NATIONAL TRANSPORTATION SAFETY BOARD
OFFICE OF AVIATION SAFETY
WASHINGTON, D.C. 20594

August 18 - 25, 2014

POWERPLANTS GROUP CHAIRMAN'S ENGINE TEARDOWN REPORT

NTSB ID No.: CEN-14-LA-278

A. ACCIDENT

Location:	Duluth, Minnesota
Date:	June 7, 2014
Time:	1123 Central Daylight Time
Aircraft:	Lancair IV, Registration: N86NW

B. POWERPLANTS GROUP

Group Chairman:	Harald Reichel National Transportation Safety Board Washington, DC
Member:	Lubomir Strihavka Air Accident Investigation Institute Prague, Czech Republic
Member:	Sam Farmiga GE Aviation Cincinnati, Ohio

Member: Zuzana Sekeresova
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C. SUMMARY

C.1 Accident Summary

On June 7, 2014, about 1123 central daylight time, an experimental, amateur-built Lancair IV, N86NW, was destroyed when it impacted Lake Superior after departing from the Duluth International Airport (KDLH), Duluth, Minnesota. The pilot, the sole occupant, received fatal injuries. The airplane was registered to A.O. Engineering Inc. and operated by the pilot under the 14 Code of Federal Regulations Part 91 as a personal flight. Marginal visual meteorological conditions prevailed at the time of the accident, and an instrument flight rules (IFR) flight plan was filed.

The airplane departed KDLH about 1115, and was en route to Goose Bay (CYYR), Newfoundland, Canada. The airplane departed KDLH and was cleared direct to Thunder Bay (YQT) during the initial climb to altitude on a northeasterly heading. The airplane climbed to about 6,600 feet above mean sea level (msl), and appeared to be turning to the right on a more southbound course. The pilot was again cleared direct to YQT. The airplane continued to descend and radar contact was lost about 7 nautical miles (nm) east of KDLH at 2,500 feet msl. A low altitude alert was provided and the airplane was instructed to climb to 3,000 feet msl; however, there were no radio transmissions from the pilot. The airplane impacted Lake Superior about 1 nm offshore from Brighton Beach, in Duluth, Minnesota.

The airplane wreckage was located in 137 feet of water. The body of the pilot was retrieved from the wreckage on July 9, 2014.

After the recovery from the water, the engine was removed from the airframe and a cursory inspection performed. The engine and propeller were subsequently packed in one wooden box, sealed and shipped to the GE Aviation Czech (GEAC) factory in Prague, Czech Republic, where it was stored until the investigation began. The propeller was transferred to the Avia factory facility in Prague, Czech Republic for a teardown examination. The team met at the Walter facility on August 19, 2014 to (a) teardown and examine the propeller at the Avia facility, (b) teardown and examine the engine at the Walter facility and (c) test, if possible and then teardown the FCU at the Jihostroj facility at Velesin, Czech Republic.

No pre-existing condition was found on the engine, propeller or fuel control unit that would have prevented normal operation of the powerplant.

D. DETAILS OF THE EXAMINATION

D.1 Engine Information

D.1.1 Engine History

The accident engine was originally built as a Walter M601M, serial number (S/N) 921002M and was manufactured on May 15, 1992. It was subsequently rebuilt at Walter company in Prague, Czech Republic and reconfigured as a Walter XM601E-Prototype with a new serial number of 921012EX in 2003 identifying it as being manufactured specifically for the Lancair installation. With the purchase of the Walter Company by GE, the engine is a GE-Walter, Model XM601E-Prototype.

The last logbook entry with a recorded engine time was on September 20, 2013 stating that the engine had operated for 666.3 hours. The last recorded cycle count was 452 cycles on March 5, 2009.

According to the Walter Company, the Time Between Overhaul (TBO) limits of the M601 engine are either 2000 hours, 2250 cycles, or 5 years, whichever comes first. Per the GEAC maintenance plan, the engine is considered to be outside its TBO calendar limit, which occurred sometime in 2008 or 2009.

D.1.2 Engine Description

The GE/Walter XM601E engine is a 2-spool turbo-shaft engine which produces a takeoff power of 560 kilowatts (KW). One power turbine stage drives the propeller through a 2-stage reduction gearbox. The gas generator consists of a compressor section, which has 2 axial, and 1 centrifugal stages driven by a single turbine. The combustion chamber is a reverse-flow annular type. The constant-speed, variable pitch propeller is a double-acting type and is hydraulically controlled. The engine power management system consists of a fuel control unit (FCU), which governs the gas generator, and a propeller governor, which governs the power turbines.

