SOUTH AFRICAN CIVIL AVIATION AUTHORITY

AIRCRAFT ACCIDENT REPORT AND EXECUTIVE SUMMARY

				Reference:	CA18/2/3/9804
Aircraft Registration	**ZS-HLJ**	**Date of Accident**	23 July 2019	**Time of Accident**	1106Z
Type of Aircraft	Bell UH-1H		**Type of Operation**	Fire-fighting (Part 137)	
Pilot-in-command Licence Type	Commercial CPL(H)	**Age**	53	**Licence Valid**	Yes
Pilot-in-command Flying Experience	Total Flying Hours	6596.7		Hours on Type	194.9
Last Point of Departure	Letaba Air Base in Politsi near Tzaneen, Limpopo Province				
Next Point of Intended Landing	Letaba Air Base in Politsi near Tzaneen, Limpopo Province				

Location of the accident site with reference to easily defined geographical points (GPS readings if possible)
Bosveld Citrus Farm in Politsi at GPS co-ordinates determined to be S23°45'22.71" E030°6'32.97" at 2643ft above mean sea level (AMSL)

Aircraft Damage	Substantial				
Meteorological Information	Wind: 250°6.5kts; Temperature: 26°C; QNH: 1017hPa, Visibility: CAVOK				
Number of People On-board	1+0	**No. of People Injured**	0	**No. of People Killed**	0
Synopsis					

On Tuesday 23 July 2019, two Bell UH-1H helicopters with registration marks ZS-HLJ and ZU-LCY, as well as a Spotter aircraft, a Cessna 182, were dispatched to a fire-fighting mission at Woodbush Forest Reserve near Tzaneen. Each aircraft dispatched with a pilot on-board. The ZS-HLJ pilot reported that after turning on course for Woodbush Forest Reserve at approximately 200 feet, he noticed a lack of engine power as the helicopter was struggling to climb. Thereafter, the pilot heard a loud bang coming from the engine compartment. Upon checking the instrument panel, he noted that both the rotor and engine revolutions per minute (rpm) were decreasing and that the master warning light had illuminated. The pilot broadcasted a Mayday call on frequency 123.55 megahertz (MHz) before partially lowering the collective; he further noted that the rotor rpm kept decreasing. The pilot then scanned the area for a possible landing site and identified an open area (to his right). He then fully lowered the collective and continued to descend to undertake a forced landing. The pilot attempted to flare the helicopter to cushion the landing, however, the aircraft landed hard and broke both skids; the main rotor blades severed the upper section of the tail boom. The helicopter sustained substantial damages and the pilot was not injured during the accident sequence.

Following the review of the evidence, it is probable that the leak in the fuel manifold caused high temperatures during repetitive engine start cycles, which caused fatigue damage and the development of oxidation in the first stage nozzle assembly, thus, resulting in engine failure and an unsuccessful forced landing.

Probable cause/s

Although the manufacturer's technical report could not determine the cause of the engine failure, it is probable that the engine was periodically started at high temperature, and as a result of not being monitored during engine start, led to the development of fatigue cracks and the subsequent internal failures.

SRP Date	11 May 2021	Publication Date	12 May 2021

ABBREVIATION	DESCRIPTION
AFT	Afterward
ALF	Aft Looking Forward
CAVOK	Ceiling and Visibility OK
C of A	Certificate of Air worthiness
C of R	Certificate of Registration
CPL	Commercial Pilot’s Licence
CT	Computed Topography
CVR	Cockpit Voice Recorder
DMWR	Depot Maintenance Work Requirement
DSC	Differential Scanning Calorimeter
FDR	Flight Data Recorder
FLA	Forward Looking Aft
FWD	Forward
GP	Gas Producer
GPS	Global Positioning System
IGV	Inlet Guide Vane
L	Litre
PT	Power Turbine
QNH	Query Nautical Height
rpm	Revolutions per Minute
SB	Service Bulletin
SIL	Service Information Letter

Reference Number	**:** CA18/2/3/9804
Name of Owner/Operator	**:** Kishugu Aviation (Pty) Ltd
Manufacturer	**:** Richard Heavy Lift Helo Inc
Model	**:** Bell UH-1H
Nationality	**:** South African
Registration Marks	**:** ZS-HLJ
Place	**:** Bosveld Citrus Farm in Politsi near Tzaneen
Date	**:** 23 July 2019
Time	**:** 1106Z

All times given in this report are Co-ordinated Universal Time (UTC) and will be denoted by (Z). South African Standard Time is UTC plus 2 hours.

Purpose of the Investigation:

*In terms of Regulation 12.03.1 of the Civil Aviation Regulations (CAR) 2011, this report was compiled in the interest of the promotion of aviation safety and the reduction of the risk of aviation accidents or incidents and **not to apportion blame or liability**.*

Investigations Process:

The Accident and Incident Investigations Division (AIID) was notified of the accident on 23 July 2019 at approximately 1106Z. The investigators dispatched to Politsi on 24 July 2019 where they co-ordinated with all authorities on site by initiating the accident investigation process according to CAR Part 12 and investigation procedures. The AIID of the South African Civil Aviation Authority (SACAA) is leading the investigation as the Republic of South Africa is the State of Occurrence. The accident was reported to the State of Manufacture and an accredited representative (AR) was appointed.

Notes:
1. Whenever the following words are mentioned in this report, they shall mean the following:

- *Accident – this investigated accident*
- *Aircraft – the Bell UH-1H involved in this accident*
- *Investigation – the investigation into the circumstances of this accident*
- *Pilot – the pilot involved in this accident*
- *Report – this accident report*

2. Photos and figures used in this report were taken from different sources and may be adjusted from the original for the sole purpose of improving clarity of the report. Modifications to images used in this report are limited to cropping, magnification, file compression; or enhancement of colour, brightness, contrast; or addition of text boxes, arrows or lines.

Disclaimer:

This report is produced without prejudice to the rights of the AIID, which are reserved.

1. FACTUAL INFORMATION

1.1. History of Flight

1.1.1 On Tuesday 23 July 2019, two Bell UH-1H helicopters with registration marks ZS-HLJ and ZU-LCY, as well as a Spotter aircraft, a Cessna 182, were dispatched to a fire-fighting mission at Woodbush Forest Reserve near Tzaneen. The flight was conducted in visual meteorological conditions (VMC) and under the provisions of Part 137 of the Civil Aviation Regulations (CAR) 2011 as amended.

1.1.2 An eyewitness who was at the scene during take-off showed investigators a video footage of the helicopter lifting off into a hover in ground effect and transitioning until climb out, with black smoke coming from the engine exhaust area.

1.1.3 The pilot reported that after turning on course for Woodbush Forest Reserve at approximately 200 feet (ft), he noticed that there was a lack of engine power as the helicopter was struggling to climb from 200ft to 280ft. He also observed that the temperature gauge and pressure gauge indicators were on green, which meant that they were functioning satisfactorily. The pilot then heard a loud bang coming from the engine compartment; thereafter, he checked the instruments and noted that both the rotor and engine revolutions per minute (rpm) were decreasing significantly on the dual tachometer on the instrument panel. He declared an emergency by broadcasting a Mayday call on frequency 123.55 megahertz (MHz); thereafter, he partially lowered the collective. At that point, he also noticed that the master warning light had illuminated and that the rotor rpm kept decreasing. The pilot then scanned the surroundings for a possible landing area; he then fully lowered the collective after identifying an open area on a farm (to his right) and steered towards it to undertake an emergency landing.

1.1.4 During descent, the pilot attempted to flare the helicopter to cushion the landing but there was insufficient rotor rpm and the helicopter landed hard, breaking both skids on impact while the main rotor severed the upper section of the tail boom. The pilot did not sustain any injuries.

1.1.5 After the emergency landing, the pilot turned off the master switch and the invertor before exiting the helicopter unaided. He reported that when he opened the door to disembark the helicopter, there was no engine noise (the engine was not running), only the main rotor blades were wind milling. He then opened the front cowl door and disconnected the battery.

1.1.6 The accident occurred during daylight at Bosveld Citrus Farm in Politsi at Global Positioning System (GPS) determined to be S23°45’22.71” E030°6’32.97” at 2 643ft above mean sea level (AMSL).

Figure 1: The approximate flight path of the ZS-HLJ helicopter. (Source: Google Earth)

1.2. Injuries to Persons

Injuries	Pilot	Crew	Pass.	Total On-board	Other on Ground
Fatal	-	-	-	-	-
Serious	-	-	-	-	-
Minor	-	-	-	-	-
None	1	-	-	1	-
Total	1	-	-	1	-

1.3. Damage to Aircraft

1.3.1 The aircraft was substantially damaged during the accident sequence.

Figure 2: The helicopter at the accident site.

