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Title: EC130T2 –N11VQ NTSB Investigation- Thales Submission
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EVOLUTION SHEET

Issue	Date	Scope of evolution	Page
-	February 21 th , 2020 April 10th, 2020	Initial version Updated in accordance with new maintenance data from BHH	All

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1. PURPOSE OF THE DOCUMENT

This document provides Thales analysis of the EC130T2, N11VQ event that occurred on January 17th, 2016. This document is built upon Investigation evidence, AIRBUS Helicopters and Safran Helicopter and Thales testing (oversite by BEA) that was performed between 2016 and 2019. Above that, Thales provides in this document, based upon this data, event scenario and also contributing factors proposals.

2. REFERENCE DOCUMENTS

- THALES AVIONICS ELECTRICAL SYSTEM
 - Datasheet : Y1-3734-100
 - 524-031 Amdt H becomes Amdt J: Y38-3485
 - Expertise Report : BPS-SST-16-262- Rev1
- AIRBUS HELICOPTER
 - N11VQ INVESTIGATION STATUS – 01-02-2017
 - ETLL N° 2016-40202 LABORATORY TEST REPORT
- SAFRAN HELICOPTER ENGINES
 - TM report N°A-2016-001/WPR16LA55
 - N11VQ - Summary of Vibration Measurements on Engine Test Bench (RA2016-010) – 20 JAN 2017
 - N11VQ – Blue Hawaiian Helicopter - Accident Investigation- Additional findings and analyses – 1 FEB 2017
 - N11VQ - Magnetic Seal - Examinations & Analyses by SHE_(update 9June2017)
 - N11VQ - Ruptured pipe - Additional examinations & Analyses - (update 20Dec.2017)

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3. EC130T2 STARTER-GENERATOR PRESENTATION

3.1. GENERAL STARTER-GENERATOR PRESENTATION

3.1.1. STARTER-GENERATOR fundamentals reminder

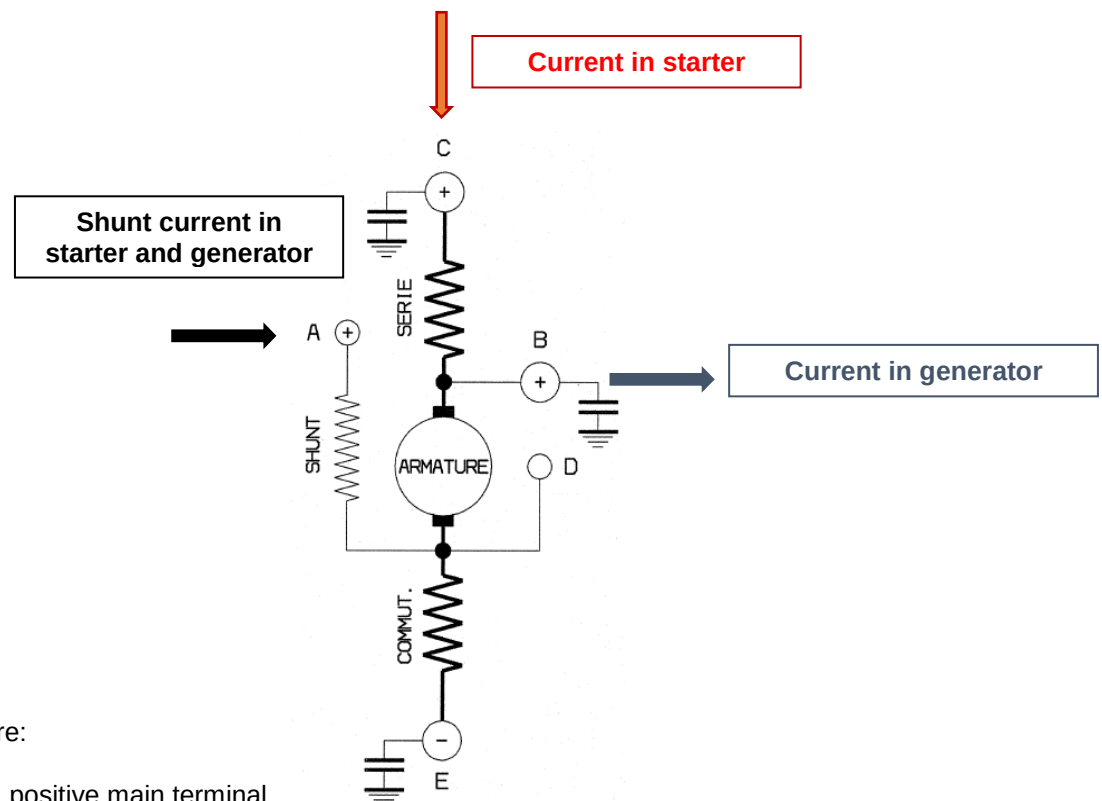
This starter-generator is a four-pole compound field machine (shunt and series windings), brush and commutator type, with commutating poles windings.

Series winding are used during starting phase only to improve starter characteristic performance.

The machine has two functions:

- Start the engine
- Provide constant voltage (28 VDC) to helicopter equipment's

Associated Generator Control Unit (GCU) provides field current to the shunt winding during start and generator mode.



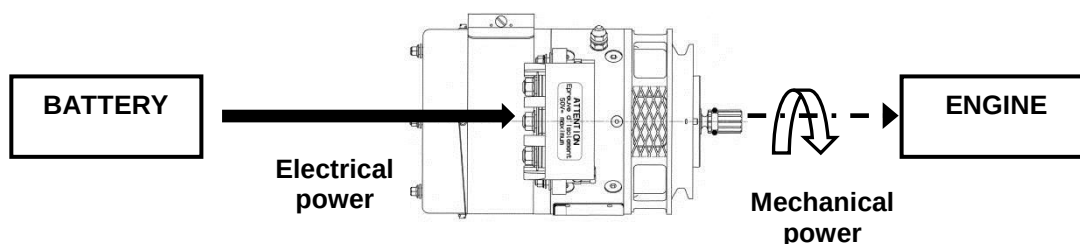
The S/G terminals are:

- (B+) : positive main terminal
- (E-) : negative main terminal
- (C) : series auxiliary starting winding terminal
- (A+) : shunt field circuit
- (D) : equalizer voltage

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The two main terminals (C+) and (E-) are used for starter mode

During engine start, in most of the cases, battery provides electrical power to the starter. Starter provides mechanical power to the engine through the flexible shaft with damper.



During the first start phase when engine is not ignited, the resistive torque is high. Starter has to provide enough torque to accelerate engine. GCU provides then high current to shunt winding.

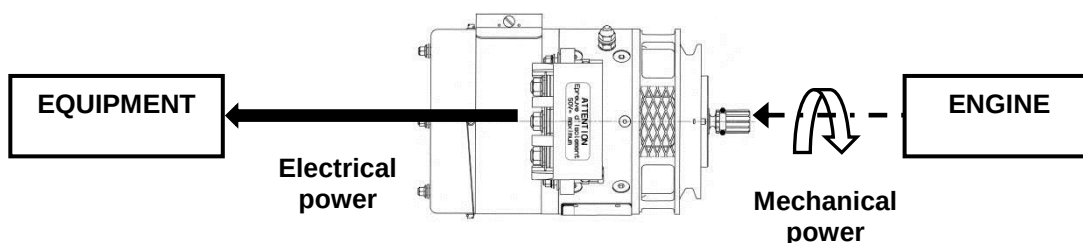
During the second phase after engine ignition, resistive torque is lower and GCU decreases current and mechanical power provided to the engine is quite constant.

When cut-out speed is reached, engine is autonomous, line contactor is opened and starter is no longer energized.

Engine accelerates to generator minimum speed and line contactor is closed.

The two main terminals (B+) and (E-) are used for generator mode

Associated generator control unit (GCU) provides field current to the shunt winding during generator mode and regulates constant voltage (28 VDC) to helicopter equipment.



Note: On the EC130T2 helicopter, the CGU is not a Thales equipment

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3.1.2. STARTER-GENERATOR equipment

3.1.2.1. Main information on starter-generator design and characteristics

The following paragraph presents the Stater-Generator Part Number 524-031 Amendment J that corresponds to the Starter-Generator S/N 5493 that was installed on the Blue HAWAIIAN EC130T2 Aircraft, registration number N11VQ, with which the helicopter was equipped.