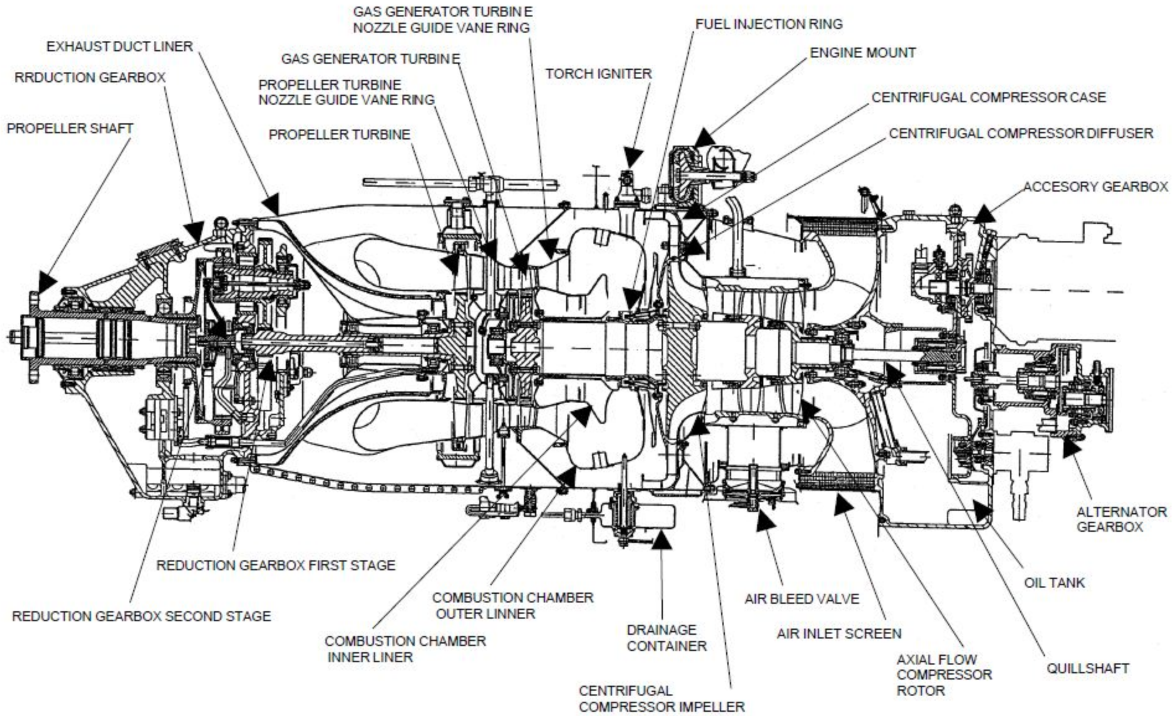

Table 1 - GE/Walter M601 Engine

D.2 Details of the Teardown

D.2.1 General External Condition

The engine was contiguous (Figure 1). All the external tubes, control cables and linkages were present, however, all were deformed and some were broken. The external accessories were present except the propeller governor. The propeller control linkage from the propeller governor to the prop-reversing cambox was present and continuous, however, it was deformed. The lever arm of the propeller governor was still attached to the forward end of the linkage.

The exhaust case was intact, however, it was buckled, with the most severe damage occurring at the 4 to 8 o'clock[1] location. The buckling direction was inward, which caused an overall bending condition of the of the exhaust case, resulting in a lower displacement of the reduction gearbox (RGB) by approximately 2 inches (Figure 2). Additionally, the angle of the gearbox was changed by approximately 20 degrees

[1] All directional references to front and rear, right and left, top and bottom, and clockwise and counterclockwise are made aft looking forward (ALF) as is the convention, unless indicated otherwise. Upstream and downstream references are in relation to gas path flow from the compressor inlet to exhaust. Top is the 12 o'clock position. The direction of rotation of the engine is clockwise. All numbering in the circumferential direction starts with the No. 1 position at the 12:00 o'clock position, or immediately clockwise from the 12:00 o'clock position and progresses sequentially clockwise ALF.

downward. The two exhaust flanges were intact, however, they were deformed and buckled. The two RGB oil transfer tubes below the exhaust case were bent inwards and partially crushed. The inter-turbine temperature (ITT) probes were still installed into the exhaust case, however, the electrical connections were separated from two ITT probes.

The 2-segment compressor/combustor or gas generator (GG) case was intact, however, it was buckled and deformed inwards in the section between 3 and 7 o'clock. The inlet screen was deformed inward and formed over the air inlet struts from the 3-9 o'clock location.

The accessory gearbox (AGB) was intact and appeared to be undamaged. All the external tubes in the lower quadrant were deformed towards the AGB case surface.

The fuel pump and fuel control unit (FCU) were still attached to the AGB (Figure 3). The oil fill and check hardware was present, secured and undamaged. The starter/generator (S/G) was not returned, however a fractured portion of the male spline from the S/G shaft was still retained in the engine splined S/G input shaft. The S/G mount pad was present, but fractured. The AGB tacho generator was still mounted on the AGB, however it was fractured. The ignitor unit was separated from the engine flange, but it was still loosely restrained by the ignitor cables.

The sheet metal firewall assembly was intact, however it was bent and deformed. At the 12 to 2 o'clock position, it was bent forward, while at the 4 to 8 o'clock position, it was crushed inward.

D.2.1.1 Filters and Chip Detectors

The RGB scavenge and pressure oil filters were removed, examined and found to be in a normal clean condition. The fluid exiting the draining RGB was a mixture of water and oil, consistent with immersion in water. The RGB chip detector was intact clean from metal particles and coated with a fine silt-like layer.

The AGB chip detector and magnetic plug were removed, examined and found to be clean of metallic particles. The fluid exiting the draining AGB was a mixture of water and oil, consistent with immersion in water. The AGB bearing last-chance screen was removed and found to be clean. The hydraulic pump pad cover was removed and the spline

The oil filter (Figure 4) and fuel filter (Figure 5) were removed, examined and found to be clean.

D.2.2 Propeller Reduction Gearbox (RGB)

The RGB was generally intact however, the housing was fractured just forward of the aft attachment flange (Figure 6). The propeller governor was no longer attached to the RGB and was not present. The propeller governor mounting threads in the RGB were stripped and the holes were elongated. The RGB was dented at the location of the propeller governor. The RGB was removed from the engine at the SN-1 flange and moved to the gearbox assembly area in the factory for disassembly.

D.2.2.1 1st Stage Reduction Gearset

The aft diaphragm and bearing support was intact (Figure 7), however, there was a through crack from the edge of one bearing housing boss to the outer edge. The quill shaft was intact, however it was bent near the mid-length (Figure 8). The gear teeth were battered, dented and fractured and were still in contact with the 3 planet gears (Figure 9). All three planet gears were intact, however all the teeth were battered, scored, distorted and fractured. The aft roller bearings were intact with only slight external corrosion in some locations, consistent with water immersion.

D.2.2.2 2nd Stage Reduction Gearset

The center diaphragm was intact, however approximately 170 degrees of the outer flange was fractured (Figure 10). The diaphragm was bowed or ‘dished’ slightly aftward, consistent with an axial impact near the center. The three large roller bearings were intact and in good condition. The three center roller bearing outer races were still in the bearing housings, however they were spalled at the locations of their retaining tabs (Figure 11). The quill shaft roller bearing was undamaged.

The ring gear was intact and undamaged (Figure 12), however the front retention lands for the conical prop shaft adapter spline had shiny witness marks around the circumference, consistent with contact against the conical prop shaft adapter spline during an axial impact. The conical prop shaft adapter spline was undamaged, however there were shiny witness marks on the spline teeth aft plane, consistent with contact against the ring gear front retention lands. The propeller shaft appeared to be undamaged (Figure 13), however it was located approximately ½ inch aft of its normal operating location. The propeller shaft roller bearing was intact, however it was no longer retained in the front RGB housing, rather 3 retaining bolts were pulled from the RGB housing and one tab of the bearing race was fractured.

The quill shaft spacer was intact, however it was axially crushed and shortened by approximately 3/8 inch, consistent with an axial impact. The quill shaft aft and center roller and ball bearings could not be turned, however, they still maintained radial integrity and were not removed from the RGB housing.