1.4. Other Damage

1.4.1 None.

1.5. Personnel Information

Nationality	South African	Gender	Male	Age	53
Licence Number	0270188683	Licence Type	Commercial Pilot Licence (H)		
Licence Valid	Yes	Type Endorsed	Yes		
Ratings	Night, Safety, Game /livestock cull and under sling/winching				
Medical Expiry Date	30 November 2019				
Restrictions	Corrective lenses				
Previous Accidents	Tail strike in ZS-HNG in 2015				

Flying Experience:

Total Hours	6596.7
Total Past 90 Days	7
Total on Type Past 90 Days	7
Total on Type	194.9

1.6 Aircraft Information

1.6.1 The Bell UH-1H Iroquois (nicknamed “Huey”) is a utility military helicopter powered by a single turboshaft engine (manufactured by Honeywell), with two-bladed main and tail rotor systems. The first member of the prolific Huey family, it was developed by Bell Helicopter to meet a 1952 US Army requirement for a medical evacuation and utility helicopter, and first flew in 1956. The UH-1H was the first turbine-powered helicopter produced for the United States military. More than 16,000 have been built since 1960.

1.6.2 T53 engines are two-spool engines. The gas generator spool consists of a five-stage axial compressor followed by a single stage centrifugal compressor, and a two-stage high pressure turbine. The power turbine spool consists of two stages. The engine has a maximum continuous rating of 1,300 shaft horsepower at an output shaft speed of 6,634 rpm.

Airframe:

Type	Bell UH-1H	
Serial Number	66-16606	
Manufacturer	Bell Helicopter Company	
Type Certified Holder	Arrow Falcon Exporters Inc. (since 15 December 1999)	
Date of Manufacture	1968	
Total Airframe Hours (At time of accident)	9280.4	
Last 100-hour/4 months inspection (Hours & Date)	9279.1	23 July 2019
Hours Since Last Check	1.3	
C of R (Issue Date) (Present owner)	9 July 2012	
C of A (Issue Date)	23 December 2015	
C of A (Expiry Date)	31 December 2019	
Operating Categories	Part 127	
Recommended Type of Fuel Used	Jet A1	

1.6.3 According to the flight folio, the helicopter had 1000 pounds (568L) of fuel which equate to 2.8 hours endurance. The flight duration was three minutes, thus, there was enough fuel for the flight.

Engine:

Type	Honeywell T53
Part Number	1-000-060-22
Serial Number	L E 18293B
Hours Since New	5918.9
Hours Since Overhaul	449.9

1.6.4 The engine was last overhauled on 19 December 2012 at 5 469 hours. It was then preserved in an engine container in accordance with the manufacturer's instruction. It was then fitted to the (ZS-HLJ) helicopter in December 2015 by Leading Edge Helicopters. Time since overhaul was 449.9 hours.

1.6.5 The overhaul facility which conducted the engine overhaul stated that they were unsuccessful in finding any records regarding the combustion chamber liner. Due to the age of these records, they no longer existed. Only the invoice in the accounting records, which listed major components that were replaced, was found. The combustion liner was not listed in the invoice. The impeller, first GP sealing disk, first GP disc, first PT disk, PT spacer and second PT disk were all replaced with new units. The GP spacer and second GP rotor were replaced with units supplied by the customer. The units were replaced in accordance with Depot Maintenance Work Requirement (DMWR) 1-2840-113-1/-2/-4 issued by Richards Heavylift Helo (type certificate holder). Following the replacement of the units, the engine was functionally tested in accordance with DMWR 1-2840-113-4 and met specifications. There were no records that indicated that the combustion chamber liner was part of the units that needed to be replaced during overhaul on 19 December 2012, however, it was inspected during overhaul as an on-condition unit; it was also found to be in good condition.

1.6.6 According to the information contained on NGT 8130-3 NGTI 100302.19 dated 19 December 2012, the last hot section inspection (HSI) was undertaken on 19 December 2012, together with engine overhaul. The engine's No. 1 carbon seal was replaced on 9 December 2016 as per NGT 8130-3 No. 161108-165.

1.6.7 There was no record or evidence that the borescope inspection was carried out during the period 19 December 2012 to the accident date on 23 July 2019.

1.6.8 A defect was noted on 6 January 2019 whereby the engine will only start after three attempts. The defect was rectified by changing the start ignitors in accordance with TM T53 Maintenance Manual. Three months later on 9 April 2019, according to flight folio SN: 0466, the helicopter experienced a defect of "no ignition" during start. The rectification action was "*plugs were cleaned, and ground run performed and found serviceable*". Since then the helicopter operated without any difficulty during start.

1.6.9 According to the engine logbook, on 22 July 2019, which is the day before the accident, the following maintenance was undertaken:

- Numbers 1, 2, 3 and 4 ignitors were removed, cleaned, tested and found satisfactory. The ignitors were re-fitted to the engine.
- Checked valve: it was dirty and sticky; removed, cleaned, inspected and re-installed.
- The helicopter was ground-run and was found satisfactory.
- Dual inspection was carried out as per task identification (ID): 12154
- Droop compensator was checked within flight. Droop went up to 20 rpm when lifting off and settled on original position as per normal droop compensator. It was found serviceable as per the Maintenance Manual TM55-1520-210-23-1 Chapter 4-128.

Main Rotor Transmission & Blades:

Gearbox Type	Main	Blade Type	Two-bladed	
Serial Number	A12-3672	Serial Number	A-1623	AMR 53402
Installation Date	14/11/2015	Installation Date	03/12/2009	15/06/2015
Hours Since New	Unknown	Hours Since New	573.5	846.9
Hours Since Overhaul	449.60			

Tail Rotor Transmission Gearbox & Blades:

Gearbox Type	Tail	Blade Type	Varn Horn	
Serial Number	B13-9306	Serial Number	A418	A419
Installation Date	14/11/2015	Installation Date	22/02/2017	
Hours Since New	Unknown	Hours Since New	290.3	
Hours Since Overhaul	449.6			

1.7 Meteorological Information

1.7.1 The weather information was obtained from the Letaba Air Base weather report for 23 July 2019 at 1100Z.

Wind direction	250°	Wind speed	6.5knots	Visibility	>10km
Temperature	26°	Cloud cover	Nil	Cloud base	Nil
Dew point	Unknown	QNH	1017hPa		

1.8 Aids to Navigation

1.8.1 The aircraft was equipped with standard navigational equipment approved by the Regulator (SACAA) for the helicopter type and operation. There were no recorded or reported defects with the navigational system prior to the flight.

1.9 Communication

1.9.1 The aircraft was equipped with standard communication equipment as per the minimum equipment list (MEL) and approved by the Regulator. There were no recorded or reported defects with the communication equipment prior to the flight.

1.10 Aerodrome Information

1.10.1 The accident did not occur at an aerodrome but at Bosveld Citrus Farm in Politsi, 12 nautical miles (nm) south-east of Tzaneen Airfield at GPS determined to be S23°45'22.71" E030°6'32.97" at 2 643 feet AMSL.

Aerodrome Location	Tzaneen, Limpopo province
Aerodrome Co-ordinates	GPS S 23°49'31.22" E 0 30°19'31.92"
Aerodrome Elevation	1888 feet (AMSL)
Runway Designations	06/24
Runway Dimensions	1444m x 20m
Runway Used	N/A
Runway Surface	Asphalt
Approach Facilities	None

1.10.2 The helicopter was based at Letaba Air Base near Tzaneen, Limpopo Province. At the Air Base, the pilots use the standard unmanned procedure and the dispatcher is on a company frequency 123.55MHz, which is also used by their traffic.

1.11 Flight Recorders

1.11.1 The helicopter was not equipped with a flight data recorder (FDR) or a cockpit voice recorder (CVR), nor were these required to be fitted to this helicopter type.

1.12 Wreckage and Impact Information

1.12.1 The helicopter crash-landed on an open field in Bosveld Citrus Farm. It impacted the ground hard with both skids. The helicopter sustained substantial damage to the tail boom and transmission mounts. The main wreckage was found at GPS co-ordinates S23°45'22.71" E030°6'32.97. The main rotor drive shaft had remained intact. The number one main rotor blade tip sustained damage but the number two main rotor blade was still intact, as well as all control cables. The skids broke on impact and the underbelly was damaged. The main rotor gear box, tail rotor and tail rotor gear box assembly were not damaged. The cabin area had remained intact.

Figure 4: Damage to the skids, tail rotor drive shaft and chin bubble.

1.12.2 The number one main rotor blade had severed the tail rotor drive shaft during the accident sequence, and the drive shaft was found 30 metres (m) south of the wreckage.

Figure 5: The severed tail drive shaft.