3.1.2.2. Main characteristics of starter-generator Part Number 524-031 Amendment J

The starter-generator Part Number (P/N) 524-031 Amendment J has following characteristics:

Generator mode:

- Rated terminal voltage : 30 V DC
- Rated load current : 160 A
- Rated output : 4.8 kW (30 V – 160 A)
- Rated speed range : 8000 rpm to 12100 rpm

Starter-generator installation:

- The starter-generator is attached onto the engine pad by a Quick Attach Detach coupling

Weight:

- 8 kg

Cooling:

- Self-cooled by internal fan on ground and blast-cooled on altitude

S/G and Engine connection:

- Flexible shaft with damper

The starter-generator P/N 524-031 is equipped with an electrical bonding stud on the frame (as shown hereafter).

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3.1.3. Design structure of starter-generator P/N 524-031 Amendment J

A flexible drive shaft mechanically connects the starter-generator to the engine gearbox.

It allows rotating with an acceptable misalignment between starter-generator and engine.

The armature is the main internal rotating part of the starter-generator. The Armature is only linked to the Shaft by a nut at the rear side of the starter-generator. The armature rotates through two bearings: one located at the front flange, one at the rear flange of the starter-generator structure. It should be noted that the torque shaft is not directly linked to the front bearing. The armature is only linked to the front bearing.

3.1.4. Starter-generator Part Number 524-031 Amendment J qualification history

Starter-generator 524 family including S/G 524-030 was initially qualified according to TSOC56 in 1978

Appendix A provides the tests required for TSOC56 certification. At that time, vibration qualification testing was not part of the requirement.

During its history, the Starter-generator P/N 524-030 was modified to be installed on AS350 helicopter and a new P/N was created to become P/N 524-031. The Thales Avionics Electrical Systems customer at time was TurboMéca which subsequently became Safran Helicopter Engines. At that time, even if TurboMéca relied on the TSO Certification approval, it validated any modification proposed by Thales Avionics Electrical Systems.

In 2003, Airbus Helicopter, formerly Eurocopter, made the decision to integrate the starter-generator to its Type Certification Baseline, which then became the Design Authority of the product. The TSO certification was no longer considered for the certification. This was established by the Design Organization/ Production Organization agreement (DO/PO agreement) that was signed at that time between Eurocopter and Thales Avionics Electrical Systems. As such, Airbus Helicopter decided and validated any modification that was brought to this product.

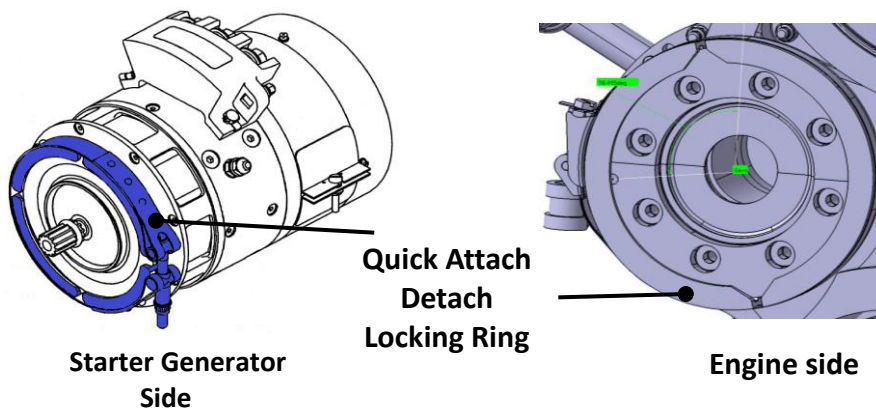
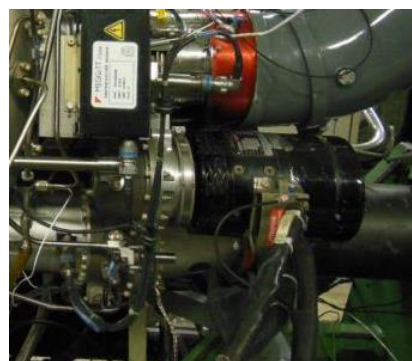
The following Table 1 indicates final approval authority for starter generator modification.

S/G P/N	Amendment	Final Approval
524-031	Up to G	TSO C56
524-031	H	EUROCOPTER (Design organization according to DO PO agreement)
524-031	J	EUROCOPTER (Design organization according to DO PO agreement)

Table 1: Starter-generator modification approval history

3.2. EC130 HELICOPTER INSTALLATION

The starter-generator 524-031 Amendment J is installed inside the EC130T2 helicopter as described hereafter. The starter generator is linked to the engine gearbox through its torque shaft. The starter generator is attached to the engine with a Quick attach/detach Locking Ring as shown hereafter.



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4. N11VQ EVENT AND EVIDENCE SUMMARY

4.1. N11VQ EVENT SUMMARY

Based on NTSB information, on January 17, 2016, about 1430 Hawaii standard time (HST), an Airbus EC130 T2, N11VQ, was in flight at 1,300 feet mean sea level (msl) when the pilot heard the low rotor rpm aural warning horn. The pilot reported that he was about 1/4 mile off shore northwest of the Honopu Sea Arch. He immediately entered an autorotation and turned towards the beach. He transmitted over the radio that he had an engine failure. As he approached the shoreline, he made a sharp low-level right turn to the south to avoid very large boulders that were in his targeted landing area and landed hard on the beach. He applied the rotor brake to slow the rotor, and at that time he noted that the engine was not running. The passengers began to exit the helicopter and he pulled the engine fuel cutoff.

The EC130 T2, N11VQ landed hard, twice, on a beach 2 miles west of Hanalei on the Hawaiian island of Kauai after a reported loss of engine power. The commercial pilot and all 6 passengers were seriously injured. The helicopter sustained substantial damage to the tail boom and airframe. The helicopter was registered to Nevada Helicopter Leasing LLC, operated by Blue Hawaiian Helicopters under the provisions of 14 Code of Federal Regulations, Part 135, and was conducting an air tour flight at the time of the accident. Visual meteorological conditions prevailed for the flight, and a company visual flight plan had been filed. The local flight originated in Lihue at 1406.

4.2. N11VQ EVENT EVIDENCE COLLECTION BY INVESTIGATION TEAM (NTSB AND BEA)

4.2.1. N11VQ Evidences – On scene collection

Based on NTSB information, except the photos provided by AIRBUS Helicopter, as far as Thales knows, little evidence was collected on scene related to the starter-generator.

4.2.2. Aircraft Examination

The operator transported the helicopter from the landing site to its maintenance hangar in Lihue, Kauai, the same day of the event. Further, (January 25, 2016), Engine manufacturer and Airbus Helicopters under the oversight of a Federal Aviation Administration (FAA) Inspector, examined the helicopter at the Lihue hangar.

The airframe had sustained structural damage to the tail boom and cockpit floor. The engine, starter-generator, VEMD (vehicle and engine monitoring display), DECU (digital engine control unit), and EDR (engine data recorder) were removed from the airframe, and placed in a shipping crate for transportation to Engine manufacturer. The Engine was also removed from the helicopter to be able to perform additional examination and testing.

Further VEMD examination shows that no failure was recorded during the flight of the accident (VEMD flight number 485). Two NR over limits were recorded as the result of the autorotation after the engine flame out that appear consistent with the further EDR analysis.

4.2.3. Engine and Fuel Pipe examination

According to the NTSB, during the first examination at the operator maintenance hangar, the engine's main fuel injection line between the adjusted valve and the injection union was found to be cracked and broken at the B-nut connection.

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As per the NTSB and Engine manufacturer reports, further examinations of the engine at Engine manufacturer facility did not reveal other issues with respect to the engine, and the engine was restarted with the starter generator S/N 5493 with a new fuel pipe (P/N: 0292737310, diameter 6 mm). During this first test, vibration was observed on the couple starter generator - fuel pipe.

4.2.4. Starter generator factual information

The starter generator Part Number (P/N) 524-031 – Amendment J, Serial Number 5493, was manufactured by Thales on October 24nd 2014. The production file did not disclose any production issues at that time (no process issue, parts compliant with design file).

The operator information reveals that this unit had accumulated, within the helicopter, 692.7 Flight Hours by the time of the event.

Following the engine's first examination and test, the starter-generator was removed from the engine and demonstrated:

- A significant presence of greasy/oil material at the engine/starter-generator interface as shown hereafter



- a play that is observable through starter generator torque shaft movement.

