to the operator's base in Norway, for it to be reviewed the following day. It was also automatically sent to the manufacturer who were responsible for continued development and support of HUMS for the worldwide S-92A fleet.

The documented procedures included a HUMS flowchart that should be followed by the licensed engineer which first required the engineer to confirm the alert status on the IMD GS software before proceeding with the IMD-HUMS ToolBar. However, the operator's own investigation into this accident identified that the flowchart omitted two items concerning the ToolBar, one of which was to conduct a review of the TGB bearing energy CI.

The TGB bearing energy CI was not subject to 'close monitoring'.

1.11.5.2 G-WNSR HUMS download

Engineer A, who was responsible for the maintenance on G-WNSR on 27 December 2016, transferred the HUMS data from the helicopter onto the GS after the final flight of the day. He then made his preliminary analysis of the data firstly using the main IMD GS software. He established that no thresholds had been exceeded and all of the mechanical diagnostics were green. He then ran the IMD-HUMS ToolBar, during which he and Engineer B, were unsuccessful in zooming in on the TGB bearing energy CI ratio chart to identify and confirm the exceedences.

Figure 9 shows the time-history chart as presented to Engineers A and B, when they visually inspected the TGB bearing energy CI ratio (this figure has been recreated, using the original data, for the purposes of this accident report). Note that the x-axis automatically scales to show the complete time-history since last TGB maintenance date, which for G-WNSR was 6 October 2016, and the y-axis automatically scales from zero to the full range of CI ratio values.

However, had either of the licensed engineers successfully zoomed in on the day's flight, the exceedences would have been clearly visible (see Figure 10 for a recreated zoomed-in version of the original data) with the highest and final exceedence being just over 17 compared to the alert limit threshold of 1.75.

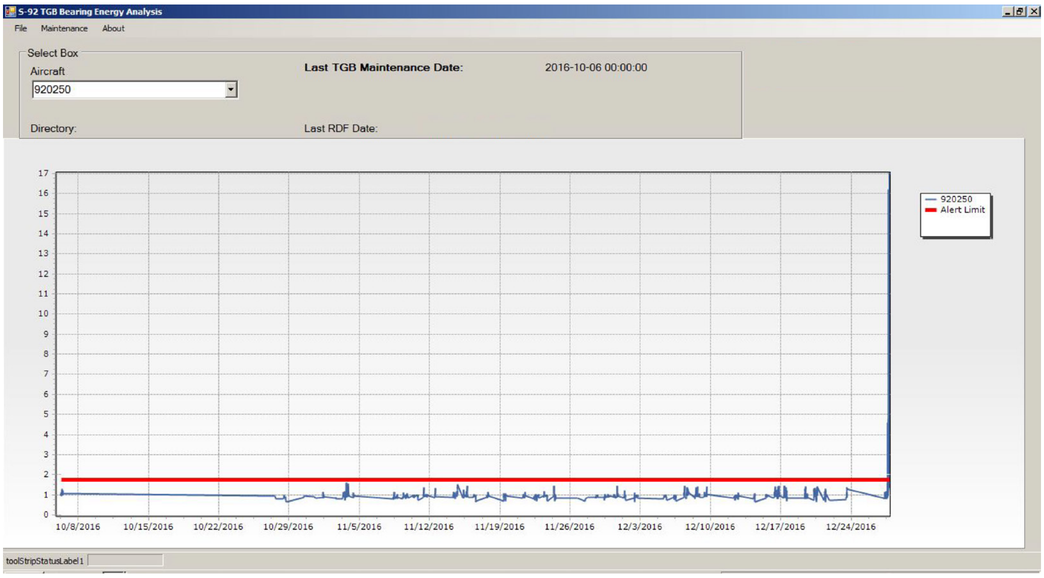


Figure 9

Recreated TGB bearing energy CI ratio time-history chart

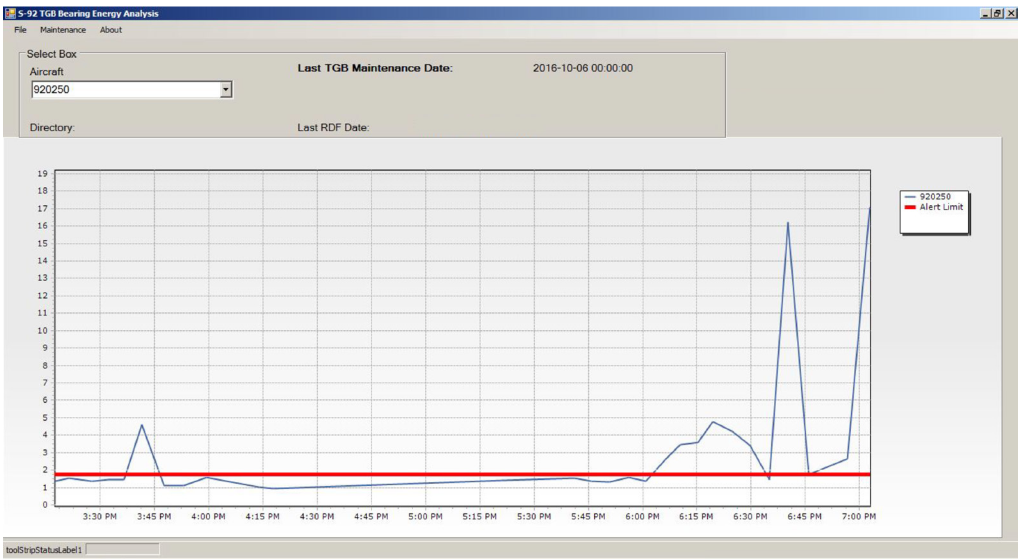


Figure 10

Recreated TGB bearing energy CI ratio time-history chart zoomed to last flight on 27 December 2016

When, on the morning of 28 December 2016, the operator's S-92A HUMS global support team in Norway reviewed the HUMS data for 27 December, the exceedences in the TGB bearing energy CI ratio were detected. At 1311 hrs they contacted the operator in Aberdeen, only to be told that the helicopter was currently on the West Franklin platform.

Figure 11 shows the TGB bearing energy CI ratio relative to the flight data for the third and final flight (comprising three sectors) on 27 December 2016 (during which the exceedences occurred), showing the various flight conditions at which data from the TGB accelerometers was acquired. The first exceedence (a single point) occurred just over an hour into the first sector of the third flight, about 45 minutes before landing. The next exceedences occurred during the last hour of the third sector back to the MOB at Aberdeen.

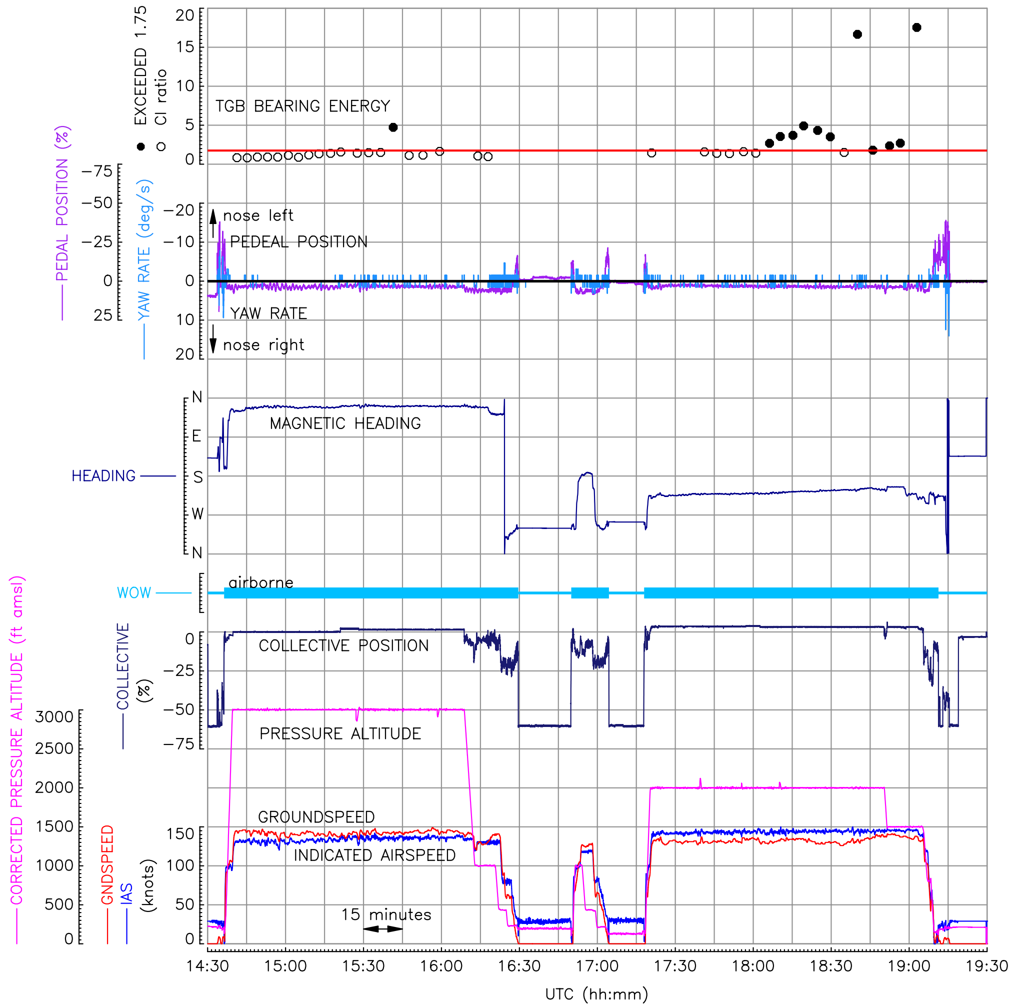


Figure 11

TGB bearing energy CI ratio and recorded data for third flight on 27 December 2016

In summary, the helicopter was operational (with rotors turning) for a total of 10.4 hours on 27 December 2016 and the first exceedence occurred after 6.9 of these operational hours. It was a further 3.5 operational hours before the helicopter returned to its MOB for the HUMS data to be downloaded and hence the first opportunity (which was missed) for the operator to become aware of the exceedence. During these 3.5 hours the helicopter landed twice (but did not shut down) – the first after about 0.7 hours and the second after a further 0.6 hours before returning to the MOB.

After G-WNSR was recovered following the accident on the West Franklin, the HUMS data for 28 December 2016 was downloaded. Figure 12 shows the TGB bearing energy CI ratio for this flight and indicates that during the first leg (from Aberdeen to the Elgin PUQ) 12 sets of data were acquired of which the last nine resulted in TGB bearing energy CI ratio exceedences.

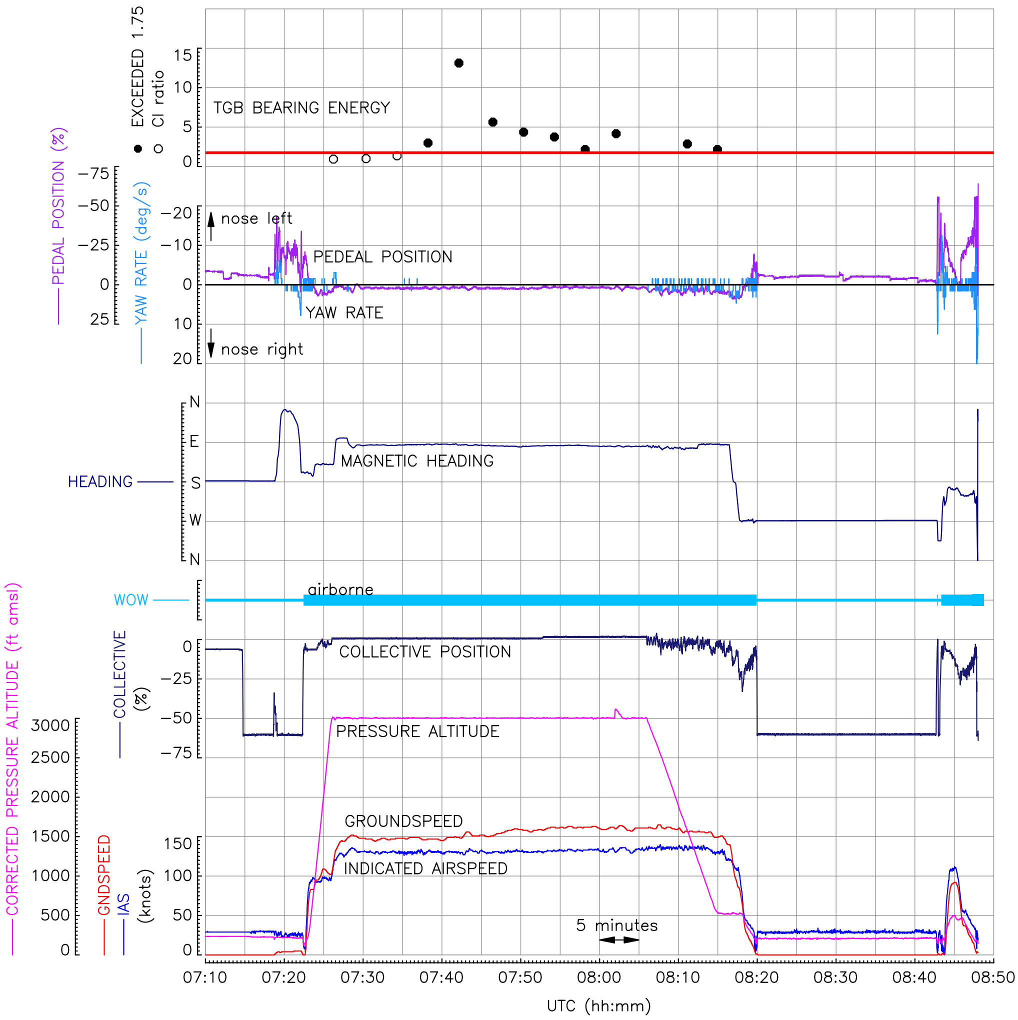


Figure 12

TGB bearing energy CI ratio and recorded data for the flight
on 28 December 2016

As the Elgin event did not happen during the cruise phase of the flight, no data from the TGB sensor was captured, nor was any during the short sector to the West Franklin.

Figure 13 shows a graphical representation of the flight schedule for G-WNSR for the two weeks leading up to the accident. During this period, G-WNSR flew on nine of these days, two of which contained two flights with a daily total operational time of over 10 hours. The timing of the exceedences concerning these flights is indicated.

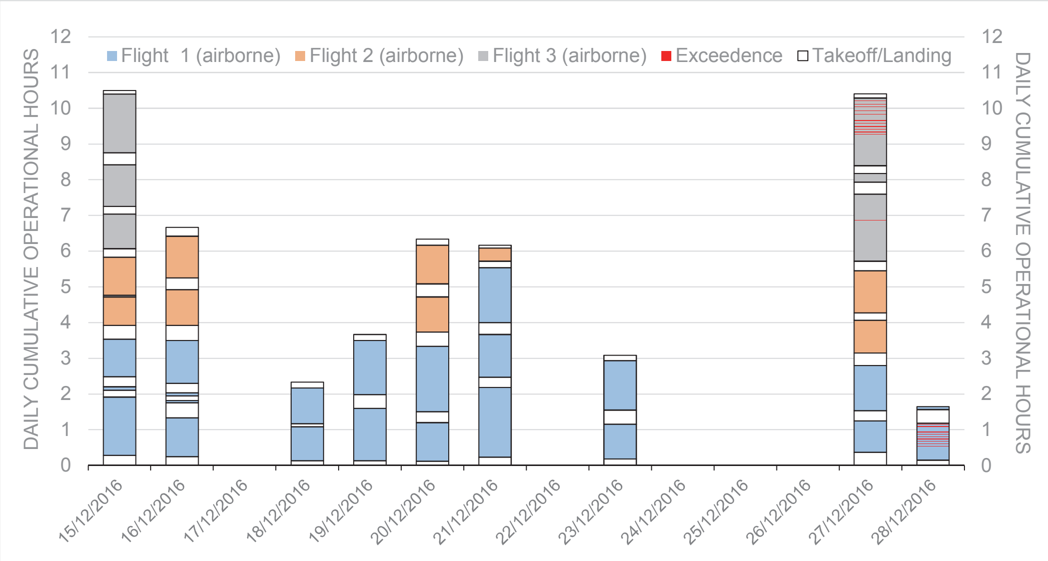


Figure 13

G-WNSR operating history for previous two weeks

Figure 14 combines the operating histories for the last two days to form a timeline beginning with the start of operations on 27 December 2016, with the first exceedence highlighted at 6.9 operational hours and the accident 5 operational hours (about 4 flying hours) later.

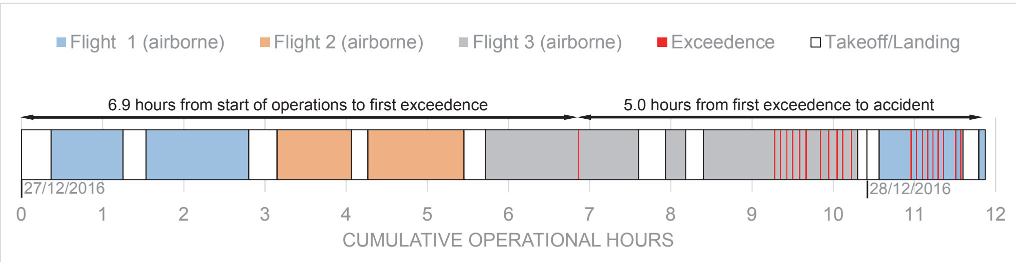


Figure 14

G-WNSR operating history for the two days prior to the accident

1.11.5.3 Operator internal HUMS training

Training for line engineers on the use of HUMS is given over three days at the end of their line training. The HUMS training, given to the operator's line engineers worldwide, was provided by an external contractor.

The material presented during the HUMS training for the S-92A includes the manufacturer's HUMS User Guide for the S-92A (SA S92A-HUM-000 – most recent revision was dated 30 December 2012).

1.11.5.4 Interrogating HUMS time-history strip charts

The manufacturer's HUMS User Guide describes the specific user commands to zoom in or out of the data presented in the time-history strip charts. These commands are applicable to the strip charts in the main IMD GS software as well as the IMD-HUMS ToolBar. For zooming it states:

> *'(a) Position the cursor over the portion of the graph you wish to enlarge.*
>
> *(b) Click and hold the left mouse button and drag the magnifier box (faint white outline) down and right over the region to be enlarged.*
>
> *(c) Release the mouse button to display the area inside the magnifier box.*
>
> *(d) Continue to Zoom in on the desired area of the graph. The entire graph will be enlarged but the area of interest will remain in view.*
>
> *(e) Once the graph has been zoomed to the desired size, the entire graph may be viewed by holding the right mouse button down and dragging the graph left and right or up and down.'*

To undo zoom it states:

> *'(a) Position the cursor in the lower right of the graph, and while holding the left mouse button down, drag the cursor to the upper left and release. The graph will return to its normal size.'*

Although the command is to drag the magnifier box down and right over the region to be enlarged, for strip charts in the main IMD GS software, dragging up and right also has the same effect. Similarly, the undo zoom, which requires the user to select any point on the strip chart and drag the resulting box up and left, also works dragging the box down and left. However, for strip charts in the IMD-HUMS ToolBar and several sub-functions within the IMD

GS software, only dragging down and right will zoom (as per the user guide); the three remaining combinations each undo zoom.

These additional zoom and undo zoom commands are not discussed in either the HUMS User Guide or any training material.

Early on in the investigation, the manufacturer was made aware of the differences in the zoom functionality within the main IMD GS software and the standalone IMD-HUMS ToolBar and the possibility of confusion this offered for users of the IMD software.

1.11.5.5 Sikorsky Ground-Based Application (SGBA)

In May 2015, Sikorsky issued their own GS HUMS software called the SGBA for use with S-92A and S-76D helicopters. This (and the corresponding user guide) was made available to operators of these helicopters to trial; however, the relevant S-92A maintenance manual revisions were not issued until March 2017. The operator of G-WNSR had been trialling the SGBA since 2015 in order to develop their knowledge of the application and be able to transfer to it at the earliest opportunity after the release of the maintenance manual revision. Meanwhile, the licensed engineers continued to use the existing IMD GS software and IMD-HUMS ToolBar.

Like the IMD GS software, the SGBA was designed to analyse, process, and compile flight data into useful information for the maintenance crew, logistics team, operations department, and engineering support. The SGBA, however, introduced many enhanced features such as enhanced diagnostics capabilities, and improved user interfaces such as colour-coded visual indicators to highlight inspection requirements. As an example, Figure 15 shows the Tail Gearbox Bearing Energy Tool for G-WNSR with the TGB bearing energy CI ratio together with two additional CIs, related to the TRPCS bearing.

One key difference is that the first page (Figure 16) automatically presented to the user gives a summary of all CI exceedences and alerts to be actioned in accordance with the AMM, including those which previously, using the IMD GS software, required manual interrogation.

To promote the enhanced features available in the SGBA, the helicopter manufacturer issued an All Operators Letter CCS-ALL-AOL-17-0008 dated 24 March 2017 (Appendix E) to inform users of the IMD software that:

(1) the IMD software would be ‘rendered obsolete’ in the near future,

(2) the maintenance manual revisions were released on 9 March 2017 to support customers transitioning from the IMD software to SGBA,

(3) highlighted some of the enhanced features of the SGBA, and

(4) reminded users of the approved zoom and undo zoom commands for interrogating time-history strip charts.

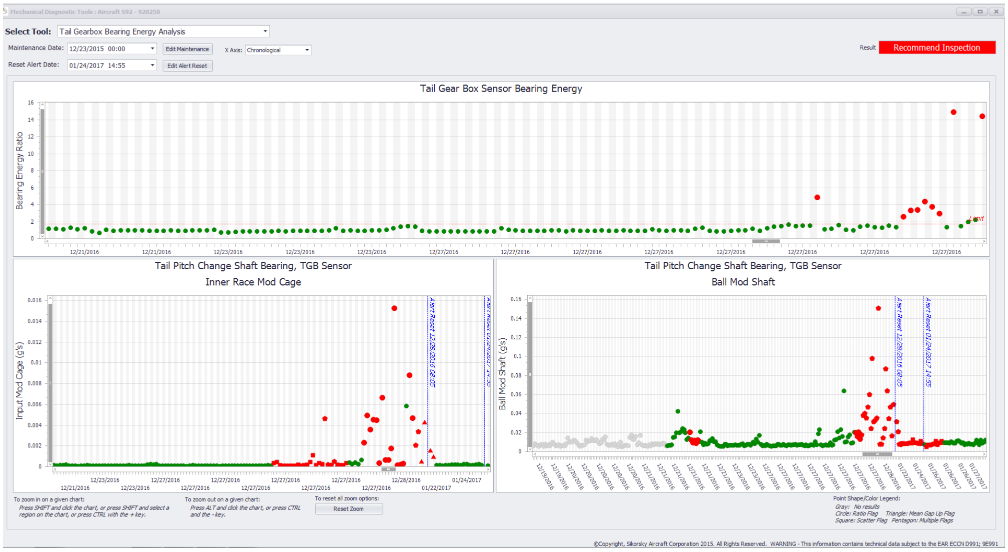


Figure 15

SGBA Tail Gearbox Bearing Energy Analysis Tool

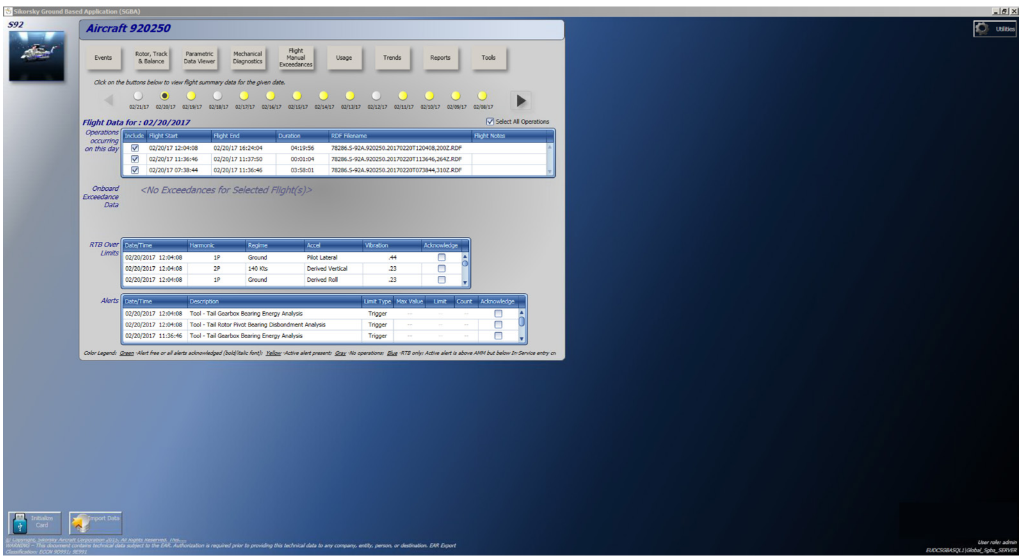


Figure 16

SGBA initial page highlighting exceedences and alerts

1.12 Wreckage and impact information

1.12.1 Helideck

Yaw control was lost at about 4 ft above the helideck. The helicopter then descended with a left rolling moment. The left main landing gear contacted the helideck first and was canted over which presented the outer edge of the wheel rim to the helideck. This resulted in a dent in the top layer of the helideck approximately 150 mm long, part of which was an 80 mm cut which penetrated the helideck surface. The cut matched the distortion in the wheel rim. Figures 17 and 18 show the rim distortion and helideck damage. Black rubber scuff marks were also made on the helideck surface consistent with the tyre scrubbing during the rotation of the helicopter in the accident sequence.

