NATIONAL TRANSPORTATION SAFETY BOARD
Office of Aviation Safety
Washington, D.C. 20594

November 20, 2018

POWERPLANTS GROUP CHAIRMAN'S FACTUAL REPORT

NTSB ID No.: WPR17FA179

A. ACCIDENT

Location:	Rio Linda, California
Date:	August 3, 2017
Time:	1503 Pacific Daylight Time
Aircraft:	Michaelian, Lancair IV-TP, N420M

B. POWERPLANTS GROUP

Group Chairman	Harald Reichel National Transportation Safety Board Washington, DC
Member:	Quentin Cook President, Power Turbine Technologies Deland, Florida
Member:	Sam Farmiga Manager, Flight Safety, GE Aviation Cincinnati. Ohio

C. SUMMARY

C.1 Accident & Investigation Summary

On August 03, 2017, at 1503 Pacific daylight time, a single-engine experimental Michaelian Lancair IV-TP, N420M, impacted a residential area in Rio Linda, California following a loss of engine power while on approach to McClellan Airfield, Sacramento, California. The commercial pilot, the sole occupant, was fatally injured; the airplane was substantially damaged. The airplane was registered to Pilot Proficiency Inc. and operated by the pilot under the provisions of 14 Code of Federal Regulations Part 91. The personal flight departed from Auburn Municipal Airport, Auburn, California at 1455 with a planned destination of San Carlos Airport, San Carlos, California. Visual meteorological conditions prevailed, and a flight plan had not been filed; the pilot was receiving flight following advisories.

After the recovery, the engine was stored at Plain Parts facility in Pleasant Grove, California, after which it was placed in a cardboard shipping box and transferred to Turbine Power Technologies (TPT) facilities in Deland, Florida where it was tested and examined. The propeller was not sent with the engine. The team met at the TPT facility on February 21-23, 2018 to test and examine the engine. The engine started and performed correctly; however, the fuel control unit (FCU), despite performing correctly during the engine runs, was found to have an internal leak. Additionally, the propeller governor (PG) was found to be too sensitive during beta operation, resulting in an overspeed condition unless intervened by the operator. When the boost pump was turned off during idle operation, a loss of .5 % gas generator (NG) speed was observed, indicating a possible cavitated condition in the high-pressure fuel pump (FP). No pre-existing condition was found in the engine that may have prevented normal operation.

The FCU, FP and PG were retained, boxed and shipped to the Jihostroj facility at Velesin, Czech Republic where they were tested on April 18-19, 2018. The Jihostroj manufactured, emergency propeller feather pump was not present in this installation. No pre-existing condition was found in the FCU, FP or PG that may have prevented normal operation.

The propeller, which had been stored at the Plain Parts facility in Pleasant Valley, California was examined there on August 7-8, 2018. The propeller blades were in the flat pitch condition at the time of the impact. No pre-existing condition was found in the propeller that may have prevented normal operation.

D. DETAILS OF THE EXAMINATION

D.1 Engine Testing

D.1.1 Engine History

The accident engine was a Diemech M601D (8) Turbine, serial number (S/N) 871020, Series 125/03/03, indicating that the engine was assembled using Walter M601 parts by the Diemech company and was manufactured as the 125th Diemech engine in March 2003. The Walter company is in Prague, Czech Republic and was purchased by GE in 2008. The engine logbook was not shipped with the engine and could not be examined. This engine model was originally designed to be installed on a Let 401 airplane, a twin-engine airplane.

D.1.2 Engine Description

The Diemech built GE/Walter M601D (Figure 1) engine is a 2-spool turbo-shaft engine which produces a takeoff power of 515 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 pump, which supplies the correct fuel pressure as well as filters the fuel, a fuel control unit (FCU), which governs the gas generator, and a propeller governor, which governs the power turbines.