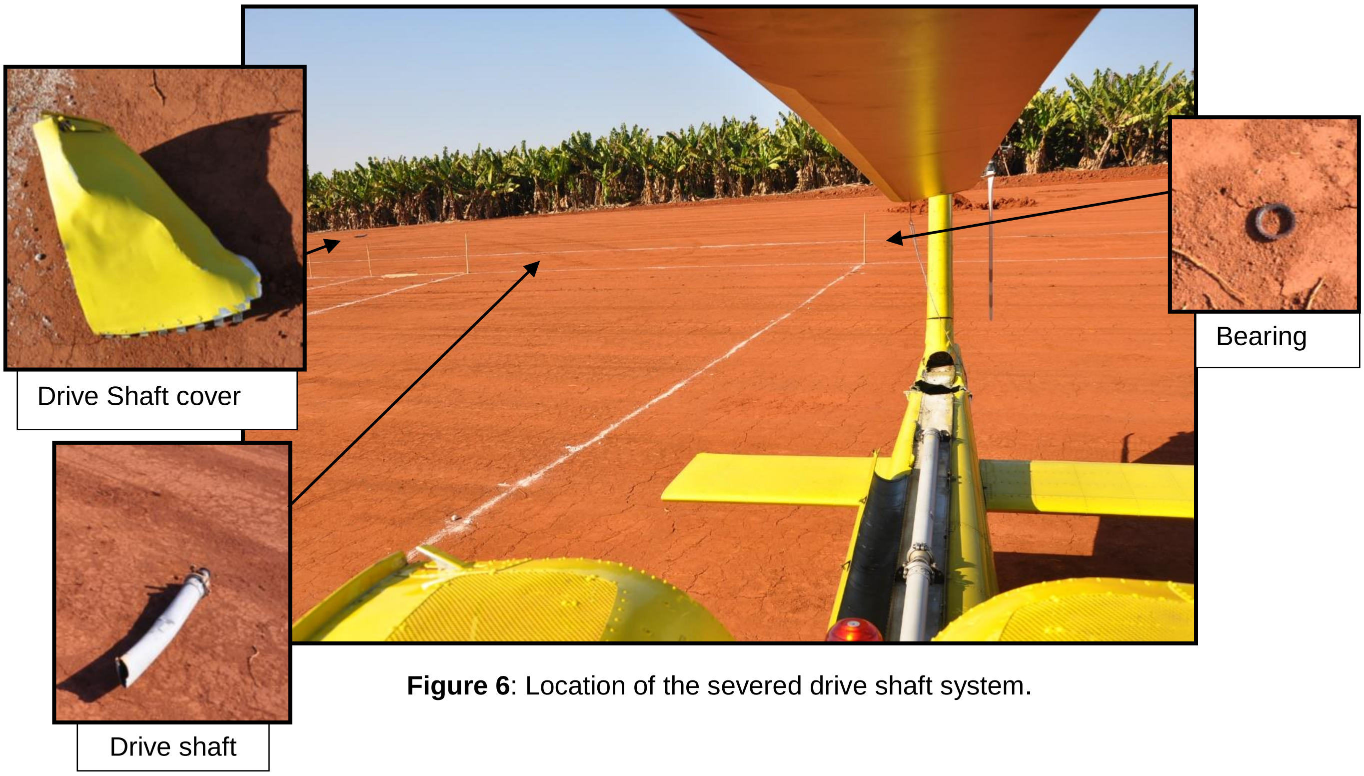


Figure 6: Location of the severed drive shaft system.

1.12.3 The empty Bambi bucket skidded for about 52m and was found west of the main wreckage. The Bambi bucket attachment did not break during the accident sequence, it only disconnected from the aircraft. The tail rotor guard skidded for approximately 13m; it had scratches but still intact. The tail rotor was not damaged. The under belly and the chin bubble were damaged. The lookout mirror was broken.

1.12.4 Due to the damage, the flight controls and transmission could not be inspected for mechanical continuity and correct operation. The engine could not be rotated and there was evidence of fine metal particles present on the exhaust and combustion side of the power turbine (see Figure 9), which indicated metal debris passed through the engine during the accident sequence.

Figure 7: The ground scar mark created by the tail rotor guard during the accident sequence.

1.12.5 The engine was still intact and attached to the mounting points, and there were no visible signs of oil and hydraulic leaks. The levels were showing ¾ on the sight glass. There were pieces of metal shavings found on the surface of the exhaust shroud of the engine (see Figure 9).

Figure 8: The position of the engine post-accident.

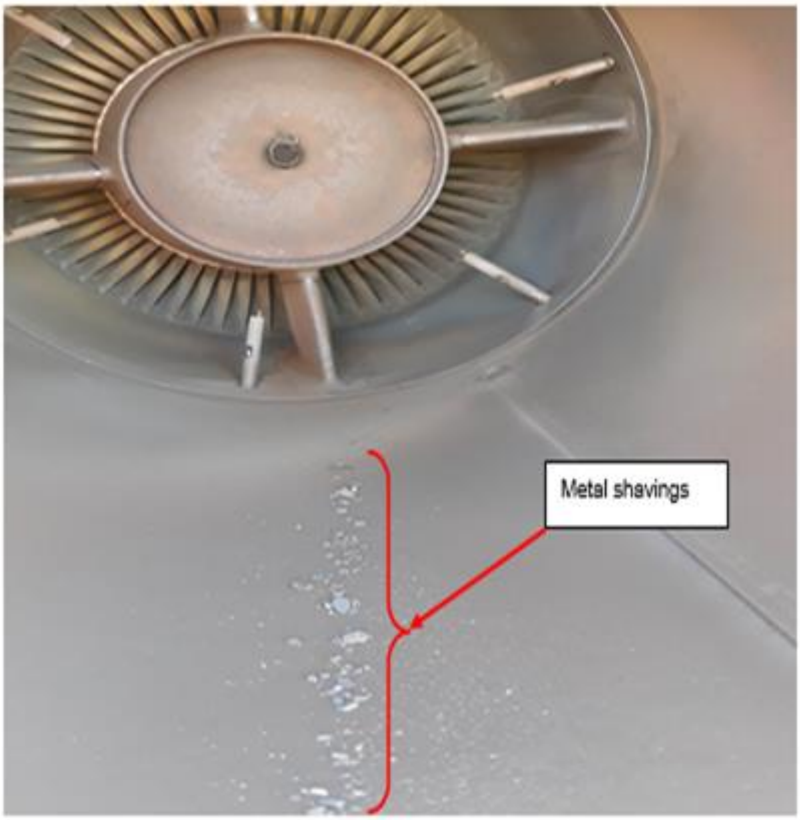


Figure 9: Metal debris found in the exhaust area.

1.13 Medical and Pathological Information

1.13.1 None.

1.14 Fire

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

1.15 Survival Aspects

1.15.1 This accident was considered survivable as there was no damage to the cabin area. The helicopter was equipped with a four-point harness, which the pilot had used.

1.16 Tests and Research

1.16.1 On 24 July 2019 (a day after the accident) the engine with serial number LE 18293B was removed from the helicopter and recovered to a hangar in Nelspruit for quarantine. The manufacturer provided a standard T53 container for the engine to be shipped to their facility for a teardown inspection.

1.16.2 The engine teardown was carried out at the manufacturer's facility in the presence of an accredited representative (AR) as per the International Civil Aviation Organisation (ICAO)

Annex 13 requirements; and the report was shared with the AIID. The summary of the examination results and findings from the manufacturer are as follows:

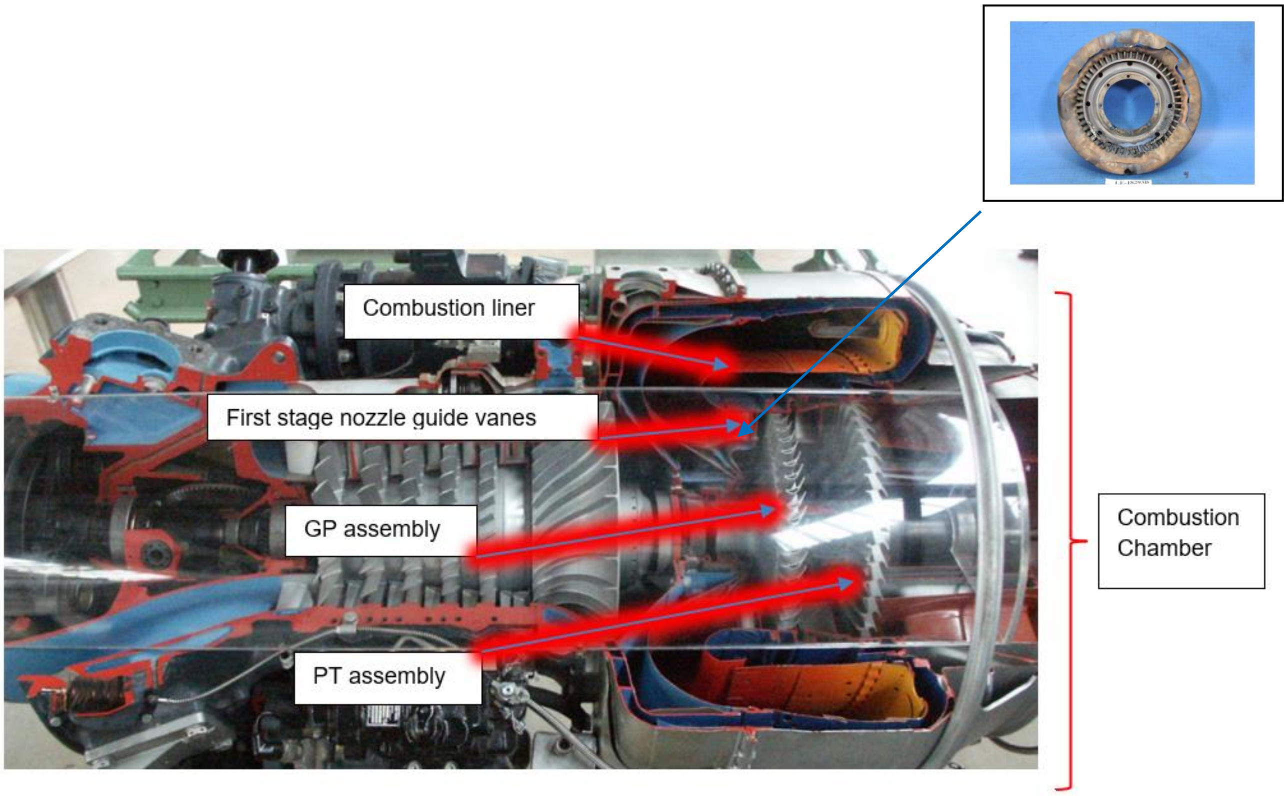


Figure 12: The cross-section cut-out of the T53-L-13B engine. (Source: vietnamwar.fandom.com)