Figure 17

Left outer wheel rim distortion (courtesy of CHC Scotia Ltd)

Figure 18

Helideck damage (courtesy of CHC Scotia Ltd)

1.12.2 Initial helicopter examination on the helideck

The crew carried out an initial examination of the helicopter whilst on the helideck. The helicopter showed no outward signs of damage apart from distortion to the outer rim of the left outer mainwheel. The tyre was seated in its rim and had remained inflated. The crew were asked, by maintenance control, to carry out a "full and free" yaw pedal check. They did this by starting the APU to energise the hydraulics and cycled the yaw pedals through their full range of motion whilst observing the TR. The results were indeterminate and the situation precluded further diagnosis at that stage. Subsequently, a team of the operator's engineers arrived by boat and the helicopter was lifted by crane from the helideck and transported by sea back to its maintenance base at Aberdeen.

1.12.3 Examination at maintenance base

Further examination of the helicopter was then carried out at the maintenance base with the assistance of the manufacturer. Without hydraulic power applied it was found that the yaw pedals moved easily. Further inspection found the TR servo piston was broken at the point where the walking beam pivot bar is attached leaving the walking beam pivot in a loose and unrestrained condition. However, the control input eye end was correctly connected to the walking beam and to both the first and second stage servo control valves. The centring spring between the two control valve linkages was also correctly connected.

The TR servo was removed and a disassembly of the TRPCS revealed severe damage to the TRPCS bearing. The bearing showed evidence of overheating and discolouration, a partial friction welding of the rollers, cages and inner race with the outer races loose and heavily scored. The PTFE seals and snap rings were not evident. There was no lubricant present in the bearing. Figure 19 shows the bearing on removal.

Figure 19

TRPCS bearing from G-WNSR

The TGB, TR hub and blades were examined in situ and no outward signs of damage found. All of the TR related components were removed from the helicopter and the TGB, TRPCS and servo were returned to the manufacturer for forensic analysis.

1.12.4 Examination by the manufacturer

The components were examined in stages at the manufacturer's facility in the USA and the examination was overseen by NTSB, FAA and AAIB representatives.

1.12.4.1 TRPCS bearing

The TRPCS bearing was severely damaged and was no longer a viable bearing. The outer races on both sides of the bearing had been subject to intense heat and were discoloured. The roller tracks were heavily scored and pitted with none of the smooth hardened surfaces remaining intact. Some roller cage material was also dispersed around the surfaces of the roller tracks. All of the barrel-shaped rollers were present and were welded to the inner races along with the remains of their cages. The rollers were also flat sided. The roller set nearest the servo linkage (the inside bearing) exhibited the most damage and the rollers had lost approximately half their diameter. The outer rollers, nearest the TR, had flat sided to a lesser extent and were still recognisable as barrel rollers.

The wear in the inner and outer races and the distortion of the rollers and cages, allowed at least a 0.5 inch (12.5 mm) linear play or looseness in the bearing.

There was no hydrocarbon component (the lubricant) of the grease present on or within the bearing. However, there was a residue of the grease thickening agent present within the remains of the bearing but not enough for useful forensic analysis.

1.12.4.2 Tail rotor gearbox

The TR gearbox casing, input and output shafts showed no evidence of external damage and were free from leakage. The gearbox was disassembled and the internal components examined. The bearings, shafts, input pinion and crown wheel were undamaged with no discernible signs of wear. The TRPCS guide grooves within the output shaft were also undamaged although there were small amounts of an unidentified deposit within the bore and at the ends of the TRPCS guide grooves. Samples of the deposits were sent for further analysis and were found to be wear products from the phosphor bronze carrier.

1.12.4.3 TR servo

An external visual examination was carried out. The servo appeared to be in a good overall condition with the exception of a fracture of the primary piston within the secondary piston sleeve. A cross-section of the servo primary and secondary pistons and cylinder with the location of the fracture is shown in Figure 20. A functional test under hydraulic pressure could not be carried out due to the damage on the primary piston. There was no evidence of hydraulic leakage and the walking beam, servo valves and body were undamaged. The anti-rotation tab showed evidence of wear on both sides with a corresponding witness mark within the anti-rotation plate slot.

The servo was disassembled as far as possible; however, the inboard face of the primary piston head was tight against the gland seal and could not be moved. Remnants of seal material were present in the vicinity of the outboard piston face. There were signs that the primary piston had been rotating within its cylinder evidenced by rotational scoring on the bore of the cylinder. This scoring was approximately 35 mm from the housing face (TGB mounting flange) and extended along the bore, in the piston retraction direction, by approximately 18 mm. Rotational marks were also present on the contact surface between the primary and secondary pistons. The clevis assembly, which attaches the primary piston to the TRPCS bearing, could not be removed despite the application of a 350 lb ft torque. Residual hydraulic fluid within the servo appeared normal. The primary piston which had parted within the secondary piston tube, was removed and sectioned for metallurgical examination. The surfaces were examined under a scanning electron microscope which revealed evidence of smearing and shear overload, consistent with a ductile overload in torsion.

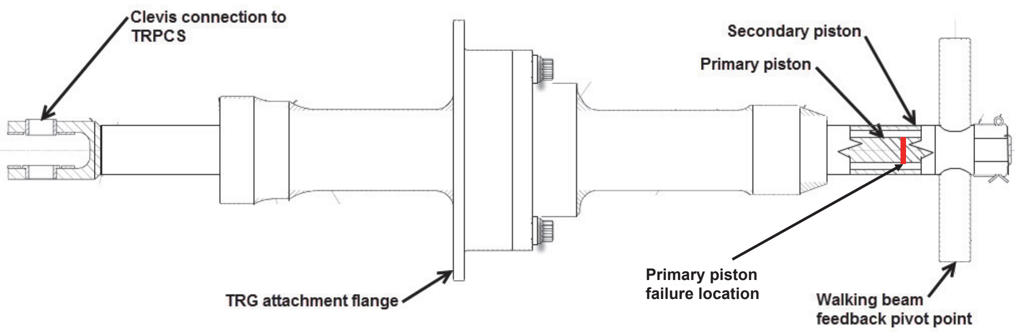


Figure 20

Servo cross-section and fracture location (courtesy of Sikorsky)

1.13 Medical and pathological information

Not applicable.

1.14 Fire

Not applicable.

1.15 Survival aspects

All persons on-board a helicopter operating offshore in the North Sea area are required to be current in Helicopter Underwater Escape Training. Survival suits and associated equipment are required to be worn.

Whilst flying operations are carried out on the West Franklin platform a safety boat is positioned nearby to respond to a helicopter ditching or man overboard situation.

1.16 Tests and research

1.16.1 Engineering

1.16.1.1 Immediate action

After the components had been removed from G-WNSR and examined, the manufacturer issued an All Operators Letter (AOL) CCS-92-AOL-16-0019 (Appendix F) on 31 December 2016 drawing attention to the event with the details as they were understood at the time. In particular it drew attention to the importance of the HUMS Tail Gearbox Bearing Energy Tool in understanding the condition of the TRPCS bearing. As the investigation progressed and as the sequence of events leading to the bearing failure became clearer, the manufacturer issued an ASB to all operators on 10 January 2017. ASB 92-64-011 (Appendix G), supported by an FAA Airworthiness Directive (AD) 2017-02-51 (Appendix H) dated 13 January 2017, gave instructions to establish the condition of the TRPCS bearing assemblies in service and action to be taken should the airworthiness of a bearing be in doubt. Concurrent with the issue of ASB 92-64-011, the manufacturer published Temporary Revision 45-03 which required operators to use HUMS GS software to review, on a reduced flight hour interval, the TGB energy analysis CIs for any alert conditions.

The AD required action to be taken on the TRPCS bearing assembly before next flight. It reinforced the ASB technical instructions to all S-92A operators to remove and inspect the TRPCS bearings. If the bearing did not rotate freely, sounded rough or chattered, was leaking grease, or had metallic particles present, or had nicked or damaged PTFE seals, the assembly should be rejected and immediately returned to the manufacturer. In addition, the AD required bearings that showed none of these issues could remain in service with a repeat 10-hourly borescope inspection programme to inspect the condition of the PTFE seals and snap rings.

The helicopter operator also introduced a number of measures to further strengthen the ability to detect impending bearing degradation. These included: a review of all HUMS data to ensure no anomalies, fleet-wide borescope inspections and a requirement for HUMS to be serviceable before flight. The operator also reviewed their HUMS processes and analytical procedures, correcting the omission in the documentation of the use of the IMD-HUMS ToolBar analysis tools. They also introduced a requirement for an additional assurance check to be carried out by a second licensed engineer prior to releasing the helicopter to service.

1.16.1.2 Inspection feedback and subsequent actions

TRPCS bearings which were deemed unsatisfactory to continue in service were returned to the manufacturer. In total, by April 2017, 19 shafts were removed for further evaluation from 253 helicopters reporting ASB compliance, out of the global fleet of 275. The reasons for these removals were as follows:

- 10 shafts removed due to a HUMS Bearing Energy CI ratio exceeding a revised limit of 1.75
- 4 shafts removed due to physical inspection identifying ratchet/rough bearing condition
- 5 shafts removed due to visual indications

The manufacturer devised a rigorous non-destructive inspection process and applied it to each of the received bearings to ensure that no evidence was lost by disassembly and the bearings were assessed in their in-service condition.

This test regime was devised to establish several important factors. A visual examination was carried out to confirm any observations made by the operator rejecting the TRPCS and to identify anything abnormal. Particular attention was paid to the condition of the seals and snap rings for signs of leakage of the grease, the presence of debris or evidence of wear. The phosphor bronze guide lugs were also examined for signs of abnormal loading or wear pattern from the TGB output shaft.

The components in the TRPCS assembly are made to a close tolerance and therefore can be assumed to not vary in weight between individual assemblies. Any variation in TRPCS weight would be attributed to the amount of grease present in the bearings. Thus, the amount of grease present can be deduced from an accurate weighing of the TRPCS assembly.

An end float measurement, carried out at room temperature, showed how much play was present within the inner and outer races of the bearing. The allowable end float or play was a minimum of 0.002 inch (0.0508 mm) to a maximum of 0.005 inch (0.127 mm).

On completion of the initial inspections, the TRPCS assembly was mounted in a specially constructed spin rig based on a TGB and hub assembly. The TRPCS was then run whilst the rig control programme subjected the bearing to the forces and loads experienced in service. The TRPCS was then disassembled and the bearings inspected.

As a control, life-expired TRPCS assemblies awaiting rework were also put through the same test regime.

1.16.1.3 Results

The majority of TRPCS assemblies were returned due to a slight 'notchiness' or stiffness when a 'by hand' examination was carried out during AD compliance inspections. All returned TRPCS assemblies were in a good overall condition and none exhibited the degraded condition of the TRPCS removed from G-WNSR.

The test results were varied. None of the assemblies showed any serious outward signs of impending failure or abnormal wear. All TRPCS weights confirmed the presence of grease within the bearings albeit in varying quantities. Some of the tight or notchy bearings had no end float, whilst other bearings were within limits. Of the 19 TRPCS removals, 18 bearings did not exhibit unusual or advanced wear or degradation, but one bearing exhibited roller wear and unusual indications on the outer race.

During spin testing, the average or normal temperature was around 240°F (115°C) peaking at around 300°F (150°C) in some cases. All TRPCS assemblies tested in this way showed no signs of further degradation or impending failure. However, it was found that some of the TRPCS bearings ran hotter than had been previously assumed or expected. During this process an unsuccessful attempt was also made to deliberately cause a TRPCS bearing to fail on a life-expired TRPCS.

To understand further the running temperature of the TRPCS bearing in service, the manufacturer developed a small temperature sensing plug which could be fitted in the bore of the TGB output shaft next to the bearing. It consisted of a set of four temperature sensitive pads which change colour depending on the temperature experienced. This plug was issued to all operators on 9 March 2017 under ASB 92-64-012 (Appendix J). Information received back from the operators suggested the running temperatures were between 320°F (160°C) and 340°F (171°C) on newer bearings. It was also found that in some cases these higher temperatures drop by approximately 40°F (22°C) over a period of 25 hours.

The temperature profiling of the TRPCS bearing resulted in two shafts being sequentially removed from one helicopter. As a result, the manufacturer requested the removal of the TRPCS, TGB and servo from this helicopter[6] as a whole assembly for further analysis.

The helicopter manufacturer has worked with the bearing manufacturer to identify and implement a number of improvements to the bearing manufacturing process. An improved end play measuring tool has been introduced to carry out more accurate measurement and bearing setting up during assembly. The grease is now drawn from sealed cartridges and injected into the races using a syringe to ensure a more consistent quantity and distribution. The bearing is also now weighed before and after grease application.

Throughout this activity the manufacturer has issued regular updates to all operators of the S-92A to keep them informed of the steps taken to ensure the continued airworthiness of the TRPCS bearings.

1.16.2 Recorded data mining

1.16.2.1 HUMS

Following the accident, the manufacturer performed a review of the S-92A fleet HUMS data to determine if modifying the TGB bearing energy CI ratio exceedence threshold, or applying new techniques, would enable additional prognostics for the HUMS Tail Gearbox Bearing Energy Tool. When retrospectively applied to the HUMS data from G-WNSR, modifying the threshold did not provide any earlier warning than the existing four flying hours. However, a review of other CIs that focused on the TRPCS bearing, and the development of new algorithms, extended the warning to just over 16 flying hours. These features have now been incorporated into SGBA.

1.16.2.2 Operational indicators

The helicopter manufacturer reviewed data from the 11 liftoffs of G-WNSR, prior to the event on the Elgin, to determine whether there was any pre-accident evidence of a degradation that could be identified through the flying controls and

6 This helicopter was flying extended range sectors relative to the rest of the fleet.

thus provide some warning to flight crews. The pedal and collective positions recorded at the point at which weight-on-wheels indicated liftoff were analysed; no trend of increasing use of left pedal prior to the event was apparent. Data for in-flight pedal position for other helicopters in the fleet during a typical offshore sector were also reviewed and no outstanding trend was apparent.

Additionally, the helicopter manufacturer reviewed their archive of flight data records to determine whether it is an unusual event for a pilot to use full pedal travel in flight. The analysis showed that the use of full pedal was very rare but had occurred in each of the previous events of TRPCS bearing failure (see paragraph 1.18.2). Conclusions from the review were that this cue is available to flight crew prior to bearing failure, but is indicative of a bearing that is already in an advanced state of degradation. Thus, the use of full pedal travel could indicate a need for prompt action to abort a flight and the helicopter manufacturer is considering whether changes to the RFM could be introduced.

1.17 Organisational and management information

During the investigation AAIB inspectors visited the operator's maintenance facility and met some of the engineers on the staff. The hangar, shift offices and crew-room were spacious, calm and well-organised; maintenance plans and shift routines were clearly promulgated.

1.18 Additional information

1.18.1 AAIB Special Bulletin (SB)

The AAIB published Special Bulletin S1/2017: '*Sikorsky S-92A, G-WNSR, loss of yaw control on landing at West Franklin platform, North Sea, 28 December 2016'* to provide initial information concerning the event and to highlight initial safety actions. The SB was published on 11 January 2017 and the safety actions presented within the SB are detailed later in this report.

1.18.2 Previous similar events

During the preliminary work to identify the cause of the TRPCS bearing failure, a review was carried out to see whether there had been any similar previous events.

In 2007, a bearing was found to have degraded as a result of foreign object debris. This resulted in issue of ASB 92-64-002 and ASB 92-64-003 (mandated by FAA AD2007-17-05 and EAD 2016-24-51 respectively) which required a once-only borescope inspection. Several additional actions were put in place and led to the introduction of a 1,250-hour Time Between Overhaul (TBO), improvements in the manufacturing process and to the seal assembly on the bearing, and introduced a bearing installation tool. It was also of significance that the HUMS Tail Gearbox Bearing Energy Tool was developed and introduced by the manufacturer as a direct result of this event.

During the remedial work conducted into the above event, a partial or full seizure of the TRPCS bearing applying torque to the servo piston was considered. It was anticipated that should this happen, the servo would fail in the threaded portion of the clevis.

In September 2016, a newly manufactured bearing failed within two hours of installation. This was caused by incorrect end play set up during assembly which led to a tight bearing. The bearing manufacturer introduced an improved bearing clamping and measurement procedure during assembly. An additional end play inspection was also introduced during overhaul.

In November 2016, ASB 92-64-009 was published which detailed a once-only inspection for improper end play on TRPCS assemblies with bearings less than 80 airframe hours since overhaul. This did not apply to G-WNSR because, by that date, its TRPCS had accrued 350 airframe hours since installation.

As a result of G-WNSR's accident the manufacturer reviewed the previous events and concluded that, for the 2007 event, there was no objective evidence to prove the cause was a foreign object in the bearing. The manufacturer now considers it more likely that the 2007 event was related to the bearing being assembled too 'tight', as identified in the later events.

In November 2016, it was found that the TGB storage process risked flooding the bearing with gearbox lubricating oil with the potential to dilute the grease. ASB 92-64-010 was issued to identify helicopters which had been subjected to long term storage procedures. Any TRPCS bearing found to have been fitted to a helicopter that had been in long term storage was replaced as a precautionary measure. The storage procedure was modified accordingly. The TRPCS from G-WNSR had not been in storage and therefore this ASB did not apply.

1.18.3 Engineering shift patterns

The operator's maintenance shift patterns are designed to make the most efficient use of manpower over 'long-days' matched to a comprehensive routine helicopter maintenance plan. It also retains the flexibility to react to unplanned rectification work on a fleet of 15 S-92A helicopters. The manpower is divided into two main sections 'X' and 'Y' then sub-divided into early and late shifts to achieve the long working day. In addition, two small teams cover the night period.

The 'X' and 'Y' main sections work a rotating system of four days on, four days off, six days on, four days off, four days on, and six days off. The shift pattern for December 2016 is shown in Figure 21 and the daily early, late and night shift pattern in Figure 22.

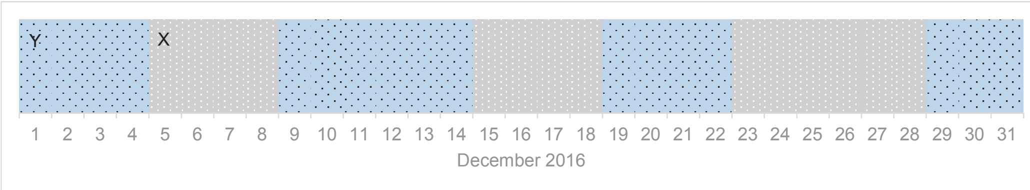


Figure 21

December 2016 shift pattern

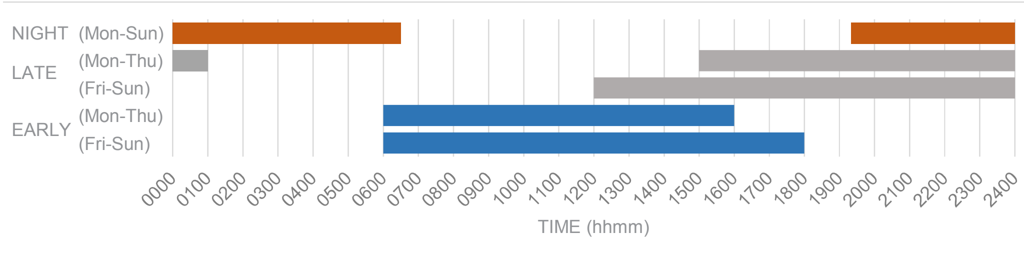


Figure 22

Daily shift pattern

There was reduced flying over the Christmas period, so the shift supervisors had carefully planned and programmed the maintenance work so that no staff were required to work on Christmas Day or Boxing Day.

Engineer A was part of the shift section that was on a six-day sequence of 'lates' which had started on 23 December 2016 and was due to finish on 28 December 2016. After the stand down on 25 and 26 December, staff returned to their normal routine on 27 December. However, Engineer A was scheduled for an additional stand down on 28 December and therefore was not required for work that day.

Engineer A's shift pattern is shown in Figure 23. Following the two stand down days, he worked from 1500 hrs on 27 December 2016 to approximately 0100 hrs on 28 December 2016.

Figure 23

Licensed Engineer A's shift pattern

1.18.4 Significance of HUMS in previous accidents

The investigation of the accidents to Eurocopter EC225 LP Super Pumas G-REDW and G-CHCN[7] resulted in the provision of a flight deck indication for an exceedence of a specific HUMS CI.

For both accidents, a CI was found, at 4.62 and 4.75 flying hours for G-REDW and G-CHCN respectively, to be capable of detecting an impending failure of the bevel gear vertical shaft in the MGB, but within the operator's existing download and review interval of 10 flying hours of the HUMS data. As a result, it was determined that the CI trend should be monitored over a shorter period of elapsed time. Interim measures were introduced for a HUMS download interval of up to a maximum of four flying hours. The helicopter manufacturer subsequently introduced a flight deck indication for an exceedence of this specific CI, removing the requirement for a four-hour download and review interval.

The investigation report also noted that for the HUMS configuration on the EC225 LP, the acquisition cycle for one complete set of samples of data from CI sensors typically lasted between 30 and 40 minutes.