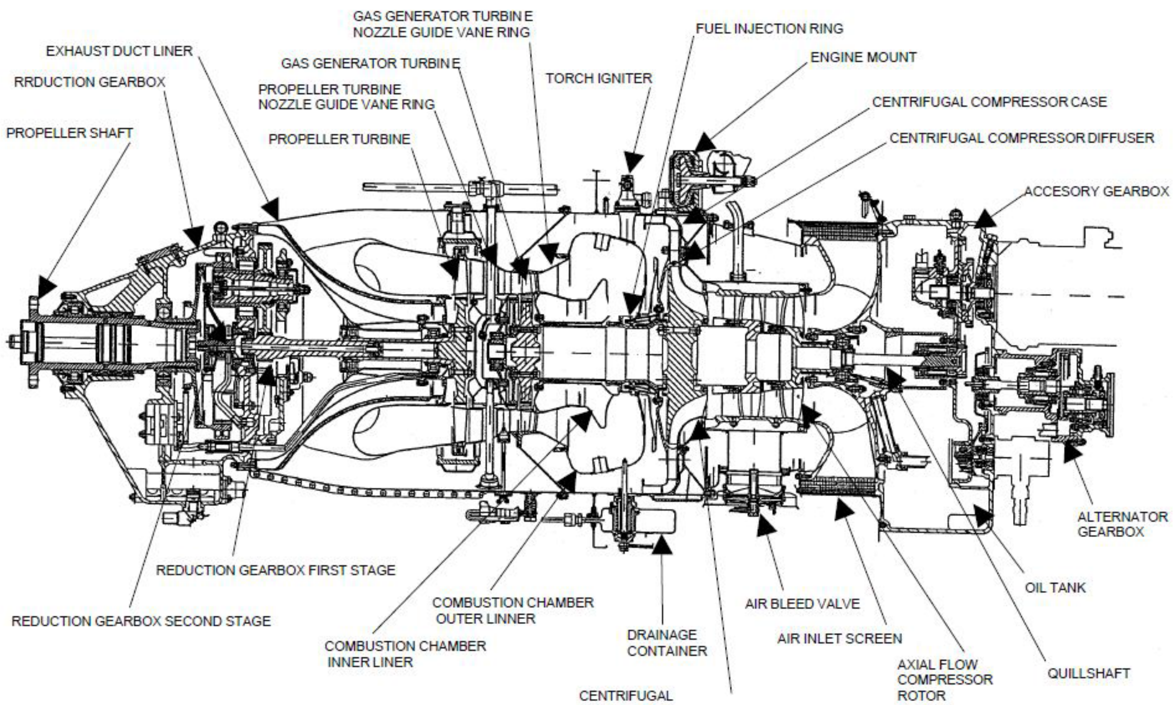

Figure 1 - GE/Walter M601 Engine (Generic)

D.1.3 General External Condition

The engine was shipped in a cardboard box and was resting at an approximately 30-degree angle, intact and contiguous (Photo 1). All the external tubes, control cables and linkages were present and intact. The external engine-related accessories were present; however, the starter/generator was not present. The propeller control linkage from the propeller governor to the prop-reversing cambox was present and continuous. The lever arm of the propeller governor was still attached to the forward end of the prop governor linkage.

The exhaust case was intact and undamaged. One oil transfer tube below the exhaust case was bent inwards and buckled (Photo 2). The inter-turbine temperature (ITT) connectors and boss were still installed in the exhaust case and appeared to be undamaged. The propeller shaft could be turned by hand and the power turbine wheel turned in unison, indicating mechanical continuity in the RGB gearbox. The power turbine blades were examined through the exhaust case and were undamaged (Photo 3). The propeller flange was undamaged (Photo 4).

The 2-segment compressor/combustor or gas generator (GG) case was undamaged as was the inlet screen (Photo 5).

The accessory gearbox (AGB) was intact, attached and appeared to be undamaged. The oil fill port and check hardware were present and undamaged (Photo 5). The fuel pump and fuel control unit (FCU) were still attached to the AGB and appeared to be undamaged (Photo 6). All the tube fittings and connections to and from the FCU and fuel pump were undamaged and secure. An input spline was rotated by hand on the AGB and the 1st stage gas generator compressor blades rotated in unison, indicating mechanical integrity of the AGB.

The ignitor boxes were not returned with the engine however the ignitor cables and torch ignitors were present.

The compressor air bleed valve (ABV) was in location, in the fully open condition and was undamaged and the ABV piston operated freely. The ABV is fully closed at 93% engine power and is fully open at idle, which is approximately 63%. During engine testing, no surges were observed at any time, indicting a properly functioning ABV.

The torque sensor, torque limiter transducers and auto-feather switch were in location and undamaged. All the tube fittings and connections were undamaged and secure. In a single engine application, the auto-feather switch is non-functional.

The sheet metal forward firewall assembly was intact and undamaged, however it was bent and deformed from the 4 to 6 o'clock[1] location (Photo 2). The aft firewall was

[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.

undamaged. The left hand and upper airframe elastomeric engine mounts were fractured, and the inner elastomers were not present, while the right hand was intact (Photo 7).

D.1.4 Fluids, Filters and Chip Detectors

The engine oil level was checked using the dip stick and indicated approximately 6 liters, which is between the acceptable limits of 5.5 liter low and 7 liters high. The oil was clean and a bright straw color. The oil filter was not removed before testing, however in an abundance of caution, the oil was drained and replaced with fresh oil.

D.1.5 Engine Testing on Test Rig

The engine was installed onto the TPT truck frame mounted test rig (Photo 8 & Photo 9). All fuel and oil cooler lines were connected with no technical difficulties. A slave ignitor box and a slave three-bladed, 99-inch diameter AVIA standard test propeller were attached to the engine (Photo 10). The propeller mounted with no technical difficulty. The typical propeller used on the Lancair airplane is an AVIA three-bladed and is 84 inches diameter.

Since one oil transfer tube was deformed (Photo 2), the engine was motored to confirm oil pump integrity and oil line flow after the oil was changed. After 3 dry motoring cycles, it was confirmed that the internal oil flow was acceptable, and the engine was moved to a remote section of the airport property for testing (Photo 11).

D.1.6 Engine Performance

The engine started normally. The propeller was cycled twice from fine to feather, to purge the propeller piston cavity of air. After an initial idle period, the engine power was increased to 85% power. Acceleration and deceleration behavior were acceptable with no indications of hesitation or stall or flameout.

D.1.7 Controls Performance

The test rig fuel tank and its boost pump, which are both approximately 4 feet below the center line of the engine, pressurizes the fuel to approximately 30 psi at the inlet of the engine-driven high-pressure fuel pump (FP). The boost pump prevents a negative pressure of the fuel at the inlet, which could cause fuel pressure fluctuation as

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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.

well as cavitation damage to the fuel pump. The test rig boost pump was turned off and a corresponding decay of approximately .5% of gas generator RPM (Ng) was noted. When the boost pump was turned on again, a corresponding increase of approximately 0.5% Ng was observed. This was especially noticeable at the idle setting.

When the engine was shut down, fuel was observed to drain from the combustor cavity drain valve, an unacceptable condition which indicates an internal leak within the FCU. To confirm an FCU internal leak, the test rig boost pump was turned on while the engine was stopped, a significant fuel leakage quantity was seen to drain from the combustor drain line.