4.2.5. Starter-generator maintenance factual information

The starter-generator P/N 524-031 Amdt J S/N 5493 was never sent back to Thales for maintenance or overall prior to the event.

The operator information also reveals that the last maintenance check was performed at 627 Flight Hours or approximately 66 flight hours before the event.

According to information provided by the operator, an inspection is performed every 150 Flight Hours and checks general condition of the starter-generator, terminal lug covers, and security clamp.

The operator represents that, at 627 hours, the starter generator was removed and that the brushes were inspected and measured. This information reported by the operator, however, is verbal only and, at this juncture, remains uncorroborated by documentary evidence - such as FAR-required log entries detailing the manner and scope of the work memorializing that the starter generator, in fact, had been removed during the inspection.

The Thales CMM 80.19.02 is referenced within the Operator Helicopter Maintenance Manual and related

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starter-generator maintenance task as shown here after :

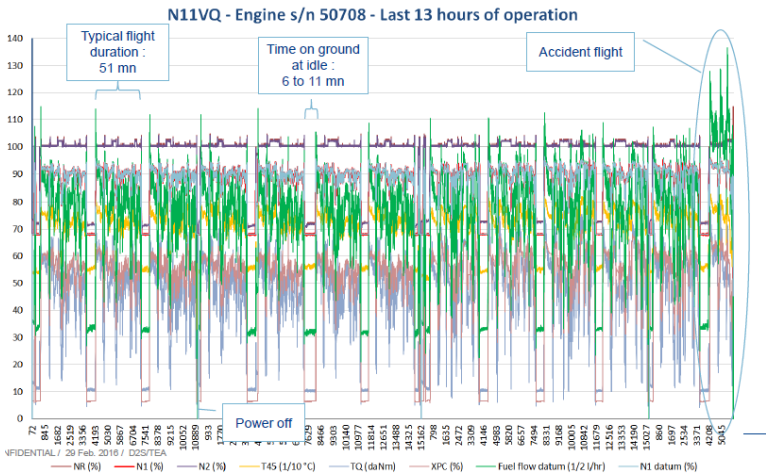
BLUE HAWAIIAN HELICOPTERS APPROVED AIRCRAFT INSPECTION PROGRAM (AAIP) EC130T2 SERIES - 150 HOUR INSPECTION (12 MONTH) (BHH FORM 002T2, 7/15/13, REVISION 3)		
10.0 Powerplant (continued)	Mechanic	Inspector
10.19 Inspect injectors. (w/o removal).		
10.20 Check general condition of starter generator, terminal lug covers and security of clamp. Inspect brushes without removal . (Ref, SL 2097-I-24). Blow out brush area with compressed air. (524-031 S/G only) Measure brush length with tool P/N PO33158. Note brush length. Green ☐ Yellow ☒ Red ☐ If brush length is in the red, change starter generator if available, not brushes. CMM 80.19.02.		
10.21 Inspect turbine casing drain valve. (w/o removal)		

In particular, the 600 Flight Hours maintenance check performed by the operator at 627 actual Flight hours demonstrated that the measured brushes were within the so-called “Yellow area”. In that situation, the Thales CMM 80.19.02 referenced within the operator maintenance task, requires that all the brushes must be changed..

4.2.6. FDR data

Over what was provided by various recording systems that were present on that particular helicopter (VISON 1000, Datatoys AirKnight HD4s Recorder), in particular, the EDR (Engine Data Recorder) provides information about how the EC130T2 N11VQ was operated.

Typically, it appears on this recording that during the last 13 hours of operations the helicopter performed a succession of four 50 minutes (approx..) flights, thereafter remaining on the ground for approximately 10 minutes with the engine maintained at Ground Idle. Then, after the fourth flight, the engine was shut down. As further Engine manufacturer testing is shown, Vibration levels appeared to be higher when the engine was being operated at ground idle (see Engine Testing chapter).



EDR Data extract (AIRBUS Helicopters report)

4.3. ENGINE TESTING SUMMARY

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4.3.1. Grand Prairie Testing (US-TX)

As mentioned above, on February 4th, 2016, the first examination, with the exception of the pipe rupture, disclosed no significant issues and a functional test was satisfactorily performed with the Starter generator S/N 5493, according the AIRBUS Helicopters report.

A testing was then performed by replacing the fracture pipe (P/N: 0292737310, diameter 6 mm) by a new one with the same width dimension. Vibration was noted at starter generator level. The coupling vibration phenomenon was clearly visible at the fuel pipe level although measured vibrations at the engine level indicated a value of **15,6mm/s** that was within the acceptable limits of 20mm/s.

In a second step, it was decided by the investigation team to replace the Pipe P/N: 0292737310 (diameter 6 mm) by another pipe type - the one that was initially certified on the Engine Type, as stated by the Engine Manufacturer. This fuel pipe P/N 0292730350 presents similar design but with the greater diameter of 10 mm instead of 6 mm on the pipe actually installed on the accident helicopter.

In fact, testing with the initially certified pipe (P/N 0292730350) revealed a better response within the vibration environment as it was further shown with the test performed at Engine Manufacturer, Bordes, France Facility.

4.3.2. AIRBUS Helicopters Tests (FR)

On March 9th and 10th, 2016, testing was organized at AIRBUS Helicopters, Marignane facility, France.

An EC130T2 helicopter outfitted with an Arriel 2D and with a fuel pipe P/N 0292737310 (diameter 6 mm) was used for this testing.

It was observed during this testing that on one of the four test runs, the vibration at the vibration pick-up point was measured at a maximum of **20.11 mm/s**, i.e., just above the limit defined by the engine manufacturer. This value was observed at a Ground idle regime. In that test and at the same moment (ground idle regime) the stress level measure at the pipe level was **62MPa** as per the engine manufacturer's test reports. Additionally, during this test it was observed that the stress level resulting from vibration, at the pipe level, was reduced to a range of 15 to 25% when the starter-generator was providing power to the helicopter. It should be noted that during normal operation, as soon as the helicopter engine is started, the starter-generator provides power to the helicopter equipment.

Additionally, similar tests were performed with starter-generator S/N 5615 (P/N 524-031 Amendment J). These tests did not reveal significant vibrations. Nevertheless, at ground idle regime using a brand-new starter-generator, the stress level recorded at pipe level reached a maximum of **35MPa**.

This testing was unable to replicate vibration conditions that could explain the fuel pipe fatigue rupture as the stress level recordings (max 62 MPa) was far below the maximum allowable limit of **160 MPa** for the fuel pipe.

4.3.3. Engine Manufacturer Bordes Testing (FR)

The testing performed by Engine Manufacturer was organized in two sequences :

- Under the oversight of BEA and in presence of Thales and AIRBUS Helicopters, testing was performed on an exemplar ARRIEL 2D engine (S/N 210) with the starter generator (P/N 524-031 Amendment J) of the event (S/N 5493).
- Additionally, outside of Thales' presence, the Engine manufacturer performed testing on the exemplar engine using the following starter-generators which designs are different from accident starter generator :

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- P/N 524-031 Amendment G S/N 3313
- P/N 524-031 Amendment H S/N 3809
- P/N 524-031 Amendment H S/N 5111
- P/N 524-031 Amendment J S/N 5466

Thales Maintenance records show that these four starter-generators had never been returned to Thales for repair or overhaul. Only the S/N 3313 was sent to another approved PART 145 station on June 15th 2004. Consequently, the use of these starter-generators, as qualified by the Engines manufacturer as Testing tools, is unknown by Thales. The status of these four starter-generators versus their performances was totally unknown by Thales prior the engine manufacturer testing.

Thales was only asked to perform in-depth analysis on the S/N 3313 and the S/N 3809. It appeared in these analyses that these two testing tools were not in their original design. Additionally, the cover of S/N 3313 was damaged and deformed.

Thales believes that testing on starter-generators S/N 3313, 3809 and 5111 are not relevant to this investigation as their technical compositions are different from the starter-generator S/N 5493 (the one present in the accident aircraft). And, consequently, any conclusion based upon the testing performed on these 3 units should not be taken into account as demonstrable evidence for this investigation.