D.2.2.3 Power Turbine (PT)

The PT assembly was intact, however the hub was rotationally scored on both faces (Figure 14). The scoring on the aft face was consistent with contact against the interstage stator baffle. The scoring on the front face was consistent with contact against the sheet metal of the inner exhaust surface. The leading edges of all the blades were rotationally scored. Additionally, all the blades were bent aft (with respect to the airflow direction). The blade tips were displaced approximately 1 inch aft (with respect to the airflow direction). Three non-consecutive blades were fractured near the mid-span. No evidence of fatigue was found on the fracture surfaces when using a 10X loupe.

D.2.2.4 Power Turbine Nozzle Guide Vane Ring (PTNGVR)

The PTNGVR was intact, however the inner and outer vane platforms and trailing edges of the vanes between 9 and 4 o'clock were rotationally scored with the most heavily scored vanes at the 10:30 o'clock location (Figure 15). The aft (with respect to the airflow direction) surface of the PT stator interstage baffle and the retaining bolt heads were rotationally scored, consistent with contact against the rotating PT hub.

D.2.3 <u>Compressor/Combustor or Gas Generator (GG) Case</u>

D.2.3.1 Compressor/Combustor Case

The combustor case was intact, however, was buckled and deformed inwards in the plane of the torch igniter plugs between 3 and 7 o'clock location. The inlet case was intact and appeared to be undamaged. The inlet screen was deformed inward and formed over the air inlet struts from the 3-9 o'clock location. The right and left torching ignitors were intact and undamaged. The left torching ignitor internal cavity was filled with a fine silt-like material, consistent with water immersion.

D.2.3.2 Air Bleed Valve (ABV)

Before removal, the compressor bleed valve (ABV) was observed to be in a partly open condition (Figure 16). The ABV is fully closed at 93% engine power and is fully open at idle, which is approximately 63%.

D.2.3.3 Gas Generator Turbine (GGT) and GGT Shroud

The GGT was intact, however the blade tips were circumferentially scored with metal transfer evident on the convex sides of the tips (Figure 17), consistent with contact against the GGT shroud. Additionally, there were randomly distributed bright shiny flakes deposited on the convex side of some of the blades (Figure 18), consistent with metal spray[2] condition.

D.2.3.4 Gas Generator Turbine Nozzle Guide Vane Ring (GGTNGVR)

The GGTNGVR was intact, however the GGT shroud was rotationally scored in the plane of the GGT blade plane from 5 to 9 o'clock ALF (Figure 19).

D.2.3.5 Combustor Liners and Slinger Ring

The combustor inner and outer liners were undamaged (Figure 20 & Figure 21). The fuel slinger ring was intact and undamaged.

D.2.3.6 Compressor Rotors and Stator

The compressor rotor, consisting of the two axial compressors and one centrifugal impeller was intact (Figure 22). The 1st and 2nd stage axial compressor blades were intact, however the tips were circumferentially scored consistent with contact against their respective shroud segments. The 1st and 2nd stage axial compressor shrouds were rotationally scored (Figure 23) from the 3 to 8 o'clock location (ALF). The impeller vanes were rotationally scored, consistent with contact against the impeller shroud. The impeller shroud was rotationally scored () from the 3 to 8 o'clock location (ALF), consistent with contact against the rotating impeller.

D.2.4 Accessory Gearbox (AGB)

The AGB was generally intact and undamaged. After the AGB was removed from the engine, the input shaft was rotated and a corresponding rotation was noted in the AGB gear-train, indicating a mechanical continuity and integrity of the system. All the

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[2] Metal Spray – During engine operation, compressor rotors turn at high speeds. Shrouds are stationary, are typically coated with a thick aluminum spray material and are in close proximity to the turning rotors. Impact forces can force these components to contact with each other. During contact, the high speed rotors shaves the soft aluminum material off the shrouds and the engine airflow sends the small shaved particles through the engine. As the aluminum particles enter the combustor, they become molten if there is a flame. The melted particles continue to flow along the air stream and become deposited on the cooler surfaces of the turbine blades and stator vanes. Visually, they appear as silver colored speckles.
The evidence of metal spray is an indication of engine operation; it indicates that there is engine rotation, positive engine airflow, and flame in the combustor.

interior surfaces of the AGB cavity were oil wetted. The AGB was not further disassembled.

E. FUEL CONTROL UNIT (FCU) AND FUEL PUMP

E.1 Fuel Control System Description

The fuel control system of the engine consists of two devices:
- LUN 6290.04-8 fuel pump
- LUN 6590.51-8 fuel control unit.

The fuel pump supplies fuel flow and pressure required by the fuel control unit for satisfying all required functions of the engine requirements.

The fuel control unit features the following sub-system functions: (a) starting circuit; (b) circuit for the metering needle pressure difference control - depending on the flight altitude; (c) automatic speed governing; (c) acceleration and deceleration control; (d) controls for engine power rating setting; (e) protection from the engine exceeding critical parameters; (e) emergency circuit for the control of fuel supply to the engine.

E.2 Fuel Control Unit (FCU)

E.2.1 FCU In Situ

The FCU was generally intact. The FCU input linkage from the FCU input shaft to the cambox was intact but deformed. The FCU power input shaft was present and could be rotated. The FCU manual over-ride (MOR) input shaft and lever were present. The input lever was bent, however the shaft could be rotated. The prop reversing feedback shaft could be rotated. The external prop cambox assembly was present but was deformed. The electrical connector for the engine start limiter was fractured. The electrical connector for the FCU emergency over-ride solenoid was fractured.

E.2.2 FCU History

The FCU was a Jihostroj, model LUN6590.05.8 and S/N 03 1 005 and was manufactured on March 3, 2003. It had not been repaired or overhauled at the Jihostroj factory since new. According to the Jihostroj Service Manual, the time between overhaul (TBO) is 3000 hours, or 5 years, whichever comes first. At the time of the accident, the FCU had been in service for approximately 11 years, and there was no record of its time in operation.

E.2.3 FCU Teardown

The FCU was transferred to the Jihostroj factory in Velesin, Czech Republic where the FCU was disassembled in the factory repair facility (Figure 25 & Figure 26).

The FCU was not functionally tested because the body of the emergency power solenoid was fractured and fluid was seen leaking from the fracture. Additionally, the case drain fitting was bent, the pressure regulator was fractured as well as the FCU trim adjuster screw No. 32 and the FCU trim adjuster screw No. 39 were bent due to impact. The fuel supply connector on the fuel pump for the start torching ignitors was also fractured.