During ‘beta’ operation, it was observed that the propeller governor (PG) control became ‘aggressive’, causing the propeller RPM to increase quickly to an overspeed condition. This was noticeable with the higher inertia 99-inch slave propeller that was used during engine test, and the comment by the technicians was that the undesirable behavior would be greatly exacerbated if an 84-inch propeller were used.

The FCU, a Jihostroj model LUN6590.03.8 was intact and undamaged. The FCU input drive spline was undamaged. The FCU input linkage from the FCU input shaft to the cambox was intact. The FCU power input shaft with lever and shut-off/manual over-ride (MOR) input shaft with lever were both present, undamaged and could be rotated. The electrical connector for the FCU emergency over-ride solenoid was intact and undamaged.

The fuel pump, a Jihostroj model LUN6290.03-8 was still mounted on the AGB, was intact and undamaged. The fuel pump input drive spline was undamaged.

The propeller governor (PG), a Jihostroj model LUN7815.02-8 was still mounted on the RGB and was undamaged. The PG input drive spline was undamaged.

D.1.8 Engine Testing Summary

No pre-existing condition was found on the engine turbomachinery that would have prevented normal operation.

All three engine control units (FCU, FP and PG) were retained, boxed and shipped to the manufacturer for detailed examination.

D.2 Engine Control System Examination & Testing

The three control units were retained, boxed and shipped to the Jihostroj facility at Velesin, Czech Republic where the controls investigation team met on April 18-19, 2018 to perform the examination and test. The Jihostroj manufactured, emergency propeller feather pump was not present in this installation

D.2.1 General Airframe Engine Control Description (See Figure 2)

The fuel pump (FP), fuel control unit (FCU), propeller governor (PG) and propeller are inter-connected via linkages, push-pull cables, and pressurized fluid passageways, and act in unison to manage the engine power in varying conditions. The pilot uses three levers, that are connected to the engine control components by push-pull cables, to manage the engine power and condition.

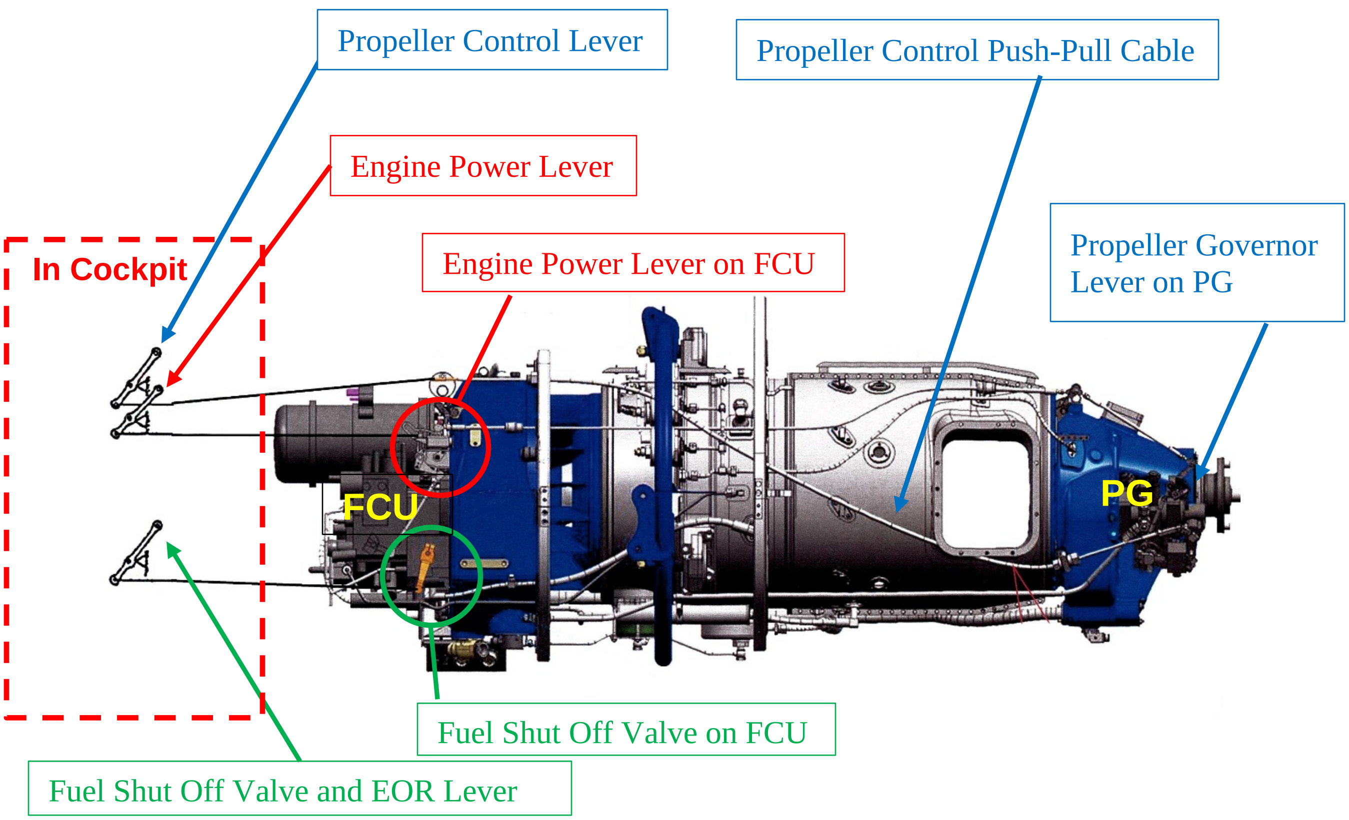


Figure 2 – Engine Control Schematic (Propeller not shown)

D.2.2 Fuel Control Unit (FCU)

D.2.2.1 Description

The FCU unit consists of 7 basic components (Figure 3): (1) The engine power input lever (EPL) and mechanism, (2) the gas generator (Ng) speed sensing unit, (3) the fuel metering and acceleration unit, (4) the start circuit, (5) the fuel limiting section, (6) the shut-off/emergency over-ride metering section and (6a) trigger solenoid, and (7) the altitude compensator.