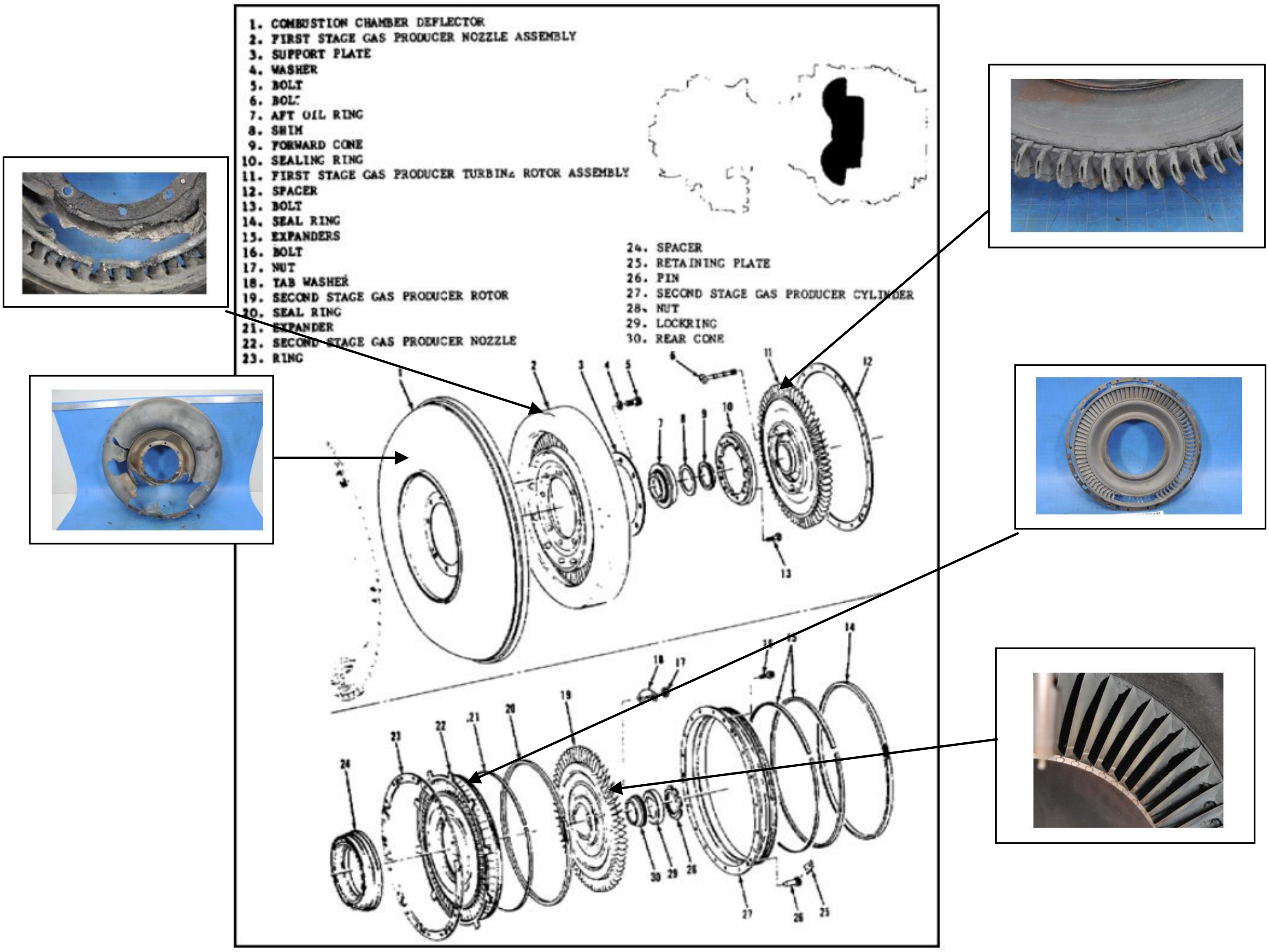


Figure 13: The exploded view of the combustion chamber assembly.

1.16.3 *Engine Cross Section - Area of Interest. The following cross section will be referenced in the upcoming analysis sections. The items coloured in red (liner) and blue (nozzle) are of the first stage gas producer turbine nozzle assembly (P/N 1-110-520-18). Both parts make up one assembly and are denoted with separate colours for clarity.*

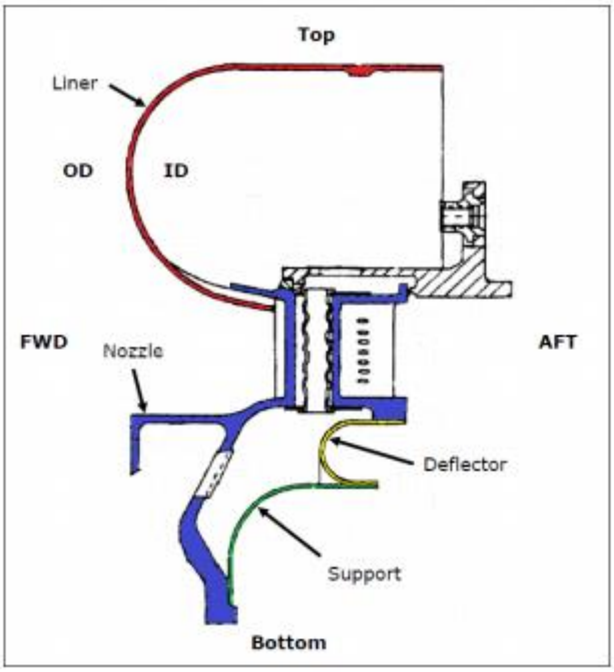


Figure 14: The first stage gas producer turbine nozzle assembly.

1.16.4 *Component Failure Analysis of the Combustor Inner Transition Liner*

The first stage gas producer turbine nozzle assembly was submitted to Honeywell's Material and Component Failure Analysis group for further investigation.

A summary of the findings is as follows:

- *Multiple cracks and separations were observed in the first stage turbine nozzle and inner transition liner from the 9 to the 3 o'clock (clockwise) location and near the 6 o'clock location. A melted area of the nozzle was observed near the 6 o'clock location.*
- *Scanning electron microscope (SEM) evaluation of the first stage turbine nozzle and inner transition liner fracture surfaces revealed evidence of fatigue and reversed bending fatigue emanating from multiple locations; however, the finer fracture features were obscured by oxidation of the fracture surface.*
- *A representative cross section through the approximate location of an initiation region revealed a trans granular fracture surface indicative of fatigue. The microstructure was indicative of the specified Hastelloy X material. No material anomalies or defects were observed in the cross section.*
- *The average hardness was measured to be approximately 203 HB (converted from HV500) which was within the drawing specification range of 116-235 HB. A non-uniform wear pattern was observed on the outside surface of the first stage turbine nozzle inner transition liner associated with contact of the combustion chamber inner panel in multiple locations. These wear patterns were associated with contact between the inner panel, inside surface, of the combustion chamber liner with the outside surface of the first stage turbine nozzle inner transition liner.*

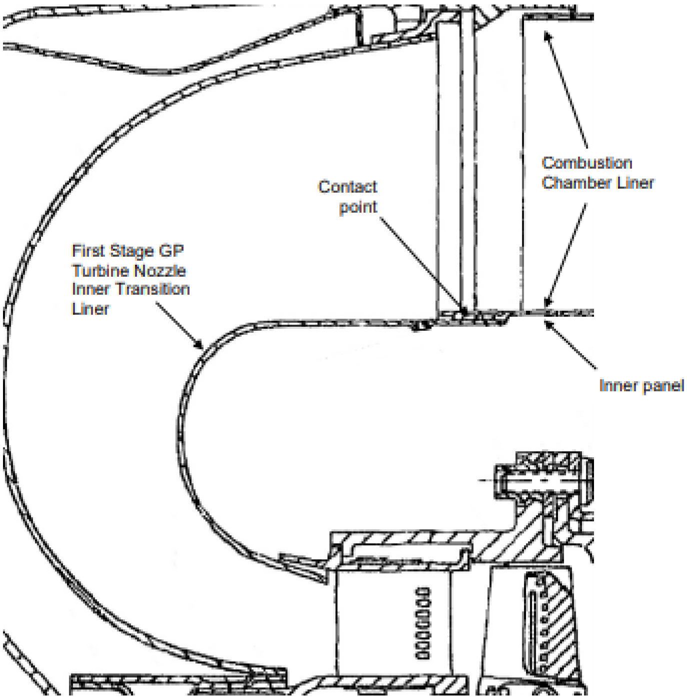


Figure 15: The first stage gas producer turbine nozzle to the combustion liner interface.

