National Transportation Safety Board
Office of Aviation Safety
Washington, DC 20594

CEN22FA317

AIRWORTHINESS

Group Chair's Factual Report

December 8, 2023

Table of Contents

A. ACCIDENT

Location: Chapelle, New Mexico

Date: July 16, 2022

Time: 1920 Mountain Daylight Time

Aircraft: Bell UH-1H+, Registration N911SZ

B. AIRWORTHINESS GROUP

Group Chair	Matthew Walker National Transportation Safety Board Washington, DC
Group Member	Shane Patterson Ozark Aeroworks LLC Springfield, MO
Group Member	Wayne Bond Ozark Aeroworks LLC Springfield, MO

C. SUMMARY

On July 16, 2022, about 1920 mountain daylight time (MDT), a Bell UH-1H+, registration number N911SZ, crashed near Chapelle, New Mexico during a firefighting positioning flight. The pilot, two tactical flight observers, and the rescue specialist sustained fatal injuries. The helicopter was operated as a Title 41 *Code of Federal Regulations (CFR)* "Public Use" aircraft by the Bernalillo County Sheriff's Department (BCSD).

The flight prior to the accident flight consisted of the helicopter departing Las Vegas Municipal Airport (KLVS), Las Vegas, Nevada at about 1838 MDT, flying to the dip site/staging area, then proceeding to firefighting location, and dropping its load and then flying back to the staging area. At the staging area, the remainder of the firefighting crew was loaded onto the helicopter and helicopter was scheduled to return to its home base at the Double Eagle II Airport (KAEG), Albuquerque, New Mexico. At about 1915 MDT, the helicopter departed the staging and heading westbound. At about 1920 MDT, the last automatic dependent surveillance-broadcast (ADS-B) data return for the accident flight was recorded; the helicopter was about 0.5 nautical miles east of the accident site flying level on a westbound course about 550 feet above ground level (AGL) with a steady groundspeed of 133 knots.

The helicopter impacted rural terrain; the debris field was in a westerly direction. The initial impact area included a tail rotor tip cap that was partially buried. The left and right skids were found about 38 feet and 77 feet beyond the initial impact area, respectively, and the main wreckage was found inverted about 160 feet beyond the initial impact area. The tail boom fractured at the aft end of the fuselage and was located about 20 feet beyond the main wreckage. The main rotor separated from the fuselage and was found about 40 feet to the left of the main wreckage, with the main rotor mass fractured immediately below the hub. One main rotor blade was minimally damaged, and the other blade was fractured at the spar, with the trailing edge separated and located nearby. The main rotor blade grips had minimal damage.

D. DETAILS OF THE ENGINE EXAMINATION

1.0 ENGINE INFORMATION

1.1 Engine Description

The accident helicopter was powered by a single Ozark Aeroworks LLC (formerly Honeywell, AlliedSignal, and Textron Lycoming) T53-L703 turboshaft engine. The T53-L703 is a military variant of the T5317B (**Figure 1**). It has a five-stage axial and single-stage centrifugal compressor, with an external annular combustion chamber, a

two-stage gas producer (GP) turbine and a two-stage power turbine (PT) (**Figure 2**).[1] The power shaft, which drives the reduction gearbox through the output shaft, rotates clockwise aft looking forward (ALF), the compressor rotates counterclockwise ALF, the GP rotates counterclockwise ALF, and the PT rotates clockwise ALF.[2]

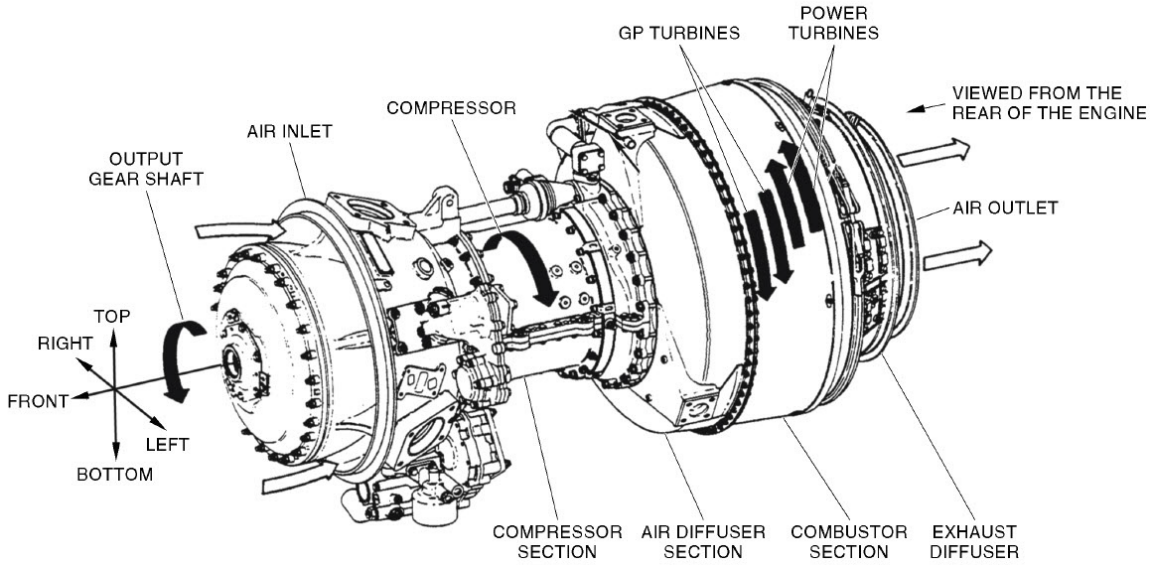


FIGURE 1: GENERIC T53 TURBOSHAFT; FIGURE COURTESY OF OZARK AEROWORKS LLC

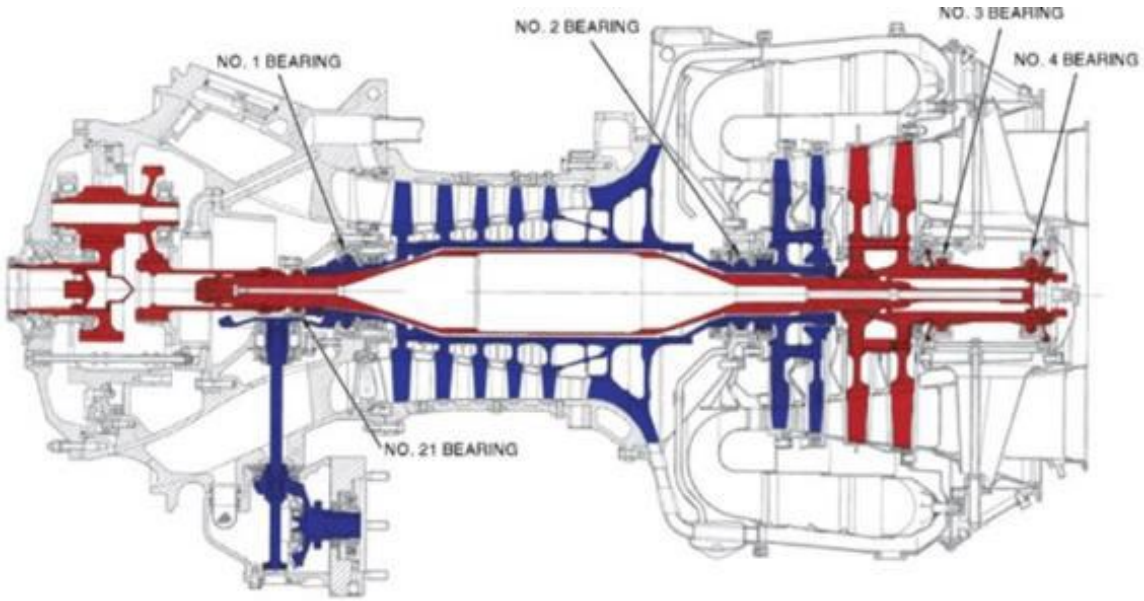


FIGURE 2: N1 (BLUE), N2 (RED), & MAIN BEARING LOCATIONS; FIGURE COURTESY OF OZARK AEROWORKS LLC

[1] The power turbine is a free turbine design and is not mechanically connected to the compressor.
[2] All directional references to front and rear, left and right, top and bottom, and clockwise and counterclockwise are made ALF, as is the convention. All numbering is in the circumferential direction, starting with the No. 1 position at the 12:00 o'clock position or immediately clockwise from the 12:00 o'clock position and progressing sequentially clockwise, ALF.