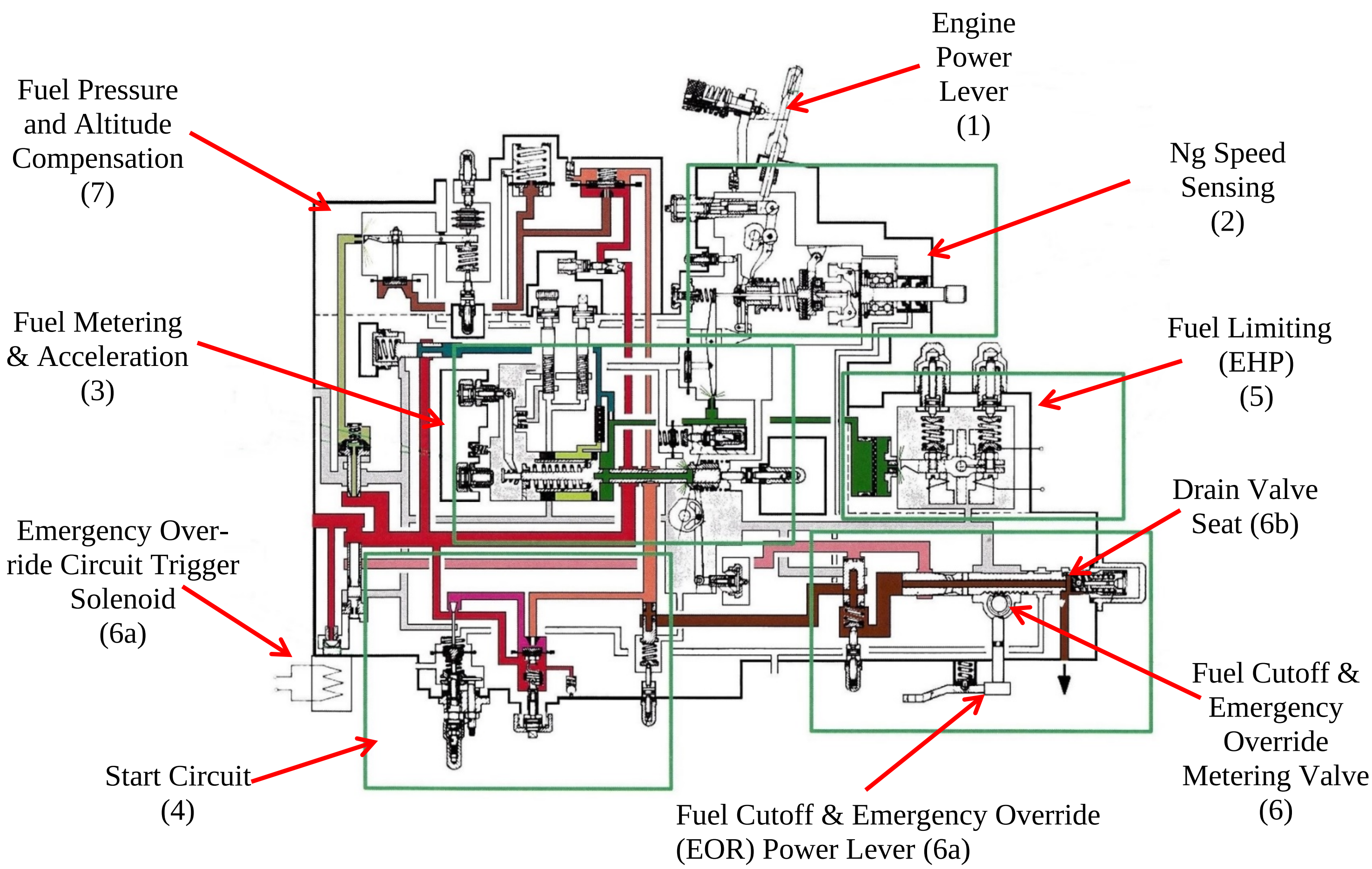


Figure 3 - FCU Schematic

In operation, The FCU and FP supply the required fuel for engine starting, steady and transient power requirements at all altitudes, and reverse thrust on the ground. The FCU contains valves, springs, bellows and restrictors, which allow the gas generator to start, idle, safely accelerate and decelerate and prevents Ng overspeed.

For shut down, the FCU has a fuel shut off valve and lever (6 & 6a) that is actuated via the fuel cutoff lever in the cockpit (Figure 2). The same fuel cutoff lever also serves a secondary function; manual emergency override (EOR) if the hydromechanical metering and limiting sections have failed. EOR is triggered when the pilot selects the electrical EOR switch in the cockpit, energizing a solenoid (6a in Figure 3), which then diverts all internal fuel supply from the hydromechanical fuel metering section of the FCU to the EOR metering valve section, causing only the EOR power lever to be in control of the engine power. Movement of the EPL will not result in any engine power changes because this section is bypassed internally. Only the EOR lever will result in engine power changes when the EOR switch is activated.