1.16.5 *A mosaic of images showing the contact locations between the first stage turbine nozzle inner transition liner and the combustion chamber inner panel. The contact pattern between the two assemblies appeared to be a non-uniform interference fit with almost no contact evident between the 3 to 8 o'clock positions (ALF) and again at the 10 and 11 o'clock positions. This indicates a non-uniform loading of the first stage turbine nozzle inner transition liner to the combustion chamber inner panel leading to crack initiation and propagation due to reverse bending fatigue in a vibratory mode.*

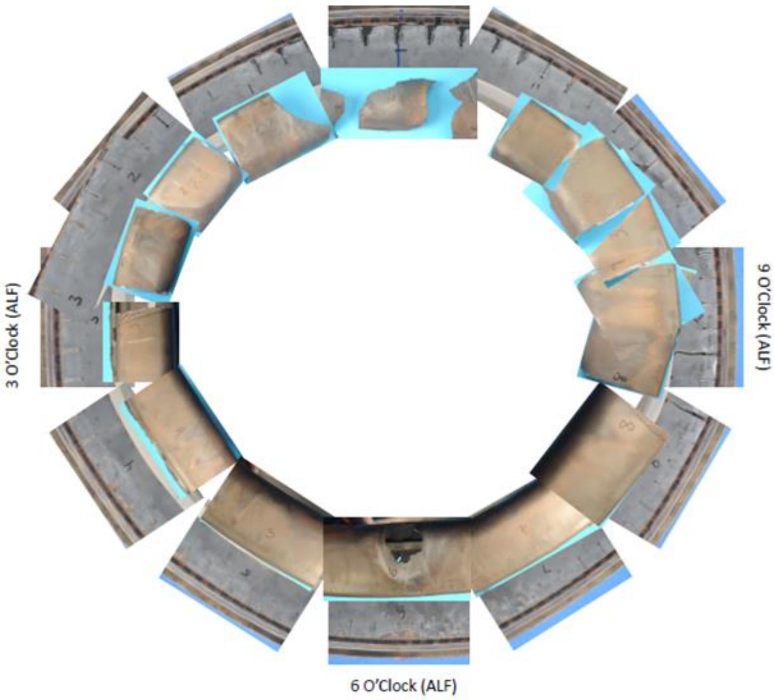


Figure 16: The mosaic of images showing contact locations between the first stage turbine nozzle inner transition liner and combustion chamber inner panel.

1.16.6 ***Fuel Control and Power Turbine Governor Testing and Analysis***

The fuel control and power turbine governor were sent to a Honeywell approved service centre for test and evaluation. The units were tested as an assembly. While some discrepancies were noted, those discrepancies are typical of adjustments made in the aircraft when the engine is installed in the airframe. No discrepancies were noted that would have prevented normal operation.

Image below depicts the various locations of the fuel manifold nozzles/seals which will be referenced in the following analysis. In addition, the image below shows the orientation of the first stage turbine nozzle in relation to the fuel manifold nozzles.

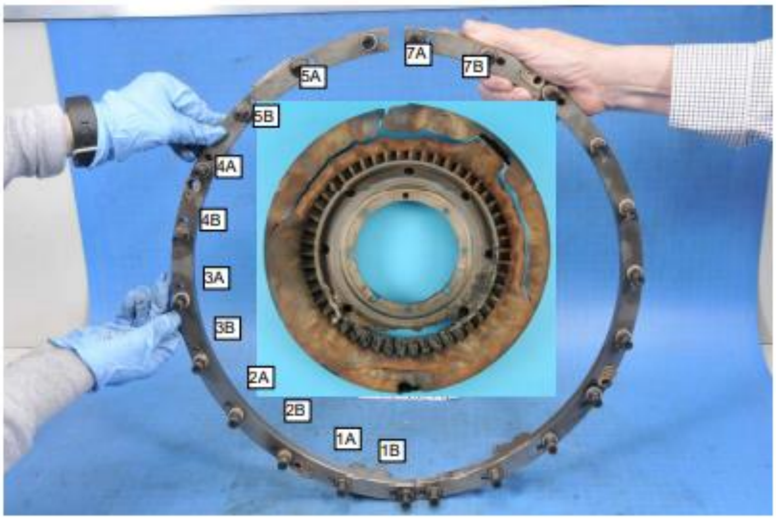


Figure 17: The fuel nozzle Designator Locations on the Engine (FLA).

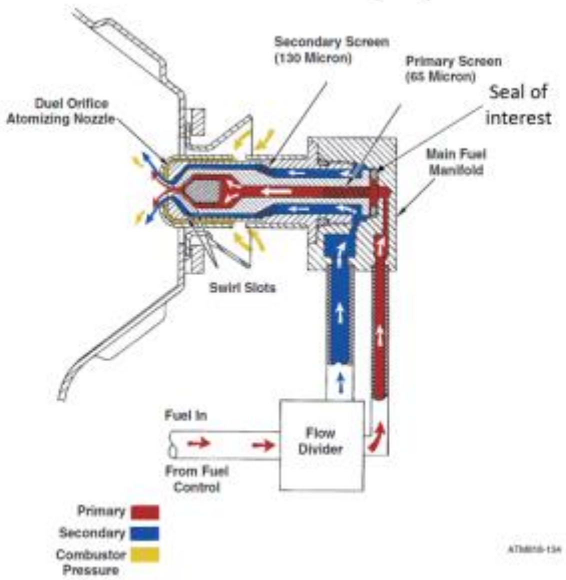


Figure 18: The fuel manifold and fuel nozzle assembly cross sections.

1.16.7 *One can see from Image above, the primary and secondary circuits are independent from one another both within the fuel manifold as well as within the fuel nozzle. Separation between the two circuits is maintained by a weld joint within the fuel manifold as well as a seal at the base of the fuel nozzle. Honeywell's flow testing setup allows for fuel pressure to* *be applied to the primary and secondary fuel circuits independent of one another. Testing showed that when the primary fuel circuit was energized, fuel was observed coming from the secondary fuel circuit. And when the secondary fuel circuit was energized, fuel was observed coming from the primary fuel circuit. This indicated that there was an unintended leak path between the primary and secondary fuel circuits. Image below was taken when the primary fuel circuit was pressurized with the cross flow occurring into the secondary circuit.*

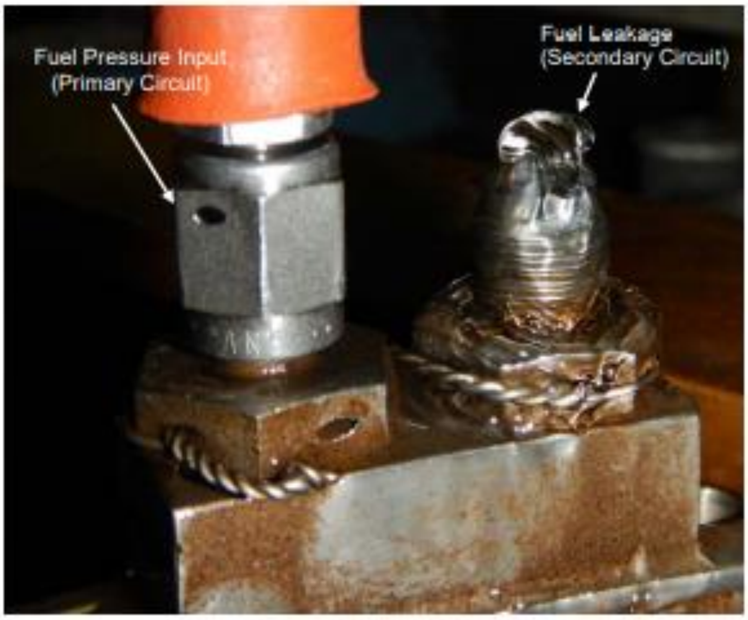


Figure 19: *The cross flow of fuel when one fuel circuit is energised.*

1.16.8 *The fuel manifold and fuel nozzle assembly were sent to Honeywell's Computed Tomography (CT) group for scanning and analysis. CT scanning of the manifold showed the two chambers within were still independent of one another with no internal leaks. Further analysis of the CT scans identified several fuel nozzle seals as possibly being out of place or damaged. The following figures show a fuel nozzle seal that appeared to be damaged along with one that did not appear to be damaged. The fuel nozzles were removed from several locations for further investigation where the CT scans showed the seals to be damaged. Examination of the seals showed the fluorosilicone elastomer material was permanently deformed and had areas of separation from the stainless-steel retainer. See the following figures. The seal is constructed of a stainless-steel retainer that is surrounded by a fluorosilicone elastomer, fuel resistant material, which acts as the sealing agent. The CT scan only shows the stainless-steel retainer and not the elastomer material around it because elastomer materials are not viewable when the CT settings are for steel materials.*