According to the Federal Aviation Administration (FAA) Type Certificate Data Sheet (TCDS) E17EA, Revision 12, dated May 6, 2022, the T5317B turboshaft engine has a maximum continuous horsepower (HP) at sea level of 1,350 with an output shaft rotation speed in revolutions per minute (RPM) of 6,229 at maximum continuous power. The takeoff (5 minute) limit at sea level is 1400 HP with an output shaft rotation speed of 6,461 RPM at takeoff power. The power turbine has a maximum speed of 21,300 RPM at all conditions including takeoff, a maximum torque at the output shaft of 1250 ft. lb. for takeoff and a max continuous of 1160 ft. lb.

1.2 Engine History

According to the engine data plate, the engine serial number (ESN) was LE-23701RX (**Photo 1**).

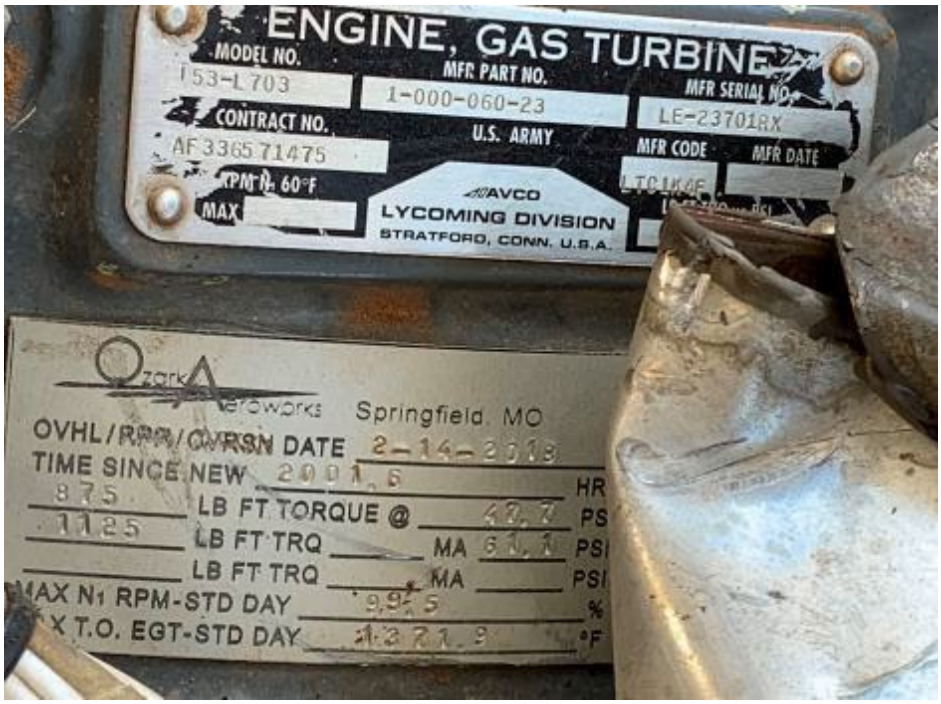


PHOTO 1: ENGINE DATA PLATE

According to the maintenance logs, the accident engine had been previously installed on helicopter registration number N703SG. The engine was removed on November 12, 2014; the engine had been previously written-up in the prior 30 days for foreign object damage (FOD) and high oil consumption. It was sent to Ozark Aeroworks LLC in Springfield, Missouri for repair and overhaul. The repair and overhaul of the accident engine was completed on February 14, 2018, and it was installed on the accident helicopter (N911SZ) on October 18, 2018. According to the engine logbooks, the accident engine had accumulated 2,001.6 hours time since new (TSN) at the time of the last overhaul.

This engine chip detector, located on the lower right side of the N1 accessory gearbox (AGB), was the newer model and compliance with Service Bulletin (SB) T53-098 was also confirmed by review of the overhaul records from 2018 at Ozark Aeroworks LLC.

Engine oil samples were taken on the following dates: May 28, 2019; August 7, 2019; September 22, 2019; May 9, 2020; October 31, 2020; February 26, 2021; March 27, 2021; June 4, 2021; and September 10, 2021. The oil analyses report summary concluded the samples were "normal" (see Attachment 1).

On September 12, 2021, an engine chip event was documented in the engine logbook and it was stated that an oil sample and the chip were collected and sent to JetCare for analysis. No other logbook entries were made in relation to this event. The aircraft flew 17 hours between the chip event and the accident. Requests were made to the Bernalillo County Sheriff's Office, through the FAA, for copies of the chip and debris analysis report. The NTSB was told that no laboratory analysis or report was received for the chip detector debris. The NTSB followed up with Jetcare directly regarding past oil analyses for the accident engine, the JetCare representative stated that no oil sample or chip was received from BCSD in relation to the stated chip event. The last maintenance on the accident helicopter was completed on July 15, 2022, as a "PMD (pre-mission daily) inspection; no defects noted". The airframe logbook noted that as part of the PMD daily inspection entry that the rear cabin doors and searchlight were removed. Pertinent maintenance logs are included as Attachment 2.

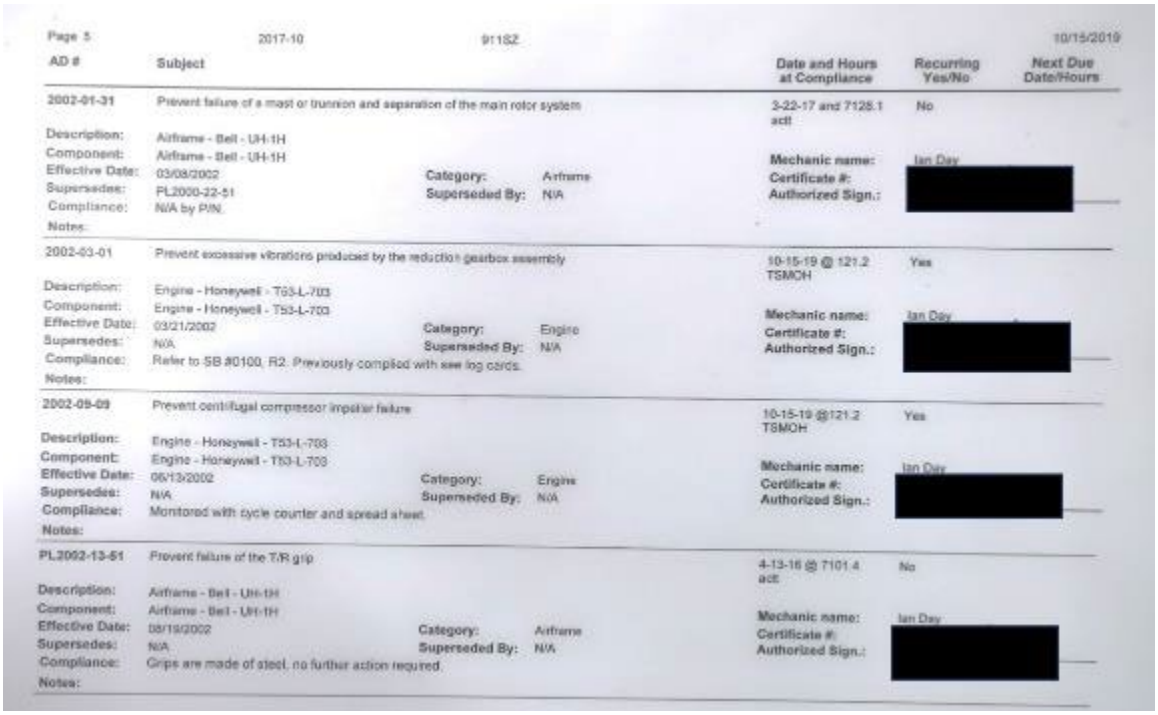
1.3 Airworthiness Directives (Ads) and Service Bulletins (SBs)