D.2.2.2 Fuel Control Unit Examination & Test

General

The FCU was P/N LUN 6590.03-8 AB and S/N 831054 and. The alphabetic designations (A and B) indicate that the FCU was overhauled. Each overhaul is marked with a successive letter, (B) indicating that the FCU had been overhauled twice. According to Jihostroj records, the FCU was newly manufactured in 1983, and first (A) overhauled at Jihostroj in September 1988. The second (B) overhaul was at Jihostroj in August 1990. Jihostroj recommends a 2000-hour time-between-overhaul (TBO) for the .03-part number. Jihostroj and GE recommend that a record of all adjustments made to the FCU after its overhaul be recorded; however, no records of FCU re-adjustment during service were found.

FCU As-Received Condition

The FCU was received in a carboard box (Photo 12) which was opened in the presence of the NTSB. A receiving inspection revealed that the FCU was generally intact (Photo 13); however, the ball-and-spring stop mechanism of the cutoff & EOR lever on the lower aft outer quadrant was deformed and not functioning (Photo 14). Internal fuel pressure against the cutoff valve causes a small torque (approximately 11 inch-pounds) on the cutoff shaft, which constantly twists the shut-off lever towards the off position. Normal friction in the airframe control cables and levers is greater than the internal torque and the cockpit cutoff lever normally stays in place. To prevent an inadvertent cutoff due to vibration, the external ball-and-spring mechanism acts as a detent stop. Because there were no discernable impact marks, it was unknown if this deformation existed before the accident.

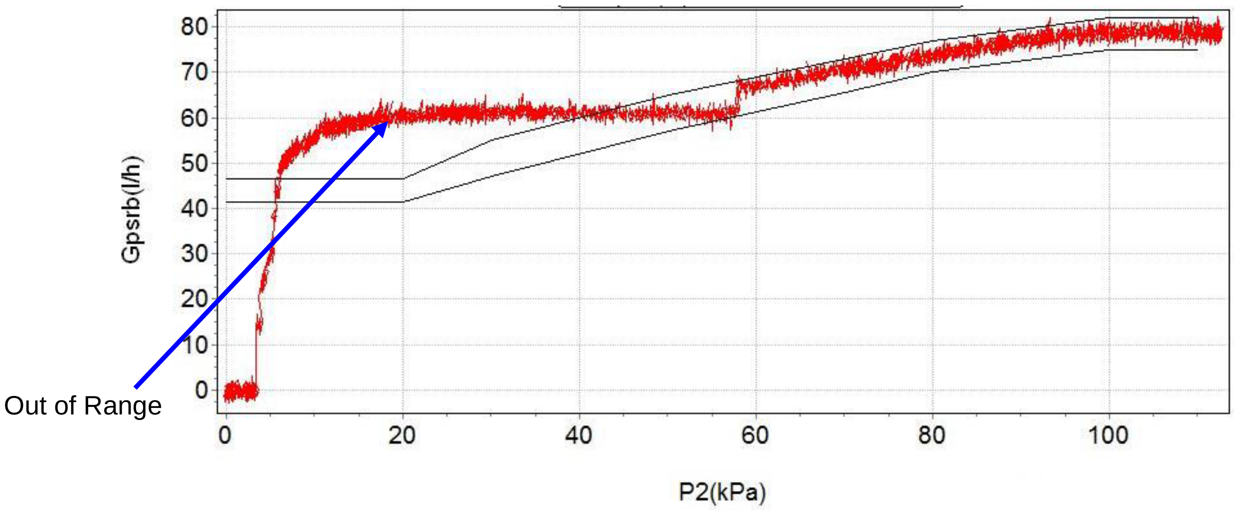
Both the engine power lever (EPL) and the cutoff & EOR lever could be rotated with no unusual internal resistance. The fuel cutoff & EOR lever was bent and it had two non-original tapped holes (Photo 14). The EPL was intact and undamaged (Photo 15); however, the witness cap of the spring-loaded detent of emergency maximum power was missing (Photo 16), indicating that emergency maximum power position had been selected at some time since the last overhaul of the FCU.

The Ng speed input drive splines were undamaged (Photo 17).

Non-standard fasteners were observed on the fuel-in flange and the #20 adjuster cover plate (Photo 18). During manufacture or overhaul, Jihostroj lock-wires all the adjustor screws of the FCU and then places a unique lead security crimped seal on the lock wire to identify modifications to the original settings. The following adjustors did not have the original crimped seal: The adjusting screws No. 33 – main metering plunger sleeve position (Photo 19), No. 40 – adjustment for start maximum fuel flow, No. 41 – adjustment for start fuel flow acceleration, and No. 50 – adjustment for minimum fuel flow during start (Photo 20).