Jihostroj lock-wires all the adjustor screws of the FCU during manufacturing and then places a unique lead security crimped seal on the lock wire to identify unauthorized modification. The following adjustors did not have the original crimped seal: #45 - adjustment screw for the electrohydraulic transducer blade relay, # 47 – emergency power adjustment screw (Note: the separate over-ride usage witness disk was still intact (Figure 27), indicating that maximum over-ride power had not been used), #39 – Starting unit pressure adjustment screw, #9 – Main metering plunger pressure drop adjustment screw.

The following main components were disassembled and examined:

1) Main metering valve (Figure 28)
2) Flyweight governor and input shafts (Figure 29)
3) Acceleration restrictor
4) Flapper nozzle or case pressure regulator
5) Ambient pressure compensator
6) Ng combiner circuit including the power lever input
7) Fuel shut off & emergency circuit
8) Emergency circuit actuator (Figure 30).

In all cavities, water could be seen mixed with the fuel, causing a general condition of mild surface corrosion, however all components were free to rotate or operate.

The two internal accelerator valve filters and the internal teeter valve filters were examined and found to be free of debris (Figure 31 & Figure 32).

The flapper nozzle cover plate had a yellow anti-tamper paint on the four attachment screws, which is not an original feature, indicating that the plate had been removed at some time during service (Figure 26). Upon inspection, it was found that the internal serialized rubber/fabric diaphragm was the original installed, however it had been improperly re-installed, causing a tear and extrusion (Figure 33) of the external rubber ridge. A leak in this diaphragm would not result in a sudden loss of power.

No pre-existing condition was found in the FCU that may have prevented normal operation (Figure 34).

E.3 Fuel Pump

E.3.1 Fuel Pump In Situ

The fuel pump was in location on the AGB, however one mounting lug, that nearest the S/G, of the flange as well as part of the housing near the lug were fractured.

E.3.2 Fuel Pump History

The fuel pump was manufactured on November 30, 1990, and was returned to the factory twice: once for a functional check on May 2001, and second, for a repair on April 2003 at which time it had accumulated 317 hours. According to the Jihostroj Service Manual, the TBO is 3000 hours, or 5 years, whichever comes first.

E.3.3 Fuel Pump Teardown

The fuel pump was disassembled and the examination found that in the inlet, gear pump (Figure 35) and outlet cavities, water could be seen mixed with the fuel, causing a general condition of mild surface corrosion (Figure 36), however all components were free to rotate and no pre-existing condition was found that may have prevented normal operation.

F. PROPELLER

The propeller was received in the same box as the engine at the GEAC facility in Prague, Czech Republic, where it was stored until the investigation began. The propeller was transferred to the Avia Propeller factory facility in Prague, Czech Republic for a teardown examination which occurred on August 19, 2014.

F.1 Description and History

The propeller, part number V508 / 84 and serial number 140651298, was manufactured by the Avia Propeller company in the Czech Republic and is a three bladed design with a propeller diameter of 84 inches. The material of the hub is steel, while the propeller blades are of aluminum. The blade pitch is controlled by a double acting hydraulically actuated piston within the hub. (See Table 2 – Cross Section of Avia Propeller).

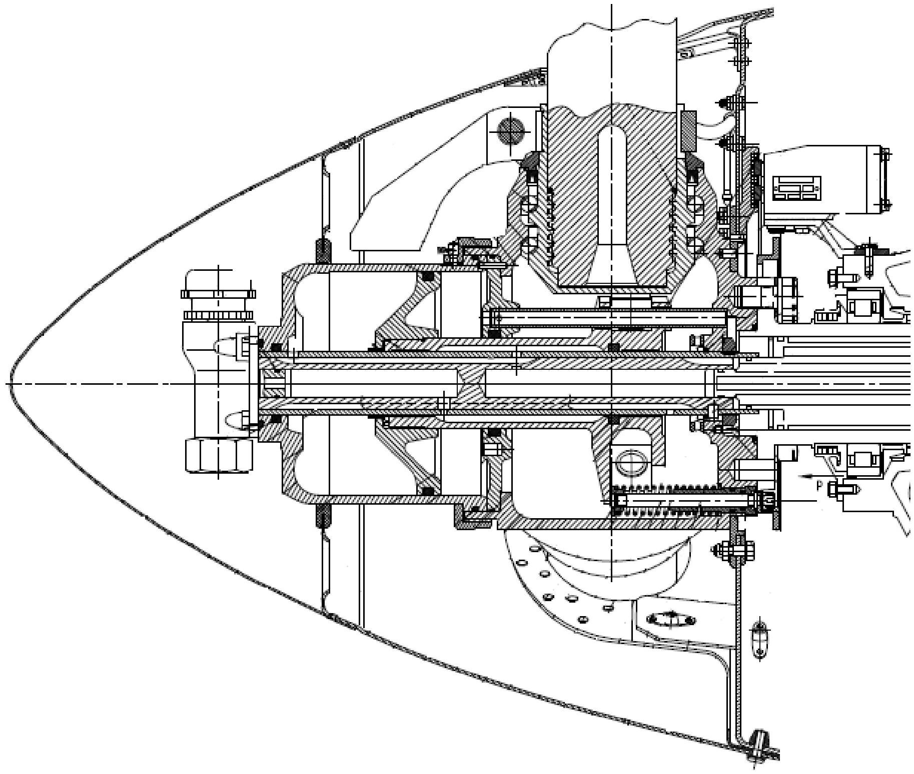

Table 2 – Cross Section of Avia Propeller

F.2 Details of the Teardown

The propeller blades are numbered and marked at the factory: 1, 2 & 3 and are inserted into the matching numbers on the hub.

Blade No. 1 was still inserted in the hub and could not be unscrewed from the blade bushing. Two blades, Nos. 1 and 2 were bent backwards at the mid-span to bend angle of approximately 90 degrees, with no evidence of twisting. Blade No. 3 appeared to be straight, however when compared to an exemplar blade, a slight bend was evident. Blade No. 3 was installed in a factory blade measurement tooling where the slight bend was confirmed. No evidence of blade twisting deformation was found.

The hub was disassembled and the inner mechanism was examined. The No. 1 blade pitch actuation flange on the piston fork was bent (Figure 37, Figure 38 & Figure 39) and impact damaged from the pitch change block. There was corresponding damage to the No.1 blade bushing (Figure 40). The No. 1 blade piston guide rod was slightly dented at the dimension 28.78 millimeters (mm) from the aft end. The dent could only have occurred during an impact that causes the piston fork flange to bend. With this dent dimension, Avia calculated the corresponded to blade pitch to be 15 degrees, a low angle corresponding to the hydraulic low pitch stop. This, in turn, corresponds to a lower power setting of the engine.