1.18.5 Royal Navy WS-61 Sea King HUMS

The Westland WS-61 Sea King helicopters operated by the Royal Navy are equipped with a combined HUMS and cockpit voice and flight data recorder (CVFDR) system (compared to the standalone HUMS on the S-92). The system includes a Cockpit Control Unit (CCU), to display HUMS/CVFDR alert information and other HUMS information, which can be configured to display exceedence alerts on landing as well as be interrogated in-flight by the crew. The exceedence alerts are limited to rotor track and balancing, airframe, engine or flight exceedence limits, and only indicate that a threshold has been exceeded (ie not the value of the exceedence). Transmission exceedences are processed and identified by the GS and therefore not available to crew via the CCU. The CCU allows a HUMS

7 AAIB Report 2/2014 https://assets.publishing.service.gov.uk/media/5422fbaaed915d1374000833/2-2014_G-REDW_and_G-CHCN.pdf

validity check to be performed by the flight crew as part of the pre-flight procedure, and maintenance personnel must be consulted before departure if there are any new or unknown 'failures'. The system is not designed to be used as an in-flight diagnostic tool.

1.19 Useful or effective investigation techniques

Not applicable.

2 Analysis

2.1 Introduction

The helicopter suffered a loss of yaw control when landing on the West Franklin platform. The crew were able to put down immediately on the helideck, although without directional control. If the loss of yaw control had occurred at an earlier stage of the flight, the helicopter would most likely have made an uncontrolled descent into the North Sea. Strip examination of the components revealed that the loss of yaw control was the result of damage to the TR pitch control servo, which had been brought about after a significant failure of the TRPCS bearing. HUMS had provided an alert of the impending bearing failure the day prior to the accident flight, but this was not identified by the maintenance engineers.

To provide assurance of safe flight a series of safety barriers are in place which are designed to prevent the catastrophic loss of an aircraft. On this occasion most of the barriers were breached and it was fortuitous that the final component failure occurred when the helicopter was in the landing phase above the helideck, in a position from which, despite the loss of control, the commander could immediately lower the collective and land. Figure 24 is a schematic representation of the applicable safety barriers.

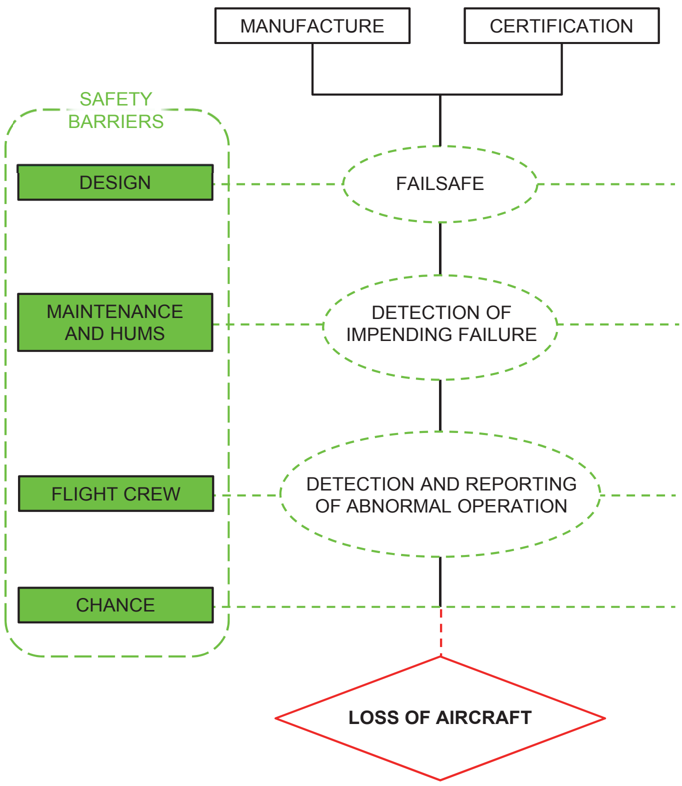


Figure 24

Schematic representation of the applicable safety barriers

Design and certification

During the certification process, the manufacturer and certifying authority must perform a design assessment to ensure that the transmission system functions safely over the full range of conditions for which certification is sought. This must include a detailed failure analysis to identify all failures that will prevent continued safe flight or landing. It must also identify the means to minimise the likelihood and effect of their occurrence. The aim through the design is to reduce the risk of component or system failure to a probability of 10^{-6} or less (categorised as 'very remote').

Certification of the design must consider component wear and tear and its effect on the risk of failure. To mitigate against the potential for failure in service, a proactive monitoring or pre-failure capture and maintenance scheme must be derived to ensure a high level of reliability.

A failsafe system or structure is designed to consider a component or part failing or malfunctioning such that it does not overload or cause other critical systems and structures to malfunction, lose control or integrity in turn.

Maintenance and HUMS

HUMS is a means of meeting the VHM regulatory requirements of CS 29.1465, applicable to applicants requesting certification of a VHM system, such as helicopter operations in the North Sea. HUMS was originally designed to monitor the health of mechanical components that form the rotor and transmission system within an operational context, providing data for trend analysis and condition-based maintenance, for which it has proved very effective. It was not intended to detect imminent in-service component failures; however, thirty years of experience and development has demonstrated the potential for it to be used in this way. Operators and manufacturers are placing more reliance on the additional assurance HUMS gives for continued airworthiness, and the download and analysis of HUMS data is often a necessary step on each return to base, and before the helicopter is released back into service.

Flight crew

The flight crew role in this context is to observe the aircraft and report on its serviceability; pilots may be able to detect changes in performance or behaviour at an early stage, prior to a component failure. However, their ability to do so effectively is subject to the limitations and constraints of human performance.

Chance

Chance can sometimes play a part in the avoidance and/or mitigation of the consequences of accidents and serious incidents.

2.2 Operational aspects

2.2.1 Conduct of the flight

The flight crew were not aware of the recorded HUMS exceedences as there was no indication on the flight deck of the helicopter. The flight progressed uneventfully until the first attempt at takeoff from the Elgin PUQ. The manufacturer's review of historic data to determine whether there may have been any preliminary cues to the flight crew through an increasing bias of the yaw control positions showed that nothing would have been apparent. Therefore, there was no in-flight indication to the crew of the impending bearing failure, before the landing on the Elgin.

On lift off from the Elgin helideck the helicopter yawed right through 45°, an unusual event. The commander's intuitive reaction, when the first attempt at takeoff was unsuccessful, was to try again so, after a short exchange about the event with the co-pilot, he lifted the helicopter back into a hover and turned to the left into wind. It now responded normally to his control inputs so he was reassured, as was the co-pilot, who thought the yaw event had occurred because of a misjudgement in a variable wind. Neither pilot considered that there was anything mechanically wrong with the helicopter, thus the departure continued.

The evidence of the degraded state of the bearing which led to the subsequent failure of the TRPCS suggests that this first yaw event was related to the bearing degradation. The manufacturer's retrospective analysis of yaw pedal positions showed that the use of full left yaw pedal could provide an indicator of advanced bearing degradation for flight crews. The flight crew, without the benefit of this information, tried to find a reasonable explanation for the yaw and considered that it arose because of local wind conditions and associated turbulence.

The commander's expectation was that the helicopter could be more awkward to handle in a left crosswind. The co-pilot's expectation was that the Elgin PUQ helideck could be 'tricky' due to the other installations and the position of the helideck and superstructure, creating a wind rolling up onto the deck or coming round from behind. Both factors could have influenced their acceptance of wind effect as an explanation for the unusual yaw.

2.2.2 RFM and Emergency Checklist procedures

This mode of failure of the TR system was not anticipated by the manufacturer and there was no RFM procedure to deal specifically with this malfunction. The RFM made reference to a loss of TR thrust with symptoms of '*uncommanded sharp right yaw, unresponsive to pedal inputs*, ('*sharp right yaw/spin'* in a hover); the associated actions required the helicopter to land immediately and shutdown.

The operator's Emergency Checklist included a procedure with similar actions entitled: '*TAIL ROTOR CONTROL FAILURE IN THE HOVER*'. However, this did not reference '*uncommanded right yaw'* as a failure indication but stated that an '*uncontrolled yaw'* would require an immediate landing. The operator's procedure '*TAIL ROTOR DRIVE FAILURE'* referenced the indication '*uncontrollable yaw to the right*'; the checklist actions for this failure would also have resulted in an immediate landing and shutdown.

The crew did not review Emergency Checklist procedures after the uncommanded right yaw at the Elgin as they did not consider the possibility of a technical malfunction. If a technical malfunction had been diagnosed and Emergency Checklist items actioned, it is considered unlikely that the crew would have continued with the flight.

2.2.3 Plan continuation bias

The flight crew's uncertainty over what had happened during the unusual yaw event on liftoff from the Elgin was not a sufficiently strong stimulus to change their original plan to depart for the West Franklin. However, the evidence of their continuing discussion suggests that, although they departed en route, they had not yet reached a satisfactory explanation for the event. The decision to continue is an example of a plan continuation bias, which is the unconscious tendency to go ahead with the original plan despite changing conditions. This type of cognitive bias works to obscure subtle cues of changing circumstances.[1]

The sector to the West Franklin was short, only five minutes, and the flight crew's focus quickly changed from the earlier event on the Elgin, to the forthcoming approach and landing on the West Franklin. During the landing, the commander, who probably had a heightened awareness following the Elgin event, sensed a similar unusual yaw to the right and was quick to respond, putting in additional left pedal to try to counter the yaw and partly lowering the collective. However, all yaw control of the helicopter was lost and it yawed to

1 Dismukes, R. K., Berman, B., and Loukopoulos, L. L. (2007) *The Limits of Expertise: Rethinking Pilot Error and the Causes of Airline Accidents.* Ashgate, Hampshire, UK.

the right and rolled left before the left mainwheels hit the helideck. The rate of yaw suggests that the TR thrust was substantially different to the yaw pedal demand, making the helicopter uncontrollable in yaw with a secondary effect in roll. The commander lowered the collective fully and maintained a full left yaw pedal input as the helicopter settled on the helideck, still rotating to the right. Brake parameters were not recorded so the status of the brakes is unknown but the helicopter came to a stop having turned through approximately 180°.

After the event the co-pilot immediately diagnosed a TR malfunction, as evidenced by his response to the Elgin radio operator after the helicopter was shut down.

2.3 Engineering analysis

The HUMS Tail Gearbox Bearing Energy Tool shows bearing degradation over a very short period of time. The first exceedence was picked up at five operating hours prior to the accident. Figure 25 shows that the bearing degradation produced inconsistent vibration levels which suggests the bearing did not follow a gradually increasing wear pattern leading to eventual failure.

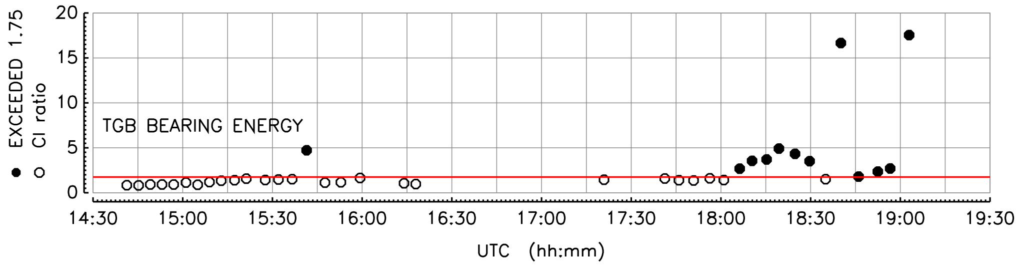


Figure 25

Extract from Figure 12 - TGB bearing energy CI ratio for third flight on 27 December 2016

The TRPCS bearing had been in service for 548 hours of its 1,250-hour life and had no recorded HUMS exceedences until five operational hours prior to its failure. This implies that there was a significant change in the bearing condition to cause the first exceedence and the bearing deteriorated rapidly thereafter.

The evidence on the bearing shows that it had undergone severe overheating whilst under load. The damage was too extreme to leave evidence of the traditional initiators of a bearing failure such as spalling, hard object contamination, cage failure or corrosion. However, those forms of bearing failure tend generally to develop slowly and produce gradually increasing but low level HUMS exceedences over a longer period of time.

The possibility of damage from within the TGB was considered, but this seems unlikely due to the absence of damage to the components in close proximity to the bearing, such as the TR shaft guide bushing. The TGB lubricating oil SOAP analysis of the routine samples taken prior to the accident show inconsistent rises in some of the metallic elements within the oil, but are inconclusive as indicators of impending bearing failure. The sample taken after the accident shows, unsurprisingly, a major metallic contamination of the lubricating oil resulting from the complete disintegration of the seals and bearing structure whilst the TGB's shafts and gears were rotating under load.

It is also possible that the bearing lubrication itself failed. If this was the case, it appears that conditions within the lubrication system of the bearing were such that an apparently normal bearing (which had run for half of its TBO and not generated any HUMS exceedences) suddenly started to produce significant HUMS exceedences and failed within a very short running time.

The bearing is a sealed self-lubricating component. Its rollers and races are surrounded in grease retained in the bearing by PTFE dust seals and covers. The grease is applied when the bearing is assembled by the OEM and is not disturbed until the 1,250-hour life on the TRPCS has been accrued. Providing that the correct type and quantity of grease is applied, the bearing should be trouble free during its TBO and beyond.

2.3.1 Cause of the uncommanded yaw on the Elgin PUQ

The uncommanded yaw event on the Elgin PUQ occurred during the lift off phase of the sector; therefore, no HUMS vibration data for the TGB were sampled at that time. However, the HUMS TGB bearing energy CI exceedence timeline prior to this event suggests that the TRPCS bearing was then at an advanced stage of degradation.

The dynamics of the interaction between the TRPCS bearing, servo and TGB shaft are difficult to quantify. However, there are two main features which are likely to cause unpredictability in the inputs to the TR.

As the servo attempted to push or pull the TRPCS via the bearing there would have been a considerable drag in the bearing as the degraded rollers and races made contact. This is likely to have imparted a torque back into the servo piston as a result. This increased dragging torque would have manifested itself as an additional load on the guide bushing, the TGB output shaft and on the lugs within the anti-rotation slot on the servo. The magnitudes of these loads are not known, but it is possible that they were enough to affect the movement of the servo piston as it responded to yaw inputs from the mixer unit and AFCS. Even though the servo can impart a considerable force into the

TRPCS, significant resistance felt against the servo piston may at least slow its movement. Furthermore, it may also have led to the servo stalling under load, resulting in wind-up of the cable system. The combination of cable wind-up and bearing free play due to wear may lead to a larger discrepancy between pedal position and actual TR blade angle (or thrust).

In addition, the degraded bearing had at least 0.5 inch (12.5 mm) linear play or looseness. As a consequence, the servo piston could have moved up to 0.5 inch with no resulting effect on the TRPCS and thus the TR itself. When considered against the range of movement of the servo in normal circumstances, the 0.5 inch linear play in a normal 3.5 inches (89 mm) of movement represents a reduction in the total range of travel of approximately 15%.

Both aspects would have affected the servo's feedback loop and manifested themselves as jerky or clumsy movements as the servo tried to achieve, and make corrections to, the required position.

2.3.2 Potential bearing lubrication problems

There are recognised to be two main problems regarding the application of grease in a bearing: either over-greasing or conversely, under-greasing.

If a bearing is over-greased, it can, under some circumstances, cause a bearing to overheat. The reason for this is that the grease can become clogged and may not stir around whilst the bearing is rotating and so becomes over-worked, heated and then oxidises. It then starts to degrade in the high-load areas and the heat generation in those areas increases leading to further degradation of the grease, a complete loss of lubrication and eventual bearing failure.

However, over-greasing will have an effect quite early in the bearing life and may manifest itself in the purging of discoloured grease past the bearing seals. The borescope inspection eight flying hours after installation of the TRPCS showed no abnormalities. This and the fact that the bearing achieved half its TBO suggests over-greasing was not a factor in this bearing failure.

Under-greasing of the bearing can also result in premature failure. In this case heat is also generated, but for different reasons. The grease may not be able to cover all of the surfaces within the bearing leading to metal-to-metal contact. This will result in accelerated wear, heat build-up and premature bearing failure.

It is also possible for a bearing to become under-greased during operation. It is normal for bearing grease to deplete during use and this is usually for two reasons: mechanical loss where there is a slight but constant seepage from race seals, or by gradual evaporation of the oil within the grease to leave a disproportionate amount of thickener. This is not always catastrophic; it is possible for a lightly loaded bearing to lose most of its grease and continue to operate correctly albeit with raised noise and vibration.

Although the hydrocarbon element of the grease was not present, forensic examination showed the presence of remnants of the thickening agent used in the grease. No meaningful data or conclusion, other than that grease had originally been present in the bearing, could be drawn.

2.3.3 Bearing loading and environment

The TRPCS bearing is designed to carry varying thrust loads from a non-rotating component to a rotating component. The orientation of the barrel rollers and races mean that each bearing is under compression from either a pull or a push from the servo. If the servo extends, the bearing race nearest the servo takes a higher proportion of the load. If the servo retracts, the same occurs on the race furthest from the servo. During operation, when the TR is at its neutral setting with no input from the TR servo, both races are relatively lightly loaded. When a yaw input is made (left induces a pull and right induces a push from the servo) the corresponding race of the bearing takes the load. The load increases proportionally to a maximum when the TR is at full pitch as the servo acts against the flexbeams within each blade. When the servo moves back to neutral the bearing load reduces and, for high rates of movement, may even act on the opposite side of the bearing.

The dynamic interaction between the inner and outer races and the rollers and their cages is complex. As described earlier, the bearing rollers are allowed, by virtue of including some end float, to move axially and radially within their cage. The scoring found in one bearing from the 19 TRPCS removals, was attributed to having been assembled too tightly; however, improved control of end play tolerance has subsequently been introduced by the manufacturer.

The TRPCS bearing is not under a constant load, the inner and outer races sustain varying push and pull loads for varying periods of time as the servo reacts to inputs from the pilot, mixer unit and other automatic systems. Although varying push and pull loads may tend to produce roller movement out of track, it should not be detrimental in this type of bearing in this application.

2.3.4 Servo damage

The failure of the bearing components created a torsional drag and ultimately led to the TRPCS 'back driving' the servo piston. Initially, as the bearing became less effective, it imparted a significant torque into the servo piston as shown by the evidence on the anti-rotation guide lugs. This torque was variable and, as continual yaw control inputs were made, the bearing condition worsened.

This eventually led to a snatch torque being applied to the piston which then failed at the outer end of the primary piston within the secondary piston sleeve. This had the effect of disconnecting the walking beam feedback pivot to allow unrestrained and random inputs to the servo control valves. Consequently, the now-rotating servo piston could move in and out of its cylinder making unpredictable pitch change inputs to the TR via the now severely damaged TRPCS and loose bearing.

Loss of TR control is a risk which was considered during certification of the helicopter. The certification process considered a TR which had either 'frozen' at a particular pitch setting or had returned to, and stuck at, its neutral pitch. The mitigation of this risk was based on the helicopter being flown with sufficient forward speed to counter any torque effects and to carry out a running landing. The loss of TR scenarios involved the servo either not receiving inputs or failing to respond to control inputs.

The work carried out to rectify the first bearing failure event in 2007 also considered a disconnection between the TRPCS and the servo piston, and considered a partial or full seizure of the TRPCS bearing applying torque to the servo piston. It was anticipated that should this happen, the servo would fail in the threaded portion of the clevis where it connects directly to the TRPCS (Figure 26). This would leave the now-disconnected, but hydraulically-driven, piston attached to the helicopter yaw control system and therefore in a relatively safe condition, albeit with the servo piston moving in and out, colliding with the remains of the clevis and its eye end.

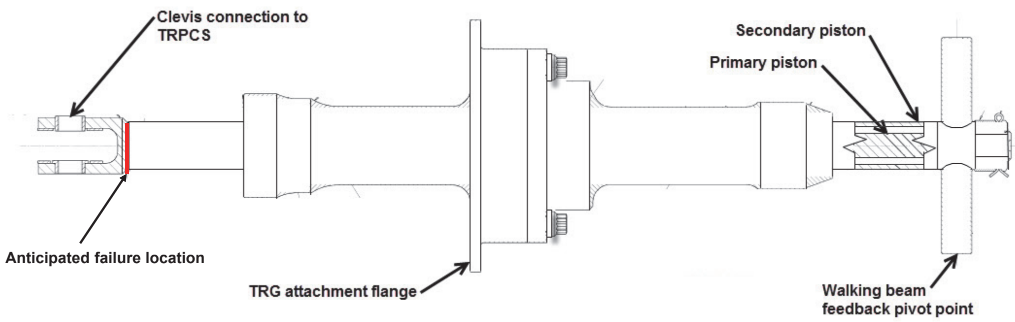


Figure 26

Anticipated servo failure location

2.3.5 Returned TRPCS assemblies

None of the TRPCS assemblies rejected by operators in accordance with the AD and ASB exhibited the same degradation as the bearing removed from G-WNSR. Furthermore, despite rigorous testing under load in the spin rig the manufacturer was unable to reproduce bearing failures.

2.3.6 Summary of engineering analysis

The damage to the TRPCS bearing has destroyed any evidence that would have identified the initiating cause of the bearing failure. However, during the failure sequence, bearing lubrication broke down drastically. It may be that loss of lubrication was the initiating cause but, as with the evidence of the possible mechanical failure mechanisms in this bearing, any evidence of this has been destroyed.

Despite extensive attempts, the manufacturer could not reproduce the bearing failure. This leads to the conclusion that the failure was because of undetermined factors which occurred within this particular bearing assembly. However, the manufacturer's analysis indicates, based on the testing during this investigation, that during the 2007 bearing event, reduced or no end play (causing tightness in the bearing) may have been the significant factor. The exact end play of the bearing assembly fitted to G-WNSR at manufacture is not known but bearing tightness cannot be discounted as a factor.

Had the HUMS exceedence generated by the TRPCS bearing been detected, the bearing would have been replaced before the helicopter was released to service.

2.3.7 Additional safety actions

Notwithstanding being unable to determine the exact cause of the bearing failure, the manufacturer has carefully analysed all the results and findings from the ASB and AD and the temperature sensing feedback. From this the manufacturer has been able to focus on all aspects of the bearing design, manufacture and assembly and has identified and implemented improvement in a number of areas. These improvements include the design and structure of the bearing races, precise control of the lubricant quality and quantity, and the dimensional tolerances allowable and achieved during assembly. In addition, the temperature profile of the TRPCS bearings in service is now better understood and can be used to influence the bearing design, maintenance and life policy.

2.3.8 Helideck resilience

Minor damage was caused to the surface of the helideck during the accident. The overall support structure of the helideck was unaffected and in this case, it would seem the helicopter presented a very high and very localised loading into the surface of the helideck in the form of a 'knife edge' created by the wheel rim. The angle was such that although the tyre wall would have deformed sideways it was not enough to break the rim seal to cause deflation of the tyre. It is possible that a momentary rim seal break occurred but then the tyre pressure instantly re-seated the tyre and maintained the seal.

The support structure, when combined with the surface material, give the crashworthiness or energy absorption capabilities of the helideck, as demonstrated in this case. The helicopter descended rapidly from about four feet (1.22 m), the landing gear compressed, the deck material distorted (dented) locally and then split within the area of the dent. Each 'step' in the process absorbed energy which in turn meant the support structure probably experienced no more than the loads imparted by the S-92A in a normal but firm landing.

The helideck requirements are set out in CAP 437 and take into consideration various normal and abnormal scenarios likely to take place during helicopter operations. The worst case assumption in CAP 437 is a single engine landing with a heavy helicopter. Unexpected scenarios are not specifically described but are considered within the overall deck strength overload allowance. Therefore, something like a loss of control leading to a roll-over is taken into consideration by the strength factors in the design being multiples of the helicopter type maximum weight.

The helideck resilience did not adversely affect the outcome of this accident, in other words, its damage did not make the situation worse or cause injury or loss of life, and so was not considered further in this investigation. However, the Helideck Certification Agency will bring this case to the attention of the CAA and the ICAO Heliport Design Working Group (HDWG) to consider whether the assumptions used in the regulations remain valid in the light of this accident.