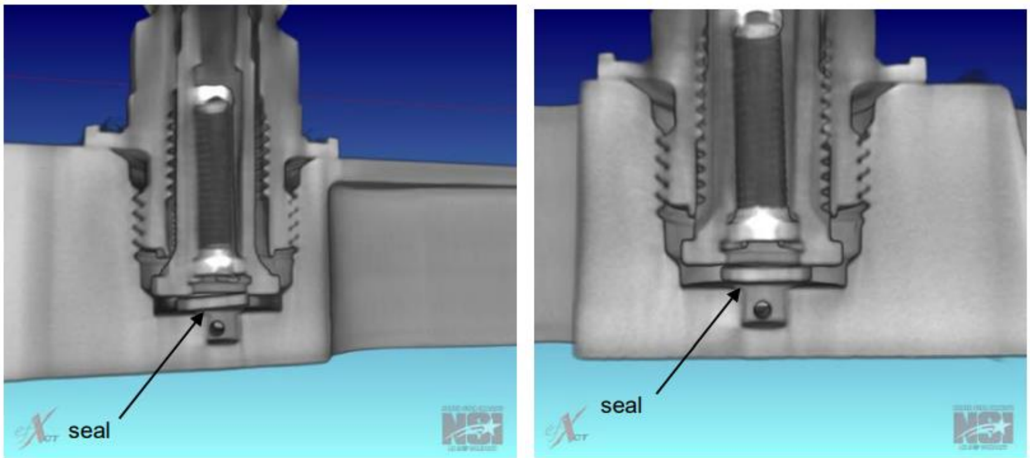


Figure 20 and 21: The CT scan of a damaged seal and the undamaged seal.

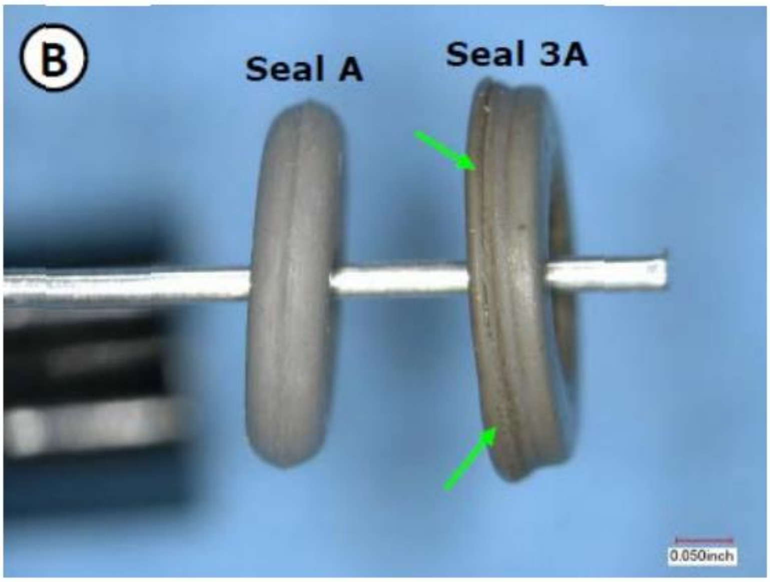


Figure 22: The physical differences between a new (Seal A) and the accident engine seal 3A.

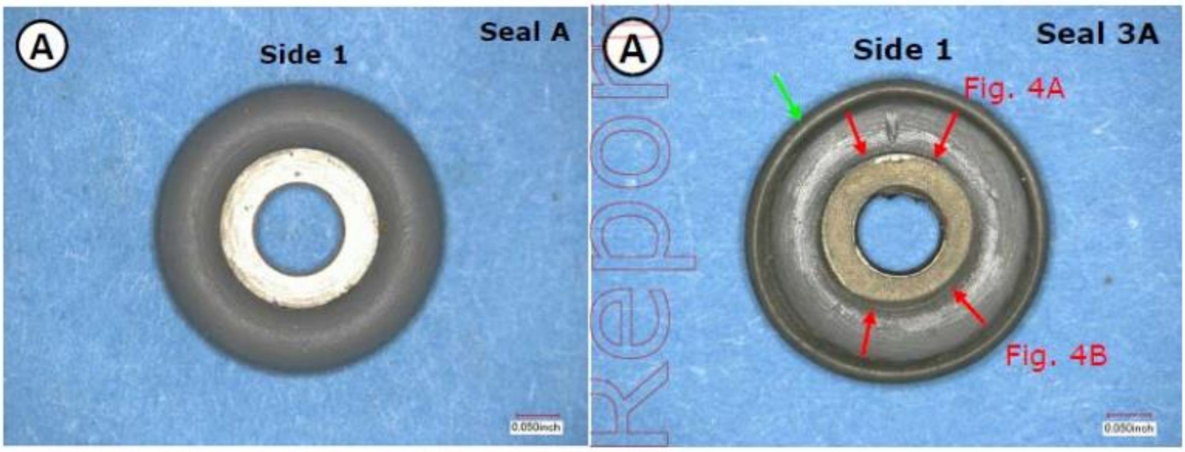


Figure 23 and 24: The physical differences between a new (Seal A) and the accident engine seal 3A.

1.16.9 *Visual observation of the seals suggested they had been exposed to temperatures in excess of their design limits and had "taken a set" as a result of the over temperature condition. The seals were subjected to Differential Scanning Calorimetry (DSC) analysis to determine if the material had been exposed to temperatures beyond its design limits. The DSC testing confirmed the visual observations; the seals had been exposed to temperatures in excess of their design limits. But the testing could not determine if this* *occurred during normal operation or as a result of the first stage nozzle failure. The damaged observed to the fuel manifold seals is what was causing the primary to secondary (and vice versa) cross flow during the manifold flow testing. Fuel flow to the primary and secondary fuel manifold circuits is controlled by the flow divider located on the bottom side of the combustor plenum. Between 22 approximately 8 to 10% N1 speed, the primary fuel circuit is energized with fuel by the flow divider. At approximately 32% N1 speed, the secondary fuel circuit is energized in addition to the primary circuit. At this point, both fuel manifold circuits are experiencing the same fuel pressure thereby negating the effects of any possible cross flow leakage issues. In both situations, the fuel control is metering the fuel flow rate to the engine. Even if the seal damage observed was pre-existing, this would have had no impact on steady state engine operation (above 32% N1). The investigation did not determine any reports of prior issues during the start sequence which may have been the result of a pre-existing manifold seal issue. Therefore, the investigation concludes that the seal damage was the result of an engine overtemperature condition beyond the design limits of the components. See Section below for the analysis of the engine overtemperature condition observed.*

1.16.10 *While researching the accident engine's fuel manifold repair history, Honeywell determined the accident engine was being maintained to the applicable Depot Maintenance Work Requirement (DMWR) created by the United States Military. Honeywell is not familiar with the details and requirements of the DMWRs. Honeywell's engine documentation specifies the following maintenance intervals with respect to the fuel manifolds.*

Note

• Honeywell Service Bulletin (SB) T53-L-13B-0001 (APPENDIX 6.1) specifies that the fuel manifolds be removed and overhauled every 600 hours.

• Honeywell Service Information Letter (SIL) D201903000027 in April of 2019 (APPENDIX 6.1) recommends 300-hour inspections where there is 1st stage nozzle and rotor erosion.

Note

According to the operator, the fuel manifolds had not been overhauled since the last engine overhaul. Honeywell does not believe the issues observed with the fuel manifold seals contributed to the inflight engine failure experienced in the accident of ZS-HLI.

1.16.11 ***Evidence of Engine Overtemperature Operating Condition***

The following observed engine damage indicates the engine experienced an over temperature event: The first-stage GP turbine nozzle, The first-stage GP turbine nozzle inner vane support, The second-stage GP turbine nozzle, The first-stage PT nozzle, The first-stage PT rotor, The second-stage PT nozzle, The second-stage PT rotor. More so the second-stage GP (turbine shroud) cylinder appeared to have *material from the second stage GP rotor partially adhering to the inner surface and all of the blades of the first stage GP turbine rotor were missing the outer ends of the blade's indicative of stress rupture.*

The teardown and examination of engine LE-18293B disclosed that the type and degree of damage to the engine was indicative of a vibratory fatigue failure of the first gas producer inner transition liner. The fatigue failure occurred due to a non-uniform interference fit between the first gas producer inner transition liner and the combustion chamber liner. The failure eventually led to an over temperature and damage to the engine to the point that it could no longer provide the power required to sustain flight. The cause for the non-uniform interference fit between the first gas producer inner transition liner and the combustion chamber liner could not be determined.