Harald Reichel
Aerospace Engineer – Powerplants

Figure 1 – Engine as Recieved

Figure 2 – Engine as Recieved

Figure 3 – Engine – Aft View

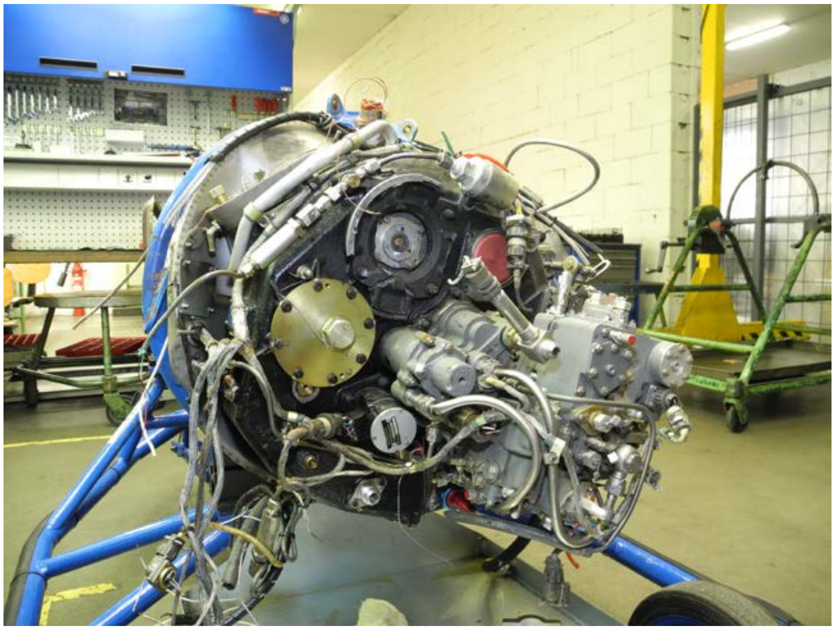

Figure 4 – Oil Filter

Figure 5 – Fuel Filter

Figure 6 – RGB Removed From Engine

Figure 7 – Aft Diaphragm And Bearing Support

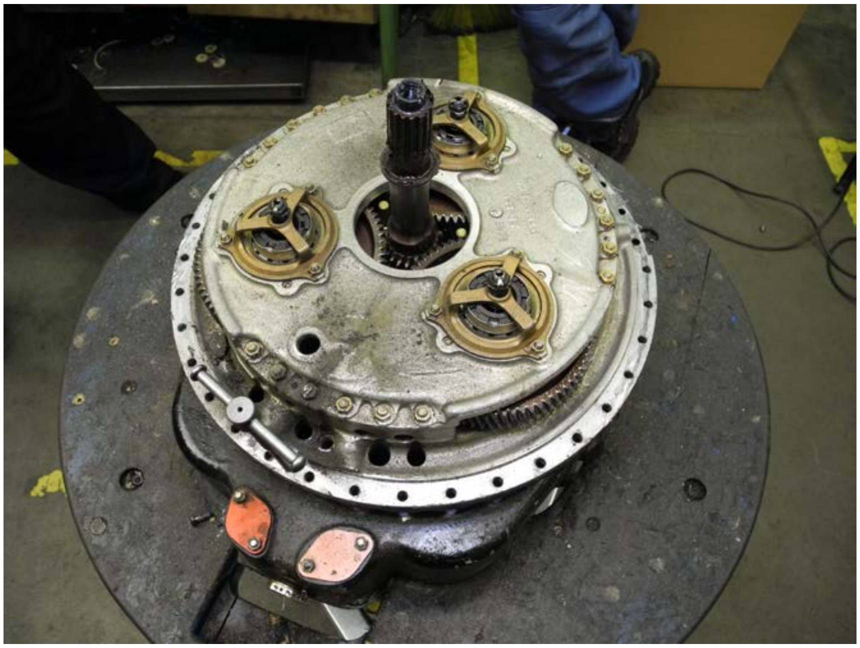

Figure 8 – Quill Shaft - Bent

Figure 9 – 1st Stage Reduction Gear mesh

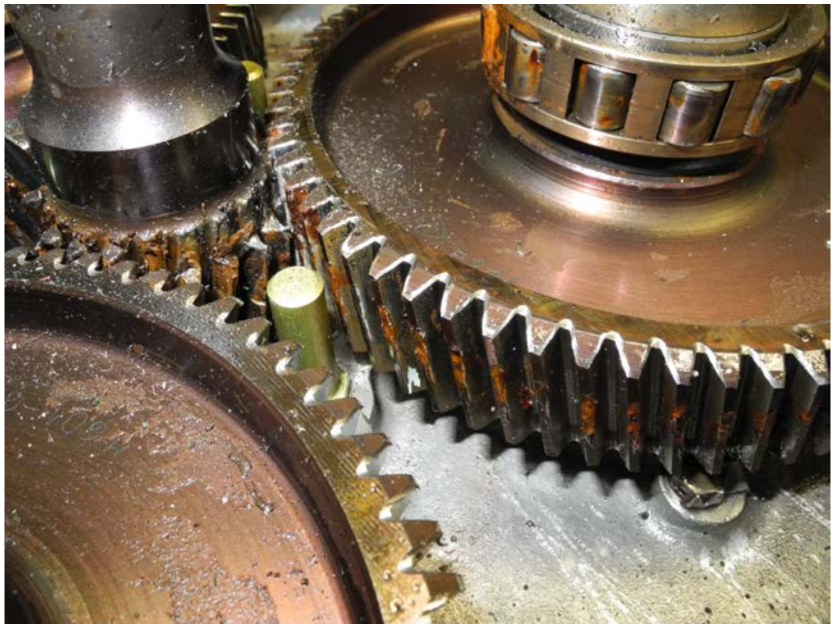

Figure 10 – Center Diaphragm – Fractured Flange

Figure 11 – Spalled Bearing Outer Races

Figure 12 – Ring Gear - Installed

Figure 13 – Propeller Shaft – Rear View

Figure 14 – Power Turbine – Aft View

Figure 15 – Power Turbine Nozzle Guide Vane Ring (PTNGVR)