The airframe logbook also included documentation for the installation of a Fast Rope Insertion / Extraction System (FRIES) on February 1, 2017, in accordance with Supplemental Type Certificate SR02545AT. On March 22, 2017, the main generator and input quill were removed, referencing US Army Technical Manual (TM) 55-1520-210-23-1, Figure 6-27 (see Attachment 2). This was also confirmed by the "inop" sticker on the main generator voltmeter on the center console (reference Wreckage Examination Factual Report), page 13). The UH-1 operating manual emergency procedures includes operating solely on the standby or starter-generator in the event the main generator fails, but not continual operation. Discussions with Bell Helicopter showed no analysis of the effects of removing the main generator has ever been done.

Airworthiness Directive (AD) 2002-03-01 , which was last completed October 15, 2019 on the accident engine (**Photo 2**), directed vibrational testing of certain helicopters with specific models of Honeywell T53 engines installed, to include military surplus UH-1s with T53-L-703s. Note 1 of this AD stated its applicability to all those helicopters and engines identified, "regardless of whether it has been modified, altered, or repaired in the area subject to the requirements of this AD". It further stated the purpose of the AD work was, "to prevent excessive vibrations produced by the

reduction gearbox assembly that could cause failure of the tachometer drive spur gear".

SB T53L703-0100 (referred to as #0100), released by AlliedSignal on May 5, 1998, required all T53-L-703 engines undergo a vibration analysis due to certain T53 engines having had vibration characteristics that could cause high cycle fatigue failures of the N2 spur gear. Failure of that gear could result in a disconnection of the N2 drive system and a potential uncontained engine failure. Engines displaying more than 0.2 inches per second (IPS) in the specified frequency bands were to be removed from service. SB T53L703-0102 was released Jul 8, 2003 (referred to as #0102) directs the replacement of the tachometer drive spur gear with a redesigned and vibration-tolerant spur gear. The 2018 overhaul records provided by Ozark Aeroworks LLC. Indicate that SB T53L703-0100 was complied with and that SB T53L703-0102 had been previously complied with.



Page 5 2017-10 911SZ 10/15/2019

AD #	Subject	Date and Hours at Compliance	Recurring Yes/No	Next Due Date/Hours
2002-01-31	Prevent failure of a mast or trunnion and separation of the main rotor system	3-22-17 and 7128.1 act!	No	
Description:	Airframe - Bell - UH-1H			
Component:	Airframe - Bell - UH-1H	Mechanic name:	Ian Day	
Effective Date:	03/08/2002 Category: Airframe	Certificate #:	[redacted]	
Supersedes:	PL2000-22-51 Superseded By: N/A	Authorized Sign.:		
Compliance:	N/A by P/N			
Notes:				
2002-03-01	Prevent excessive vibrations produced by the reduction gearbox assembly	10-15-19 @ 121.2 TSMOH	Yes	
Description:	Engine - Honeywell - T53-L-703			
Component:	Engine - Honeywell - T53-L-703	Mechanic name:	Ian Day	
Effective Date:	03/21/2002 Category: Engine	Certificate #:	[redacted]	
Supersedes:	N/A Superseded By: N/A	Authorized Sign.:		
Compliance:	Refer to SB #0100, R2. Previously complied with see log cards.			
Notes:				
2002-09-09	Prevent centrifugal compressor impeller failure	10-15-19 @121.2 TSMOH	Yes	
Description:	Engine - Honeywell - T53-L-703			
Component:	Engine - Honeywell - T53-L-703	Mechanic name:	Ian Day	
Effective Date:	06/13/2002 Category: Engine	Certificate #:	[redacted]	
Supersedes:	N/A Superseded By: N/A	Authorized Sign.:		
Compliance:	Monitored with cycle counter and spread sheet.			
Notes:				
PL2002-13-51	Prevent failure of the T/R grip	4-13-16 @ 7101.4 act	No	
Description:	Airframe - Bell - UH-1H			
Component:	Airframe - Bell - UH-1H	Mechanic name:	Ian Day	
Effective Date:	08/19/2002 Category: Airframe	Certificate #:	[redacted]	
Supersedes:	N/A Superseded By: N/A	Authorized Sign.:		
Compliance:	Grips are made of steel, no further action required.			
Notes:				

PHOTO 2: PAGE ENGINE MAINTENANCE LOG SHOWING AD COMPLETION

1.4 Oil Analysis

Jet-Care, the company utilized for oil analysis by the Bernalillo County Sheriff's Office, performs a standardized test for oil samples which includes viscosity, total acid number and spectrometric analysis results. An example of their test form is included in the Attachment 3, along with the oil analysis for the accident engine. Water content is an optional test requested by some but not all operators. To date, Jet-Care is unaware of any published oil analysis recommendations from the original engine manufacturers: Lycoming, Honeywell and now Ozark Aeroworks LLC. While Jet-Care

has the capabilities to conduct statistical and trend analysis on oil samples and thereby develop limits, none of their current customers have requested such services.

Honeywell Maintenance Manual[3] 72-00-00 for the T53-L-703, Part No. 1-000-060-23, included engine oil sampling and testing requirements for wear metals including silicon, aluminum, chromium, copper, iron, magnesium, nickel, silver, and titanium (reference attachment 3). The manual stated the values are guidance, are not "go/no-go" criteria, and lists normal wear ranges in parts per million by weight for metals except nickel, silicon, and titanium, which are reported values only. The guidance mentioned trend analysis, with a graphic depicting normal versus abnormal wear, though no specific numerical values were provided. It specifies metal sources "for use on determining maintenance action requirements", with iron specifically for gears, bearings and liners, and the oil pump. Per Attachment 3, while none of the metals tested exceeded the guidance, the iron content was significantly higher than any other metal and saw a 3-fold increase from May 9, 2020, to the chip event sample on September 12, 2021.

2.0 SALVAGE YARD ENGINE EXAMINATION (S/N LE-23701RX)

2.1 General Condition

On October 11, 2022, the engine was examined at Beegles Recovery & Storage in Greeley, Colorado, with representatives from the NTSB, Bell Textron Inc. and Ozarks Aeroworks LLC being present. There was no evidence of uncontainment or external fire (**Photo 3**). There was minimal foreign debris, primarily dirt, in the intake and exhaust.

PHOTO 3: ENGINE AS UNPACKED

There was a large dent stretching from approximately 9:00 to 11:00 o'clock from the ignition unit aft to the air diffuser section (**Photo 4**). Looking through the exhaust,

[3] Ozark Aeroworks LLC purchased the type certificate for the T53 from Honeywell in May 2022. As of this report, no changes or updates were noted to the maintenance or training manuals.

all 2nd stage PT blades were all present, whole, and intact. There was no evidence of metal splatter on the airfoils. The PT rotated freely by hand while GP section could not be turned by hand through the air intake.

PHOTO 4: DENT ON THE IGNITER AND AIR DIFFUSER

2.2 Accessory Gearbox

The N1 tachometer-generator was clean but would not rotate. Removal of the starter-generator revealed that its driveshaft was sheared (**Photo 5**). The starter-generator turned freely by hand via the remains of the input shaft. According to the maintenance records, the starter-generator was previously overhauled and installed on the accident engine on February 14, 2022, during the Phase 5 maintenance inspection.