2.4 HUMS data analysis on the S-92

2.4.1 Human machine interface

The analysis of vibrational HUMS data currently relies on the use of software running on a GS that has access to the helicopter's complete HUMS data history. The software is an inherent and critical part of the HUMS but it still requires a human to be 'in the loop' to inspect and make decisions based on what the software is telling them. This interaction between the system and user is, therefore, fallible and dependent on the design of the Human Machine Interface (HMI) for ease of use and ability to reduce the risk of failure due to human performance.

The HMI for the S-92 HUMS was the IMD GS software. This was first developed in 2001 and had grown in its capability to the extent that additional functionality, such as the TGB bearing energy analysis, could not be supported by the original IMD GS software and had to be made part of a standalone IMD-HUMS ToolBar, still installed on the GS, but run independently of the main IMD GS software. This meant that the HMI at the time of the accident comprised two independent parts that, due to variations in design, differed from each other in how they were used and how they provided information to the user. The crucial difference between the standalone ToolBar and the main IMD GS software was the fact the IMD-HUMS ToolBar did not inform the user that exceedences were present, but instead relied on the user to visually inspect the CIs for exceedences.

The use of the standalone IMD-HUMS ToolBar was taught during the operator's HUMS training of licensed engineers and routinely used by them when analysing the HUMS data from the S-92A helicopters. This was despite the omission of a step in the flowchart within the operator's documented HUMS S-92A download procedures. This omission was identified by the operator during their investigation of this accident and an updated HUMS manual was released within a month of the accident.

As part of the visual inspection of the CIs in the IMD-HUMS ToolBar, the user was able to zoom in and out. The method documented in the software user guide, and taught during training, worked on both the main software and standalone tool. However, a second method (differing only in the direction that the rectangle was made for selecting the region of interest to be zoomed in) that worked on main IMD GS software had the opposite effect on the IMD-HUMS ToolBar and several sub-functions within the IMD GS software. Therefore, any attempt to zoom in using this method, which was neither documented nor taught, resulted in zooming fully out, or no effect if fully zoomed out already.

The largest exceedence of the TGB bearing energy CI ratio on 27 December 2016 was 970% greater than the alert limit threshold (just over 17 compared to 1.75) and followed one of slightly less magnitude 23 minutes earlier. These would have been evident on initial inspection of the data only by the fact that the y-axis would have automatically rescaled and expanded to fit all the data on the plot, and the red alert threshold line, normally near the top of the plot, would have been much closer to the bottom. The x-axis, also automatically rescaled and expanded to fit all the CI ratio data since the last TGB maintenance date of 6 October 2016, 82 days earlier. As these two large exceedences happened in the last hour of these 82 days (so taking up less than 0.05% of the x-axis), the exceedences were hardly visible on the right hand edge of the plot.

Although the repositioning of the red alert threshold line attracted the attention of the licensed engineer, the unsuccessful attempts to zoom in on the data by two licensed engineers prompted them to attribute the unfamiliar look of the data plot to a software glitch. Nevertheless, Engineer A made a mental note to draw this anomaly to the attention of his supervisor later. Since this accident, the manufacturer has raised awareness of the standard procedure for the zoom function amongst the users of this software.

2.4.2 SGBA GS software

Since May 2015, the manufacturer had made available to operators of S-92 helicopters their own GS HUMS software called SGBA. The operator of G-WNSR made the decision to trial SGBA and had been doing so since 2015 to develop a knowledge and understanding of the software, with a view to transferring to it at the earliest opportunity given that the relevant S-92A maintenance manual revisions were yet to be issued. Some of the key benefits of the SGBA were that the functionality of the standalone IMD-HUMS ToolBar was incorporated into the software, and that a summary of all CI exceedences and alerts were presented to the user automatically once the HUMS data had been uploaded. It also introduced many features such as enhanced diagnostics and colour-coded visual indicators to highlight inspection requirements. Following release of the maintenance manual, and to promote uptake of SGBA with its improved analytical features and user interface, the manufacturer has notified operators of the intention to discontinue the older IMD software.

2.5 Licensed engineer human performance

2.5.1 Introduction

The safety intervention designed to identify a problem with a safety critical component failed for two reasons. This was mainly due to an HMI problem with the HUMS TGB bearing energy tool and its zoom facility. This was then compounded by human factors, in particular an individual forgetting to carry out a simple but important intended action. During discussions after the accident, Engineer A used the well-known phrase it ‘slipped my mind’. This is a very familiar predicament and has been a factor of many accidents and incidents in the past. In this particular case, the evidence suggests two different issues that came together which led to him forgetting to carry out an intended action despite a ‘mental note’ being made.

2.5.2 Environment

The AAIB observed, during a visit to the operator’s maintenance facility, that the hangar, shift offices and crew-room were spacious, calm and well-organised with shift routines and personnel availability clearly promulgated. The two supervisors had produced a shift routine over the Christmas period which meant the workforce was not too disrupted and could have quality downtime on Christmas Day and Boxing Day. These observations suggested a supportive, well-organised work environment where positive action is taken to keep external stresses and distractions to a minimum.

Engineer A appears to have suffered a failure of his prospective memory. This is a common phenomenon and is more likely to happen in a stressful, chaotic and noisy environment. However, in this case, the environment in the offices and hangar offered minimal adverse distraction and so was not considered to be a factor.

2.5.3 Prospective memory

Prospective memory is a form of memory that involves remembering to perform a planned action or recall a planned intention at some future point in time. It is used when a non-urgent task or sequence of tasks, which are already underway, become disrupted by a distraction and have to be resumed later. A failure of prospective memory is then a risk and can lead to steps being missed out in the original task or it not being completed at all. The reasons why prospective memory is used are varied: it is often because of a constraint on a task or the need for other factors to be in place to carry out the action or task. The common method is the mental note, "I must remember to....." and this might be sub-vocalised[2].

Prospective memory is susceptible to failure, usually due to distraction; for example, being absorbed in a task or where something else is competing for attention to the extent that the mental note is lost.

The absence of a specific physical reminder leaves a reliance on the 'mental note' which is fallible. A specific reminder such as a strategically placed post-it note or a phone alert can 'trip' the memory into recalling the task to be done. If for some reason the prompt or trigger is deferred or there is an interruption or distraction, the prospective memory can further decay over time. The intention to carry out a task or action then becomes forgotten unless a significant and very prominent prompt is experienced.

2.5.3.1 Causes of prospective memory failure in the engineer

In this case, Engineer A had an idea why the HUMS chart had rescaled and decided to address it later. Accordingly, he made his mental note with a plan to discuss the abnormality with his supervisor before closing the aircraft documentation. However, he forgot and the causes for this were probably two-fold. Firstly, it was apparent that this individual was conscientious and took his airworthiness responsibility seriously. This was demonstrated by his normal method of work: he always started with the HUMS download, then he would go into the hangar and personally double-check the safety critical areas on the helicopter prior to panel closure. He would have given his full attention to this action as he was absorbed in a task he considered important and therefore this subconsciously moved the mental note further from the short term memory.

2 Sub-vocalisation is a term used to describe the silent speech which is often carried out whilst reading but may be used when committing something to memory, eg "I must remember to……".

Secondly, the effect on him of the attempted break-in and his reaction to the police was an aggravating factor. It is known that being a victim of crime can adversely affect people in a variety of ways[3]. In this case he was observed to be upset and show signs of distress, which is a normal reaction. It can also preoccupy a person's mind, although this may not be constant, it can arise in quieter moments or when reminded by another seemingly unrelated situation. In this case it is possible that the experience with the attempted break-in and the police was dormant at the back of the engineer's mind throughout the evening. However, as he was starting to think about going off shift it is possible that the thought of returning home reminded him of the stressful experience earlier and this now began competing for his attention. This meant that his mental note to speak to the supervisor, which may have already been usurped by his physical double-checking of the helicopter, was now 'pushed aside' again by the reminder of his earlier experience.

During the morning and early afternoon before he went on shift and during his subsequent interview with the AAIB, he made no mention of having been engaged on any tiring activities. Although there is no evidence of fatigue, the shift was winding down late in the evening, so fatigue may also have been a minor contributory factor.

The loss of a mental note is not always permanent and may be brought back to mind by a prompt which may or may not be related. There was no work on G-WNSR which needed to be handed over to the oncoming night shift, so there was no handover discussion. Thus, there was no step-by-step description of the helicopter technical status which would probably have prompted the engineer into remembering the HUMS anomaly. As time moved on, the mental note was forgotten until he was given the information about G-WNSR the next day. The mental note was recalled from his memory, leaving him with the uncomfortable realisation that he had forgotten to mention the HUMS matter the night before.

2.5.4 Mutual reinforcement

The discussion between Engineer A and Engineer B tried to make sense of the exceedence line. They made several attempts to use the zoom function to look at a suspected data peak in more detail. Despite having no other evidence of a problem with the HUMS analysis tools, in the absence of visible reasons for the exceedence line position and unsuccessful attempts to zoom in for the detail, they both concluded there was a problem with the software.

The fact that both drew this conclusion is likely to have been due to their shared experience whilst at the G-WNSR's GS. Their discussion re-enforced their

3 Dinisman, T. & Moroz, A. (2017). *Victim Support – Understanding Victims of Crime – The impact of crime and support needs*. London: VS.

conclusion and confirmed their mutually-held theory that it was an unknown software problem. In this case, they had an expectation that an exceedence had occurred as indicated by the axis rescale. Their expectation was for the zoom function to allow the peak to be visible by causing the rescale and the exceedence to be clearly identified. Instead, they interpreted the failure of the software to zoom as being due to the fact that there was no peak to reveal and therefore no exceedence. Nevertheless, Engineer A still had misgivings about the anomaly and resolved to follow it up later.

2.6 Timeliness of VHM data

2.6.1 Maximum interval between downloads

The AMC to CS 29.1465 currently requires operators to specify a maximum interval between HUMS data downloads. It must not exceed the system memory capacity (which must be a minimum of 25 flying hours). CAA guidance material (CAP 753) specifies that the interval should not exceed 25 flying hours and that this is reduced to 10 hours for components or indicators that require 'close monitoring'. CAP 753 also states that 10 flying hours is not atypical of a day's flying for North Sea operations.

The operator of G-WNSR had procedures which were more stringent and had reduced the interval to a maximum of five flying hours between downloads. It had provisions in place, through the use of card readers or repositioning the GS laptop computer, for occasions when the helicopter would not be able to return to a main operating base before the 5-hour limit expired.

2.6.2 Timeliness of VHM alerts

Given the existing HUMS procedures in place by the operator, there were opportunities to capture the failure of the TRPCS bearing before it resulted in the accident. The first detected exceedence of the TGB bearing energy CI was five operational hours before the accident. The HUMS data was downloaded 3.5 operational hours after this initial exceedence, when the helicopter returned its main operating base at Aberdeen at the end of that day's flying, but the opportunity to detect the impending bearing failure was missed. Overnight, the HUMS data was routinely and automatically sent to the operator's base in Norway; however, their general review of the data was made on the morning of the accident flight when G-WNSR was already airborne, and by the time they had established that exceedences had occurred, the bearing had already failed.

A typical flying day for North Sea operations may exceed 10 operational hours duration during which multiple landings are often made, many of them not at a main operational base. This is more than twice the time between first exceedence and the bearing failure and also exceeds the initial-exceedence-to-failure time seen for G-CHCN (4.75 flying hours) and G-REDW (4.62 flying hours). The UK requirement of a maximum time interval between HUMS downloading (and analysis) of 25 flying hours means that failures of this nature could go undetected for several days before the next download (and analysis) is conducted. The operator's procedures for a maximum time of five flying hours is more stringent than the UK requirements and more likely to detect these types of failures; however, even this reduced interval was in excess of the four flying hours between G-WNSR's first detected exceedence and bearing failure. Had the exceedence happened at the beginning of the first flight of the day or at the start of a flight following a scheduled download, it would not have been detected before the bearing failed.

For an impending and potentially catastrophic failure to be detectable, but for this information to remain unknown to flight crews and maintainers for a significant period, is unacceptable; a more timely method of acquiring, accessing, analysing and promulgating the data needs to be devised and implemented.

2.6.3 Acquisition of VHM data

The current method of sampling VHM vibration data from multiple sensors is to take data snapshots by sampling and processing the data of each sensor in turn. Continuous monitoring is not necessarily required to provide effective detection. The AMC to CS 29.1465 prescribes that as a minimum for flights of greater than 30 minutes in stabilised conditions, at least one data set for all the sensors is obtained. If these stabilised conditions cannot be met then the data set should be acquired '*at an appropriate rate and quantity for the VHM signal processing to produce robust data for defect detection*'.

Most of the time is spent in processing the data. For example, sensor data used by the TGB bearing energy CI is sampled for a minimum of 10 seconds and takes about 1.5 minutes to process. It is also one of a number of sensors that are sampled during the cruise phase of flight, and the total time taken to sample data and process the data from all of these sensors is about eight minutes. This means that the individual sensor data available equates to only about 2% of the time in the cruise. In reality it is less than this as data is only sampled if the helicopter is in a steady state condition. This limitation also exists for other sensors collected in other phases of flight such as the hover. Therefore, for the other 98% of the time on the S-92, potential opportunities to detect individual CI exceedences are being missed, and the opportunity for a much earlier indication of an impending and potentially catastrophic failure is lost.

Therefore, the following Safety Recommendation is made:

Safety Recommendation 2018-006

It is recommended that the European Aviation Safety Agency commission research into the development of Vibration Health Monitoring data acquisition and processing, with the aim of reducing the data set capture interval prescribed in the Acceptable Means of Compliance to CS 29.1465 and thereby enhancing the usefulness of VHM data for the timely detection of an impending failure.

2.6.4 Download and analysis of VHM data

A typical North Sea flying day contains multiple landings and, as an example, advantage could be taken of time on the ground to download HUMS data. The technology to automatically download data wirelessly from aircraft already exists and is routinely used with fixed wing aircraft for Flight Data Monitoring and Flight Operations Quality Assurance purposes at the conclusion of a flight. In addition to downloading data whilst on the ground, larger commercial transport aircraft use VHF radio or satellite communications to transmit and receive data whilst the aircraft is in flight. Once data has been downloaded, modern VHM software, such as SGBA, can identify exceedences and generate alerts automatically. It is recognised that human intervention will still be required to carry out maintenance action at a later stage for any alerts generated.

2.6.5 Promulgating VHM data

With improvements through automatic downloads, analysis and alert generation, significant benefit would be gained by providing this vital safety information to the flight crew of the helicopter so that they can take timely action, as deemed appropriate, to safeguard the helicopter and its occupants.

More timely indications to the crew are possible via a cockpit HUMS-pilot interface. For example, in-cockpit HUMS CIs were implemented because of the investigations into the EC225 accidents to G-CHCN and G-REDW to remove a requirement for a maximum of four flying hours between HUMS downloads (and analysis). The HUMS philosophy applied to some UK military helicopter fleets appears more proactive compared to civil operations in that certain exceedences can be displayed and interrogated in the cockpit by the crew and form part of the post-flight and pre-flight procedures. The CAA (paper 2012/01) also recognised the importance of more timely indications to the crew, concluding that 'on-board, post-flight indications' are needed to make new technologies, that are able to detect impending failures, effective.

2.7 Strengthening the safety barriers

In this event, most of the safety barriers were breached and it was only by chance that the outcome was not more severe.

The design and certification had not foreseen the unusual mechanism of the TRPCS failure and, although the HUMS had detected an impending problem, that barrier, which required an engineer to correctly interrogate the software to display the exceedence, failed due to the limitations of human performance and the design of the HUMS GS HMI. In the future there may well be other flight critical components in helicopters which fail as a result of unanticipated circumstances, some of these may be detectable in advance by HUMS.

The final barrier could have been that of flight crew intervention. However, they too have human performance limits and, as they had no knowledge of, or access to, the detected HUMS exceedences, an opportunity to discontinue the flight was lost. The potential cue of full left pedal travel had not previously been identified by the manufacturer and a review is being undertaken to determine whether this information should be incorporated in the RFM.

The investigation identified that had HUMS exceedence data been available on the helicopter in near real-time, the flight crew would have had at least two pre-departure opportunities to safely abort the flight.

Additionally, should G-WNSR have had such a capability, it is considered likely that, after the initial incident and re-land on the Elgin, the flight crew would have made use of it and that it would have informed their judgement as to whether to depart for the West Franklin.

Furthermore, given the circumstances of this event and the short timescale over which the problem developed, providing flight crews with a simple means to establish the health and serviceability of their helicopter whilst away from a maintenance base could be the only effective barrier remaining to prevent an accident.

Therefore, the following Safety Recommendation is made:

Safety Recommendation 2018-007

It is recommended that the European Aviation Safety Agency amend the regulatory requirements to require that Vibration Health Monitoring data gathered on helicopters is analysed in near real-time, and that the presence of any exceedence detected is made available to the flight crew on the helicopter; as a minimum, this information should be available at least before takeoff and after landing.

Intentionally left blank

3 Conclusions

3.1 Findings

1. The helicopter was equipped with HUMS and its use by the operator as part of its maintenance programme satisfied the regulatory requirements for helicopter VHM.

2. The operator's HUMS procedures stipulated a maximum of five flying hours between HUMS downloads rather than the maximum of 25 flying hours required by the UK Regulations, but even this reduced interval would not necessarily provide timely warning of impending TRPCS bearing failure.

3. The IMD GS software was in two distinct parts that had different interface characteristics for identifying and alerting exceedences to the user which led to a situation whereby an exceedence was missed.

4. Checks of the TGB bearing energy CI were routinely carried out by the maintenance personnel despite the omission of this step in the flowchart within the operator's documented HUMS S-92A download procedures.

5. The HUMS detected a failing TRPCS bearing.

6. The time between detectable degradation of the bearing by HUMS and failure of the bearing was four flying hours.

7. Due to an anomaly in the way that exceedences are viewed in the main IMD GS software and the GS ToolBar by maintenance personnel, coupled with the limitations in human performance, the HUMS exceedence was not identified during routine maintenance and the helicopter was released to service.

8. By the time that the HUMS data was reviewed by a second organisation the TRPCS bearing had already failed.

9. The pilots were properly licensed, qualified and sufficiently rested to conduct the flight.

10. There was no in-flight indication to the crew of the impending bearing failure before the landing on the Elgin.

11. During the departure from the Elgin helideck, the helicopter did not respond as expected to the commander's yaw pedal inputs, including the use of full left yaw pedal. Following a satisfactory check of the yaw control response, this was attributed to a wind effect and the final opportunity to terminate the flight was missed. However, it was established during the investigation that the event was due to the degraded condition of the TRPCS bearing.

12. A review of the historic S-92 fleet data by the manufacturer established that the use of full yaw pedal is a rare event in flight.

13. The TRPCS bearing failed whilst the helicopter was in flight.

14. The TRPCS bearing failure precipitated damage to the TR servo. This damage manifested itself during the landing on the West Franklin helideck.

15. The TR servo primary piston fractured within the secondary piston sleeve and not, as previously anticipated, in the threaded portion of the clevis.

16. The fracture of the servo primary piston disconnected the feedback pivot of the walking beam, resulting in loss of control of the TR servo.

17. The flight crew reacted expeditiously to an uncontrollable yaw whilst landing on the West Franklin helideck.

18. The helideck surface was punctured during the abnormal landing, but this did not adversely affect the outcome of this accident.

19. There were no injuries.

20. If the loss of yaw control had occurred at an earlier stage of the flight, the helicopter would most likely have made an uncontrolled descent into the North Sea.

21. The helicopter operator filed an MOR with the CAA on the day of the accident. However, when further evidence became available as to the seriousness of the event, it was not reported to the AAIB as it should have been.

22. The helideck operator was unaware of their responsibility to report an accident to the AAIB.

23. The TRPCS bearing was too badly damaged to determine the reason for its failure.

24. Additional inspections on in-service TRPCSs were introduced and, as a result, a number were returned to the manufacturer for further investigation. Of those bearings, 18 did not exhibit unusual or advanced wear or degradation, but one exhibited roller wear and unusual indications on the outer race.

25. Despite extensive and prolonged testing of the returned TRPCSs, the manufacturer could not reproduce a TRPCS bearing failure.

26. The current VHM regulatory requirements for the maximum interval between data downloads (and analysis) are ineffective for detection of imminent in-service component failures.

27. The yaw event on the Elgin was not captured by HUMS.

28. The low frequency of data capture from individual VHM sensors means that, for the majority of the time, they are not utilised and opportunities to detect problems are missed.

3.2 Causal factors

The investigation identified the following causal factors to the loss of yaw control:

- The TRPCS bearing failed for an undetermined reason.
- The TRPCS bearing failure precipitated damage to the tail rotor pitch control servo.

3.3 Contributory factors

The investigation identified the following contributory factors:

- Impending failure of the TRPCS bearing was detected by HUMS but was not identified during routine maintenance due to human performance limitations and the design of the HUMS Ground Station Human Machine Interface.
- The HUMS Ground Station software in use at the time had a previously-unidentified and undocumented anomaly in the way that data could be viewed by maintenance personnel. The method for viewing data recommended in the manufacturer's user guide was not always used by maintenance personnel.

Intentionally left blank

4 Safety Recommendations

4.1 Safety Recommendations

The following Safety Recommendations have been made:

Safety Recommendation 2018-006

It is recommended that the European Aviation Safety Agency commission research into the development of Vibration Health Monitoring data acquisition and processing, with the aim of reducing the data set capture interval prescribed in the Acceptable Means of Compliance to CS 29.1465 and thereby enhancing the usefulness of VHM data for the timely detection of an impending failure.

Safety Recommendation 2018-007

It is recommended that the European Aviation Safety Agency amend the regulatory requirements to require that Vibration Health Monitoring data gathered on helicopters is analysed in near real-time, and that the presence of any exceedence detected is made available to the flight crew on the helicopter; as a minimum, this information should be available at least before takeoff and after landing.

4.2 Summary of safety actions

AAIB Special Bulletin

The AAIB published Special Bulletin S1-2017 which provided the initial facts of this investigation. The Special Bulletin and this report present the following safety actions:

Safety action by the helicopter operator

The operator subsequently introduced a number of measures to further strengthen the ability to detect impending bearing degradation. These included: a review of all HUMS data to ensure no anomalies, fleet-wide borescope inspections and a requirement for HUMS to be serviceable before flight. The operator also reviewed their HUMS processes and analytical procedures, correcting the omission in the documentation of the use of the IMD-HUMS ToolBar analysis tools. They also introduced a requirement for an additional assurance check to be carried out by a second licensed engineer prior to releasing the helicopter to service.

Safety action by the helicopter manufacturer

On 31 December 2016 the helicopter manufacturer issued to all operators an 'All Operators Letter' (AOL), CCS-92-AOL-16-0019, which described the event. It emphasised the use of the HUMS Tail Gearbox Bearing Energy Tool, provided on the ground station, to detect a TRPCS bearing that is experiencing degradation, and recommended that this tool was utilised as often as reasonably possible.

ASB 92-64-011 was issued by the manufacturer on 10 January 2017 and introduced a once-only inspection of the TRPCS and bearing assembly for ratcheting, binding, or rough turning. It also called for a review of the HUMS Tail Gearbox Bearing Energy Tool. The manufacturer recommended that compliance was essential and to be accomplished prior to the next flight from a maintenance facility; three flight hours are allowed in order to return directly to a maintenance facility. The once-only inspection was mandated by FAA Airworthiness Directive (FAA AD) 2017-02-51 issued on 13 January 2017 and added a requirement to carry out a 10-hourly borescope inspection of the bearing in situ until further notice.