This result demonstrates that vibration regime at pipe level is mainly observable at Ground Idle engine setting. As Per Engine Manufacturer testing report Ground Idle is located around of 7600 rpm (see Engine Manufacturer testing report –Jan 2017)

Engine Manufacturer testing also shows that even the worst case scenario in terms of Vibration (Ground Idle) the stress level induced by vibration measured on the Pipe remained within the acceptable limits (160MPa) as stated in the Engine Manufacturer testing report (Jan 2017)

Detail measurements at Ground Idle regime demonstrates that, on the engine only, the observed vibrations were at a frequency between **130 and 165Hz with the S/G 5493**. The stress level, at Ground Idle, at the Fuel Pipe (P/N 0292737310 (the one of the accident helicopter) was at 146 MPa well within the maximum value defined by The Engine manufacturer at 160 MPa. The natural frequency of the fuel pipe (P/N 0292737310) is estimated in theory to be at **128Hz**

During this testing, it appears, as per the engine manufacturer's report that, using the initially certified fuel pipe (P/N 0292730350) (and even if tested with the S/G S/N 5493), the stress level is measured at a value close to **50 MPa**. This stress level with the initially certified fuel pipe (P/N 0292730350) is clearly well under what was observed with the Pipe P/N 0292737310. The 50MPa value, observed on the pipe initially certified, represents 31% of the maximum value defined by the engine manufacturer at 160 MPa. In that case the Vibration frequency is at range of **175Hz**. This pipe demonstrates a better behavior under this vibration condition.

This exhibits the coupling phenomenon. Such phenomenon needs to have a vibration producer and at the same time a mechanical receiver sensitive to such a vibration in terms of frequency and level.

To summarize this phenomenon, as shown by testing on the engine:

- With the starter-generator S/N 5493 using the pipe P/N 0292737310 there exists vibration at 130hz range with up to 146MPa fuel pipe stress
- With the starter-generator S/N 5493 with the pipe P/N 0292730350 there exists vibration at 175hz range with close to 50Mpa fuel pipe stress (limited vibration effect)

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- With starter-generator S/N 5466 (with radial play <0,01mm) associated with fuel pipe type P/N 0292737310 (no vibration impact: Stress level < 10 Mpa)

The material characteristics as provided by the engine manufacturer exhibit the following performances:

- Yield Strength = 220 Mpa
- Ultimate Strength = 530 Mpa

The fatigue phenomena result from two parameters:

1. the stress level applied to the part considered (here the fuel pipe) and,
2. the number of cycles applied over a certain stress limit called the fatigue limit.

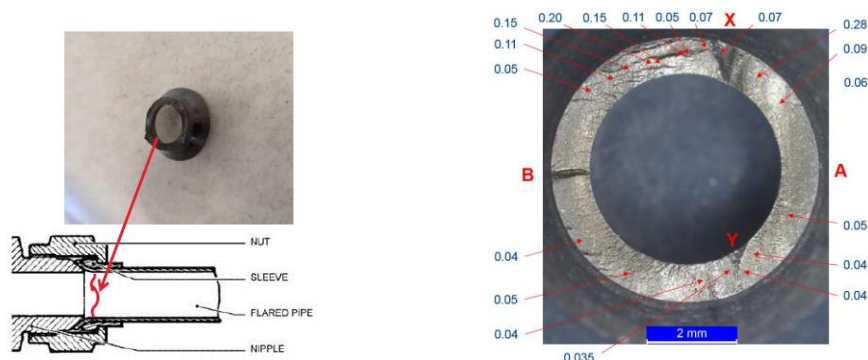
The number of cycles could also be translated in bending movement frequency. As the bending movement frequency is growing, the number of cycles is increasing as well.

As explained before, during the test a measurement of maximum stress was made at 146 MPa (at engine ground idle regime) which was well under the 160MPa (manufacturer limit) and greater under the Yield strength of 220 MPa.

That implies that the measured stress level during the testing with pipe type of the N11VQ was not to such an extent that it could be used to permit or to explain, nor to reproduce, the pipe fatigue fracture. This remains to be explained.

4.3.4. Fuel Pipe Examination (FR)

Additional to the NTSB examination, Engine Manufacturer under BEA supervision, performed additional and detailed physical analysis using binocular and Scanning Electron Microscope (FEG-SEM). This analysis was thoroughly reviewed by the BEA, Airbus Helicopter and Thales.



The BEA System group (BEA, AH, Engine Manufacturer, Thales) concluded that the rupture of the pipe was mainly due to fatigue phenomenon.

4.3.5. Magnetic seal examination (FR)

It should be kept in mind that the Magnetic seal is an engine part. This Engine part was analyzed by the engine manufacturer. No specific discrepancy was noted during this investigation that could explain the Oil leak within the Engine – starter-generator interface. It was considered by the engine manufacturer that the oil leak could have resulted from vibration phenomenon.

4.3.6. Engine Pad (interfacing with the starter-generator) inspection (FR)

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On June 18th 2019, additional examination was performed on the starter generator and the Engine Pad as some marks appears to be dissymmetrical on the starter generator.

The examination reveals that these on starter-generator marks correspond to the Engine Pad fixation screw holes locations.

Alignment measurement was made and no misalignment was observed on functional parts diameters (Engine pad and Starter-generator drive flange).

The two, Engine and starter-generator, were confirmed compliant.

4.4. STARTER-GENERATOR TESTING

4.4.1. On engine Testing (Grand Prairie, TX, USA)

This test reveals that the engine could be started with this starter-generator, and as far as known by Thales, this equipment was able to provide electrical power. Even if a play was observed at that time, this testing reveals that the starter generator remained functional (see following paragraphs).

Nevertheless, this testing revealed that during the visual inspection, it has been observed a presence of greasy/oil material; play was also observable with a hand movement on the starter-generator torque shaft. The starter-generator was cleaned before this testing on the Exemplar EC130T2 helicopter

4.4.2. Testing of the starter generator at Airbus Helicopters (Marignane, France)

On March 9th and 10th the starter-generator was tested on an exemplar EC130T2 helicopter that was fitted with an ARRIEL 2D Engine.

It was decided by the system group to perform some testing with the starter-generator on this exemplar helicopter and engine. It had to be notice on this exemplar engine (ARRIEL 2D), that the starter generator was able to start the engine and deliver power as expected.

Vibrations were present with the Starter-Generator S/N 5493. These vibrations were clearly evident at Ground-Idle regime. Even if at an engine level of 20,11 mm/s was observable just above the acceptable limit it appears during this testing that the stress level, on the pipe flare end, was measured at a maximum value of 62Mpa (around). This value is clearly within the allowable limit that was determined by Engine manufacturer at 160 Mpa. This testing also demonstrates that when the Starter-Generator is delivering electrical power to the Helicopter, as it does during normal in-flight operations, the stress at pipe level is reduced by 15 to 25% in amplitude.

Vibrations were reduced when the testing was performed with a new S/G, (S/N 5615) with 524-031 Amdt J definition.

This testing showed that when an engine is subjected within a helicopter environment, the measured vibrations differ from what is measured on a bench-tested (or stand-tested) engine. On the bench-tested engine, the measured level was à 15.6 mm/s then on EC130T2 Helicopter at 20.11mm/s at a maximum on one of the 4 test runs performed. Additionally, the frequency of the phenomena is measured in a range of 120 Hz instead of 128Hz and 134 Hz at Starter Generator Level. It should also be noted that the stress level measured on the fuel pipe when tested when the fuel pipe is within the helicopter, resulted in a stress level measuring **62 MPa** under this vibration environment..

4.4.3. Investigation Testing (Meru, FR)

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This phase of investigation was performed under BEA supervision, in presence of Airbus Helicopters and the Engine manufacturer.

As it had been observed by the Blue Hawaiian Helicopter Technician prior the accident flight, It was observed on the starter-generator S/N 5493 that all the brushes were confirmed in the yellow area of the measuring tools.

In details, the brushes were measured as follow (in absolute length) : Brush 1 = 18.03mm, Brush 2 = 18.35mm, Brush 3 = 18.70mm, Brush 4 = 18,15mm. Within the measuring tool (brush gauge P/N P033158) reference that give the following measurements: Brush 1 = 6.03mm, Brush 2 = 6.35mm, Brush 3 = 6.70mm, Brush 4 = 6,15mm. For background information, the measurement area on the measuring tools is indicated as follows:

- The green zone is for a measurement between 17mm and 9,8 mm
- The yellow zone is for a measurement between 9,8mm and 3,4mm
- The red zone is for a measurement between 3,4 mm and 0 mm

The brushes measurements of the brushes of S/N 5493 exhibits inhomogeneous and nonlinear wear on all four brushes. This type of measurement is typical given the number of flight hours. In fact, this confirms the need to check all of the four brushes as per Thales CMM 80.19.02. Thales once again notes that when brushes are in the yellow area, they must be changed.