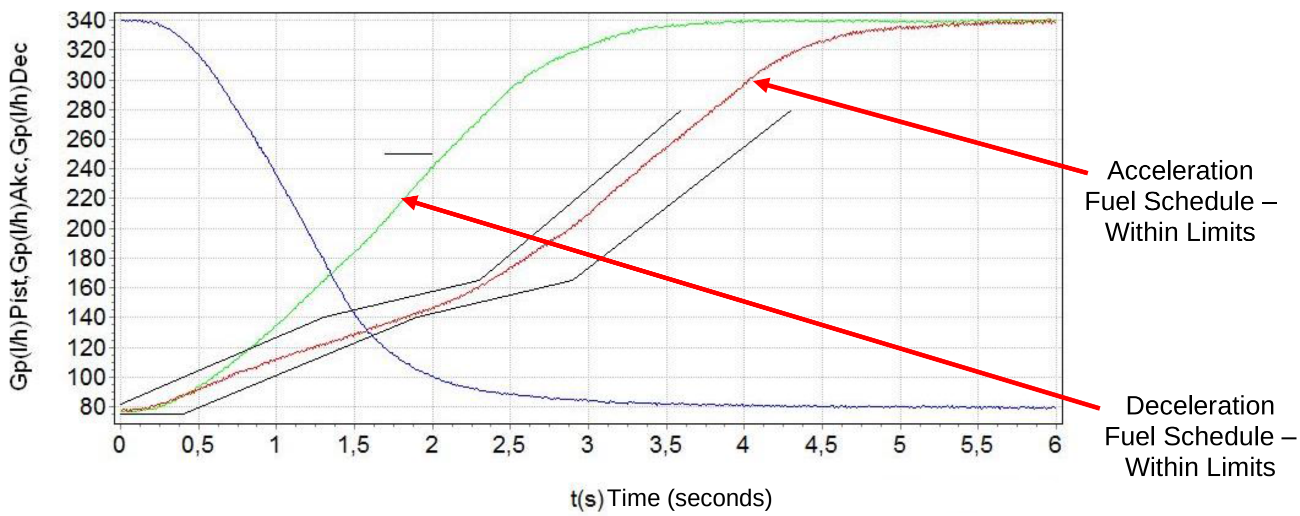
D.2.2.3   FCU Functional Test Procedure (FTP) on Test Stand

The FCU was mounted on the production test stand and supply fuel pressure of 30 psi was applied to the fuel inlet fitting (Photo 21). Two fuel leaks from the housing were observed; one from the drain system and the other from the Nos. 16 & 17 - adjuster screws for the acceleration and deceleration flow schedule. After the de-aeration procedure, the FCU was subjected to an abbreviated new-part functional test procedure (FTP). The test cell could record the FCU parameters. Five tests were performed: Starting Performance, Acceleration & Deceleration Performance, Altitude Characteristics, Fuel Flow vs. EPL Position, and Flyweight Governor Performance and their results follow:



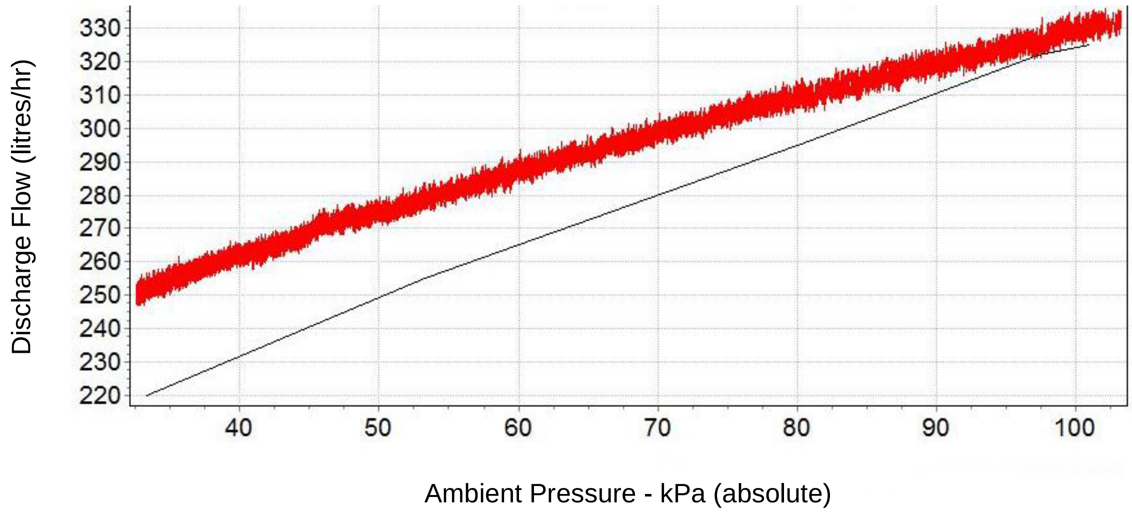
Graph 1 – Starting Performance

During the start FTP (Graph 1), the fuel flow response at the P2 (compressor discharge) pressures between 8 and 50 Kilo Pascals (KPa) is higher than nominal, which could be reflected as higher start temperature, however this is not a consideration during engine operation after start or during flight.



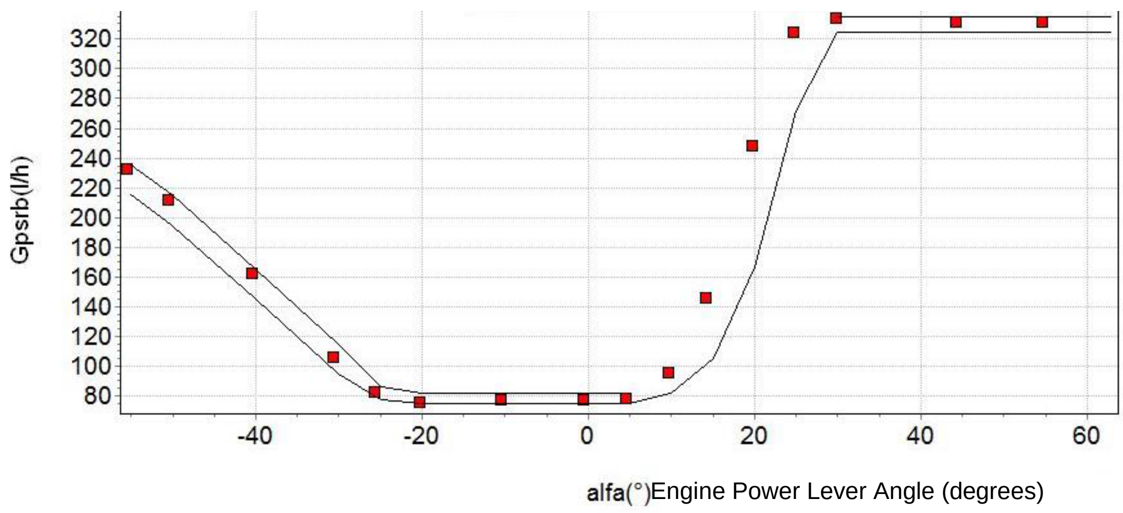
Graph 2 - Acceleration & Deceleration Performance