Concurrent with the release of ASB 92-64-011, the manufacturer published Temporary Revision 45-03 to require operators to use S-92A HUMS ground station software to review Tail Rotor Gearbox energy analysis CIs for alert conditions on a reduced flight hour interval. CIs in excess of published alert levels required inspection of the pitch change shaft and bearing.

The manufacturer developed a temperature sensing plug which could be retrofitted to in-service TRPCSs to establish fleet-wide trends. The temperature sensing plug installation was carried out under the authority of ASB 92-64-012, issued on 9 March 2017 with a scheduled compliance date of 13 April 2017.

On 24 March 2017 the manufacture issued All Operators Letter CCS-ALL-AOL-17-0008 to remind users of the IMD software of the approved zoom and undo zoom commands for interrogating the HUMS CI data. It also informed users that the IMD software would be obsolete in the near future and that the maintenance manual revisions for the SGBA were now available.

The helicopter manufacturer has worked with the bearing manufacturer to identify and implement a number of improvements to the bearing manufacturing process. An improved end play measuring tool has been introduced in order to carry out more accurate measurement and bearing setting up during assembly. The grease is now drawn from sealed cartridges and injected into the races using a syringe to ensure a more consistent distribution. The bearing is also now weighed before and after grease application.

Safety action by the helideck operator

Since the accident the '*Helicopter Occurrence - Communication Process*' procedures for the helideck operator's UK operations have been revised to include a requirement to report an accident or serious incident to the AAIB.

Helideck certification safety action

The Helideck Certification Agency will bring this case to the attention of the CAA and the ICAO HDWG to consider whether the assumptions used in the regulations remain valid in the light of this accident.

Intentionally left blank

Appendix A

Tail rotor malfunctions and associated emergency procedures applicable at the time of the event

RFM emergency procedures related to 'uncommanded yaw'.

11.1 LOSS OF TAIL ROTOR THRUST IN FORWARD FLIGHT

Symptoms:

Uncommanded sharp right yaw, unresponsive to pedal inputs.

Action:

1. Enter autorotation.
2. Maintain 80 to 100 KIAS.
3. LDG GEAR – DOWN.
4. Throttles – STOP prior to touchdown.

11.2 LOSS OF TAIL ROTOR THRUST IN A HOVER

Symptoms:

Uncommanded sharp right yaw/spin, unresponsive to pedal inputs.

Action:

1. Hold the aircraft in level attitude, attempt to achieve zero groundspeed and drift in a low hover.
2. Throttles – STOP (5 to 10 feet).
3. Collective – Increase to cushion landing.

After ground contact:

4. Lower collective to minimum.
5. Apply wheel brakes.

Appendix A (Cont)

Emergency Checklist references to 'uncontrolled yaw'.

62	TAIL ROTOR CONTROL FAILURE IN HOVER

Indications:

- Loss of response to yaw pedal inputs
- Yaw pedals may be stuck or restricted

A. IF THE AIRCRAFT STARTS AN UNCONTROLLED YAW:

Actions:

1. Collective .... Lower to **LAND IMMEDIATELY**
2. Attitude .... Maintain with cyclic
3. Groundspeed / drift .... Minimise

B. IF NO YAW INDICATED:

Actions:

1. **If the aircraft is over a suitable landing area:**
   a. Collective .... Maintain
   b. Attitude .... Maintain with cyclic
   c. Reduce N_R to initiate a descent
   d. **After ground contact:**
      - Collective .... Set minimum pitch
      - Use differential braking to control heading
2. **If NOT over a suitable landing area:**
   a. Attempt to fly away using cyclic only
   b. Go to CHECKLIST 63 TAIL ROTOR CONTROL MALFUNCTION IN FORWARD FLIGHT

Appendices

Appendix A (Cont)

60 TAIL ROTOR DRIVE FAILURE

Indications:

- Uncontrollable yaw to the right, possibly preceded by excessive noise or vibration from the tail section or IGB CHIP or IGB HOT or TGB CHIP or TGB HOT cautions

A. IN THE LOW HOVER:

Actions:

1.	Attitude	Maintain with cyclic
2.	Groundspeed / drift	Minimise
3.	Throttles (5 to 10 feet)	STOP
4.	Collective	Increase to cushion landing

5. After ground contact:

- **a.** Collective .... Set minimum pitch
- **b.** Brakes .... Apply

B. IN FORWARD FLIGHT:

Actions:

1.	Autorotation	Enter immediately (80 to 100 knots, 105% N_R)
2.	APU CTRL	ON
3.	Landing gear	Down
4.	Radio call	Complete
5.	**If over water:**	
a.	Floats	ARM (<80 knots)

6. Throttles .... STOP (before touchdown)

7. If time and altitude permit:

- **a.** Passenger .... Brief
- **b.** Satellite communications .... Emergency

Appendices

Appendix B

Elgin Helideck Landing Area Certificate, Helideck Information Plate and Temporary Limitations Notice 15-2016

HCA Helideck Certification Agency

HELICOPTER LANDING AREA CERTIFICATE

Elgin PUQ

The above named helideck has been inspected in accordance with CAP 437, BSL D 5-1, and HCA requirements for Offshore Helidecks.

The helideck has been found suitable for helicopter operations subject to:

1. Such non-compliances and restrictions as may be listed below; and,
2. Authorization by the helicopter operator.

Wind (T°)	Kts	Limitation /Comment
• • 015-055	• • 0-15	Platform • Possible turbulence from Turbine Exhaust and Exhaust Stack • Table 1 (T) for all operations due to anti turbulence panels.

	Non Compliance
210°	Handrail @ 1.1m South East sector (Parking area) Securing eyes for NDB aerial attached to Perimeter net supports 300mm above deck level
5:1	Anti turbulence panels around outboard perimeter
Misc	Shuttle Aircraft or Containers may be in Parking Area, check clearance from SLA.

Valid for helicopters with: Maximum 'D' value:	**'D' = 22.8**
Maximum take-off weight:	**'t' = 15.0**
This certification shall remain in force until (unless previously revoked or suspended)	**10th January 2017**

Notes:
1. This certificate is non-transferable.
2. The certificate holder is responsible for ensuring that the helideck, its environs and related equipment are at all times fit for purpose and that the helideck crew are suitably qualified, equipped and trained in the exercise of their duties.
3. This certificate shall cease to be valid if:
   - Changes of ownership or name of installation/vessel are made without notification to the HCA.
   - Changes to the helideck, its environs and/or related equipment are made without prior agreement of the HCA.
   - Levels of Helideck crew qualifications/competency are not maintained to the levels described in the UKOOA Guidelines for Management of Offshore Helidecks or suitable alternative standards.
4. Any proposed changes are to be accompanied by drawings in plan and elevation with photographs where possible, particularly when such changes concern:
   - Modification to installation/vessel physical characteristics within the 150°, 210° and 180° falling gradient obstacle protected surfaces; and/or structural modifications to other areas of the installation/vessel that may affect or alter the airflow or turbulence experienced over the helideck
5. The Norwegian 1.25D requirement is only relevant to vessels constructed (keel laid) after 1 January 2008.

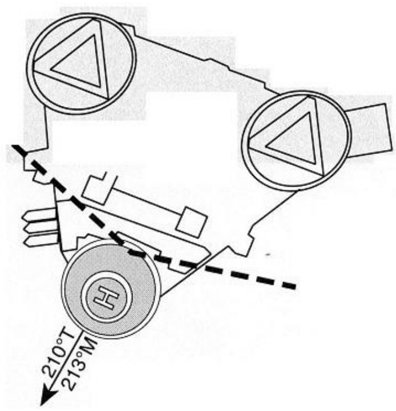
Date: 27th September 2016

Helideck Certification Agency

Appendix B (Cont)

HELIDECK INFORMATION PLATE

HELIDECK Elev **166** ft	VAR **3 W**	POSITION **N57.00.7 E001.50.2**	**Elgin PUQ**		
HEIGHT OF INSTALLATION: **509** HIGHEST OBSTACLE WITHIN 5NM: **Top of Rig**			VHF	NDB **EGN 421.5**	Issue Date **09 Dec 2014**
FUELLING INSTALLATION: **Yes** STARTING EQUIPTMENT: **Yes**			Operating Company		Issued By
(Norway 1.25D - 'D' =) HELIDECK D value: **22.8** P/R/H Category: **F** Max Weight: **15.0**			**Total**		**Helideck Certification Agency**



Wind (T°)	Kts	Limitation /Comment
• • 015-055	• • 0-15	Platform • Possible turbulence from Turbine Exhaust and Exhaust Stack • Due to turbulence panels AS332 - Hover with nose wheel near to deck edge - Nil limitation S76 - Table 1 (T) Other types - TBA

	Non Compliance
210°	Handrail @ 1.1m South East sector (Parking area) Securing eyes for NDB aerial attached to Perimeter net supports 300mm above deck level
5:1	Anti turbulence panels around outboard perimeter
Misc	Shuttle Aircraft or Containers may be in Parking Area, check clearance from SLA.

Appendices

Appendix B (Cont)

HLL
Temporary Limitations Notice

TO:	ALL PILOTS	DATE:	9 May 2016
TLN NUMBER:	15 - 2016		
SUBJECT:	**Galaxy 1 and Prospector 5 Rigs alongside Elgin Wellhead Platforms**		

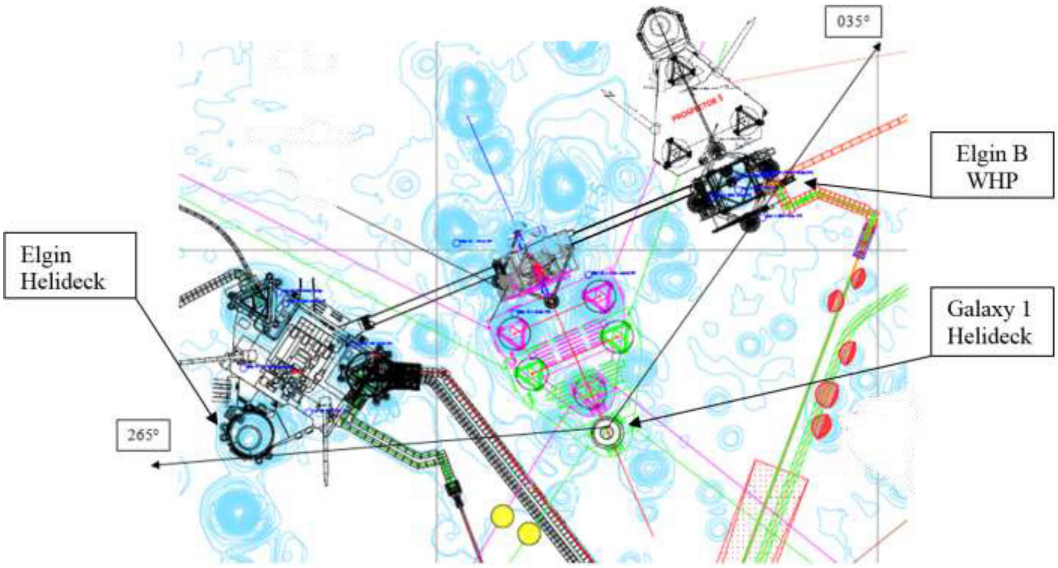
1. **Comments**

The Galaxy 1 and Prospector 5 Jack-up rigs will be repositioning at the Elgin Wellhead Platform. The Galaxy 1 will be stationed on the south side of the Elgin WHPA and the Prospector 5 will be stationed on the north side of the Elgin WHPB as per the diagram below.

As an interim measure and until such time as FDM Turbulence analysis has been completed the following restrictions are to be applied when operating to the Galaxy 1 and Prospector 5 Heli-deck.

Please ensure that you remain compliant with PC2E and PC2DLE as applicable.

2. **Photo/Dwg**



Form 09 Rev 00 Apr 09

Appendix C

West Franklin Helideck Landing Area Certificate and Helideck Information Plate

HCA Helideck Certification Agency	HELICOPTER LANDING AREA CERTIFICATE

West Franklin

The above named helideck has been inspected in accordance with CAP 437, BSL D 5-1, and HCA requirements for Offshore Helidecks.

The helideck has been found suitable for helicopter operations subject to:

1. Such non-compliances and restrictions as may be listed below; and,
2. Authorization by the helicopter operator.

Wind (T°)	Kts	Limitation /Comment
		NUI • Circle and H lights fitted

	Non Compliance

Valid for helicopters with: Maximum 'D' value: Maximum take-off weight:	**'D' = 21** **'t' = 12.8**
This certification shall remain in force until (unless previously revoked or suspended)	**09/09/2017**

Notes:
1. This certificate is non-transferable.
2. The certificate holder is responsible for ensuring that the helideck, its environs and related equipment are at all times fit for purpose and that the helideck crew are suitably qualified, equipped and trained in the exercise of their duties.
3. This certificate shall cease to be valid if:
   - Changes of ownership or name of installation/vessel are made without notification to the HCA.
   - Changes to the helideck, its environs and/or related equipment are made without prior agreement of the HCA.
   - Levels of Helideck crew qualifications/competency are not maintained to the levels described in the UKOOA Guidelines for Management of Offshore Helidecks or suitable alternative standards.
4. Any proposed changes are to be accompanied by drawings in plan and elevation with photographs where possible, particularly when such changes concern:
   - Modification to installation/vessel physical characteristics within the 150°, 210° and 180° falling gradient obstacle protected surfaces; and/or structural modifications to other areas of the installation/vessel that may affect or alter the airflow or turbulence experienced over the helideck
5. The Norwegian 1.25D requirement is only relevant to vessels constructed (keel laid) after 1 January 2008.

Date: 14/11/2016

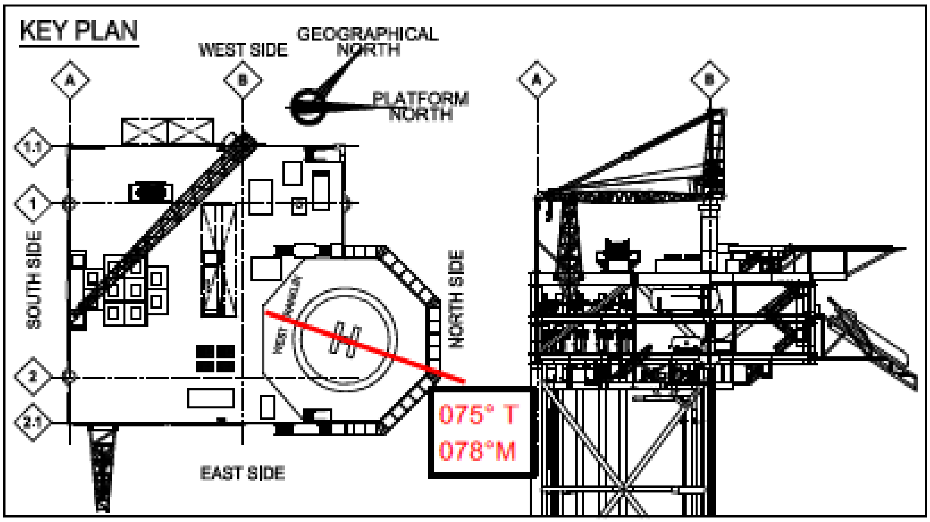
Helideck Certification Agency

Appendix C (Cont)

HELIDECK INFORMATION PLATE

HELIDECK Elev 140 ft	VAR 4° W	POSITION N 56.57.47 –E 001.48.22	West Franklin	
HEIGHT OF INSTALLATION: **204** HIGHEST OBSTACLE WITHIN 5NM: **Check**		VHF **Tr 122.325 Log 129.7**	NDB	Issue Date **14 Nov 2016**
FUELLING INSTALLATION: **No** STARTING EQUIPMENT: **No**		Operating Company **Total**		Issued By **Helideck Certification Agency**
HELIDECK D value: **21.0m** P/R/H Category: **F** Max Weight: **12.8 t**				

No photo available



Wind (T°)	**Kts**	**Limitation /Comment**
		NUI • Circle and H lights fitted
		Non Compliance
		Nil

Appendix D

Sikorsky Temporary Revision 45-03

S-92

MAINTENANCE MANUAL, SA S92A-AMM-000

TEMPORARY REVISION NO. 45-03

FILING INSTRUCTIONS: Insert in Task 45-45-10-710-001, HUMS Displayed Exceedances and Associated Maintenance Actions, immediately following page 163/164, dated Nov 30/16.

SUBJECT: Review of Tail Gear Box (TGB) Bearing Energy HUMS Tool

This temporary revision adds new Section 11. Review of TGB Bearing Energy HUMS Tool to Task 45-45-10-710-001, HUMS Displayed Exceedances and Associated Maintenance Actions, dated Nov 30/16.

MANUAL CHANGES:

In Task 45-45-10-710-001, HUMS Displayed Exceedances and Associated Maintenance Actions, dated Nov 30/16, add new Section 11. Review of TGB Bearing Energy HUMS Tool as follows:

11. Review of Tail Gear Box (TGB) Bearing Energy HUMS Tool.

A. The following review shall be performed as follows:

NOTE: A functioning TGB mechanical diagnostic function of the HUMS is required.

(1) If using IMD and TGB energy analysis software contained in the standalone software tool for the S-92 HUMS GS, a review shall be accomplished every three (3) flight hours.

(2) If using Sikorsky Ground Based Application (SGBA) TGB bearing energy tool version released prior to January 10, 2017, a review shall be accomplished every three (3) flight hours.

(3) If using SGBA TGB bearing energy tool version released on or after January 10, 2017, a review shall be accomplished every six (6) flight hours.

(4) If customer seeks extension to six (6) flight hours and are using methods one (1) or two (2) above contact Aircraft on Ground (AOG) Center at 1-800-WINGED-S or Email: sikorsky.aog@lmco.com.

B. For users with Integrated Mechanical Diagnostics (IMD) bearing energy tool, review the HUMS Tail Gear Box Bearing Energy Tool per the HUMS user guide, SA S92A-HUM-000, Chapter 11.4 with the following exceptions:

(1) A condition indicator (CI) exceedance of 1.75 for any one data point shall require inspection per AMM Task 64-22-03-290-001 "Off AC Inspection of TR PCS Bearing Assembly", steps A.(6)(j) thru A.(6)(o) and contact Sikorsky Aircraft Customer Service Engineering at 1-800-WINGED-S or Email: wcs_cust_service_eng.gr-sik@lmco.com . Submit any findings to local Sikorsky FSR.

C. For users with the SGBA HUMS Toolbar, review the HUMS Tail Gearbox Bearing Energy Tool per the Sikorsky Ground Based Application (SGBA) Users Guide, SA S92A-GBA-000, Chapter 15.5 with the following additions:

MAINTENANCE MANUAL, SA S92A-AMM-000

WARNING: A CI RATIO GREATER THAN 1.75 WILL NOT AUTOMATICALLY DISPLAY AS AN ALERT.

(1) This automated TGB Bearing Energy Analysis software consists of the following four steps:

(a) The 15-20 kHz energy data for a specific helicopter tail number is extracted from the HUMS Ground Station Software (GSS) Raw Data Files (RDFs). This 15-20 kHz energy is referred to as a CI.

(b) The average 15-20 kHz energy is computed for that helicopter tail number since the last maintenance date. This date is important, since removing/replacing the TGB, the pitch change shaft assembly, or the TGB accelerometer can change the absolute value of the CI.

(c) The 15-20 kHz energy is normalized by the helicopter-specific mean. This normalized energy is referred to as the “CI ratio”. The intent of the software is create a baseline for the helicopter that is nominally at 1.0. The baseline data consists of 200 points. If 200 points have not been collected since the last maintenance date the tool will indicate “Insufficient Data”.

(d) The trend history for the normalized energy is plotted for each specific tail number. The limit threshold for this normalized data is 1.75.

NOTE: The current alert limit display of 2.5 should not be used and will be updated in the next release. The 1.75 alert limit exceedance will not automatically display as an alert until the next release.

NOTE: See Figure 129 for example of exceedance requiring maintenance inspection. Note data prior to exceedance is nominally centered around 1.0 indicating good baseline data.

(2) A condition indicator (CI) exceedance of 1.75 for any one data point shall require inspection per AMM Task 64-22-03-290-001 “Off AC Inspection of TRPCS Bearing Assembly”, steps A.(6)(j) thru A.(6)(o) and contact Sikorsky Aircraft Customer Service Engineering at 1-800-WINGED-S or Email: wcs_cust_service_eng.gr-sik@lmco.com . Submit any findings to local Sikorsky FSR.

S-92

MAINTENANCE MANUAL, SA S92A-AMM-000

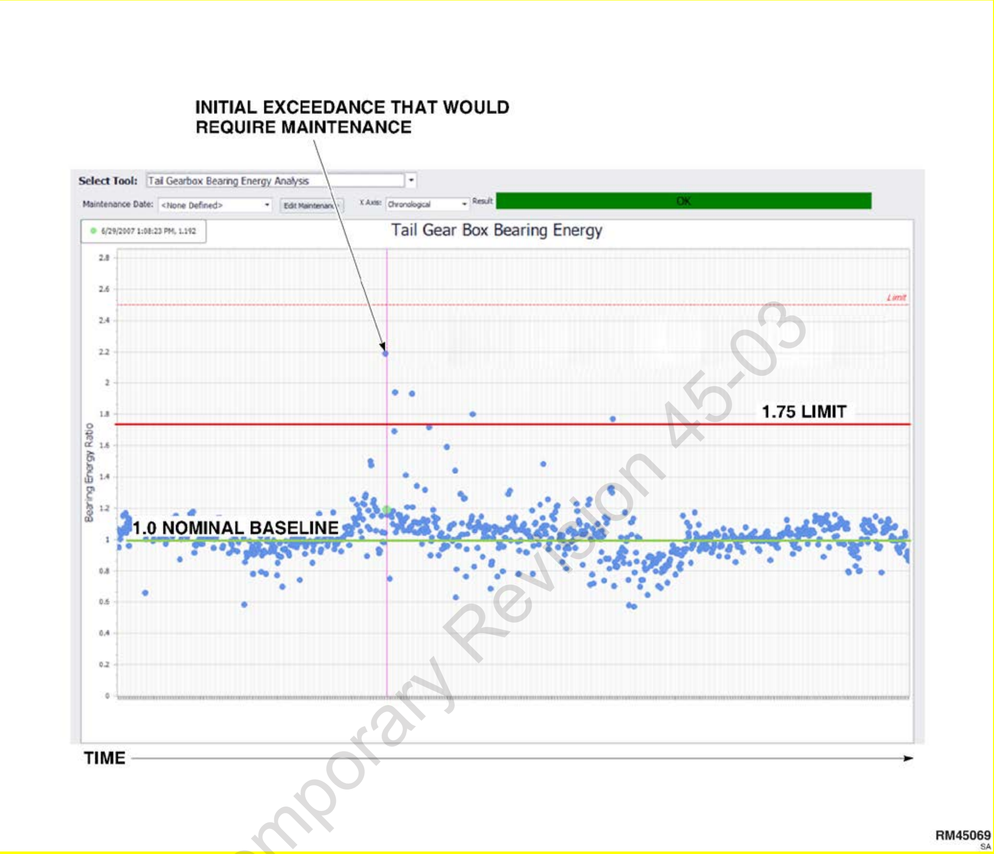


Figure 129. Example of Recorded Exceedence of TRPCS that Requires Maintenance.

WARNING: A CI RATIO GREATER THAN 1.75 WILL NOT AUTOMATICALLY DISPLAY AS AN ALERT.

NOTE: The 1.75 limit may be manually defined as a threshold.