Vibrations are evident during the testing at a frequency range around 134 Hz. It should be noted that at the first order, the vibrations are more pronounced on the B accelerometer placed on the Y axis of the helicopter (up to 112,7 m/s²).

This test also confirmed that the starter-generator remained functional in both starting and generator modes, and that no discrepancies were noted related to its electrical performance in either mode.

When the starter-generator was torn down, wear was only noted at the front-bearing cage and greasy material was present at the front bearing location. No other discrepancies were noted (e.g., there was no rotor impact/chocks, no armature friction trace, no other bearing/cage impact, and the front bearing appeared to be in good condition with the exception of minor traces of radial fretting).

4.4.4. BEA/CETIM Investigation Testing (FR)

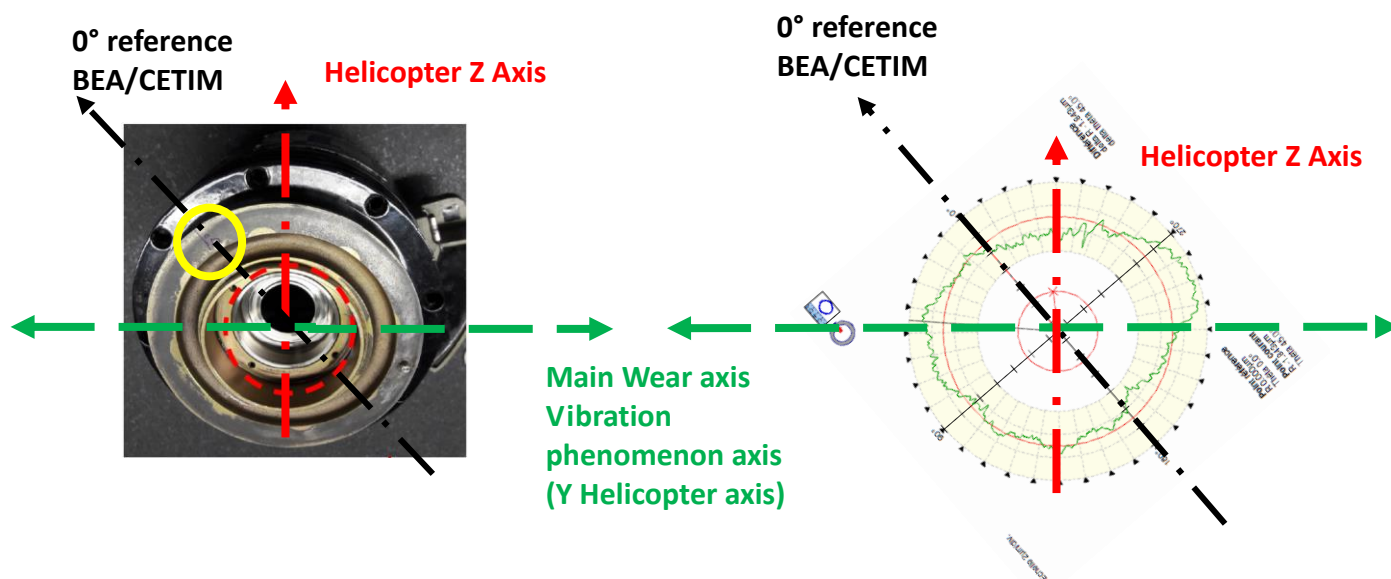
As requested by the BEA, the front bearing Cage and flange, and front bearing itself were thoroughly analyzed by CETIM, an independent laboratory.

The Bearing measurement does not show significant wear or deformation.

The front bearing cage shows wear with “rugby balloon” shape. This wear is out of acceptable tolerance and measured by the BEA and the CETIM independent laboratory with a difference around 0.650 with a maximum of 0.680 mm between a local diameter and the nominal diameter.

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This “rugby balloon” shape on this longer dimension axis is along the Y axis of the helicopter as shown hereafter.



This observation, in which the wear is not uniform around the bearing cage and appears to be under on one axis, taking into account that no other discrepancy was noted, indicates that the starter generator may have been subjected to an external vibration phenomenon or force on that preferred axis of degradation.

The measurements made by Airbus Helicopter and Thales, confirm that finding that the vibration of the starter-generator occurs along the Helicopter Y axis.

4.5. OILY/GREASY BLACK SUBSTANCE ANALYSIS

The black oily/greasy substance was analyzed by BEA. In order to do so, the BEA used a gas chromatography-mass spectrometry (GC-MS), by Fourier transform infrared (FTIR) spectroscopy and X-ray fluorescence.

This analysis reveals that the black substance was made of:

- Oil : O-156
- Loctite 8012 (Grease for the starter-generator bearing assembly)

The ratio of this material was not determined by the BEA.

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4.6. ADDITIONAL INFORMATION

4.6.1. Protective measures and fleet return analysis

Following the start of the investigation, an industry-working group was formed in order to find technical and protective measures so as to avoid re-occurrence of similar event. This working group was led by Airbus Helicopters with the participation of Thales and the engine manufacturer.

4.6.1.1. Protective measures

First, it must be recalled that wear on a bearing system is a well-known mechanical phenomenon. Consequently, maintenance intervals are established as a fail-safe in order to detect such issues before any problems arise. In this regard, it should be noted that maintenance checks were mandated by Thales at every 600 flight hour intervals (all brushes check), 1200 flight hours (brushes and bearing changed) and 2400 flight hours (complete overhaul).

Following the accident, in early 2017, Airbus Helicopters issued Information notice No. 3144-I-80 in order to remind operators of the appropriate maintenance practices for the starter-generator. This Information notice underscores in particular the need for operators to remove the starter-generator from the engine and the helicopter so as to be able to perform required inspections of all brushes, and to check any issues such as oil slippage, radial play and any starter-generator degradations.

In early 2018 (March 12th, 2018) Airbus Helicopter issued a Recommended Service Bulletin SB EC130-24-008 that asks to check on time the starter-generator for radial play (0.05 mm radial play criteria) of the front bearing before reaching 450 Flight hours as well as for any oil slippage at the starter-generator – engine interface. Additionally, the Service Bulletin requests that operators report all measurements and observations to Airbus. Of course, the SB also requests that appropriate measures are taken if any discrepancies are observed.

At the end of 2018 (December 24th, 2018) Airbus Helicopters issued Service Bulletin (N°EC130-05-030) that strongly recommend to modify the starter-generator maintenance intervals and required inspections every 300 Flight hours, the equipment for radial play and potential oil slippage at the starter-generator – engine interface. The service bulletin also requires to take appropriate measures if discrepancies are noted during the Service Bulletin required inspections. This service bulletin is based on the Thales Service bulletin n° 524-03X-80-011 that gives the appropriate radial play measurement method.

Other protective measures are also envisaged at the platform level but are out of the Thales scope.

4.6.1.2. Fleet return analysis

4.6.1.2.1. Maintenance records analysis just after the accident (2016)

4.6.1.2.1.1. Thales Maintenance records

At the start of the industry working group, just after the accident, only limited evidence was available and showed that out of 44 returns on this particular starter generator (P/N 524-031 Amendment J) only three cases may have displayed some similarities: namely radial play, front bearing cage wear.

In only one case was the wear measured. But this wear, measured at 45µm, was not within the range that was observed in the N11VQ event (between 0.650 and 0.680 mm at bearing cage level).

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These three starter-generators came from another helicopter type fleet.

In sum, these facts underscore the fact that, at the time of the accident, notable wear on the front bearing cage (0.5 mm and above) on the starter generator (P/N 524-031 Amendment J) was totally unknown with respect to the EC130 model fleet.

4.6.1.2.1.2. Blue Hawaiian Helicopters and Air Methods Maintenance records

Following the accident, Blue Hawaiian helicopters and Air Methods (Blue Hawaiian Helicopters parent company) checked their maintenance records and this revealed that 6 starter-generators (P/N 524-031 Amendment J) were returned to Thales for due overhaul in the six months prior to the accident.

Two were apparently noted to have a radial play (namely S/N 5144 and S/N 5146). Moreover these two starter-generators were sent to Thales for overhaul without mentioning any radial play or vibrations issue. As the measurement of the radial play of the front bearing case was not mandatory at that time, this information was not recorded therefore it not possible to know the extent of the alleged radial play.