Photo 5: Sheared Starter-Generator Driveshaft

Removal of the N1 AGB magnetic chip detector plug revealed a large quantity of large metallic chips on the magnetic tip (**Photo 6**). The electrical half of the chip detector was broken at the housing. This was the new style, SB) T53-098 compliant, chip detector.

PHOTO 6: N1 AGB CHIP DETECTOR WITH DEBRIS

2.3 Lubrication Oil and Fuel Systems

The main oil supply line was full of lubrication oil. Multiple metallic fragments were found in all the bearing compartment oil return/scavenge lines (**Photo 7**); the supply lines were clean of debris or obstructions. The engine-mounted oil filter was clean and oil-wetted. The airframe-mounted oil cooler was empty of oil, and the attached oil filter was missing and not recovered. The No. 2 bearing last chance oil

filter was clean and oil-wetted. The Nos. 3 and 4 bearing last chance oil filter was also clean and oil-wetted.

PHOTO 7: DEBRIS FROM THE N1 AGB

The N1 AGB main oil pump rotated freely. Small metallic shards were found in the scavenge pump strainer (**Photo 8**).

PHOTO 8: SCAVENGE FUEL PUMP (LEFT) AND STRAINER W/DEBRIS (CENTER, RIGHT)

Two helical-cut gear teeth were found in the N1 AGB oil, similar to starter/generator drive gear (also referred to as the zerol gear) teeth. Both teeth exhibited expected wear patterns, with no other damage noted (**Photo 9**, right-most photo).

PHOTO 9: GEAR TEETH FOUND IN THE N1 AGB

With the N1 AGB separated from the engine, the fuel manifold and fuel control unit were accessible. Fuel was present at both the manifold and fuel control unit.

2.4 Engine-to-Helicopter Main Transmission Driveshaft

The Kaflex driveshaft coupling is an airframe supplied part and is designed to allow some misalignment between the engine and the helicopter's main transmission gearbox. The Kaflex driveshaft coupling is comprised of three flex frames, each with two L-brackets, installed at each end fitting and an interconnect shaft that connects the two ends (**Figure 3**).

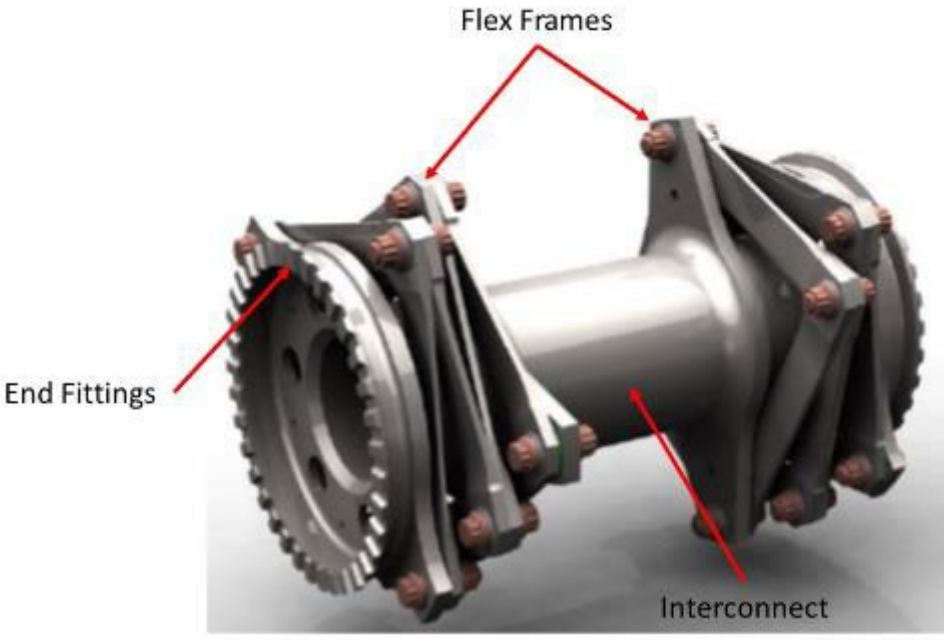


FIGURE 3: KAFLEX DRIVESHAFT COUPLING; COURTESY OF KAMATICS

The accident Kaflex driveshaft coupling was installed in the helicopter on June 26, 2022, as part of the Phase 5 maintenance inspection, which included significant main rotor inspections and component replacements. The Kaflex had accumulated 2,031 hours total time, and helicopter had accumulated 7,583.2 hours aircraft total time (ATT) when the Kaflex driveshaft coupling was installed. The airframe logbook stated the previous Kaflex driveshaft coupling was replaced due to time and was replaced with the driveshaft found on the accident flight. The FAA issued AD 2021-26-16, with an effective date of February 25, 2022, requiring the replacement of Kaflex driveshaft couplings with any notable damage or more than 5,000 hours, time in service (TIS).

The accident Kaflex driveshaft coupling was part number (P/N) SKCP 2281-103, serial number (S/N) 2562. (**Photo 10**, right side). Roughly half of the flex frames at each end of the interconnect shaft were fractured but remained with the end fittings at the engine and main gearbox, respectively (**Photo 10**, left side).

PHOTO 10: KAFLEX DRIVESHAFT COUPLING INTERCONNECT SHAFT, WITH P/N AND S/N

The Kaflex driveshaft coupling engine-side end fittings were clamped in the correct position, with the nut and cotter pin in place and tight (**Photo 11**). Uneven wear and scuffing to the lip and exterior of the shaft, which sits inside the interconnect (**Photo 12**).

PHOTO 11: ENGINE-SIDE END FITTING (LEFT), FLEX FRAMES (CENTER), AND RETAINING CLAMP (RIGHT)

PHOTO 12: KAFLEX DRIVESHAFT COUPLING ENGINE END FITTING SHAFT

The flex frames on the engine-side exhibited evidence of contact between the fittings, and the retaining nuts showed wear (**Photo 13**). The broken flex frame pieces spun within the plane of rotation for the Kaflex driveshaft coupling (**Photo 14**).

PHOTO 13: CONTACT DAMAGE ON THE ENGINE END FITTING FLEX FRAMES

PHOTO 14: BROKEN FLEX FRAMES ATTACHED TO THE ENGINE END FITTING

The adapter plate from the Kaflex driveshaft coupling to the engine was intact, properly torqued, safety wired, and otherwise unremarkable (**Photo 15**). It remained attached to the engine during the impact.

PHOTO 15: ENGINE-KAFLEX COUPLING ADAPTER PLATE

The helicopter's main transmission gearbox side end fitting remained attached to the gearbox by roughly half the flex frames (**Photo 16**). The flex frames were fractured and displayed similar evidence of contact between the flex frames (**Photo 17**).

PHOTO 16: END FITTING AND FLEX FRAMES ATTACHED TO THE HELICOPTER MAIN TRANSMISSION GEARBOX

PHOTO 17: BROKEN FLEX FRAMES AT THE HELICOPTER MAIN TRANSMISSION GEARBOX END FITTING

The interconnect shaft, which was recovered approximately 120 feet away from the main wreckage, had half of the flex frames still attached at each end. The flex frames were twisted in the plane of rotation of the retaining nuts, roughly 180-degrees from their normal position **(Photo 18**).

PHOTO 18: INTERCONNECT SHAFT WITH FLEX FRAMES STILL ATTACHED

Shiny, rough-edged scuffing was noted inside the interconnect shaft. Both ends of the Kaflex driveshaft coupling were deformed to an elliptical shape. One end was cracked in three locations along the greatest deformation (**Photo 19**).

PHOTO 19: INTERCONNECT SHAFT DEFORMATION

Two sections of airframe cowling that would have covered the particle separator and Kaflex driveshaft coupling were recovered. Both sections exhibited scrape marks and were torn (**Photo 20**).

PHOTO 20: AIRFRAME COWLING AROUND THE PARTICLE SEPARATOR AND DRIVESHAFT

Visual examination by both the NTSB Materials Lab and Kamatics, the manufacturer of the Kaflex driveshaft coupling, concluded that the fractures noted on the Kaflex driveshaft coupling flex frames appeared consistent with an overload condition and with minimal corrosion present. No reports were generated from these exams.