Appendix D (Cont)

Appendix E

Sikorsky All Operators Letter CCS-ALL-AOL-17-0008 dated 24 March 2017

Sikorsky, a Lockheed Martin Company
6900 Main Street • P.O. Box 9729
Stratford, Connecticut 06615-9129

March 24, 2017 CCS-ALL-AOL-17-0008

To: All S-92® and S-76D™ Operators
All Service Centers
All Field Service Representatives

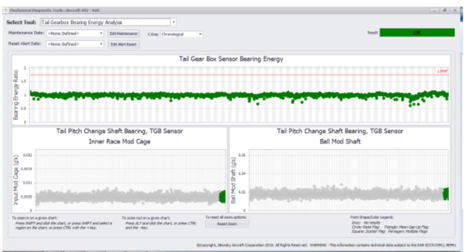
Attention: Aviation Director
Chief of Maintenance
Chief Helicopter Pilot

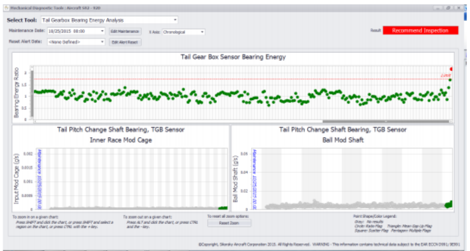
Subject: IMD Software

Ref: (A) HUMS Users Guide for Sikorsky Helicopter Model S-92A, SA S92A-HUM-000
(B) HUMS Users Guide for Sikorsky Helicopter Model S-76D, SA S76D-HUM-000
(C) Sikorsky Ground Based Application (SGBA) Users Guide for Sikorsky Helicopter Models S-92 AND S-76D, SA S92A-GBA-000

The S-92 and S-76D Health and Usage Monitoring System ground stations have 2 software versions available for use by our operators: Integrated Mechanical Diagnostics (IMD); and, Sikorsky Ground Based Application (SGBA). SGBA software was released with the intention to render the original IMD ground station software obsolete in the near future.

Sikorsky released S-92 maintenance manual revisions March 9, 2017 to support customers fully transitioning from IMD to SGBA. There are many enhanced features of SGBA, including enhanced diagnostics capabilities and improved user interfaces. The following figures depict some of the enhancements in SGBA, including color-keyed visual indicators that highlight inspection requirements.

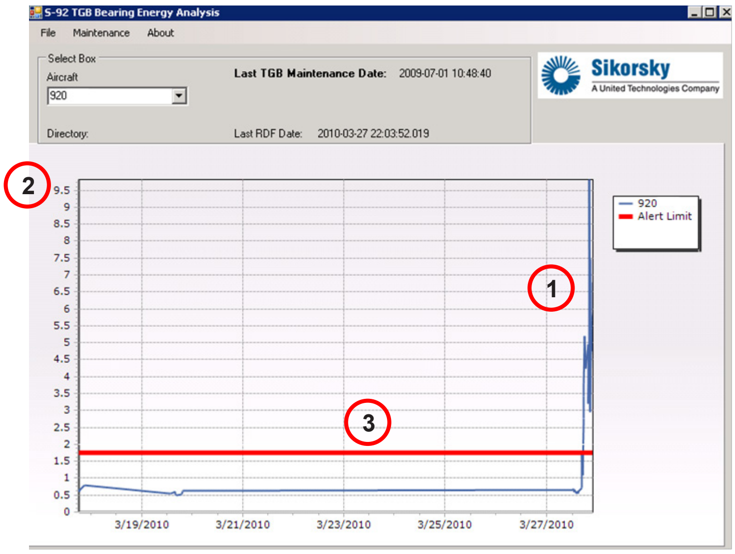




This AOL is issued to follow up on findings from the December 2016 S-92 Tail Rotor Pitch Change Shaft incident and is not connected to the tragic accident involving a Search & Rescue S-92 in Ireland earlier this month (reference CCS-92-AOL-17-0012, S-92 Helicopter Accident Notification).

The importance of technicians easily and consistently identifying any (potential) anomaly using the HUMS ground station software is clear – the aim of this AOL is to support success in this area. It has been noted that when the IMD HUMS Toolbar or strip charts display a large number of data points, the data becomes compacted and some data points may potentially be obscured on the right side of the graph. This may result in a rapidly rising trend being less readily apparent to the technician reviewing the data.

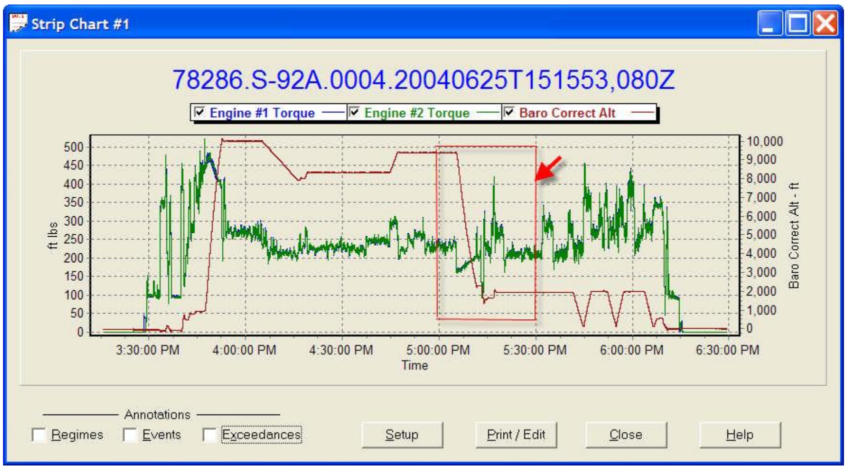
IMD HUMS Toolbar and strip charts are presented based on user selected parameters, and by default, are set up to display Parameter(s) versus Time, with the unit of time set to Calendar. The parameter scales are automatically generated based on the magnitude of the largest and smallest parameters within the Time range. The most recent data will be presented near or aligned with the right frame of the strip chart report. In cases where the displayed parameter has trended above a threshold only in the most recent flight records, the magnitude of the recent data may not be apparent without zooming in to view the data with a reduced timescale. In this latter case threshold or alert levels will be biased towards the bottom of the parameter scale in direct relation to the magnitude of the maximum parameter. The following figure illustrates the conditions described above: ① most recent data presented near or aligned with right frame; ② expanded parameter scale; and, ③ alert reference line biased towards bottom of chart.



IMD software permits zooming in and out with specific commands described in Chapter 9.1 of the HUMS User Guide referenced above and reproduced below.

A. Zoom

Note: Only works on unstacked graphs
(a) Position the cursor over the portion of the graph you wish to enlarge.
(b) Click and hold the left mouse button and drag the magnifier box (faint white outline) down and right over the region to be enlarged (See following figure).



(c) Release the mouse button to display the area inside the magnifier box. (See following figure).

(d) Continue to Zoom in on the desired area of the graph. The entire graph will be enlarged but the area of interest will remain in view.
(e) Once the graph has been zoomed to the desired size, the entire graph may be viewed by holding the right mouse button down and dragging the graph left and right or up and down.

B. Undo Zoom

(a) Position the cursor in the lower right of the graph, and while holding the left mouse button down, drag the cursor to the upper left and release. The graph will return to its normal size.

Several IMD functions enable alternate Zoom and undo Zoom commands, including vibration diagnostics (vibe data) interface, RTB interface, and TR Bearing Energy Analysis tool. These functions permit Undo

3

Appendix E (Cont)

Zoom commands to also be entered by selecting data from Lower-Right to Upper-Left and Lower-Left to Upper-Right & Upper-Right to Lower-Left.

> **Sikorsky recommends that all technicians analyzing S-92 or S-76 aircraft HUMS data using the IMD software use standardized procedures to Zoom (see section A above) and Undo Zoom (see section B above) function to ensure effective post-flight data analysis.**
>
> **Routinely zoom in on the very latest data, to ensure that any parameter trend deviation is readily identifiable.**

Further, Sikorsky encourages all operators to promptly transition to the SGBA ground station, in advance of IMD obsolescence. Sikorsky will continue to update only SGBA software with new advanced diagnostic tools.

Please contact your Sikorsky Field Service Representative with any questions that you may have on this topic.

Chief Engineer
Sikorsky, a Lockheed Martin Company

Appendix F

Sikorsky All Operators Letter CCS-92-AOL-16-0019 dated 31 December 2016

Sikorsky
6900 Main Street P.O. Box 9729
Stratford. Connecticut 06615-9129

SIKORSKY
A LOCKHEED MARTIN COMPANY

December 31, 2016 CCS-92-AOL-16-0019

To: All S-92® Operators
All Service Centers
All Field Service Representatives

Attention: Aviation Director
Chief of Maintenance
Chief Helicopter Pilot

Subject: Follow Up: S-92 Aircraft Incident Notification

As previously notified, Sikorsky is offering additional information to our operators regarding the S-92 event on December 28. The technical issue that resulted in the helicopter unscheduled landing on an oil and gas installation platform in the North Sea has been identified as a loss of tail rotor authority.

The condition involved a degradation of the Tail Rotor Pitch Change Shaft (TRPCS) bearing. Although the failure condition presents a loss of control authority, it does not result in a loss of tail rotor drive or tail rotor thrust. Initial review of the actions taken by the crew indicate that appropriate standard emergency procedure was used, which resulted in the safe landing without any injuries to passengers or crew.

The specific root cause determination is in the early stages of investigation, and the components involved are en route to our facility in Connecticut for detailed laboratory analysis. The aircraft did not otherwise experience significant damage and is expected to be returned to service following replacement of the affected components.

We note that two recent Alert Service Bulletins were issued regarding the TRPCS (ASB-92-64-009 and ASB-92-64-010, issued in Nov and Dec 2016 respectively). A review of the information confirms that neither of the ASB's were applicable to this particular TRPCS. The bearing design has proven to be a highly reliable component in the more than one million fleet hours of global S-92 service. Regardless of their impact on the recent event, Sikorsky recommends all operators ensure compliance to the two Alert Service Bulletins listed above.

Additionally, Sikorsky continues to work with the operator on reviewing data obtained from our on-board Health and Usage Monitoring System (HUMS). The parametric and vibration data is being reviewed from this occurrence to determine if any operational improvements can be made. We remind our operators that the HUMS data from each S-92 helicopter should be processed regularly through the available Groundstation, and that all available HUMS Mechanical Diagnostic Tools should be used as often as reasonably possible. Many of our operators have reported success in utilizing Diagnostic Tools more frequently, such as prior to every departure from the aircraft base. Sikorsky developed these tools for use as part of successful maintenance programs, and recommends their use as often as reasonably possible.

Sikorsky recommends specific emphasis on utilization of the HUMS Tail Gearbox Bearing Energy Tool. This Tool will detect a PCS bearing that is experiencing degradation. The Tail Gearbox Energy Tool should be processed through the available Groundstation as often as reasonably possible.

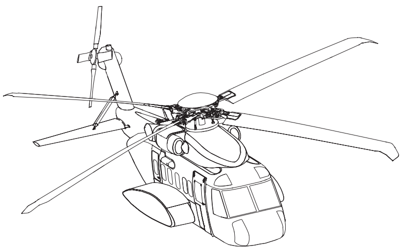
Sikorsky will be planning an operator Webcast shortly to discuss this matter. We will further communicate findings if the investigation reveals any safety or airworthiness issues that affect the S-92 helicopter fleet.

Appendix G

Sikorsky ASB 92-64-011
dated 10 January 2017

SIKORSKY
A LOCKHEED MARTIN COMPANY

Sikorsky Aircraft Corporation
6900 Main Street P.O. Box 9729
Stratford, Connecticut 06615-9129
(203) 386-4000



S-92® HELICOPTER
ALERT SERVICE BULLETIN

ASB 92-64-011

Basic Issue ▪ January 10/17

SUBJECT: TAIL ROTOR – Tail Rotor Pitch Change Shaft Bearing Assembly – One-Time Inspection of Tail Rotor Pitch Change Shaft (TRPCS) and Bearing Assembly for Ratcheting, Binding, or Rough Turning

Section 1. PLANNING INFORMATION

A. Effectivity — All S-92A model helicopters with TRPCS assembly (92358-06303-041 and/or -042) installed, including spares, delivered as of the issue date of this Alert Service Bulletin (ASB).

B. Purpose — To provide instructions for a one-time inspection of TRPCS and bearing assembly for ratcheting, binding, or rough turning.

C. Description — Helicopter records and log cards are reviewed. Helicopter is prepared for maintenance. TRPCS and bearing assembly is removed from helicopter and inspected, including spares. Tail Gear Box (TGB) bearing energy HUMS tool is reviewed. If TRPCS and bearing assembly fails inspection, it is returned to Sikorsky Commercial Inc. (SCI) for evaluation, and replaced with a serviceable TRPCS and bearing assembly. If TRPCS and bearing assembly passes inspection, reinstall TRPCS and bearing assembly. TGB Bearing Energy Tool maintenance date shall not be updated or reset. Helicopter is returned to service.

ONE-TIME INSPECTION | ATA 64-22-03

Section 1. PLANNING INFORMATION (Continued)

D. Compliance Compliance is essential. The instructions outlined herein shall be accomplished prior to next flight originating from a maintenance facility, not to exceed 30 days from the issue date of this ASB.

- If TRPCS and bearing assembly was manufactured, repaired or overhauled after November 2, 2016, the instructions outlined Section 3., step C.(1) shall be accomplished within ten (10) flight hours.
- If helicopter(s) is not at a maintenance facility, three (3) flight hours are allowed in order to return directly to a maintenance facility. If three (3) hours are not sufficient, contact Sikorsky Aircraft Customer Service Engineering at 1-800-WINGED-S or Email: wcs_cust_service_eng.gr-sik@lmco.com for further guidance.
- Helicopter(s) involved in emergency services operation, contact Sikorsky Aircraft Customer Service Engineering at 1-800-WINGED-S or Email: wcs_cust_service_eng.gr-sik@lmco.com for guidance regarding compliance time extension for the inspections herein.
- If the instructions outlined in Section 3., step C.(1) were accomplished within the previous three (3) flight hours, they do not need to be repeated.

E. Approval Inspection item.

F. Manpower (Estimated)

Task	No. of Men	No. of Hours	Man-Hours*
Removal of Tail Rotor Pitch Beam	1	1.0	1.0
Removal of Tail Rotor Servo	2	1.0	2.0
Removal of TRPCS	1	1.0	1.0
Do TRPCS and Bearing Assembly Inspection	1	1.0	1.0
Installation of TRPCS and Bearing Assembly	1	1.0	1.0
Installation of Tail Rotor Servo	2	2.0	4.0
Installation of Tail Rotor Pitch Beam	1	1.0	1.0
Total Man-Hours			11.0
*Estimate does not include time required to prepare helicopter or return it to flight status.			

G. Tooling

None.

Appendix G (Cont)

ASB 92-64-011
Basic Issue ▪ January 10/17

S-92 ALERT SERVICE BULLETIN

Section 1. PLANNING INFORMATION (Continued)

H. Weight and Balance

Not affected.

I. Electrical Load Data

Not affected.

J. Software Load Data

Not changed.

K. References

(1) ASB 92-64-009, One-Time Inspection of Tail Rotor Pitch Change Shaft (TRPCS) and Bearing Assembly for Improper Axial Play, latest revision.

(2) HUMS User Guide, SA S92A-HUM-000, Chapter 11.4 (15).

(3) Maintenance Manual, SA S92A-AMM-000, Task 64-22-03-290-001.

(4) Maintenance Manual, SA S92A-AMM-000, Tasks 64-22-03-900-001/-002.

(5) Maintenance Manual, SA S92A-AMM-000, Tasks 67-32-01-900-001/-002.

(6) Sikorsky Ground Based Application (SGBA) Users Guide, S92A-GBA-000, Chapter 15.

L. Publications Affected

Temporary Revision 45-03 against Maintenance Manual, SA S92-AMM-000, Task 45-45-10-710-01, is issued concurrently with this ASB.

M. Attachment

None.

Section 2. MATERIAL INFORMATION

A. Basis for Material Data

Per helicopter.

B. Bill of Material

New Part No.	Qty	Key Word	Old Part No.	Instructions/ Disposition
978008	1	GASK-O-SEAL	978008	(1)(2)

ONE-TIME INSPECTION

ATA 64-22-03

Page 3

This Document Contains Technical Data Controlled by the EAR. See WARNING and classifications on first page.

Appendices

Appendix G (Cont)

Section 2. MATERIAL INFORMATION (Continued)

(1) For part availability and lead time requirements contact your Customer Service Representative at SCI. Submit a no-cost purchase order referencing this ASB number and the helicopter serial number(s) on which these parts will be used. This will allow SCI and the operator to track shipment and receipt of parts. Orders will be accepted by letter, telephone, facsimile (FAX) or through the SCI website: www.HSIUS.com. For prompt shipment, reference address of each shipping destination. Direct your order to:

Sikorsky Aircraft Corporation
Commercial Systems and Services
Mailstop K100
124 Quarry Road
Trumbull, CT 06611 U.S.A.
Attn: Account Service Manager
FAX: (203) 416-4291, Telephone: (203) 416-4000
https://customerportal.sikorsky.com

(2) A one-time re-use of Gask-O-Seal (978008) is permissible if replacement is not available. (Refer to Section 3, step C.(1)(a)).

C. Consumable Material

None.

Section 3. ACCOMPLISHMENT INSTRUCTIONS

A. Review helicopter records and log cards to determine if TRPCS and bearing assembly was manufactured, repaired, or overhauled on or after November 2, 2016.

B. Prepare helicopter for maintenance:

WARNING TO PREVENT ELECTRICAL SHOCK OF PERSONNEL OR POSSIBLE DAMAGE TO HELICOPTER COMPONENTS, MAKE SURE TO TURN OFF ALL ELECTRICAL POWER.

(1) Turn off all helicopter electrical and hydraulic power.

(2) Engage rotor brake.

NOTE: If stand-alone bearing energy analysis software is being used, the HUMS maintenance date associated with the TRPCS and bearing assembly shall not be updated or reset, even upon removal and installation of the TRPCS bearing assembly. (Refer to HUMS User Guide, SA S92A-HUM-000, Chapter 11.4, Section C, step 12).

C. Remove TRPCS and bearing assembly. (Refer to Maintenance Manual, SA S92A-AMM-000, Task 64-22-03-900-001).

Appendix G (Cont)

ASB 92-64-011
Basic Issue ▪ January 10/17

S-92 ALERT SERVICE BULLETIN

Section 3. ACCOMPLISHMENT INSTRUCTIONS (Continued)

NOTE: For further guidance on any questionable inspection results, contact Sikorsky Aircraft Customer Service Engineering at 1-800-WINGED-S or Email: wcs_cust_service_eng.gr-sik@lmco.com.

(1) Perform inspection of TRPCS and bearing assembly, including spares. (Refer to Maintenance Manual, SA S92A-AMM-000, Task 64-22-03-290-001, steps A.(6)(j) through A.(6)(o)).

(a) Contact Customer Service Program Manager if any TRPCS and bearing assemblies fail inspection. Submit any findings to local Sikorsky FSR. Rejected parts shall be returned to Sikorsky for evaluation with the reason for failure clearly identified.

NOTE: A one-time re-use of Gask-O-Seal (978008) is permissible if replacement is not available and inspection criteria is met.

(b) If no damage, cuts, tears, or distortion is found on Gask-O-Seal (978008), proceed to step (2).

(c) If damage, cuts, tears, or distortion is found on Gask-O-Seal (978008), replace with new Gask-O-Seal. (Refer to Maintenance Manual, SA S92A-AMM-000, Tasks 67-32-01-900-001/-002).

NOTE: If HUMS data isn't available for review, contact Sikorsky Aircraft Customer Service Engineering at 1-800-WINGED-S or Email: wcs_cust_service_eng.gr-sik@lmco.com.

(2) Review TGB bearing energy HUMS tool per HUMS User Guide, SA S92A-HUM-000, Chapter 11.4, not applicable to spare TRPCS bearing assemblies. Compliance can be accomplished via the legacy HUMS toolbar or the integrated Sikorsky Ground Based Application (SGBA) toolbar.

(a) For users with stand-alone bearing energy analysis software, review the HUMS Tail Gear Box Bearing Energy Tool per the HUMS user guide, SA S92A-HUM-000, Chapter 11.4 with the following exceptions:

1. A condition indicator (CI) exceedance of 1.75 for any one data point shall require inspection per Maintenance Manual, SA S92A-AMM-000, Task 64-22-03-290-001, steps A.(6)(j) thru A.(6)(o) and contact Sikorsky Aircraft Customer Service Engineering at 1-800-WINGED-S or Email: wcs_cust_service_eng.gr-sik@lmco.com.

(b) For integrated SGBA HUMS toolbar, refer to Sikorsky Ground Based Application (SGBA) Users Guide, S92A-GBA-000, Chapter 15 with the following additions:

1. This automated TGB Bearing Energy Analysis software consists of the following four steps:

a The 15-20 kHz energy data for a specific helicopter tail number is extracted from the HUMS Ground Station Software (GSS) Raw Data Files (RDFs). This 15-20 kHz energy is referred to as a CI.

ONE-TIME INSPECTION | ATA 64-22-03

This Document Contains Technical Data Controlled by the EAR. See WARNING and classifications on first page.

Appendix G (Cont)

Section 3. ACCOMPLISHMENT INSTRUCTIONS (Continued)

b The average 15-20 kHz energy is computed for that helicopter tail number since the last maintenance date. This date is important, since removing/replacing the TGB, the pitch change shaft assembly, or the TGB accelerometer can change the absolute value of the CI.

c The 15-20 kHz energy is normalized by the helicopter -specific mean. This normalized energy is referred to as the "CI ratio". The intent of the software is create a baseline for the helicopter that is nominally at 1.0. The baseline data consists of 200 points. If 200 points have not been collected since the last maintenance date the tool will indicate "Insufficient Data".

d The trend history for the normalized energy is plotted for each specific tail number. The limit threshold for this normalized data is 1.75.

WARNING A CI RATIO GREATER THAN 1.75 WILL NOT AUTOMATICALLY DISPLAY AS AN ALERT.

2. A CI exceedance of 1.75 for any one data point shall require inspection per Maintenance Manual, SA S92A-AMM-000, Task 64-22-03-290-001, steps A.(6)(j) thru A.(6)(o) and contact Sikorsky Aircraft Customer Service Engineering at 1-800-WINGED-S or Email: wcs_cust_service_eng.gr-sik@lmco.com.

D. Install serviceable TRPCS and bearing assembly. (Refer to Maintenance Manual, SA S92A-AMM-000, Task 64-22-03-900-002).

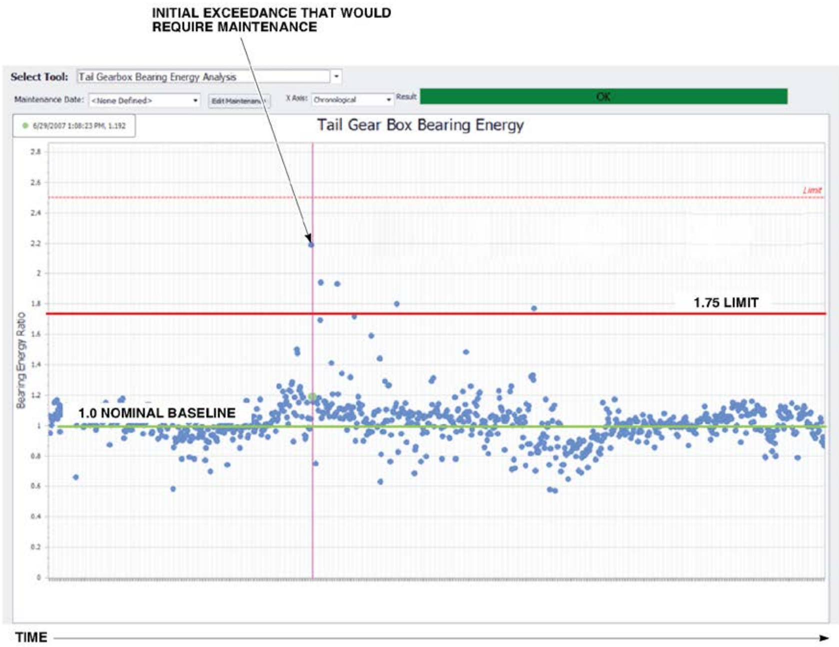
E. Make sure the TGB mechanical diagnostic function of the HUMS is functioning.