1.16.12 **Fuel Control and Power Turbine Governor Assembly Test Results**

Functional tests were performed on the fuel control and power turbine governor assembly and no discrepancies found on (emergency schedule, 59 degree acceleration and altitude schedule, steady state and face cam schedule/N1 droop, deceleration schedule, 30 degree acceleration and face cam schedule and IGV schedule) except the air bleed schedule which was low and out of limits due to the external adjustment made for the engine requirement as well as 100 degree accel and face cam schedule slightly high and out of limits due to RPM limits on droop setting because of where the take-off trimmer was set.

1.17 Organisational and Management Information

1.17.1 The operator was issued an Air Operating Certificate (AOC) No. CAA/G921D on 30 January 2019 with an expiry date of 31 December 2019. The aircraft was duly authorised to operate under the AOC.

1.17.2 The operator had the following Air Service Licences: Class II and Class III issued on 10 August 2016. Class II – Licence No: N1109D, Types of Air Services: N1 and N2, Categories of Aircraft: A3, A4 and H. Class III – Licence No: G921D, Types of Air Services: G3, G5, G8, G10, G15 and G16 Categories of Aircraft: A2, A3, A4 and H2.

1.17.3 The aircraft maintenance organisation (AMO) which carried out the last maintenance inspection of the helicopter prior to the accident flight was in possession of a valid AMO approval certificate that was issued by the SACAA on 13 December 2018 with an expiry date of 12 December 2019.

1.17.4 The last maintenance was conducted on 22 July 2019, a day before the accident, at 9279.1 hours. The helicopter was flown for 1.3 hours since its last maintenance.

1.18 Additional Information

1.18.1 *UH-1H Pilot Operating Handbook*

9-9. Engine Malfunction-Partial or Complete Power Loss.

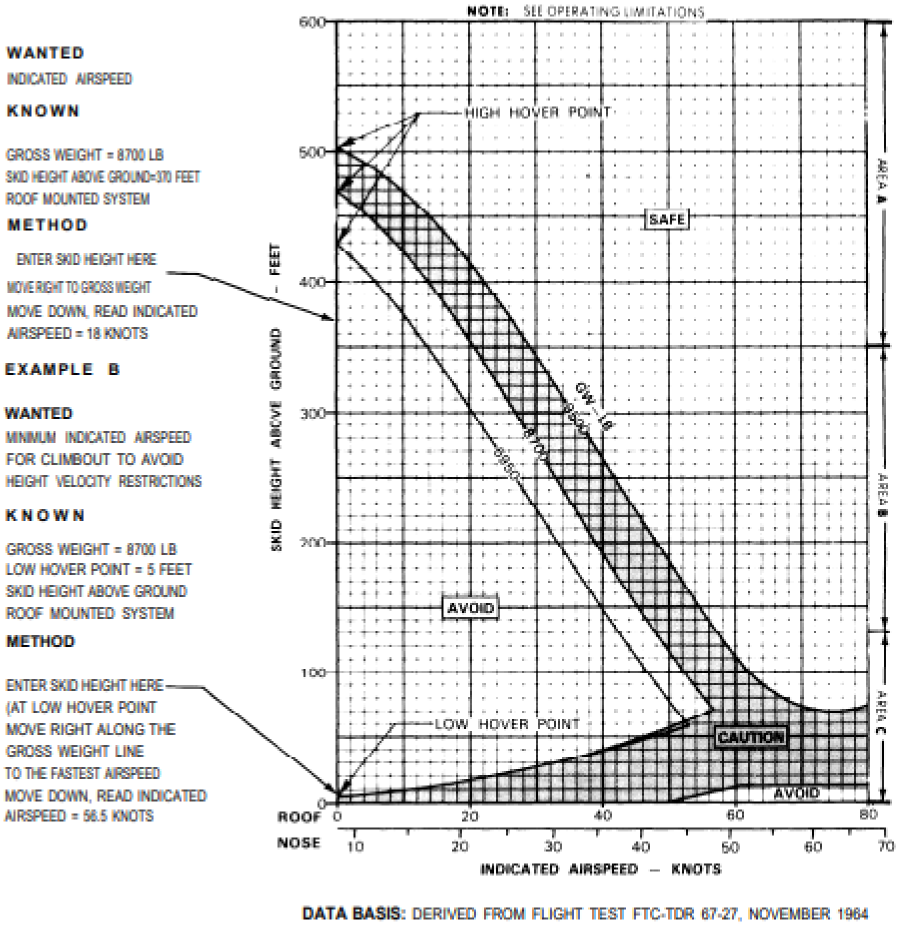
a. *The indications of an engine malfunction, either a partial or a complete power loss are left yaw, drop in engine rpm, drop in rotor rpm, low rpm audio alarm, illumination of the rpm warning light, change in engine noise.*

b. *Flight characteristics: (1) Control response with similar to a descent with power. an engine inoperable is (2) Airspeed above the minimum rate of descent values will result in greater rates of descent and should only be used as necessary to extend glide distance. (3) Airspeeds below minimum rate of descent airspeeds will increase rate of descent and decrease glide distance. (4) Should the engine malfunction during a left bank manoeuvre, right cyclic input to level the aircraft must be made simultaneously with collective pitch adjustment. If the collective pitch is decreased without a corresponding right cyclic input, the helicopter will pitch down and the roll rate will increase rapidly, resulting in a significant loss of altitude.*

c. *Partial power condition: Under partial power conditions, the engine may operate relatively smoothly at reduced power or it may operate erratically with intermittent surges of power. In instances where a power loss is experienced without accompanying power surging, the helicopter may sometimes be flown at reduced power to a favourable landing area. Under these conditions, the pilot should always be prepared for a complete power loss. In the event a partial power condition is accompanied by erratic engine operation or power surging, and flight is to be continued, the GOV switch may be moved to the EMER position and throttle adjusted in an attempt to correct the surging condition. If flight is not possible, close the throttle completely and complete an autorotational landing.*

d. *Complete power loss: (1) Under a complete power loss condition, delay in recognition of the malfunction, improper technique or excessive manoeuvring to reach a suitable landing area reduces the probability of a safe autorotational landing. Flight conducted within the caution area of the height/velocity chart (fig 9-3) exposes the helicopter to a high probability of damage despite the best efforts of the pilot. (2) From conditions of low airspeed and low altitude, the deceleration capability is limited, and caution should be used to avoid striking the ground with the tail rotor. Initial collective reduction will vary after an engine malfunction dependent upon the altitude and airspeed at the time of the occurrence. For example, collective pitch must not be decreased when an engine failure occurs at a hover in ground effect; whereas, during cruise flight conditions, altitude and airspeed are sufficient for a significant reduction in collective pitch, thereby, allowing rotor rpm to be maintained in the safe operating range during autorotational descent. At high gross weights, the rotor may tend to overspeed and require collective pitch application to maintain the rpm below the upper limit. Collective pitch should never be applied to reduce rpm below normal limits for extending glide distance because of the reduction in rpm available for use during autorotational landing.*

NOTE: If time permits, during the autorotative descent, transmit a "May Day" call, set transponder to emergency, jettison external stores, and lock shoulder harness.



MB **Figure 9-3 Height Velocity Diagram**

1.18.2 *Extracts from the CAR 2011 as amended*:

127.09.1 *General*

An operator shall not operate the helicopter unless such helicopter is maintained in accordance with the regulations in Part 43.

127.09.3 *Maintenance contracted to approved aircraft maintenance organisation*

If maintenance on any helicopter operated under this Part is carried out by the holder of an aircraft maintenance organisation approval with the appropriate rating issued in terms of Part 145, the operator of the helicopter shall ensure that all contracted maintenance is carried out in accordance with the regulations in Part 43.

127.09.4 *Operator's maintenance responsibilities*

(1) An operator shall establish procedures acceptable to the Director that ensure—

(a) each helicopter they operate is maintained in an airworthy condition;

(b) the operational and emergency equipment necessary for an intended flight are serviceable; and

(c) the Certificate of Airworthiness of each helicopter they operate, and any appropriate special conditions, remains valid.

(2) The operator shall not operate a helicopter unless it is maintained and released to service by an organisation approved in accordance with Part 145 in the manner referred to in regulation 127.09.3.

(3) The operator shall be resourced sufficiently to ensure that all maintenance is carried out in accordance with the maintenance control manual referred to in regulation 127.09.5.

(4) The operator shall ensure that the maintenance of its helicopters is performed in accordance with the maintenance programme referred to in regulation 127.09.2.

43.04.2 *Requirements for certifying release to service*

No person shall certify an aircraft or aircraft component for release to service after maintenance unless such maintenance has been carried out in accordance with the provisions of this Part and, in respect of such maintenance, the aircraft or aircraft component is fit for release to service.