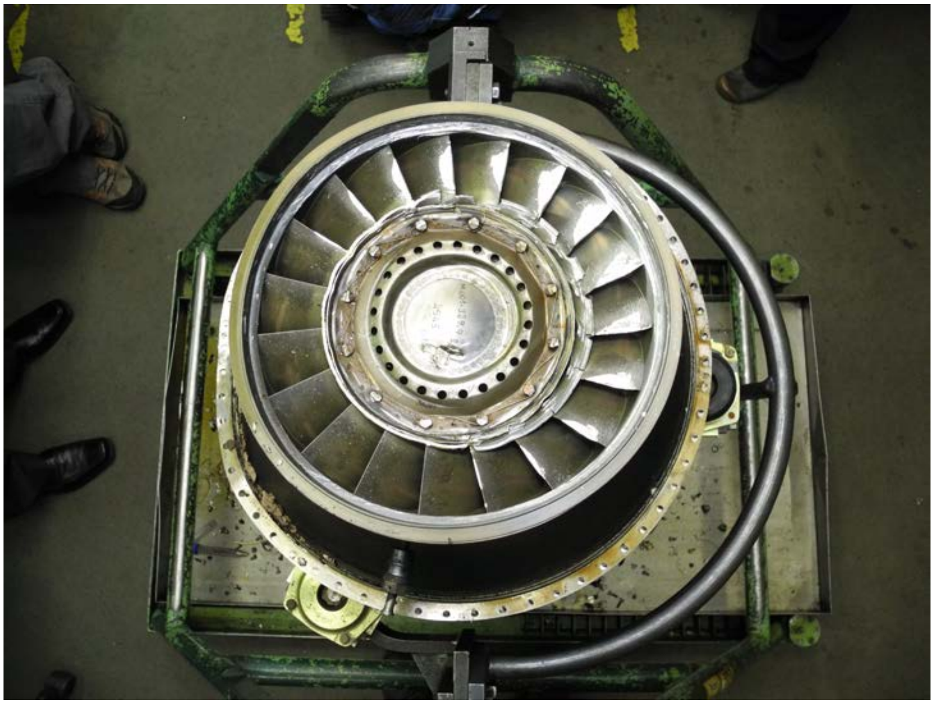

Figure 16 – Bleed Valve – Partially Open

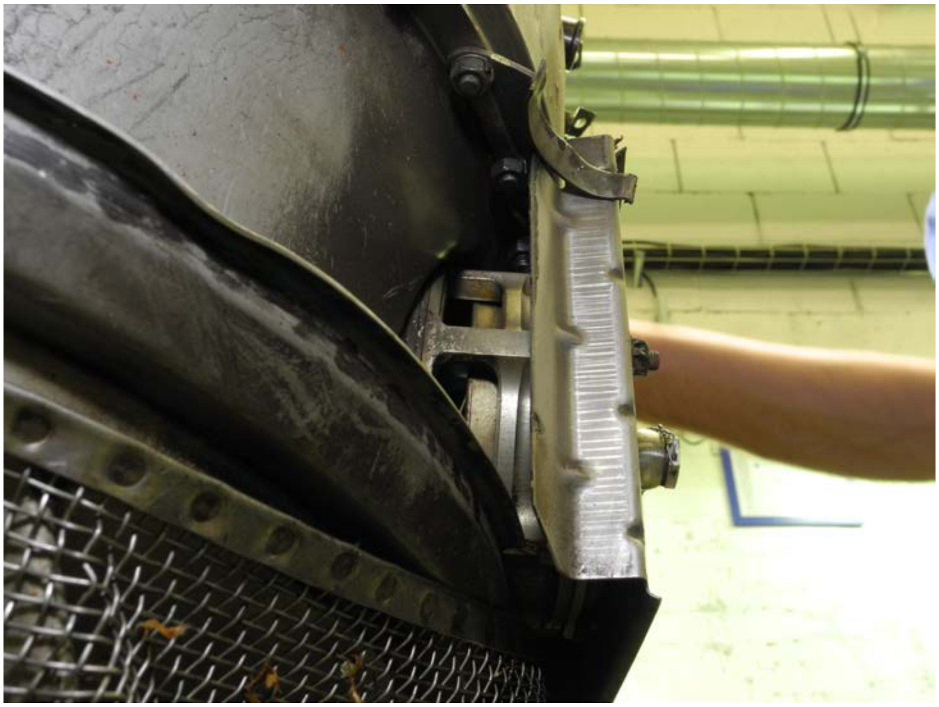

Figure 17 – Gas Generator Turbine Blade Tips – Rotationally Scored

Figure 18 – Gas Generator Turbine Blades

Figure 19 – Gas Generator Turbine Nozzle Guide Vane Ring (GGTNGVR)