F. Review and incorporate the newly established recurring review of TGB bearing energy HUMS tool into the helicopter's maintenance plan. (Refer to Temporary Revision 45-03 against Maintenance Manual, SA S92-AMM-000, Task 45-45-10-710-01).

G. Return helicopter to service.

Appendix G (Cont)

Section 3. ACCOMPLISHMENT INSTRUCTIONS (Continued)



TD4096

EXAMPLE OF RECORDED EXCEEDANCE OF TRPCS THAT REQUIRES MAINTENANCE
WARNING: A CI RATIO GREATER THAN 1.75 WILL NOT AUTOMATICALLY DISPLAY AS AN ALERT.
NOTE: The 1.75 limit may be manually defined as a threshold.
FIGURE 1

ONE-TIME INSPECTION | ATA 64-22-03

Appendices

Appendix G (Cont)

Section 3. ACCOMPLISHMENT INSTRUCTIONS (Continued)

H. Record of compliance:

(1) Make helicopter logbook entries to show compliance with this ASB as follows:

(a) Make helicopter level logbook entry on form SA7343-15 (Aircraft ASB Release Signoff).

(b) Make component log card entries on forms SA7343-22 (Aircraft Component Log Cards) and the PCS and bearing assembly SA7343-21 (Component Log Cards).

(2) Make an appropriate electronic compliance entry in the E-Notification section at www.Sikorsky360.com. Refer to User Guide located on the www.Sikorsky360.com/E-Notification Search page.

(3) Upon compliance with this ASB, complete and return the following compliance record card by mail, fax, or scan and e-mail.

Appendix G (Cont)

(Fold over and tape closed)

SIKORSKY AIRCRAFT CORPORATION

FACSIMILE NUMBER (817) 762-9715

EMAIL ADDRESS: product_safety.gr-sik@lmco.com

ATTENTION: Gr-SIK, Product_Safety
SIKORSKY AIRCRAFT CORPORATION

IMPORTANT NOTICE

Upon COMPLIANCE with the attached ASB, Sikorsky requests your cooperation in completing and returning this ENTIRE PAGE by MAIL, FAX, or scan & EMAIL.

Please fill in the requested information at the bottom of the page, so we may maintain proper records documenting the configuration of your aircraft. This information is useful when determining configuration and effectivity of issues affecting fielded aircraft.

This request is in keeping with our policy to assure that our customers receive the latest information applicable for the maintenance of your aircraft. Thank you.

ALERT SERVICE BULLETIN: No. 92-64-011 **Compliance Record Card**

TITLE: TAIL ROTOR – Tail Rotor Pitch Change Shaft Bearing Assembly – One-Time Inspection of Tail Rotor Pitch Change Shaft (TRPCS) and Bearing Assembly for Ratcheting, Binding, or Rough Turning

OWNER/OPERATOR: ______________________

SUBMITTED BY: ______________ **DATE:** ____________

☐ **FOLLOWING SERIAL NUMBERS ARE NOT AFFECTED BY THIS ASB**

☐ **ASB HAS BEEN COMPLIED WITH ON HELICOPTER SERIAL NUMBERS:**

________ ________ ________ ________ ________ ________

________ ________ ________ ________ ________ ________

(Fold Up to Arrows)

This Document Contains Technical Data Controlled by the EAR. See WARNING and classifications on first page.

Appendix G (Cont)

No Postage Necessary

BUSINESS REPLY MAIL
FIRST-CLASS MAIL PERMIT NO. 432 BRIDGEPORT CT

POSTAGE WILL BE PAID BY ADDRESSEE

SIKORSKY AIRCRAFT CORPORATION

Commercial Systems and Services
Mailstop K100
124 QUARRY ROAD
TRUMBULL, CT 06611 U.S.A.
ATTENTION:
Gr-SIK, Product_Safety

Please complete the form on the reverse side and FAX to

FACSIMILE NUMBER (817) 762-9715

Or scan and email to:

EMAIL ADDRESS: product_safety.gr-sik@lmco.com

or fold and return ENTIRE form to Sikorsky Aircraft Corporation

This Document Contains Technical Data Controlled by the EAR. See WARNING and classifications on first page.

Appendices

Appendix H

FAA Airworthiness Directive AD 2017-02-51 dated 13 January 2017

FAA
Aviation Safety

EMERGENCY AIRWORTHINESS DIRECTIVE
www.faa.gov/aircraft/safety/alerts/

DATE: January 13, 2017
AD #: 2017-02-51

This Emergency Airworthiness Directive (Emergency AD) 2017-02-51 is being sent to owners and operators of Sikorsky Aircraft Corporation (Sikorsky) Model S-92A helicopters.

Background

This Emergency AD was prompted by three reports of operators losing tail rotor (TR) control caused by a failed tail rotor pitch change shaft (TRPCS) assembly bearing. Following the first two reports, the FAA issued and subsequently published as a final rule Emergency AD 2016-24-51 (81 FR 95425, December 28, 2016). That AD applies to Sikorsky Model S-92A helicopters with a TRPCS assembly that has less than 80 hours time-in-service (TIS) with bearings that were manufactured prior to November 3, 2016. Emergency AD 2016-24-51 is intended to address an unsafe condition with low-time bearings by requiring removal of TRPCS assemblies that have less than 5 hours TIS and one-time inspections for certain conditions.

Actions Since Emergency AD 2016-24-51 Was Issued

Since Emergency AD 2016-24-51 was issued, a third report of an S-92A helicopter losing TR control was reported, and a preliminary investigation determined that the bearing failed despite having more than 80 hours TIS. We have determined that the unsafe condition can exist on TRPCS bearings regardless of hours TIS. Therefore, this Emergency AD applies to all TRPCS assemblies. This Emergency AD requires a one-time visual inspection and a repetitive borescope inspection of the TRPCS assembly bearing. The repetitive inspection is intended to detect bearing deterioration. The actions in this Emergency AD are intended to detect a binding bearing, prevent loss of TR control, and possible loss of control of the helicopter.

FAA's Determination

We are issuing this Emergency AD because we evaluated all the relevant information and determined the unsafe condition described previously is likely to exist or develop in other products of the same type design.

Related Service Information

We reviewed Sikorsky Alert Service Bulletin 92-64-011, Basic Issue, dated January 10, 2017 (ASB). The ASB describes procedures for inspecting the TRPCS and bearing assemblies for ratcheting, binding, and rough turning. The ASB also specifies periodic review of the health and usage monitoring system (HUMS) tail gearbox bearing energy tool.

Emergency AD Requirements

This Emergency AD requires, before further flight, removing the TRPCS assembly and inspecting the bearing. If the bearing does not rotate freely; the bearing sounds rough or chatters; there is any purged grease with metal particles; a nick or dent; or if there is a cut, tear, or distortion in

1

Appendices

the bearing seal, before further flight, replacing the TRPCS assembly is required. This Emergency AD also requires, within 10 hours TIS, and thereafter at intervals not to exceed 10 hours TIS, inspecting the TRPCS assembly with a borescope. If the white Teflon seal or snap ring is missing, or if there is a rip, tear, or heat damage on the seal or if there is no gap in the snap ring, replacing the TRPCS assembly is required before further flight.

Differences Between This Emergency AD and the Service Information

This Emergency AD requires repetitive borescope inspections of the TRPCS; the ASB does not. The ASB specifies that operators review HUMS data in addition to the one-time inspection and specifies contacting Sikorsky if any discrepancies are found; this Emergency AD does not.

Interim Action

We consider this Emergency AD to be an interim action. If final action is later identified, we might consider further rulemaking then.

Authority for this Rulemaking

Title 49 of the United States Code specifies the FAA's authority to issue rules on aviation safety. Subtitle I, Section 106, describes the authority of the FAA Administrator. "Subtitle VII, Aviation Programs," describes in more detail the scope of the Agency's authority.

We are issuing this rulemaking under the authority described in "Subtitle VII, Part A, Subpart III, Section 44701, General requirements." Under that section, Congress charges the FAA with promoting safe flight of civil aircraft in air commerce by prescribing regulations for practices, methods, and procedures the Administrator finds necessary for safety in air commerce. This regulation is within the scope of that authority because it addresses an unsafe condition that is likely to exist or develop on products identified in this rulemaking action.

Adoption of the Emergency Airworthiness Directive (AD)

We are issuing this Emergency AD under 49 U.S.C. Sections 106(g), 40113, and 44701 according to the authority delegated to me by the Administrator.

2017-02-51 **Sikorsky Aircraft Corporation:** Directorate Identifier 2017-SW-003-AD.

(a) Applicability

This Emergency AD applies to Sikorsky Aircraft Corporation (Sikorsky) Model S-92A helicopters, certificated in any category, with a tail rotor pitch change shaft (TRPCS) assembly part number (P/N) 92358-06303-041 or P/N 92358-06303-042 installed.

(b) Unsafe Condition

This Emergency AD defines the unsafe condition as a binding TRPCS bearing. This condition could result in loss of tail rotor (TR) control and possible loss of control of the helicopter.

(c) Effective Date

This Emergency AD is effective upon receipt.

2

(d) Compliance

You are responsible for performing each action required by this Emergency AD within the specified compliance time unless it has already been accomplished prior to that time.

(e) Required Actions

(1) Before further flight, unless already done, remove the TRPCS assembly and inspect the SB2310 angular contact bearing for free rotation, purged grease with metal particles, a nick or a dent, and any cut, tear, or distortion on the bearing seal. If the bearing does not rotate freely; the bearing sounds rough or chatters; there is any purged grease with metal particles; a nick or dent; or if there is a cut, tear, or distortion in the bearing seal, before further flight, replace the TRPCS assembly.

(2) Within 10 hours time-in-service (TIS), unless already done within the last 10 hours TIS, and thereafter at intervals not to exceed 10 hours TIS, on the TR side of the TRPCS bearing, remove the plug from the end of the TRPCS, insert the borescope into the TRPCS, and determine whether the white Teflon seal and snap ring are installed. If the white Teflon seal or snap ring is missing, or if there is a rip, tear, or heat damage on the seal or if there is no gap in the snap ring, before further flight replace the TRPCS assembly.

(f) Alternative Methods of Compliance (AMOCs)

(1) The Manager, Boston Aircraft Certification Office, FAA, may approve AMOCs for this Emergency AD. Send your proposal to: Aerospace Engineer, Boston Aircraft Certification Office, Engine & Propeller Directorate, 1200 District Avenue, Burlington, Massachusetts 01803; telephone (781) 238-7161; email blaine.williams@faa.gov.

(2) For operations conducted under a 14 CFR part 119 operating certificate or under 14 CFR part 91, subpart K, we suggest that you notify your principal inspector, or lacking a principal inspector, the manager of the local flight standards district office or certificate holding district office, before operating any aircraft complying with this Emergency AD through an AMOC.

(g) Additional Information

(1) For further information contact: Aerospace Engineer, Boston Aircraft Certification Office, Engine & Propeller Directorate, 1200 District Avenue, Burlington, Massachusetts 01803; telephone (781) 238-7161; email blaine.williams@faa.gov.

(2) For a copy of the service information referenced in this Emergency AD, contact: Sikorsky Aircraft Corporation, Customer Service Engineering, 124 Quarry Road, Trumbull, CT 06611; telephone 1-800-Winged-S or 203-416-4299; email: wcs_cust_service_eng.gr-sik@lmco.com.

3

Appendix H (Cont)

(h) Subject

Joint Aircraft Service Component (JASC) Code: 6720 Tail Rotor Control System.

Issued in Fort Worth, Texas, on January 13, 2017.

4

Appendix J

Sikorsky ASB 92-64-012
dated 16 May 2017

ASB 92-64-012
Revision C – May 16, 2017

TRANSMITTAL

Alert Service Bulletin (ASB) 92-64-012 dated March 9, 2017 has been revised. This page accompanies revision C, dated May 16, 2017.

ASB 92-64-012C dated May 16, 2017 supersedes revision B of ASB 92-64-012, dated April 13, 2017. Text changes are indicated by a vertical line in the outer margin of the page. Illustration changes are indicated by a vertical line next to the figure title.

INSTRUCTIONS TO OPERATORS:

For operators that have complied with ASB 92-64-012 revision B, no further action is required.

Operators that have not complied with ASB 92-64-012 revision B must comply with revision C in its entirety.

HIGHLIGHTS OF THIS REVISION:

COMPLIANCE

Revised TRPCS part number.

Added TRPCS that that were repaired.

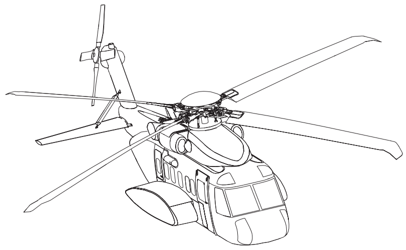
PUBLICATIONS AFFECTED

Revised publications affected to none.

Page 1 of 1

Appendix J (Cont)

Sikorsky Aircraft Corporation
6900 Main Street P.O. Box 9729
Stratford, Connecticut 06615-9129
(203) 386-4000



S-92® HELICOPTER

ALERT SERVICE BULLETIN

ASB 92-64-012
March 9/17
Revision C ▪ May 16/17

SUBJECT: TAIL ROTOR – Tail Rotor Pitch Change Shaft Bearing Assembly – Installation of Temperature Indicator Plug

Section 1. PLANNING INFORMATION

A. Effectivity S-92A model helicopters with serial numbers 920006 through 920302.

B. Purpose To provide instructions to install temperature indicator plug.

C. Background A temperature indicator plug was designed to be installed in the inner diameter of the Tail Rotor Pitch Change Shaft (TRPCS) bearing as a method to visually inspect for a bearing that is operating at higher temperature than normal. The intent of the temperature indicator plug is to help identify bearings that are degrading.

D. Description TRPCS log card is reviewed. Helicopter is prepared for maintenance. Temperature Indicator Plug is installed. Helicopter is returned to service.

E. Compliance Compliance is essential.

- TRPCS (92358-06303-041, or -042) that were last overhauled, repaired, or fabricated new (not yet overhauled) prior to February 28, 2017, as noted on the component maintenance record, shall comply with this Alert Service Bulletin (ASB) no later than April 13, 2017.

ONE-TIME INSTALLATION	ATA 64-22-03

Appendix J (Cont)

S-92 ALERT SERVICE BULLETIN

ASB 92-64-012
Revision C ▪ May 16/17

Section 1. PLANNING INFORMATION (Continued)

- TRPCS (92358-06303-041, or -042) that were last overhauled, repaired, or fabricated new (not yet overhauled) on or after February 28, 2017, as noted on the component maintenance record, with more than 100 flight hours (Time Since New (TSN)/Time Since Overhaul (TSO)/Time Since Repair (TSR) as applicable), shall comply with this ASB no later than April 13, 2017.
- TRPCS (92358-06303-041, or -042) that were last overhauled, repaired, or fabricated new (not yet overhauled) on or after February 28, 2017, as noted on the component maintenance record, with less than 100 flight hours (TSN/TSO/TSR as applicable), shall install temperature indicator plug no later than 100 flight hours (TSN/TSO/TSR of the TRPCS (92358-06303-041, or -042), as applicable).

F. Approval — The design change specified by this document is FAA approved in accordance with the applicable requirements of United States Federal Aviation Regulations 14 CFR Part 29. FAA approval constitutes EASA and Transport Canada approval under the terms of current bilateral agreement procedures.

G. Manpower (Estimated)

Task	No. of Men	No. of Hours	Man-Hours*
Removal of Retaining Ring and Plug.	1	0.25	0.25
Installation of Temperature Indicator Plug	1	0.50	0.50
Inspection of Temperature Indicator Plug for Proper Seating	1	0.25	0.25
Re-Installation of Plug and Retaining Ring	1	0.25	0.25
Total Man-Hours			1.25
*Estimate does not include time required to prepare helicopter or return it to flight status.			

H. Tooling

Qty	Nomenclature	Part No.	Source
1	Tool Kit, Pitch Change Shaft	92700-10391-041	(1)
	Made up of:		
1	Installation Rod Assembly	92700-10391-042	
1	Gage Mount Assembly	92700-10391-043	
1	Handle	92700-10391-103	
1	Dial Indicator	711FSZ	
1	Dead Blow Hammer	57-530	
1	Non-Bright, White, Flashlight	Commercially available or equivalent	(2)

Page 2 ATA 64-22-03 ONE-TIME INSTALLATION

Appendices

Appendix J (Cont)

ASB 92-64-012
Revision C ▪ May 16/17

S-92 ALERT SERVICE BULLETIN

Section 1. PLANNING INFORMATION (Continued)

Qty	Nomenclature	Part No.	Source
1	Orfit Tool Kit	WE301K	(2)

(1) Tools are available at no cost during the compliance period of this ASB to predetermined locations to support the current fleet. Tools shall be available after the compliance period at standard Sikorsky Commercial Inc. (SCI) rates. For tools availability and lead time requirements contact your Customer Service Representative at SCI. Submit a no-cost purchase order referencing this ASB number and the helicopter serial number(s) on which these tools will be used. This will allow SCI and the operator to track shipment and receipt of tools. Orders will be accepted by letter, telephone, facsimile (FAX) or through the SCI website: www.HSIUS.com. For prompt shipment, reference address of each shipping destination. Direct your order to:

Sikorsky Aircraft Corporation
Commercial Systems and Services
Mailstop K100
124 Quarry Road
Trumbull, CT 06611 U.S.A.
Attn: Account Service Manager
FAX: (203) 416-4291, Telephone: (203) 416-4000
https://customerportal.sikorsky.com

(2) Available through normal supply channels.

I. Weight and Balance

None.

J. Electrical Load Data

Not applicable.

K. Software Load Data

Not applicable.

L. References

(1) Temporary Revision 45-07 against Maintenance Manual, SA S92A-AMM-000, Task 45-45-10-710-001.

(2) Temporary Revision 45-08 against Maintenance Manual, SA S92A-AMM-000, Task 45-45-11-710-001.

ONE-TIME INSTALLATION | ATA 64-22-03

S-92 ALERT SERVICE BULLETIN

ASB 92-64-012
Revision C ▪ May 16/17

Section 1. PLANNING INFORMATION (Continued)

M. Publications Affected

None.

N. Attachment

None.

Section 2. MATERIAL INFORMATION

A. Basis for Material Data

Per helicopter.

B. Bill of Material

New Part No.	Qty	Nomenclature	Old Part No.	Instructions/ Disposition
92358-06134-041	1	TEMPERATURE INDICATOR PLUG		(1)
AS3209-029	1	PACKING	AS3209-029	(2)

(1) Parts are available at no cost during the compliance period of this ASB. Parts shall be available after the compliance period at standard Sikorsky Commercial Inc. (SCI) rates. For part availability and lead time requirements contact your Customer Service Representative at SCI. Submit a no-cost purchase order referencing this ASB number and the helicopter serial number(s) on which these parts will be used. This will allow SCI and the operator to track shipment and receipt of parts. Orders will be accepted by letter, telephone, facsimile (FAX) or through the SCI website: www.HSIUS.com. For prompt shipment, reference address of each shipping destination. Direct your order to:

Sikorsky Aircraft Corporation
Commercial Systems and Services
Mailstop K100
124 Quarry Road
Trumbull, CT 06611 U.S.A.
Attn: Account Service Manager
FAX: (203) 416-4291, Telephone: (203) 416-4000
https://customerportal.sikorsky.com

(2) Available through normal supply channels.

ASB 92-64-012
Revision C ▪ May 16/17

S-92 ALERT SERVICE BULLETIN

Section 2. MATERIAL INFORMATION (Continued)

C. Consumable Material

WARNING

OBSERVE ALL CAUTIONS AND WARNINGS ON CONTAINERS WHEN USING CONSUMABLES. WHEN APPLICABLE, WEAR NECESSARY PROTECTIVE GEAR DURING HANDLING AND USE. IF A CONSUMABLE IS FLAMMABLE OR EXPLOSIVE, MAKE CERTAIN CONSUMABLE AND ITS VAPORS ARE KEPT AWAY FROM HEAT, SPARK AND FLAME. MAKE CERTAIN FIREFIGHTING EQUIPMENT IS READILY AVAILABLE PRIOR TO USE. FOR ADDITIONAL INFORMATION ON TOXICITY, FLASHPOINT AND FLAMMABILITY OF CHEMICALS, CONSULT YOUR MEDICAL DEPARTMENT OR THE MANUFACTURER OF THE CONSUMABLE.

Qty	Nomenclature	Part No.	Source
A/R	Corrosion Preventative	Cor-Ban 27L or equivalent	(1)
A/R	Lubricating Oil	DOD-PRF-85734 or equivalent	(1)
A/R	Lubricating Oil	Ultrachem or equivalent	(1)
A/R	Lubricating Oil	Boelube® or equivalent	(1)

(1) Available through normal supply channels.

Section 3. ACCOMPLISHMENT INSTRUCTIONS

A. Review TRPCS log card:

(1) If bearing (SB2310) is in the Serial Number (S/N) 0087 to 0101 range, contact Sikorsky Aircraft Customer Service Engineering at 1-800-WINGED-S or Email: wcs_cust_service_eng.gr-sik@lmco.com.

(2) If bearing (SB2310) is not in the S/N 0087 to 0101 range, proceed to next step.

B. Prepare helicopter for maintenance:

WARNING

TO PREVENT ELECTRICAL SHOCK OF PERSONNEL OR POSSIBLE DAMAGE TO HELICOPTER COMPONENTS, MAKE SURE TO TURN OFF ALL ELECTRICAL POWER.

(1) Turn off all helicopter electrical and hydraulic power.

(2) Engage rotor brake.

C. Remove plug to gain access to the interior of the TRPCS and bearing assembly as follows:

(1) Remove retaining ring (M2742630142D) securing plug (92358-06610-101) in TRPCS. (Refer to Figures 1 and 2).

ONE-TIME INSTALLATION | ATA 64-22-03

Page 5

This Document Contains Technical Data Controlled by the EAR. See WARNING and classifications on first page.

Appendices

Section 3. ACCOMPLISHMENT INSTRUCTIONS (Continued)

(2) Remove plug (92358-06610-101) and packing (AS3209-029) from TRPCS.

(3) Visually inspect packing (AS3209-029) for tears or excessive stretching and reuse if no tears or excessive stretching are present.

D. Install temperature indicator plug (92358-06134-041) as follows:

NOTE: The 180°F temperature dot is pre-tripped to provide a visual comparison of when a dot is tripped. (Refer to Figure 3 for an example).

(1) Visually inspect temperature indicator plug (92358-06134-041) to verify that three (3) indicator dots are not tripped. If any of the three (3) temperature dots are found tripped, contact Sikorsky Aircraft Customer Service Engineering at 1-800-WINGED-S or Email: wcs_cust_service_eng.gr-sik@lmco.com.

(2) Thread temperature indicator plug (92358-06134-041) onto installation rod assembly (92700-10391-042) until threads bottom on installation rod shoulder. (Refer to Figure 4).

NOTE: Make sure no corrosion preventative compound (Cor-Ban 27L or equivalent) is applied to face of temperature indicator plug (92358-06134-041) with temperature dots.

(3) Apply light coat of corrosion preventative compound (Cor-Ban 27L or equivalent) on temperature indicator plug (92358-06134-041). (Refer to Figure 5).