It had to be noted that the S/N 5146 was sent to Thales for the 2400 Flight hours overhaul check. This particular S/N, as per Thales record, had been sent by Blue Hawaiian Helicopters/Air Methods, at 2598 Flight hours. The maximum life limit time for overhaul as defined by Airbus Helicopters, is 2500 Flight Hours. All four brush lengths of this unit were measured in the red area (close to the last limit).

No radial play was noted on the four other starter-generators

4.6.1.2.1. Maintenance records analysis following SB EC130-24-008 application (2018)

As mentioned above, in March 2018 Airbus Helicopter decided to provide a recommended Service Bulletin in order to ask operator to send back to Airbus and Thales any starter-generator that may have a front-bearing wear over 0.05 mm. A specific measurement method was established by Thales for such. This method aimed at measuring the potential armature radial displacement without starter-generator teardown (but with only removal from the engine and helicopter). This method is described in the SB EC130-24-008.

Based upon that SB, Airbus and Thales were able to collect by the end of year 2018 information that showed the following:

- Five starter-generators (P/N 524-031 Amendment J) appeared to be above the defined limit: 0.05 mm. They come from EC130 helicopters. The radial plays were measured on four of these five units and were found to be at or above 0.5 mm
- Two of these detailed observed starter-generator exhibit traces of oil/greasy substance at the starter-generator – engine interface.

It should also be noted that 3 of these four returns came from a Canadian helicopter touring operator, which like Blue Hawaiian Helicopter, subject to verification, likely had the same type of operations, i.e., a succession of flights with on ground engine running at ground idle in between two flights. The fourth return starter generator came from a Swiss helicopter training school that, subject to verification, likely may also have had a kind of operation with multiple ground idle usage similar to that of Blue Hawaiian. It had to be noted that AIRBUS Helicopters considers that today in place protective measures cover such type of operations.

It has to be noted that the starter-generators 524-031 amendment J, at the time of the accident, represented 46% of the EC 130 fleet installation. The other major helicopter type fleet where this starter-generator model is installed, accounts for only 7% of the installations.

Based on the small sample numbers, it is not possible to equate a clear correlation between the starter-generator P/N 524-031 amendment J front bearing wear with the helicopter fleet.

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4.6.1.2.1. Maintenance records analysis following SB EC130-05-030 application (2019)

As mentioned above, at the beginning of 2019 Airbus helicopter published Service Bulletin N° EC130-05-030 that required inspections of all the starter-generators that have accumulated 300 Flight hours since their last overhaul (or new) and, in particular, checks of the radial play at the front bearing cage level.

It should be noted that by the end of 2019, Airbus Helicopter incorporated Service Bulletin EC130-05-030 within its EC130 T2 Aircraft Maintenance Manual. This was also extended to any fleet that incorporates starter-generators P/N 524-031.

In the one-year period between January 2019 and January 2020, four starter-generators P/N 524-031 Amendment J were returned to Thales displaying an out of SB criteria radial play value (over 0,05mm). All of these four starter-generators P/N 524-031 Amendment J had a radial play at or below 0.1 mm and all came from another model fleet. Appropriate maintenance measures had obviously been applied by replacing the front bearing cage and associated bearings as required by Service Bulletin EC130-24-008.

4.6.1.1. Reliability analysis

534 Starter-generators 524-031 Amendment J were produced at the end of January 2016. In this analysis it had to be consider that Thales estimates that Thales repair stations cover 30% of the maintenance market on this starter generator.

Figures available at Thales shows the following at the end of January 2016:

- It is estimated by Airbus that at the time of the Accident that 100 000 Flight Hours had been accumulated by similar Helicopters (EC130T2, ARRIEL2D with fuel Pipe 6 mm with starter-generator P/N 524-031 Amendment J). This starter-generator represents 46% of the EC130T2 starter-generator installations
- On 44 starter-generator 524-031 Amendment J removals, 4 were recorded as installed on EC130 by Thales repair stations. 43 of them were returned for due maintenance or overhaul. Just one was returned for unscheduled maintenance operation. This unit was returned from an EC130.
- On the other Airbus Helicopters fleets (others models), the starter-generator 524-031 (all amendments) had accumulated 30 137 00 Flight hours for 2117 units produced by Thales. Airbus considers that the 524-031 Amendment J represent 7% of the installations on theses fleets.
- The general reliability figures gave for the starter-generator 524-031 (all amendments) an MTBF of 13 500 Flight hours (for an Airbus requirement of 6200 Flight hours)
- On all Airbus Helicopters fleets 12 starter-generators 524-031 Amendment J unscheduled removals where observed

This analysis reveals that, at the time of the accident, no reliability issues were noted on the starter-generators 524-031 Amendment J when installed on EC130 helicopter. Again, that shows that the observed phenomenon on the N11VQ was totally unknown on the starter-generators 524-031 Amendment J when installed on EC130 type before the accident.

4.6.2. Thales production investigation

It has to be mentioned that sole Amendment J types are pertinent in this investigation as the design of the previous version is different in particular for the front bearing cage and bearing assembly into the Drive Flange.

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As per Thales record, it appears that 534 starter-generators P/N 524-031 Amendment J were produced at the time of the accident from April 13th, 2011 up to January 20th, 2016.

After the accident and within this investigation, Thales reviewed its production data and maintenance history based on all serial numbers (11 units) that had been identified having an actual radial play over the Service Bulletin EC130-24-008 (or SB EC130-05-030) criteria (0.05,mm) or have been reported as having a radial play. These units were produced between 2011 and 2016.

Based on Thales production and maintenance records reviewed, it appears that there is no evidence that particular production batches have any specific issues. Additionally, neither Airbus Helicopters nor Thales have received large number of returns for repair for such radial play. Therefore, no production issue could be considered as a potential factor.

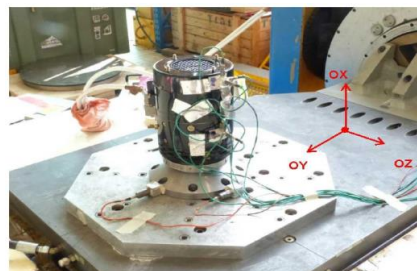
4.6.1. Starter-generator Vibration Qualification tests (DO160G)

As part of the industry working group, in 2019 Airbus Helicopter provided to Thales relevant Vibration testing criteria for the EC130T2.

SOPEMEA, an independent laboratory performed the qualification test (starter-generator 524-031 amendment J without modification) as per Thales request.

As shown hereafter, the tests result under these Vibration criteria (DO160G, (Group 2, ZC) confirm that the starter-generator 524-031 amendment J is fully compliant.

The following photo depicts the testing installation used for this qualification test by SOPEMEA.



Photograph n°2 - Overall view along OY axis

The following give a summary of the Qualification test results:

 1E32071 M2 of 16 January 2019

3. TEST PROGRAM AND SUMMARY RESULTS

The test program, designated by the representatives of THALES AVIONICS ELECTRICAL SYSTEMS, is defined in the Qualification test procedure vibration referenced Y15-3618 dated on 10 October 2018.

TESTS	RESULTS	PARAGRAPH
Vibration tests	Tests are fully performed according to prescriptions. No observation on the equipment was reported during the tests.	4.3

4.3 TEST RESULTS

Personnel conducting the tests:

NAME	FUNCTION
QUENTIER Olivier	Test technician
GALLO Quentin	Test technician

Persons attending the tests:

NAME	COMPANY
Mr. LOUVIOT	THALES AVIONICS ELECTRICAL SYSTEMS
Mr. LUCAS	THALES AVIONICS ELECTRICAL SYSTEMS

4.3.1. TESTS SCHEDULE

DATE	AXIS	PROGRAM	DURATION	GRAPH NO	COMMENTS
18/10/2018	OX	A	1 sweep	1 - 9	Initial frequency search. Nothing to report.
18/10/2018	OX	B	10 min	10 - 19	Performance vibrations. Nothing to report.
18/10/2018	OX	C	2 h	20 - 29	Endurance vibrations. Nothing to report.
18/10/2018	OX	B	10 min	30 - 39	Performance vibrations. Nothing to report.
18/10/2018	OX	A	1 sweep	40 - 49	Final frequency search. Nothing to report.
18/10/2018	OY	A	1 sweep	49 - 57	Initial frequency search. Nothing to report.
18/10/2018	OY	B	10 min	58 - 67	Performance vibrations. Nothing to report.
18/10/2018	OY	C	2 h	68 - 77	Endurance vibrations. Nothing to report.
18/10/2018	OY	B	10 min	78 - 87	Performance vibrations. Nothing to report.
18/10/2018	OY	A	1 sweep	88 - 96	Final frequency search. Nothing to report.
18/10/2018	OZ	A	1 sweep	97 - 105	Initial frequency search. Nothing to report.
18/10/2018	OZ	B	10 min	106 - 115	Performance vibrations. Nothing to report.
18/10/2018	OZ	C	2 h	116 - 125	Endurance vibrations. Nothing to report.
18/10/2018	OZ	B	10 min	126 - 135	Performance vibrations. Nothing to report.