Applicability

137.01.1 *(1) This part applies to—*

(a) aircraft engaged in commercial or non-commercial agricultural or fire-fighting operations within the Republic;

(b) aircraft registered in the Republic and engaged in commercial or non-commercial international agricultural or international fire-fighting operations;

(c) persons acting as flight crew members of the aircraft operated in terms of this Part;

(d) foreign-registered aircraft operated by an air service operator licensed in terms of the Air Services Licensing Act, 1990 or the International Air Services Act, 1993 and engaged in commercial agricultural or commercial fire-fighting operations; and

(e) persons acting as operations personnel and fire-fighting personnel in respect of a fire-fighting operation conducted in terms of this Part.

(2) Unless the context otherwise indicates, the provisions of Part 91, Part 96, Part 121, Part 127, Part 128 and Part 135 apply, with the necessary changes, to an aircraft operated in terms of this Part.

1.18.3 Extracts from an engine technical manual (TM 55-2840-229—23-1)

Starting fuel manifold

Mounted at rear of combustion chamber housing and secured to support cone. Receives fuel from fuel control through starting fuel solenoid valve. Delivers fuel to starting fuel nozzles. Starting fuel nozzles are located at the 2, 4, 8 and 10-o'clock positions in rear of combustion chamber housing. Nozzles deliver fuel to combustion chamber during starting.

Starting Fuel System

During engine start this system delivers starting fuel to combustion chamber. Actuating primer fuel switch opens starting fuel solenoid valve. This allows fuel from the control to flow through starting fuel manifold, two starting fuel nozzles, and into combustion chamber where it is ignited by two igniter plugs. When N1 reaches sufficient speed, ignition system is deenergized. Solenoid valve closes and stops flow of starting fuel. Starting fuel nozzles are self-purging and automatically remove excess fuel. At low ambient temperatures, JP-5 fuel may cause slow engine starts.

1.19 Useful or Effective Investigation Techniques

1.19.1 None.

2. ANALYSIS

2.1. General

From the evidence available, the following analysis was made with respect to this accident. These shall not be read as apportioning blame or liability to any particular organisation or individual.

2.1.1 The pilot was initially issued a Commercial Pilot Licence (CPL) Helicopter with the type endorsed on it on 18 July 2005. The pilot's last validation was on 30 November 2018 with an expiry date of 31 March 2020. The pilot had a total of 3 204.7 hours on helicopters, of which 194.9 were on the helicopter type. The pilot had an aviation medical certificate issued on 30 November 2018 with an expiry date of 30 November 2019, and with corrective lenses restriction. Records indicated that the pilot was licensed and qualified to undertake the flight.

2.1.2 The pilot took off from Letaba Air Base on a fire-fighting mission to Woodbush Forest Reserve. As per the eyewitness' video evidence, there was black smoke exiting from the rear of the engine exhaust during start-up, increase in speed, and take-off/climb out phases. The largest emission of black smoke could be seen during climb out phase. After turning on course for Woodbush Forest Reserve, the helicopter had difficulty climbing. Thereafter, the engine lost power and the pilot elected to do an emergency landing on an open field; the helicopter landed hard on its skids.

2.1.3 The last engine overhaul was conducted on 19 December 2012, and combustion chamber liner was removed for inspection but was not changed during this overhaul. During this engine overhaul, the fuel manifold was overhauled. The manufacturer had issued a Service Bulletin (SB) No. *T53-L-13B-0001* which requires a 600-hour overhaul of the fuel manifold. The manifold had a leak due to a damaged seal after operating for 449.9 hours since its last overhaul on 19 December 2012, thus, it had not reached its operating limits. The leak in the fuel manifold was due to both the independent primary and secondary systems engaging at the same time during the engine start sequence. It is also probable that a leak in the fuel manifold resulted in the four starting fuel nozzles operating in both the primary and secondary systems, thus, excessive fuel entered the combustion chamber during engine start. The operation of both primary and secondary systems at engine start had resulted in the combustion chamber having excess fuel during engine starting phase, which led to high temperatures at N1 speed of 13% with little to no protection of the combustion chamber lining and the first stage gas producer nozzle assembly. As a result, they failed due to exposure to temperatures above the design limits, thus, leading to an engine failure.

2.1.4 The manufacturer's report stated that: "*…except the air bleed schedule which was low and out of limits due to the external adjustment made for the engine requirement as well as 100 degree accel and face cam schedule slightly high and out of limits due to RPM limits on droop setting because of where the take-off trimmer was set."* This indicates that the engine had a possible difficulty in starting, resulting in lack of ignition during the starting sequence.

2.1.5 The requirements of Service Information Letter (*SIL) No. D201903000027* issued on 1 April 2019 are not mandatory and, at the time of the accident, the engine had not reached 300 hours in operation after the issuance of the SIL.

2.1.6 The report submitted by the manufacturer through the NTSB accredited representative indicated that the failure of the first stage nozzle was caused by vibration, however, the cause of the damage in the engine was a result of excessive heat or temperatures which were above the design limits. The cause for the non-uniform interference fit between the first gas producer inner transition liner and the combustion chamber liner could not be determined. Following the review of evidence, it is probable that the leak in the fuel manifold caused high temperatures during repetitive engine start cycles, which caused fatigue damage and the development of oxidation in the first stage nozzle assembly, thus, resulting in engine failure and an unsuccessful forced landing.

2.1.7 Although the manufacturer's technical report could not determine the cause of the engine failure, it is probable that the engine was periodically started at high temperatures, and as a result of not being monitored during engine start, led to the development of fatigue cracks and the subsequent internal failures.

3. CONCLUSION

3.1. General

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

To serve the objective of this investigation, the following sections are included in the conclusions heading:

- **Findings –** are statements of all significant conditions, events or circumstances in this accident. The findings are significant steps in this accident sequence, but they are not always causal or indicate deficiencies.

- **Causes –** are actions, omissions, events, conditions, or a combination thereof, which led to this accident.
- **Contributing factors –** are actions, omissions, events, conditions, or a combination thereof, which, if eliminated, avoided or absent, would have reduced the probability of the accident or incident occurring, or mitigated the severity of the consequences of the accident or incident. The identification of contributing factors does not imply the assignment of fault or the determination of administrative, civil or criminal liability.

3.2. Findings

3.2.1 The pilot was initially issued a CPL (H) with the type endorsed on it on 18 July 2005. His last validation was on 30 November 2018 with an expiry date of 31 March 2020. The pilot had an aviation medical certificate issued on 30 November 2018 with an expiry date of 30 November 2019, and with corrective lenses restriction.

3.2.2 This was a fire-fighting flight conducted in VMC weather from Letaba Air Base to Woodbush Forest Reserve. According to the eyewitness' video footage, black smoke was seen coming from the engine exhaust during start-up, increase in speed, and take-off/climb out phases. Thereafter, the engine lost power and the pilot elected to undertake an emergency landing. The helicopter landed hard.

3.2.3 The engine lost power because of a vibration fatigue failure of the first gas producer inner transition liner. The fatigue failure occurred due to a non-uniform interference fit between the first gas producer inner transition liner and the combustion chamber liner. The failure led to an over temperature and damage to the engine to a point that it could no longer provide the required power to sustain flight.

3.2.4 The aircraft had enough fuel for the planned flight.

3.2.5 The aircraft had a Certificate of Registration (C of R) issued on 9 July 2012.

3.2.6 The aircraft had a Certificate of Airworthiness (C of A) initially issued on 23 December 2015 with an expiry date of 31 December 2019.

3.2.7 The last Phase 1 inspection was conducted on 28 November 2018 at 9 240.40 hours. The helicopter was issued a Certificate of Release to Service (CRS) on the same day, with an expiry date of 1 September 2019 or at 9 390.40 hours, whichever occurs first. The aircraft had accumulated a further 38.7 hours since the last Phase 1 inspection.

3.2.8 The AMO that performed the last MPI on the aircraft had a valid AMO approval certificate issued on 13 December 2018 with an expiry date of 12 December 2019.

3.2.9 The requirements of Service Information Letter (*SIL) No. D201903000027* issued on 1 April 2019 are not mandatory and, at the time of the accident, the engine had not reached 300 hours in operation after the issuance of the SIL.

3.2.10 Although the manufacturer's technical report could not determine the cause of the engine failure, it is probable that the engine was periodically started at high temperatures, and as a result of not being monitored during engine start, led to the development of fatigue cracks and the subsequent internal failures.

3.3. Probable Cause/s

3.3.1 Although the manufacturer's technical report could not determine the cause of the engine failure, it is probable that the engine was periodically started at high temperatures, and as a result of not being monitored during engine start, led to the development of fatigue cracks and the subsequent internal failures.

Contributory factor:

3.3.2 None.

4. SAFETY RECOMMENDATIONS

4.1. General

The safety recommendations listed in this report are proposed according to paragraph 6.8 of Annex 13 to the Convention on International Civil Aviation and are based on the conclusions listed in heading 3 of this report; the AIID expects that all safety issues identified by the investigation are addressed by the receiving States and organisations.

4.2. Safety Recommendation/s

4.2.1 None.

5. REFERENCES USED IN THE REPORT

5.1 Bell UH-1H Pilot Operating Handbook

5.2 Engine teardown report from Honeywell

This Report is issued by:

Accident and Incident Investigations Division

South African Civil Aviation Authority

Republic of South Africa