Figure 20 – Outer Combustor Liner

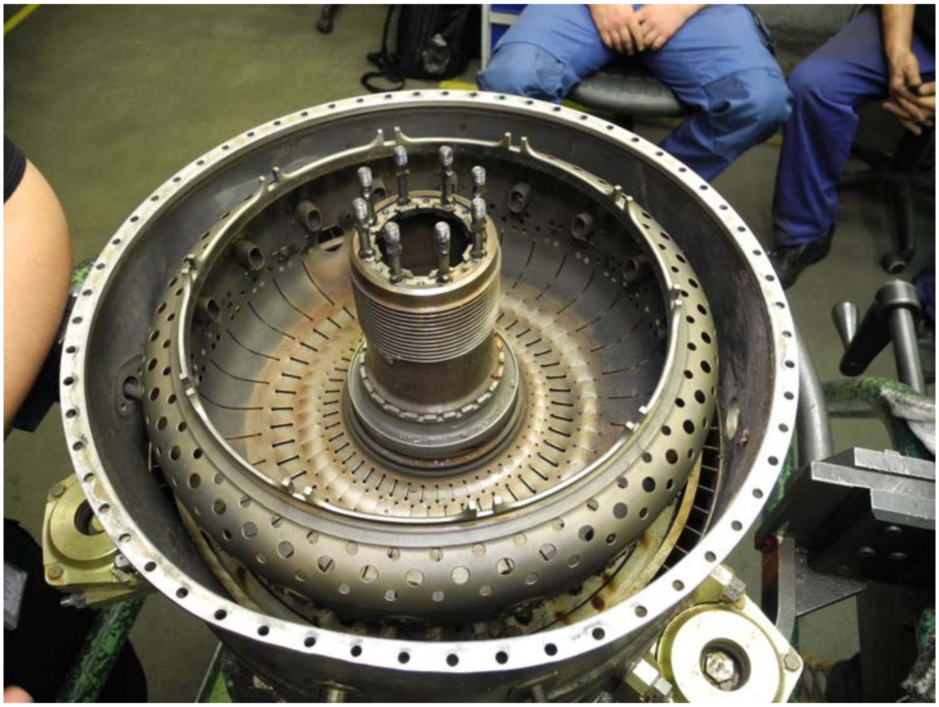

Figure 21 – Inner Combustor Liner & GGTNGVR

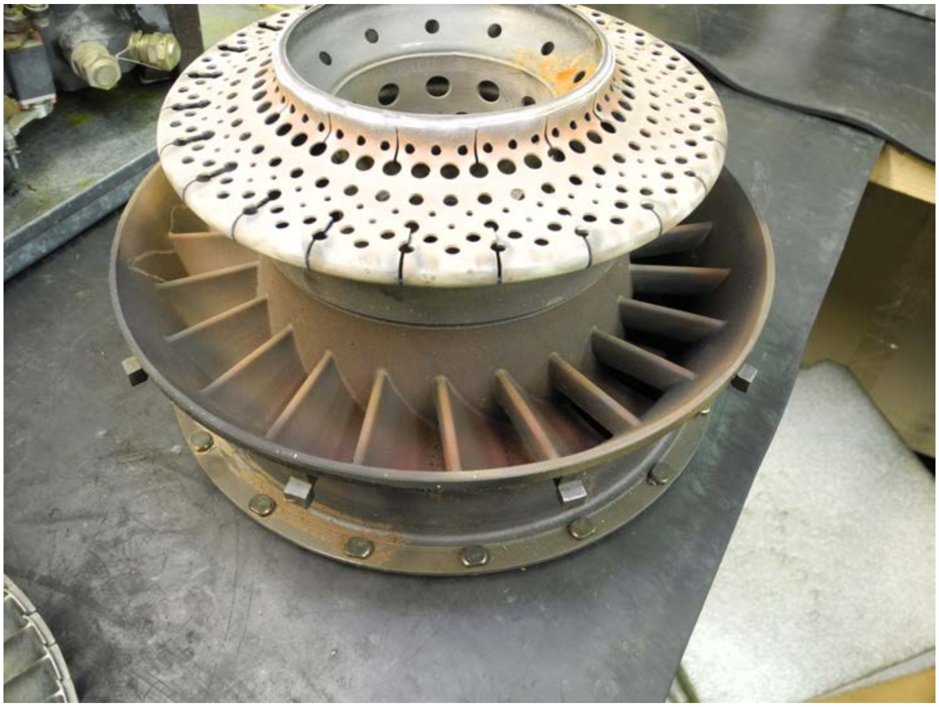

Figure 22 - Compressor Rotors

Figure 23 - 1st and 2nd Stage Axial Compressor Shrouds

Figure 24 - Impeller Shroud - Rotationally Scored

Figure 25 – FCU Prior to Teardown

Figure 26 – FCU Prior to Teardown

flapper nozzle cover plate had a yellow anti-tamper paint

Figure 27 - Over-Ride Usage Witness Disk

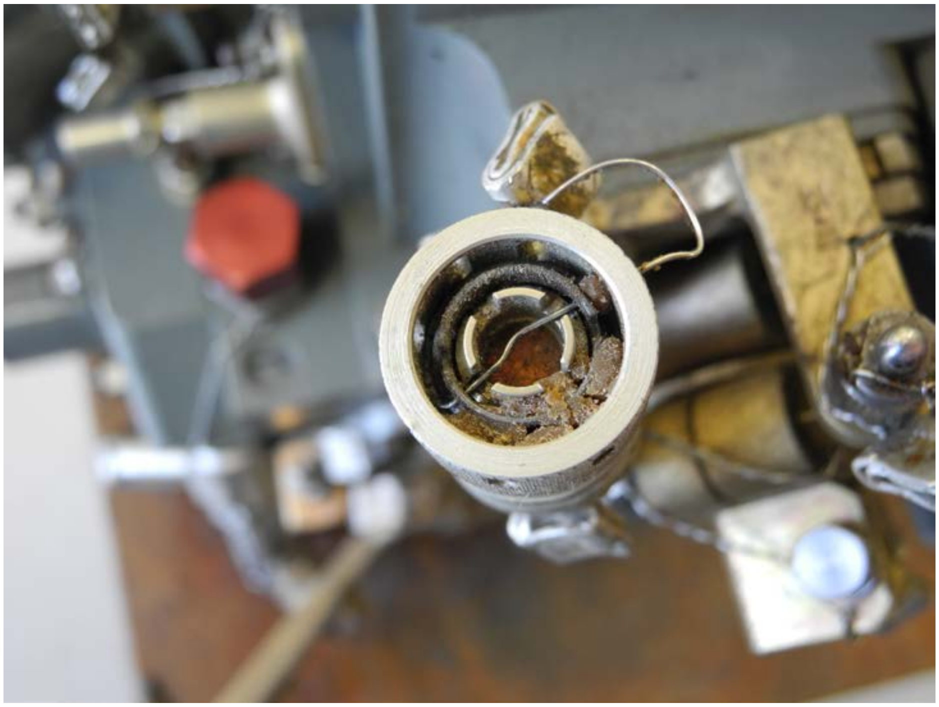

Figure 28 – Main Metering Valve

Figure 29 - Flyweight Governor and Input Shafts

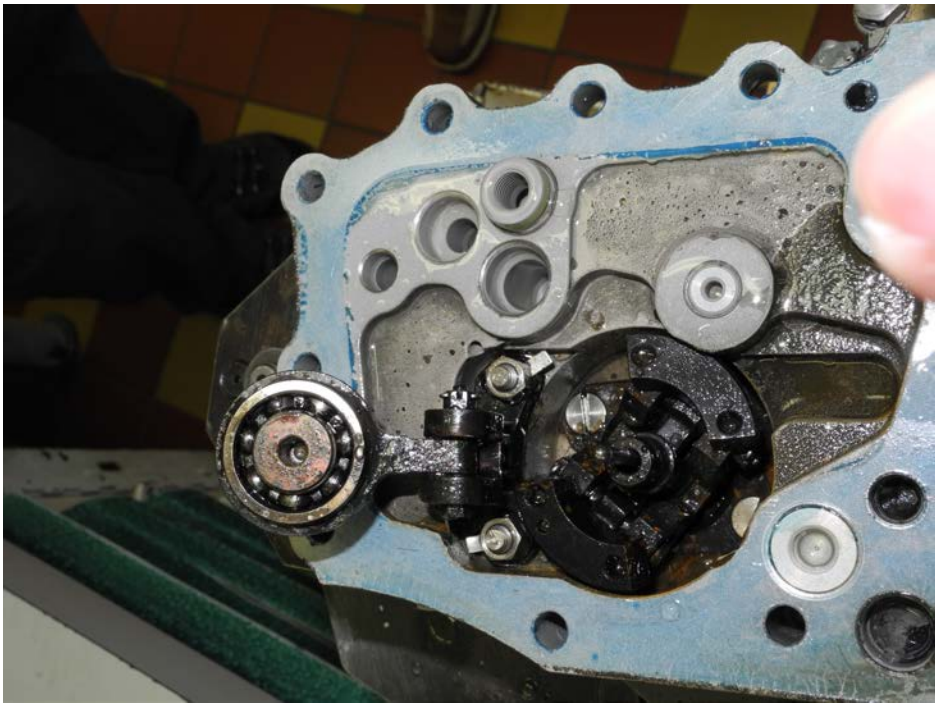