Airbus Helicopter requested for EC130 dedicated Vibration criteria (Group 2, ZC) that shows a larger tested bandwidth (up to 361hz) with higher levels (16g operational, 20g endurance) compared to other criteria (group 3, ZC) applicable to other helicopter models (bandwidth up to 130 Hz, level: 10,5g performance, 13g Endurance).

Conclusion: Taking into account the 524-031 Amendment J returns analyses that exhibit only a handful of wear cases (at 0.5mm or above), as well as the DO160G test results, it is concluded that the starter generator design complies the requirement.

Consequently, the observed failure mode was unknown before the accident and, therefore, could not be readily anticipated.

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5. THALES ANALYSIS

At Helicopter Operator Level

- Helicopter use

It is a fact that the operator usage of the helicopter consisted of a succession of four flights between two engine shutdowns. Between each of these four flights, the helicopter remained running on the ground with the engine set at Ground Idle. Following discussion with Airbus Helicopters, this way to use the helicopter is not in contradiction with Airbus Helicopters recommended operations practices.

The testing shows however that, even if the vibration level was not sufficient to reproduce the fatigue phenomenon, the engine and starter-generator vibrations, with this worn starter-generator, are more pronounced during these ground idle phases.

This particular operator helicopter usage seems to multiply the vibrations periods.

Nevertheless, this type of usage is inconsistent with the play seen on the accident starter generator 60h after the 627h maintenance.

- Maintenance

This investigation shows that the periodic maintenance performed by the operator did not-comply with Airbus and Thales requirements.

Maintenance records showed that the starter-generator (P/N 524-031 Amendment J; S/N 5493) had been inspected on January 6, 2016, at engine total time of 627.2 hours.

At that time, several of the brush lengths were measured and found to fall within the yellow range as confirmed by operator maintenance records and further Thales examination.

Nevertheless, the starter-generator was returned to service without replacing the brushes contrary to the requirements of Thales CMM 80-19-02 (listed within the operator Maintenance documentation).

Examination of all four brushes would have required the starter-generator to be removed from the helicopter.. In fact, the operator's written maintenance report of the inspection performed at 627.2 hours does not state - or even suggest - that this removal occurred, and does not record the observation of any play on the starter generator.

Furthermore, the customer was applying a FAA-approved maintenance program which, on its face, seems to be more rigorous in terms of workload than the existing one as it allegedly requires the removal of the starter generator every 150h hour.

The rigor of these extreme precautions is, at least, inconsistent with the fact that the replacement of brushes in yellow zone was not undertaken as required in CMM 80-19-02. Stated otherwise, a seemingly more rigorous testing schedule is trumped by the fact that brushes found to be in the yellow were not replaced at 627.2 hours. At a minimum, it is important to understand the reasons for this.

And, even at this late stage in the investigation, the section of the Operator Maintenance program devoted to the starter generator has not made available to Thales or the BEA as part of the evidentiary record.

At starter-generator level

Prior to this accident, it appears that the Thales starter-generator was degraded. The root cause of this radial play was undetermined within the investigation because multiple factors or various phenomena may have contributed.

This degradation appears to be more pronounced within the Helicopter's Y, or horizontal, axis. This fact suggests, in our expert engineering judgment, and because no starter-generator armature/stator degradation was observed, that another force or vibration phenomenon could have been associated with the Y axis. Such a potential phenomenon was not identified in the investigation.

Nevertheless, in order to build safeguards against unexpected failure, Thales had required maintenance inspection every 600FH, 1200FH and starter-generator overhaul at 2400FH.

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Additionally, Airbus issued a relevant Service Bulletin, followed by an Aircraft Maintenance manual amendment, in order to enhance the starter-generator inspections (with the front bearing radial play check to be performed every 300 flights hours) that additionally reinforces other protective measures.

A Significant Oil leak was observed at the Engine / Starter-Generator interface (Oil, of course, is not part of the Starter-generator Bill Of Material). The starter-generator return analyses, including that relating to the N11VQ starter-generator, showed an oily/greasy substance observed three times over the five starter-generators (including S/N 5493) that had been examined in detail. The presence of Oil/greasy black substance may potentially have facilitated the front bearing wear, but it was not possible to determine which factor appeared first: the front bearing wear or the oil leak.

Testing at the starter-generator level showed that vibrations mainly occur in the Y helicopter Axis. Teardown and front bearing case measurements were consistent with such observations.

Additionally, Thales' investigation did not uncover any evidence that would support a finding that a specific manufacturing issue for the starter-generator P/N 524-031 Amendment J existed. Neither Thales reliability analysis evidence such type of issue prior to the accident.

An independent laboratory performed vibration qualification tests, for Thales, according to DO160G. The results of the test show that the P/N 524-031 Amendment J design is fully compliant with all vibration requirements.

At engine Level:

Testing at engine level revealed The Stress level observed on the N11VQ fuel pipe type, as found in coupling with the starter-generator S/N 5493, remained at all times within the allowable limits as defined by the engine manufacturer:

- During the engine testing, observed maximum stress Value was 146 MPa which is under the allowable limit of 160 MPa. This maximum stress level is observable at Ground Idle Regime
- - o thus pipe P/N 0292737310 identical to the one installed in the accident helicopter did not fracture during the tests performed.
 - o As mentioned earlier, flight operations with multiple flights consisting of periodic ground idle regime periods, may have, in this specific case, multiplied vibrations and fuel pipe bending cycles, even though this type of operation is not considered by Airbus to be out of the helicopter's normal usage
- Vibration recorded just after the accident revealed a level of 15,6 mm/s that is under the allowable limit of 20 mm/s

The testing revealed that the observed vibration is a coupling phenomenon.

It was observed during the engine tests that, when tested using the starter-generator S/N 5493, both models of fuel pipes vibrated in the range of their natural frequency:

- For the Pipe P/N 292737310 the natural frequency is measured in a range of 130 Hz;
- For the P/N 0292730350 the natural frequency is measured in a range of 175Hz.

Additionally the maximum stress level observed was:

- For the Pipe P/N 292737310 : 146 MPa
- For the P/N 0292730350 : around 50 MPa

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- Results obtained show that pipe P/N 0292737310 (N11VQ one) develops an approximately three times greater stress level than the one observed with pipe P/N 0292730350 (initial certification fuel pipe) when exposed to the same engine vibration conditions

These values remain below the maximum allowable limit defined by the engine manufacturer

As explained, a coupling vibration phenomenon between the degraded (for undetermined reasons) starter-generator and this specific fuel pipe (P/N 0292737310 diameter 6mm) is observed.

As exhibited in the testing, when this specific fuel pipe is not used, there is no such vibration frequency and level (see, e.g., testing with pipe PN 0292730350 diameter 10mm). If there is no degraded starter-generator with this specific 6 mm diameter fuel pipe, there is also no coupling vibrations (refer to engine manufacturer on bench testing).

According to the engine manufacturer, NTSB and BEA examination, no pre-existing constraints were observed at the pipe flare end.

The engine manufacturer also report that similar fuel pipe rupture was never observed on the ARRIEL 2D fleet.

At Helicopter level,

The testing was not able to demonstrate levels that could explain the fatigue rupture phenomenon in presence of the starter-generator S/N 5493. The summary of testing results shows;

- the vibration frequency is modified and observed in a range of 120Hz (lower than – 130Hz)
- Within this helicopter test, over vibrations at engine level were measured once (over four runs) at 20,11 mm/s at ground idle regime. At the pipe level, the stress level induced by these vibrations were measured at 62 MPa at a maximum during ground idle regime.