3.0 ENGINE EXAMINATION AND DISASSEMBLY (S/N LE-23701RX)

3.1 General Condition

The accident engine was examined and disassembled at the Ozark Aeroworks LLC facility in Springfield, Missouri on November 16, 2022, with persons from the NTSB and Ozark Aeroworks LLC present. The engine was removed from the shipping container and placed on an engine stand (**Photo 21**).

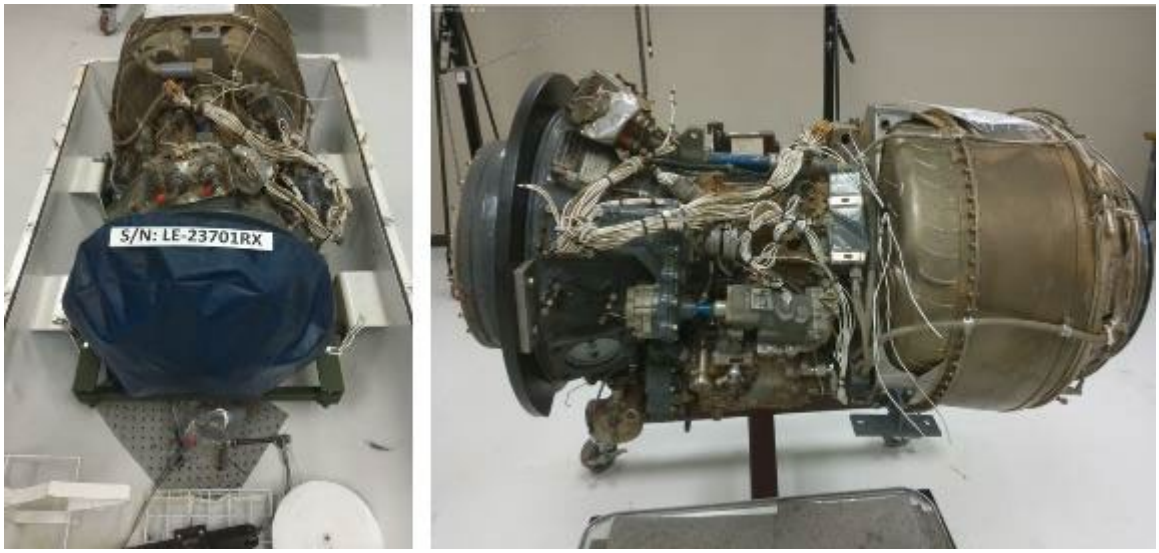


PHOTO 21: IN THE SHIPPPING CONTAINER (LEFT) AND IN THE STAND (RIGHT)

The oil pump, which was removed at the salvage yard, was bagged, and placed in the shipping container with the engine; the oil pump was oil-wetted, clean, and turned freely.

N2 (PT assembly) continuity was re-affirmed, as the PT rotor was turned by hand, the power shaft was seen to rotate (**Figure 4**). As previously tested, N1 (GP system) did not rotate by hand.

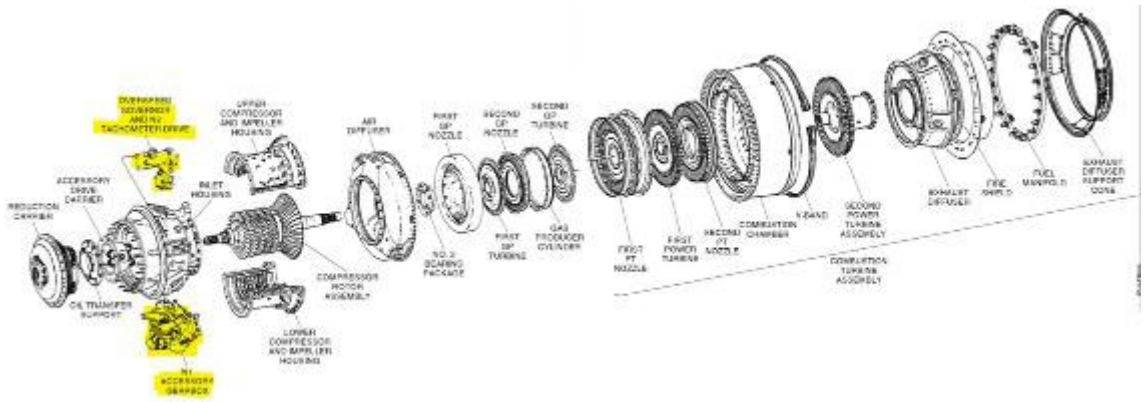


FIGURE 4: T53 ENGINE EXPLODED VIEW; COURTESY OF OZARK AEROWORKS LLC

3.2 Reduction Gearbox

All required safety wire for the reduction gearbox was intact and in-place. The reduction gearbox (RGB) oil transfer tubes and filters were clean and oil wetted (**Photo 22**).

PHOTO 22: RGB ACR INDUSTRIES INC OIL TRANSFER TUBES AND FILTERS

The reduction gear carrier front cover was removed, and metallic flakes were noted inside at the 3:00 and 9:00 o'clock positions (**Photo 23**). The N2 drivetrain was rotated by hand with no binding and the sun gear turned in unison. The N2 power shaft was also clean, oil wetted, and otherwise unremarkable.

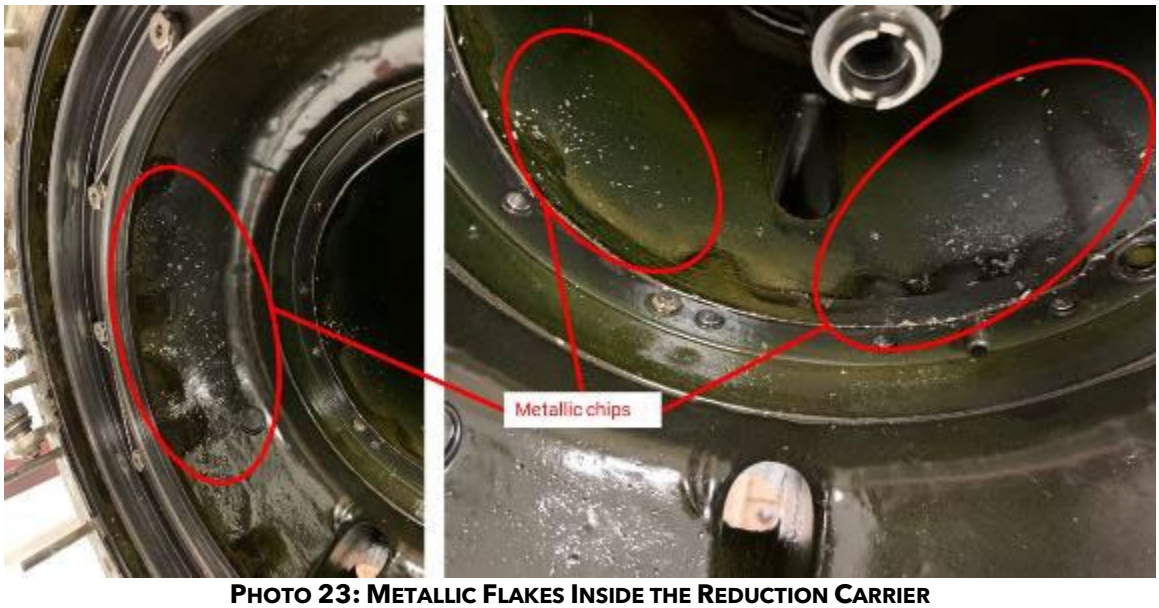


PHOTO 23: METALLIC FLAKES INSIDE THE REDUCTION CARRIER

3.3 Accessory Gearbox

Once disconnected from the engine, the N1 AGB (**Figure 5**) was found to be oil-wetted. The torquemeter booster pump was confirmed as the most current model, clean, oil wetted, and rotated freely.