The acceleration and deceleration characteristic (Graph 2) of an FCU determines how fast the fuel flow changes in response to the power lever being moved quickly to a new power setting. Too fast a response could lead to a flameout. The acceleration (red) response of the FCU is within limits (black). The deceleration (blue) time was approximately 2 seconds, longer than the minimum requirement of 0.5 seconds and acceptable performance.



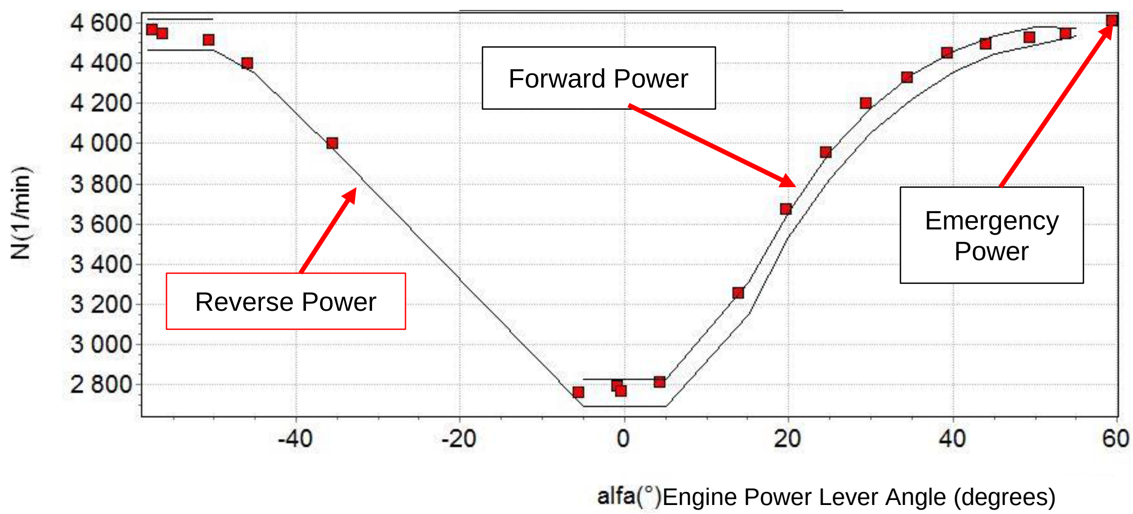
Graph 3 - Altitude Characteristic

The required fuel flow at altitude (Graph 3) is above the required limit and exhibits low hysteresis and acceptable behavior.



Graph 4 - Fuel Flow vs. EPL Position

This test measured the fuel flow at engine power lever (EPL) positions (Graph 4). The required fuel flow rate for all static conditions were within limits along the entire range, including reverse. The maximum fuel flow was achieved.



Graph 5 - Flyweight Governor Performance

In this test, the EOR is set to 103% of gas generator speed, removing the influence of the hydromechanical section of the FCU and testing the performance of the governor (Graph 5). Three points are very slightly outside of limits, consistent with the unauthorized disassembly of the power lever.

D.2.2.4 Fuel Control Unit Disassembly

The power lever shaft (Ref. Figure 3- Item 1) seal was a non-factory seal and inspection of the seal retainer revealed that the seal housing was modified to accept the non-standard shaft seal (Photo 22). This is an unapproved modification according to the manufacturer.

The start fuel flow assembly was disassembled, revealing corrosion on the rubber diaphragm and spring (Photo 23). The diaphragm was intact; however, it was slightly soft. The discrepancy may have been consistent with a slow start condition and caused compensating adjustments.

The accelerator restrictor assembly was removed, revealing clean 40-micron filters (Photo 24). The No. 16 restrictor was undamaged, while the No. 17 restrictor was bent, consistent with external impact.

The main fuel valve was intact and undamaged (Photo 25).

The emergency metering valve assembly was removed from the FCU and examined and found to be intact and undamaged (Photo 26). The pressure regulating valve of the EOR circuit was removed from the FCU housing (Photo 27) and minor corrosion was observed on the active spool outer surface; however, the spool moved freely in its sleeve. The fuel cutoff valve was removed from the FCU housing, examined and found to be intact, however a small amount of corrosion was observed on the internal sleeve, but it did not affect the operation of the valve, which moved freely in the sleeve (Photo 28). According to the manufacturer, the corrosion observed in this valve is not common, but is consistent with the component being stored for an extended time without proper preservation. It could also be caused by the presence of water in fuel. The emergency circuit solenoid valve was removed (Photo 29) and functionally tested, passing the minimum switching voltage of 17 volts (V) and drop-off voltage of 15 V.

The emergency check valve assembly (Ref. Figure 3, item 6b) was removed and the drain poppet valve seat examined (Photo 30), revealing an asymmetrically worn seat. This is consistent with the fuel leak observed during the engine testing in Deland, Florida. Jihostroj technical advisors stated that this was a very deep imprint and is consistent with an FCU that had sustained an extended time of disuse and non-preservation. Leakage from the drain poppet valve influences the engine only during the starting process and manifests itself as high ITT or even flames from the exhaust during start.