(4) Apply light coat of lubricating oil (DOD-PRF-85734, Ultrachem, Boelube® or equivalent) on gage mount assembly (92700-10391-043) o-rings.

(5) Gently position installation rod assembly (92700-10391-042), temperature indicator plug (92358-06134-041), and gage mount assembly (92700-10391-043) inside TRPCS. Firmly seat gage mount assembly against shaft end face. (Refer to Figure 6).

(6) Using installation rod assembly (92700-10391-042), insert temperature indicator plug (92358-06134-041) into inner diameter of TRPCS bearing bore by hand, until resistance is felt.

(7) Measure distance from end of installation rod assembly (92700-10391-042) to gage mount assembly (92700-10391-043) and record value as “Pre-Installation Measurement.” (Refer to Figure 7).

CAUTION TOO MUCH IMPACT COULD RESULT IN DAMAGE TO BEARING.

(8) Using provided dead blow hammer (57-530), gently tap installation rod assembly (92700-10391-042) to drive temperature indicator plug (92358-06134-041) into bore of TRPCS bearing. (Refer to Figure 8).

Section 3. ACCOMPLISHMENT INSTRUCTIONS (Continued)

(9) Measure distance from end of installation rod assembly (92700-10391-042) to gage mount assembly (92700-10391-043) and record as “Post-Installation Measurement.” Subtract “Post-Installation Measurement” from “Pre-Installation Measurement.” (Refer to Figure 7).

(a) If value is less than 0.180 inch, repeat step (8) until measurement is achieved.

(b) If value is greater than or equal to 0.180 inch, proceed to next step.

(10) Using handle (92700-10391-103), rotate installation rod assembly (92700-10391-042) counter-clockwise to unthread from temperature indicator plug (92358-06134-041). (Refer to Figure 9).

(11) Remove installation rod assembly (92700-10391-042).

(12) Remove gage mount assembly (92700-10391-043).

(13) Using a non-bright, white, flashlight (commercially available or equivalent), inspect TRPCS for foreign object debris (FOD), and remove if found. (Refer to Figure 10).

E. Re-install plug as follows (Refer to Figure 11):

(1) If previously installed packing was found torn or excessively stretched, install new packing (AS3209-029) on plug (92358-06610-101) using Orfit tool kit (WE301K).

(2) Install plug (92358-06610-101) and packing (AS3209-029) in TRPCS. (Refer to Figures 1 and 11).

(3) Secure plug (92358-06610-101) in TRPCS with retaining ring (M2742630142D).

F. Review and incorporate applicable changes to recurring review of tail gear box bearing energy HUMS tool into the helicopters maintenance plan. (Refer to Temporary Revision 45-07 against Maintenance Manual, SA S92A-AMM-000 Task 45-45-10-710-001 or Temporary Revision 45-08 against Maintenance Manual, SA S92-AMM-000, Task 45-45-11-710-001).

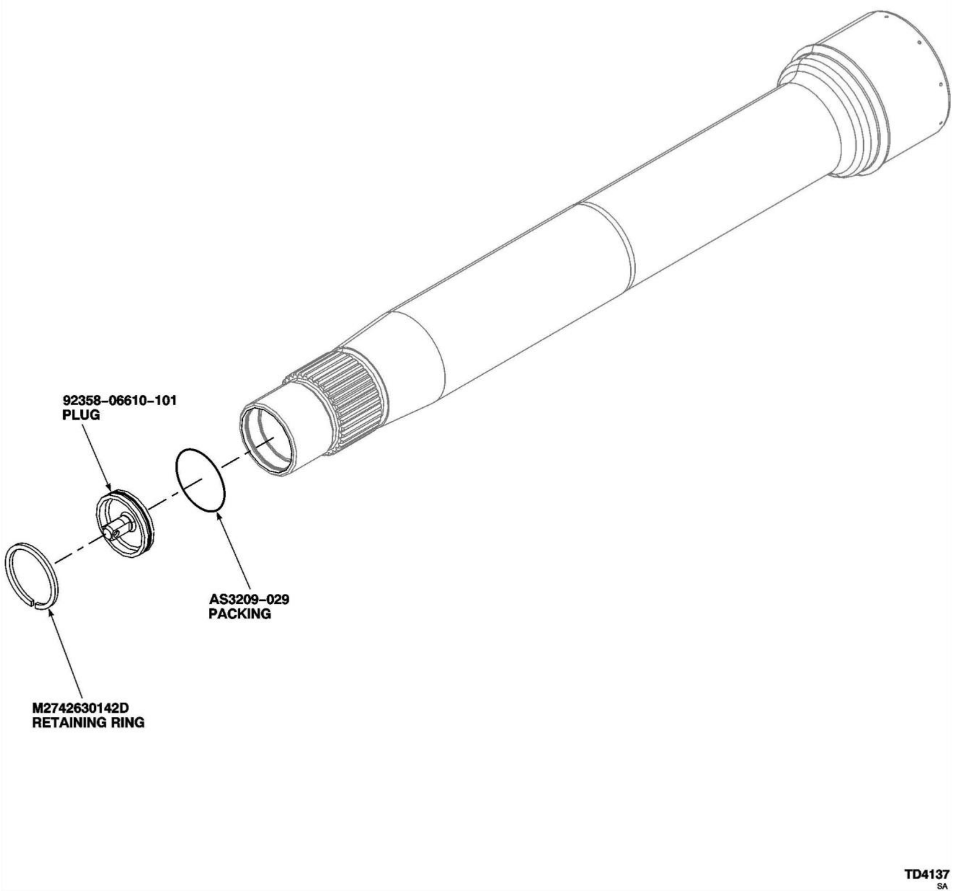
G. Return helicopter to service.

Appendix J (Cont)

S-92 ALERT SERVICE BULLETIN

ASB 92-64-012
Revision C ▪ May 16/17

Section 3. ACCOMPLISHMENT INSTRUCTIONS (Continued)



TAIL ROTOR PITCH CHANGE SHAFT PLUG
FIGURE 1

ATA 64-22-03	ONE-TIME INSTALLATION

Page 8

This Document Contains Technical Data Controlled by the EAR. See WARNING and classifications on first page.

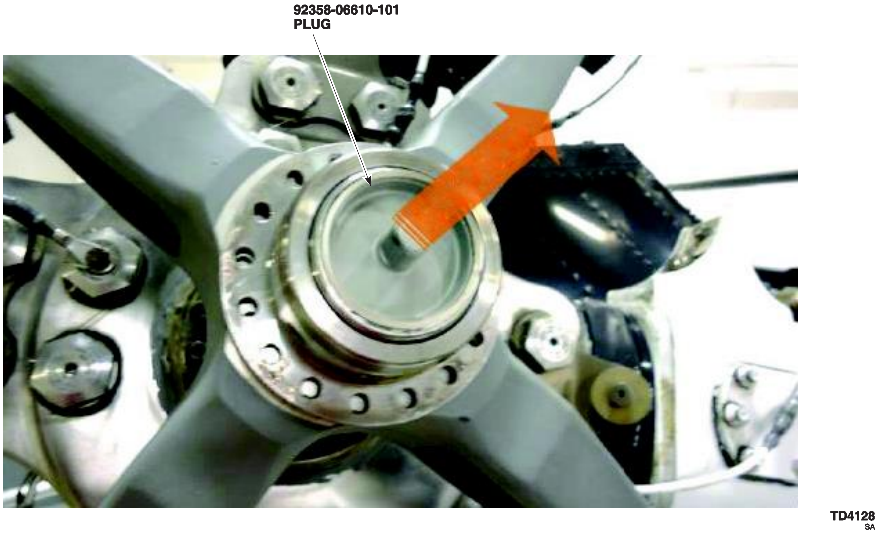
Appendices

Appendix J (Cont)

ASB 92-64-012
Revision C ▪ May 16/17

S-92 ALERT SERVICE BULLETIN

Section 3. ACCOMPLISHMENT INSTRUCTIONS (Continued)



REMOVAL OF PLUG
FIGURE 2

ONE-TIME INSTALLATION

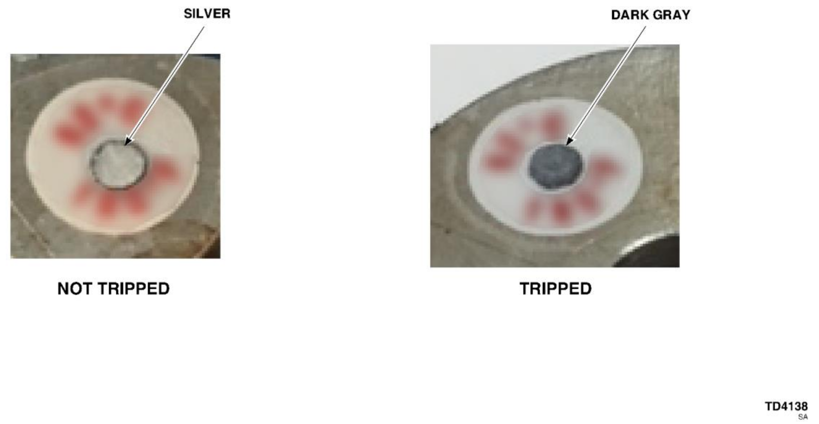
ATA 64-22-03

Page 9

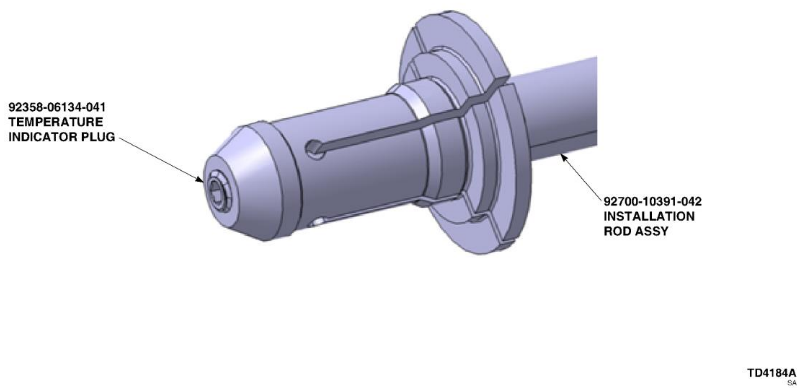
This Document Contains Technical Data Controlled by the EAR. See WARNING and classifications on first page.

Appendices

Section 3. ACCOMPLISHMENT INSTRUCTIONS (Continued)



TEMPERATURE DOTS
FIGURE 3



INSTALLATION ROD ASSEMBLY INSTALLED ON TEMPERATURE INDICATOR PLUG
FIGURE 4

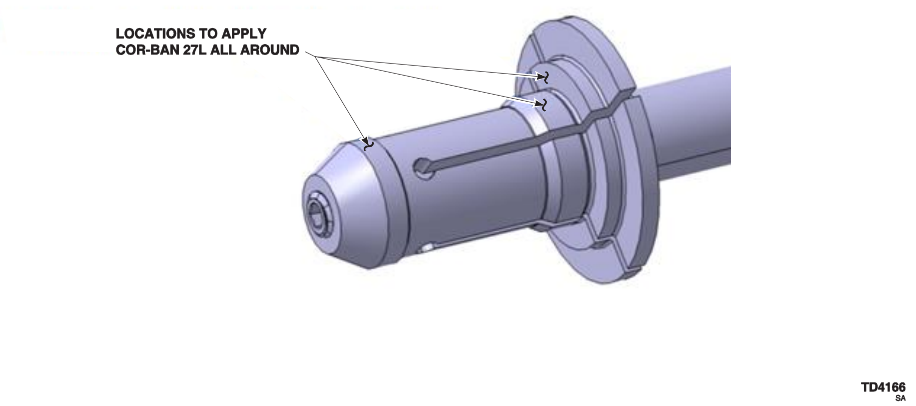
Appendices

Appendix J (Cont)

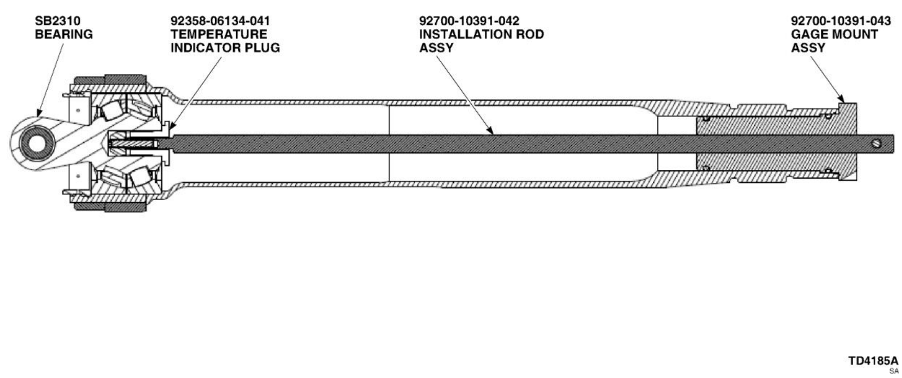
ASB 92-64-012
Revision C ▪ May 16/17

S-92 ALERT SERVICE BULLETIN

Section 3. ACCOMPLISHMENT INSTRUCTIONS (Continued)



LOCATIONS TO APPLY CORROSION PREVENTATIVE
FIGURE 5



INSTALLATION OF TEMPERATURE INDICATOR PLUG
FIGURE 6

ONE-TIME INSTALLATION | ATA 64-22-03

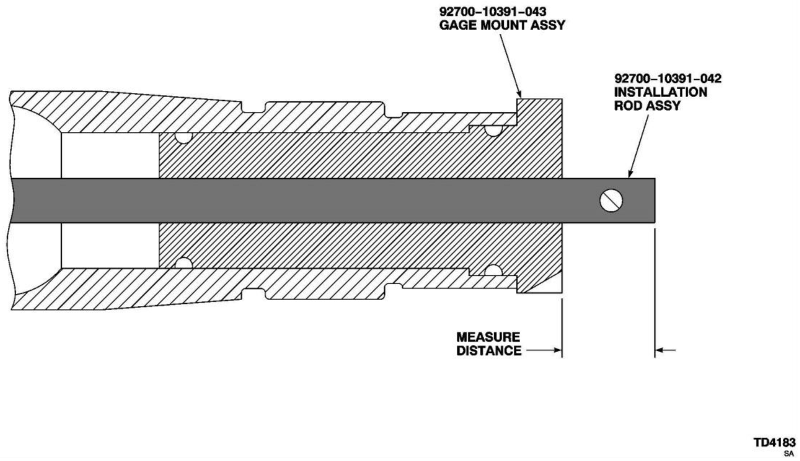
Page 11

This Document Contains Technical Data Controlled by the EAR. See WARNING and classifications on first page.

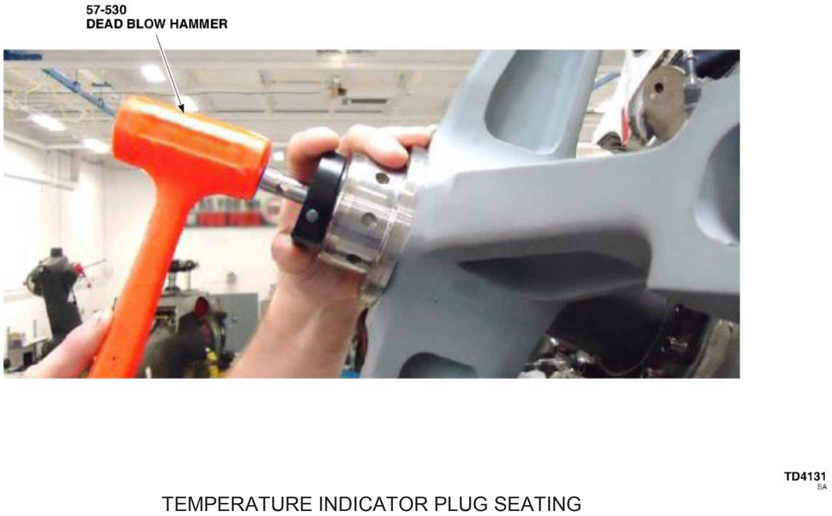
Appendices

Appendix J (Cont)

Section 3. ACCOMPLISHMENT INSTRUCTIONS (Continued)



TEMPERATURE INDICATOR PLUG INSTALLATION MEASUREMENT
FIGURE 7



TEMPERATURE INDICATOR PLUG SEATING
FIGURE 8

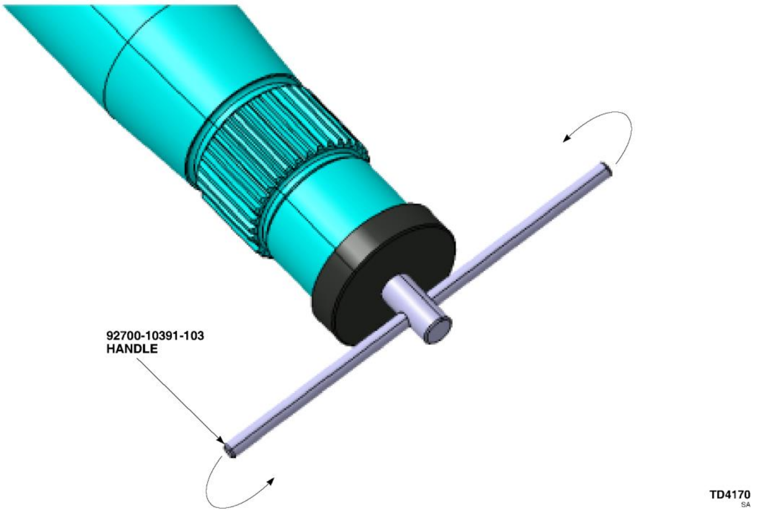
Appendices

Appendix J (Cont)

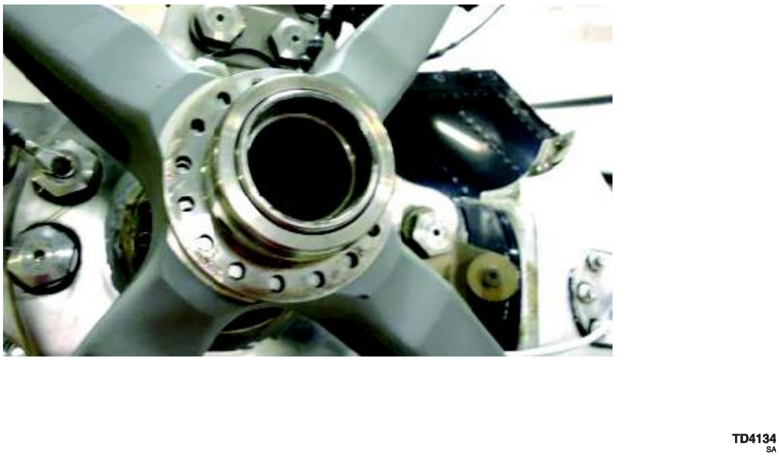
ASB 92-64-012
Revision C ▪ May 16/17

S-92 ALERT SERVICE BULLETIN

Section 3. ACCOMPLISHMENT INSTRUCTIONS (Continued)



UN-THREAD INSTALLATION ROD ASSEMBLY
FIGURE 9



INSPECT PCS BORE
FIGURE 10

ONE-TIME INSTALLATION | ATA 64-22-03

Page 13

This Document Contains Technical Data Controlled by the EAR. See WARNING and classifications on first page.

Appendix J (Cont)

Section 3. ACCOMPLISHMENT INSTRUCTIONS (Continued)

INSTALLATION OF PLUG
FIGURE 11

Appendix J (Cont)

ASB 92-64-012
Revision C ▪ May 16/17

S-92 ALERT SERVICE BULLETIN

Section 3. ACCOMPLISHMENT INSTRUCTIONS (Continued)

H. Record of compliance:

(1) Make helicopter logbook entries to show compliance with this ASB as follows:

(a) Make helicopter level logbook entry on form SA7343-15 (Aircraft ASB and CSN Release Signoff).

(b) When ASB modifies a component that can be removed from this helicopter:

1. Make component log card entries on forms SA7343-22 (Aircraft Component Log Cards) and SA7343-21 (Component Log Cards), as applicable.

2. If a component modified by this ASB does not have a log card and the ASB does not create one, then annotate compliance on the next higher assembly that the component belongs to which does have a log card.

NOTE: If access to www.Sikorsky360.com is unavailable, complete attached ALERT SERVICE BULLETIN COMPLIANCE RECORD CARD and return it to Sikorsky Aircraft Corporation.

(2) Make an appropriate electronic compliance entry in the E-Notification section at www.Sikorsky360.com. Refer to User Guide located on the www.Sikorsky360.com/E-Notification Search page.

ONE-TIME INSTALLATION | ATA 64-22-03

Page 15

This Document Contains Technical Data Controlled by the EAR. See WARNING and classifications on first page.

Appendices

Appendix J (Cont)

(Fold over and tape closed)

SIKORSKY AIRCRAFT CORPORATION

FACSIMILE NUMBER (817) 762-6715

EMAIL ADDRESS: product_safety.gr-sik@lmco.com

ATTENTION: Gr-SIK, Product_Safety
SIKORSKY AIRCRAFT CORPORATION

IMPORTANT NOTICE

Upon COMPLIANCE with the attached ASB, Sikorsky requests your cooperation in completing and returning this ENTIRE PAGE by MAIL, FAX, or scan & EMAIL.

Please fill in the requested information at the bottom of the page, so we may maintain proper records documenting the configuration of your aircraft. This information is useful when determining configuration and effectivity of issues affecting fielded aircraft.

This request is in keeping with our policy to assure that our customers receive the latest information applicable for the maintenance of your aircraft. Thank you.

ALERT SERVICE BULLETIN: No. 92-64-012C **Compliance Record Card**

TITLE: TAIL ROTOR – Tail Rotor Pitch Change Shaft Bearing Assembly – Installation of Temperature Indicator Plug

OWNER/OPERATOR: ______________________

SUBMITTED BY: ______________ **DATE:** ______________

☐ **FOLLOWING SERIAL NUMBERS ARE NOT AFFECTED BY THIS ASB**

☐ **ASB HAS BEEN COMPLIED WITH ON HELICOPTER SERIAL NUMBERS:**

(Fold Up to Arrows)

This Document Contains Technical Data Controlled by the EAR. See WARNING and classifications on first page.

Appendix J (Cont)

No Postage Necessary

BUSINESS REPLY MAIL
FIRST-CLASS MAIL PERMIT NO. 432 BRIDGEPORT CT

POSTAGE WILL BE PAID BY ADDRESSEE

SIKORSKY AIRCRAFT CORPORATION

Commercial Systems and Services
Mailstop K100
124 QUARRY ROAD
TRUMBULL, CT 06611 U.S.A.
ATTENTION:
Gr-SIK, Product_Safety

Please complete the form on the reverse side and FAX to

FACSIMILE NUMBER (817) 762-6715

Or scan and email to:

EMAIL ADDRESS: product_safety.gr-sik@lmco.com

or fold and return ENTIRE form to Sikorsky Aircraft Corporation

This Document Contains Technical Data Controlled by the EAR. See WARNING and classifications on first page.

Intentionally left blank

Unless otherwise indicated, recommendations in this report are addressed to the appropriate regulatory authorities having responsibility for the matters with which the recommendation is concerned. It is for those authorities to decide what action is taken. In the United Kingdom the responsible authority is the Civil Aviation Authority, CAA House, 45-49 Kingsway, London WC2B 6TE or the European Aviation Safety Agency, Postfach 10 12 53, D-50452 Koeln, Germany.

Aircraft Accident Report 1/2018

Report on the accident to

Sikorsky S-92A, G-WNSR

West Franklin wellhead platform,

North Sea

On 28 December 2016