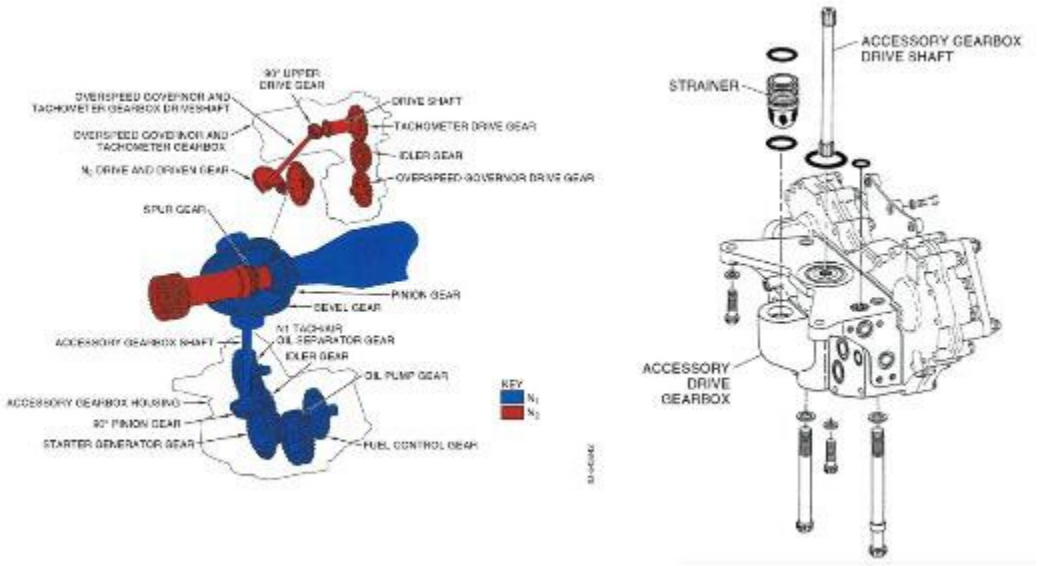


FIGURE 5: N1 ACCESSORY DRIVE GEARBOX; COURTESY OF OZARK AEROWORKS LLC

The N2-tachometer-generator housing was partially fractured circumferentially (**Photo 24**).

PHOTO 24: PARTIALLY FRACTURED N2-TACH GENERATOR HOUSING

Metallic fragments were found on the mount pad for the PT overspeed governor-tachometer drive, including one large piece and some smaller flakes (**Photo 25**). The two oil lines, one for lubrication and the other for provide torque indications, were intact and free of debris.

PHOTO 25: METALLIC FRAGMENTS ON THE N2 OVERSPEED GOVERNOR MOUNT PAD

The fuel control unit (FCU) PT governor was oil wetted with no visible debris. Once separated from the rest of the N1 AGB, the FCU was rotated using a rachet and moved as expected.

The zerol gear (also referred to as the starter/generator gear (See Figure 5 and Figure 6), was fractured (**Photo 26**), and the cover plate bulged outward. The zerol gear assembly had the following identification markings: P/N 1-080-153-01 (the gear, without the plug installed, is P/N 1-080-153-03), National Stock Number 3040-00-475-0058, S/N EG 1553, manufacturing cage code number 23715[4], government cage code number 81996. The starter/generator gear was identified as an U.S. Army Aviation and Missile Command military surplus part by its cage code number 81996[5].

PHOTO 26: FRACTURED ZEROL GEAR (STARTER/GENERATOR GEAR ASSEMBLY)

[4] Cage code 23715 identifies the part as being manufactured by Eastern Gear Corporation.
[5] A Commercial and Government Entity (CAGE) code is a unique identifier assigned to suppliers to various government or defense agencies, as well as to government agencies themselves and also various organizations.

The outside of FCU gear drive shaft was scored circumferentially 360-degrees (**Photo 27**, lower left). The baffle and N1 AGB housing were both scored (**Photo 27**, upper right and upper left), and a hole was present in the N1 AGB housing.

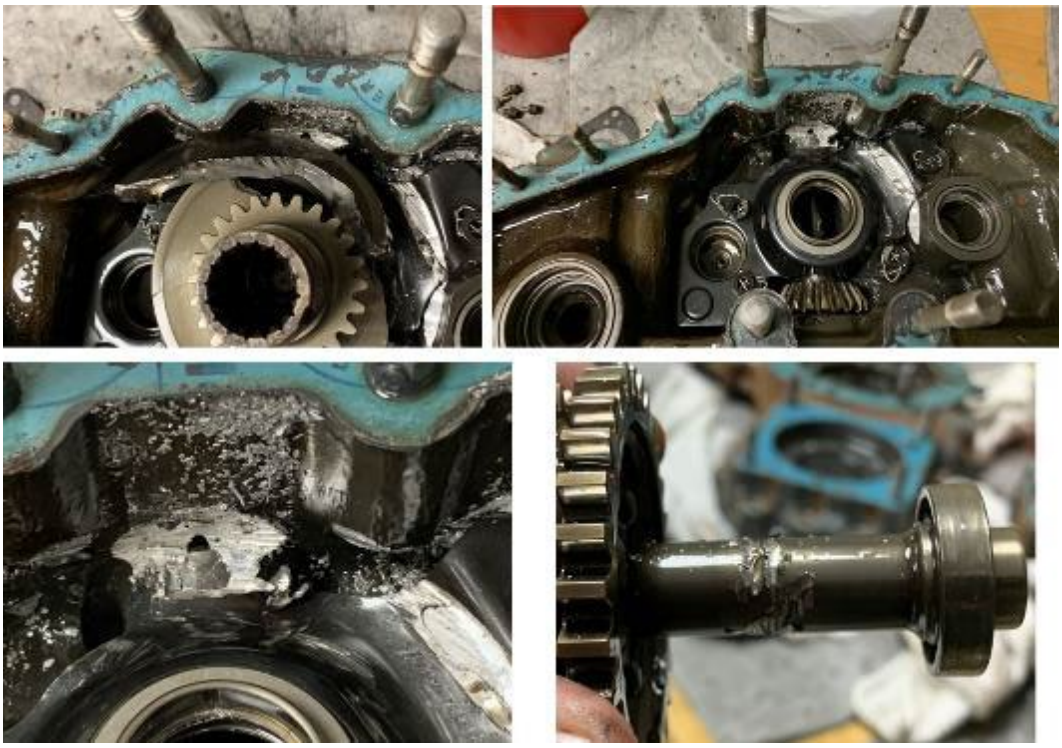


PHOTO 27: INTERIOR OF THE N1 AGB HOUSING; SCORED FCU GEAR SHAFT

3.4 Gas Generator Section – Compressors

Dirt was found throughout the compressor section, but the all the blades were present, intact, and appeared undamaged (**Photo 28**).

PHOTO 28: COMPRESSOR SECTION

Once the N1 AGB was removed, the compressor turned freely. One tab was missing from the upper pinion lock ring, which holds the AGB drive shaft to the zerol gear (See Figure 5). The starter lip seal runner lock cup spanner nut was also loose.

3.5 Gas Producer and Combustion Chamber Sections

More dirt was found throughout the gas producer section, predominantly at the 6:00 o'clock position along the combustion chamber deflector (**Photo 29**).

PHOTO 29: COMBUSTION CHAMBER DEFLECTOR, WITH DIRT BUILD-UP AT THE 6:00 O'CLOCK POSITION

The 1st and 2nd stage GP wheels showed no evidence of rubbing. A blade tip clearance check of the 1st stage GP rotor and the 2nd stage GP nozzle was performed and found to meet the minimum specification of 0.020 inches. The 1st and 2nd stage GP nozzles were undamaged (**Photo 30**). Seeing no damage, the gas generator was not disassembled further.