Figure 30 - Emergency Circuit Actuator Valve

Figure 31 - Accelerator Valve Filter (1 of 2)

Figure 32 - Teeter Valve Filter

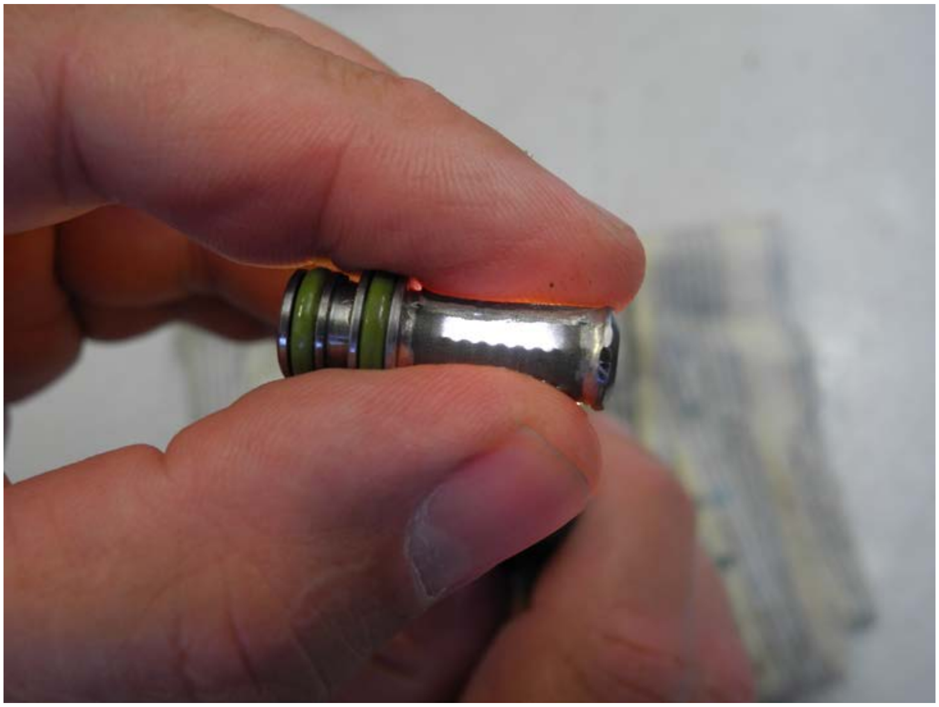

Figure 33 – Flapper Nozzle Rubber/Fabric Diaphragm

Figure 34 – Complete FCU Components

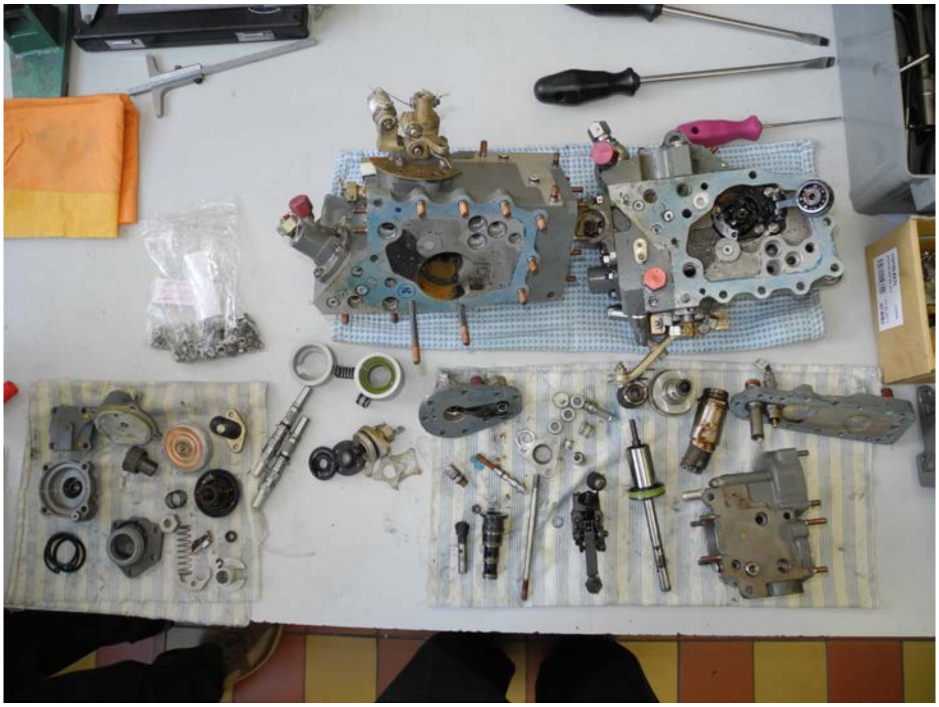

Figure 35 – Fuel Pump Gear Cavity

Figure 36 – Complete Fuel Pump Components

Figure 37 – No. 1 Blade Pitch Actuation Flange On The Piston Fork

Figure 38 - No. 1 Blade Pitch Actuation Flange On The Piston Fork

Figure 39 - No. 1 Blade Pitch Actuation Flange On The Piston Fork

Figure 40 - Corresponding Damage to the No.1 Blade Bushing