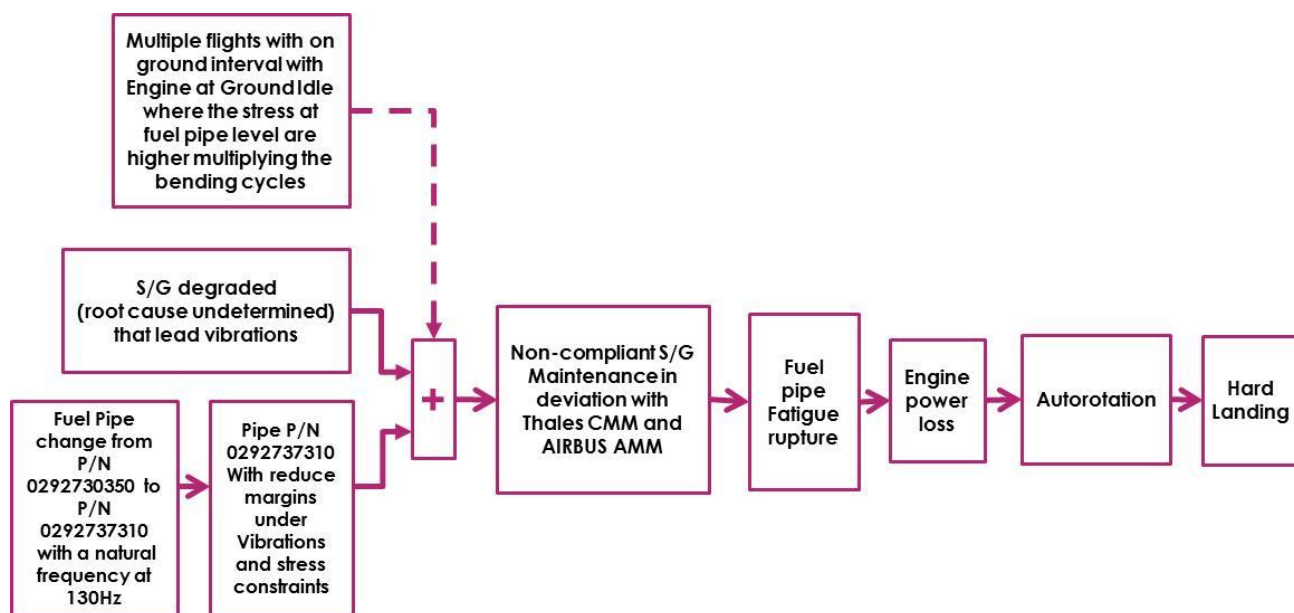
This coupling phenomenon between the starter generator and the specific fuel pipe, that may have led to resonance vibration as preconditions to initiate unexpected fuel pipe fatigue failure, was totally unknown, by the industry, before the N11VQ accident.

6. As therefore, based on this analysis, Thales proposed in the next chapter its probable contributing factor determination.

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6. THALES PROBABLE ROOT CAUSE DETERMINATION

6.1. EVENT CHAIN



This event chain presents the succession of factual elements of this event. It does not present the contributing factor chain.

As explained, it is a fact that the operator used the helicopter with multiple successive flights with on ground intervals with the Engine at ground Idle. Although this fact led to the multiplication of vibration phase, the use is not in contradiction with the helicopter manufacturer operations recommendations. Thus, this fact could not be considered as a contributing factor to the accident.

6.2. CONTRIBUTING FACTORS AND ROOT CAUSE DETERMINATION

Thales considers that the following Factors have contributed to the accident:

- 1 –Wear was observed on the starter-generator front-bearing cage during the investigation but not reported during maintenance 60h before the accident. Investigators were unable to determine the root cause of the wear.
- 2- Coupling between the degraded generator and the specific fuel pipe likely led to resonance vibrations. These two preconditions needed to initiate unexpected fuel pipe fatigue failure that then resulted in fuel starvation of the engine. The testing conditions did not allow investigators to replicate the pipe fatigue failure as vibrations leading to possible stress remained under allowable levels.

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6.3. REMAINING QUESTIONS

The following questions must be answered :

- The starter generator was returned to service at 627.2 hours at which time no play or degradation was visible or reported. The play observed visually only 66 flight hours later and measured > 0,5mm is at the very least surprising. In fact, Thales' experience with SG returns is completely inconsistent with the finding of play after such a short time in service as measured from a previous successful inspection:

On the four SG Amendment J, play has been measured with a play > 0,5mm. Inspections of other returned SGs evidencing such considerable play values occurred, at the very least, after 391Flight hours, (piloting school) ; more typically, in fact, other observed excessive play values have been observed after more than 747 Flight hours (since last overhaul).

What could explain such an inconsistency, namely, the observation of a play of > 0,5mm after less than 1/6 of the shortest time previously documented (i.e., 66 v. 391 flight hours after inspection)?

Furthermore, we do not have clear documentary, recorded evidence that this starter generator was removed at 627.2 hours. In fact, the FAA-required Maintenance log provided by the NTSB does not corroborate the verbal representation that the starter-generator S/N 5493 was removed from the helicopter at 627 Flight hours.

It is respectfully suggested that the NTSB produce evidence of the following:

- Extract from the Blue Hawaiian Helicopter Maintenance Program, as it existed before the accident, demonstrating the alleged mandatory removal of the starter-generator every 150 Flight Hours and then, also, at 600 Flight hours.
 - Other written and/or recorded maintenance documentation that demonstrates that the removal of the starter-generator S/N 5493 at 627h Flight time.
- The inspection program used by Blue Hawaiian Helicopters is decidedly more rigorous than those which both Airbus and Thales recommend, allegedly requiring removal of the starter generator every 150h instead of 600h in CMM. What would cause an operator to so greatly shorten a manufacturer's preventive maintenance recommendations? Was the tremendously shortened inspection schedule the result of some concerns that Blue Hawaiian Helicopters had for this equipment ? Additionally, why would an operator greatly shorten a preventive maintenance inspection schedule, only to then change the requirement for replacing brushes only when they fell into the red zone instead of the much earlier approached yellow zone, as required in CMM.

Does a reasonable rationale for this exist?

- The much shortened 150h maintenance inspection allegedly requires the removal of the starter generator, but the 600h maintenance inspection does not.

In order to address the reasons for this glaring inconsistency, it would be very helpful for all participants in the investigation to be able to review the written maintenance procedures for both the 150h inspection and the 600h inspection ?

Could you provide the two maintenance reports related to starter generator 5493 ?

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APPENDIX

A. TSO C56 REQUIREMENTS

Paragraphs of TSO-C56 requirements Code of Federal regulations - Title 14 - Aeronautics and space Part 37 : Technical Standard Order Authorizations §37.155 of FAR Part 37: Engine-driven direct current generators for aircraft certificated under Part 25 - TSO-C56	
a-i <u>TESTS CONDITIONS</u>	
(a) Mounting	
(b) Excitation	
(c) Ambient temperature	
(d) Altitude	
(e) Location of load	
(f) Warm-up	
a-ii <u>TESTS METHODS</u>	
(a) Manufacturer's declaration	
(b) Maximum speed for regulation	
(c) Heating, commutation, minimum speed and equalizing voltage	
(1) Heating	
(2) Commutation	
(3) Minimum speed	
(4) Equalizing voltage	
(d) Overspeed	
(e) Dielectric strength	
(f) Ripple voltage	
(g) Humidity	
(h) Flexible drive	

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Paragraphs of TSO-C56 requirements Code of Federal regulations - Title 14 - Aeronautics and space Part 37 : Technical Standard Order Authorizations §37.155 of FAR Part 37: Engine-driven direct current generators for aircraft certificated under Part 25 - TSO-C56
(i) Performance of commutator, bearings and brushes
(j) Drive shear section
b <u>MARKING</u>
c <u>DATA REQUIREMENTS</u>

McKenny Van

From: MISSION Helene [REDACTED]
Sent: Tuesday, April 14, 2020 2:22 AM
To: McKenny Van
Cc: David BECOUR; Johan CONDETTE; arnaud.toupet [REDACTED] WALTER Arnaud; MATUSZAK Philippe; THUBERT Benoit
Subject: Thales submission update
Attachments: TAES-20_048_DIN_PMA EC130 N11VQ NTSB Investigation- Thales Submission_B.pdf

[CAUTION] This email originated from outside of the organization. Do not click any links or open attachments unless you recognize the sender and know the content is safe.

Dear Van,

[REDACTED]

Find here enclosed the update of Thales Submission related to the EC130T2 N11VQ accident investigation with some more days than expected due to locked down directive.

Thales team stays at your disposal for any question you may have.

Best regards

Hélène Misson