PHOTO 30: 2ND STAGE GP ROTOR (L), 2ND STAGE NOZZLE (C), 1ST STAGE ROTOR (R)

3.6 Power Turbine

Dirt was noted throughout the 1st and 2nd stage PT. No metal splatter, scoring, scuffing, tip rub, or bending of the blades was noted; therefore, the power turbine section was not disassembled further.

3.7 Exhaust Section

The dust cover was intact and otherwise unremarkable. The exhaust diffuser and diffuser support cone were intact, with no signs of corrosion (**Photo 31**).

PHOTO 31: EXHAUST DIFFUSER HOUSING, SUPPORTS, AND RETAINING CUP

4.0 Testing

4.1 Fuel Control Unit and Power Turbine Governor

After separating the FCU from the engine, the FCU filter was inspected and found to be clean (**Photo 32**).

PHOTO 32: FCU FILTER

An Acceptance Test Procedure (ATP) was conducted on the FCU and PT governor at the Ozark Aeroworks LLC facility (**Photo 33**). The fuel line, which provides boost pump pressure to the FCU, was not safety wired. The FCU and the PT governor were placed on the test bench at the Ozark Aeroworks LLC facility for operational checks, both were found to be operating within limits. A copy of the completed test cards is included in Attachment 4.

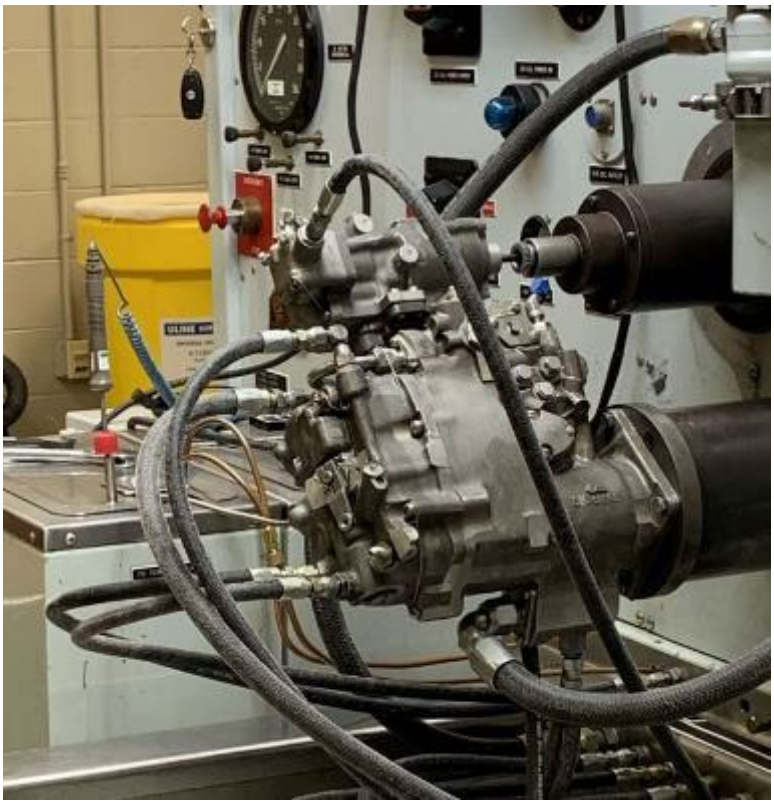


PHOTO 33: FCU ON THE TEST BENCH

5.0 Zerol Gear (also knows at the starter/generator gear)

5.1 Zerol Gear Description

According to the T53 Engine Series Maintenance Training Manual, ATM 821, the:

> "N1 drive is provided from a pinion gear mounted on the forward end of the compressor rotor shaft. It drives two bevel gears located in the accessory gear carrier. The bevel gear located at the 6-o'clock position in the carrier is the accessory gearbox drive gear. It is splined internally to accept the accessory gearbox shaft. This drive shaft connects the gear carrier to the accessory gearbox through the 90-degree pinion gear, which, in turn, is splined directly to the starter-generator drive gear. The starter-generator drive gear provides drive to all subordinate gears

located in the accessory gearbox housing, N1-tachometer drive and oil separator gear, idler gear, main oil pump drive, and fuel control drive gear"[6]. See **Figure 5** and **Figure 6** for an illustration of the N1 accessory drive.

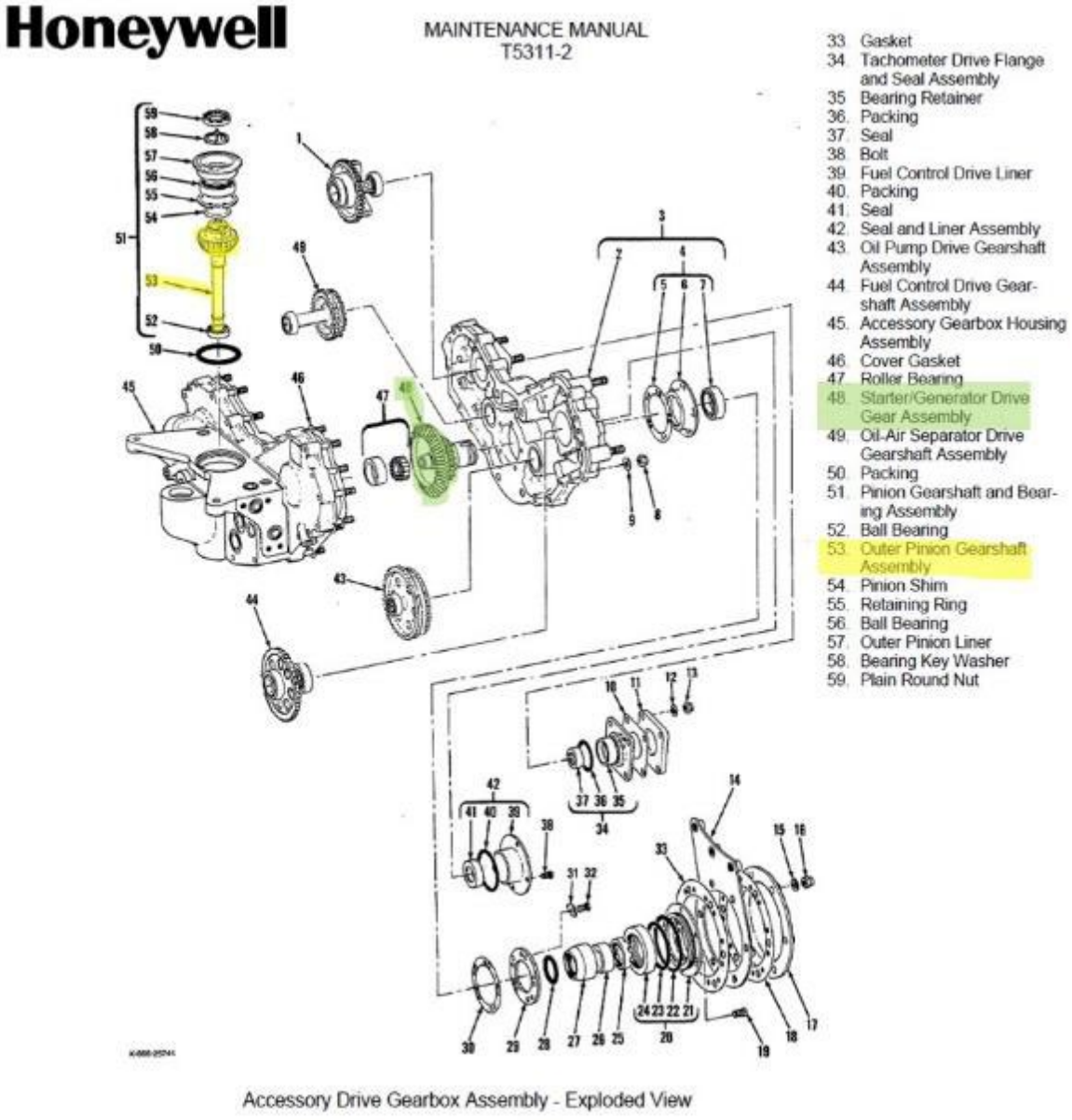


FIGURE 6: ACCESSORY DRIVE; COURTESY OF OZARK AEROWORKS LLC; MODIFIED BY NTSB

[6] ATM 821, T53 Engine Series Maintenance Training Manual. June 2015, Rev. 0. Pg 59

5.2 Zerol Gear Metallurgy

The zerol gear was shipped to the NTSB Materials Lab in Washington DC for examination. The gear fractured along a fatigue crack. The crack initiated on the face of one tooth of the gear from multiple sites (**Photo 34**). Multiple initiation sites and indicators of fatigue and crack propagation were present on both the initial and secondary fracture surfaces, as well as features consistent with ductile overstress fracture. The gear did not exhibit any corrosion pits or oxide inclusions at the initiation sites and no local deformation adjacent to the fracture surface was seen.

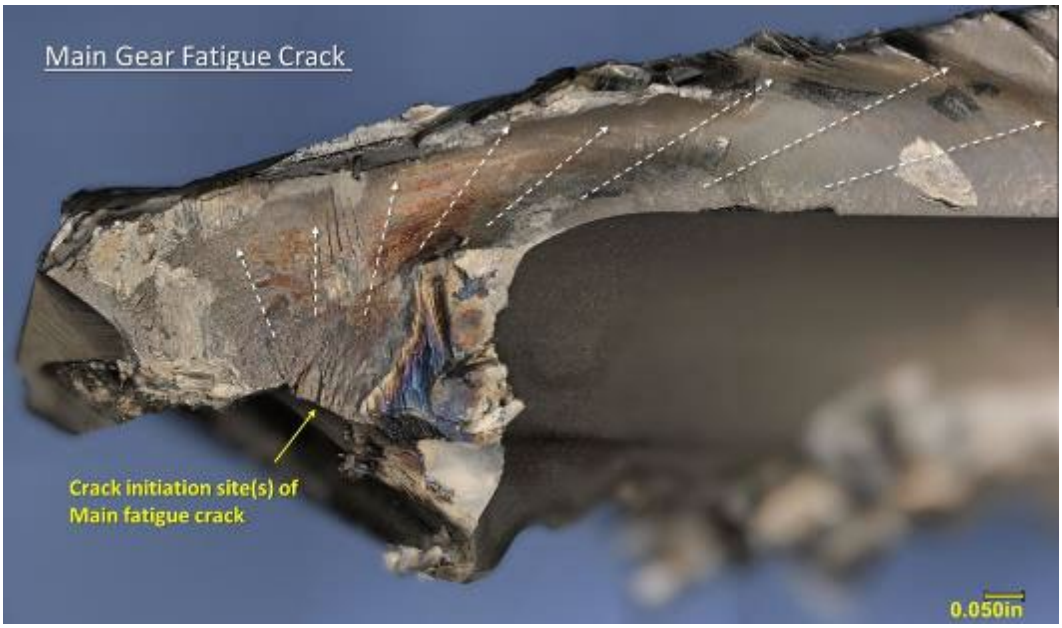


PHOTO 34: MAIN FRACTURE IN THE ZEROL GEAR

The zerol gear, however, exhibited at least six other fatigue cracks in other teeth locations, though those cracks did not grow as large (**Photo 35**). Gouging was present on both the leading and lagging flanks and lands of the gear teeth (**Photo 36**). Optical metallography discovered small microcracks in these locations, significant enough to likely develop stress concentrations and surface defects.

PHOTO 35: GOUGING ON ZEROL GEAR TOOTH

PHOTO 36: EXAMPLE OF ADDITIONAL FATIGUE CRACKING

The chemical composition of the gear was examined using EDS and XRF with results showing the material to be consistent with AMS 6260, a low-alloy steel. The hardness was inspected per ASTM E18.1, resulting in an average hardness of 68 HRA. Case hardening depth was also found to be consistent with drawing requirements. Further details can be found in the NTSB Materials Laboratory Lab Report in the docket of this investigation.

5.3 Zerol Gear History

According to the U.S. Army Aviation & Missile Command (USAAMC), the zerol gear assembly is P/N 1-080-310-01 (NSN 3040-00-475-0058[7]) and made up of detail P/N 1-080-153-01 (the gear without the plug installed (NSN 3040-00-488-7492). USAAMC has no record of a direct purchase of the Accessory Drive Outer Gearshaft (P/N 1-080-153-03) from the Eastern Gear Corporation, but they indicated that it is likely this gear was manufactured and supplied by Eastern Gear Corporation directly to Lycoming or Honeywell (the previous manufacturers and type certificate holders[8]). The Propulsion Division (AMR-SP) of the Systems Readiness Directorate (SRD) at USAAMC provided documentation that Eastern Gear Corporation was an approved parts supplier to Honeywell, however, Eastern Gear Corporation is no longer in existence; therefore, the NTSB could not get confirmation on when and how the failed zerol gear came into service.

The AMR-SP's research of US Army Maintenance Management System-Aviation (TAMMS-A) did not reveal any installation or overhaul information for the zerol gear with or without the plug, suggesting neither were a tracked part nor did they identify any failures of the zerol gear or accessory drive outer gearshaft similar to that found in the accident engine. In 2014, the Engine Design Authority for the T53 was transferred to the U.S. Air Force. Per the U.S. Air Force's engineering supervisor for the T53, located at the U.S. Air Force Life Cycle Management Center, no technical data package exists for the zerol gear, nor any record of procurements or alterations made by the U.S. Air Force, however, there is a technical data package for the zerol gear and plug assembly for the purposes of re-procurement through contracts with Honeywell, but no changes to the engineering drawings have occurred since 1961[9].

A non-destructive inspection was performed utilizing a magnetic particle method during the engine's last overhaul (3,000 hours) in 2018 at Ozark Aeroworks LLC, where the part was found acceptable. Upon re-installation, the backlash between the outer pinion gear shaft assembly and accessory drive gear assembly was measured at 0.011 inches using a dial indicator (see Attachment 5 – Inspection Card); the backlash limit is 0.006 to 0.012 inches (see Attachment 6 – T53 Overhaul Manual).

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[7] NSN 3040-00-475-0058 has been replaced by NSN 2840006717824.

[8] The R serial number suffix on the engine serial number designates an engine as remanufactured by one of the 3 remanufacture orgs: Corpus Christi Army Depot (CCAD), Lycoming, Sabreliner. Amcom Engineering Directive P-0691D is the process for remanufacture. This document requires the 1-080-310-01 gear be replaced with a new gear during the remanufacturing process. The subject gear's history is unknown, with potential pathways to being installed in the event engine including: provided as Government Furnished Property (GFP), Lycoming/Sabreliner may have purchased it from a surplus supplier, purchase directly from the manufacturer (Eastern Gear) or it may have been embodied during overhaul in 2013 by Cappsco. The zerol gears are readily available in the surplus market that have traceability a US Army contract.

[9] Drawing revisions between the military and Ozark Aeroworks may differ as they are managed differently. Ozark currently has drawing P/N 1-080-310-01 dated 11/3/1981 and drawing P/N 1-080-153-03 dated 5/12/1983.

ATTACHMENTS

1. Typical Oil Sample Report Provided by Jet-Care
2. Applicable pages from the Airframe, Engine, and Phase 5 Maintenance logbooks
3. T53 Engine S/N LE-23701RX Oil Samples Report & Oil Analysis Maintenance Manual
4. Ozark Results for the FCU and PT Governor Bench Test
5. T53 Engine S/N LE-23701RX Work Order No.1157, page 5
6. T53 Overhaul Manual, pages 521-523

Submitted by:
Matthew Walker
Powerplant / Helicopter Engineer