D.2.3 Fuel Pump

D.2.3.1 Description

The fuel pump (FP) (Figure 3) is a gear-driven, positive displacement, pressure-regulated pump which is driven, via splines by gearing within the engine AGB and supplies fuel flow and pressure required by the fuel control unit as well as a starting circuit for satisfying all the functions of the engine requirements. The FP is mounted on its own dedicated flange on the AGB and it is mechanically connected to the FCU and they share two fuel transfer manifolds: one is used for supply of fuel required for FCU, while the other serves as a by-pass fuel flow from the FCU back to the pump inlet. There is a replaceable fuel filter, pressure regulator and a solenoid to supply the torch ignitors with fuel during starting.

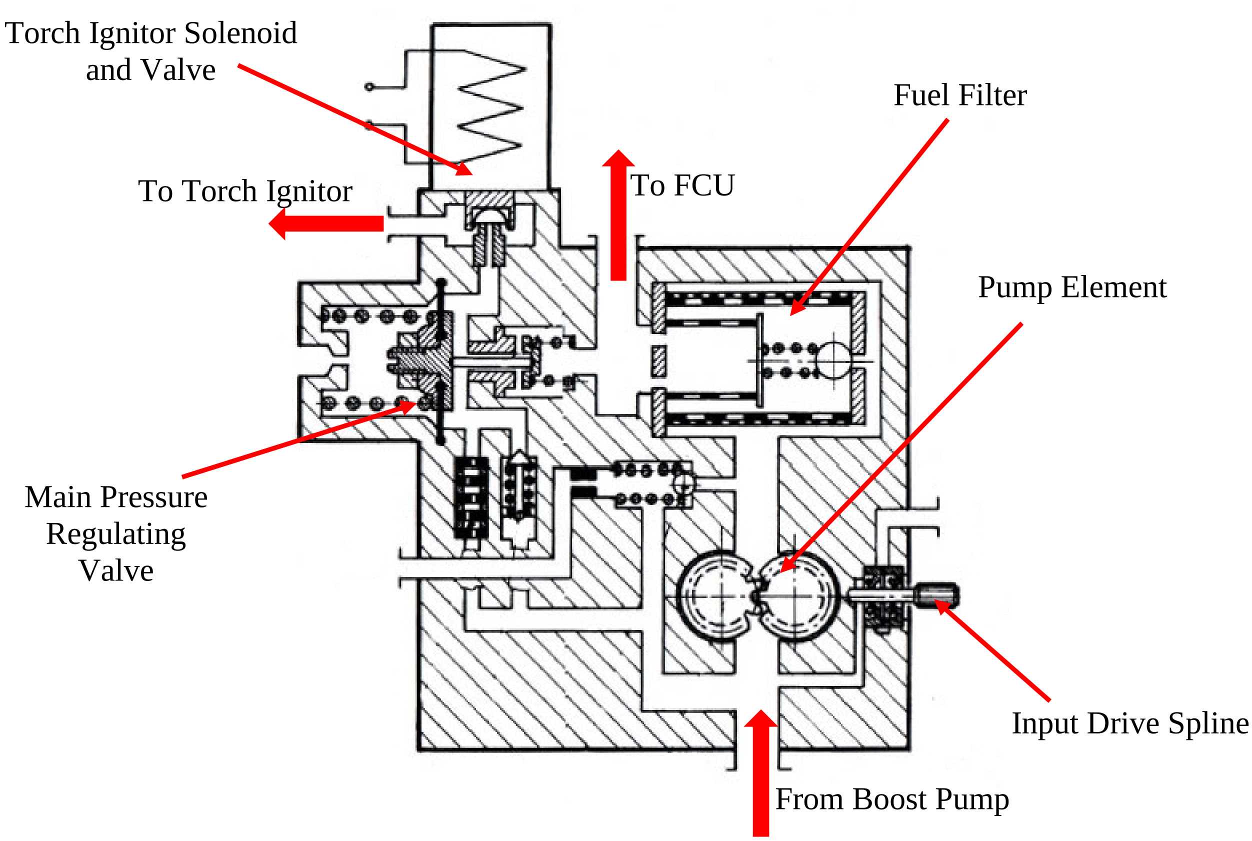


Figure 4 – Fuel Pump Schematic

D.2.3.2 Fuel Pump Examination & Test

General

The fuel pump (FP) was P/N LUN 6290.03-8 A, and S/N 841053. It was manufactured in February 1984 and has had one overhaul, but not by the Jihostroj factory so the records could not be examined. It has a recommended 2000-hour TBO.

Fuel Pump As-Received Condition

The FP was received in a carboard box which was opened in the presence of the NTSB investigator (Photo 31). A receiving inspection revealed that the FP was intact and undamaged. All the lock wire on the adjustable elements was original. The input shaft splines were intact and undamaged (Photo 32).

The fuel filter was removed and examined, revealing a clean element (Photo 33). The filter cavity was intact and filled with a small amount of straw-colored fluid, consistent with fuel that contained a small amount of extremely fine shiny metallic debris at the bottom (Photo 34).

D.2.3.3 Fuel Pump Functional Test Procedure (FTP) on Test Stand

The FP was mounted onto the factory production test cell at the same time as the FCU (Photo 21). The minimum flow requirement for 100% Ng is 1000 liters/ hour with a corresponding minimum discharge pressure of 2.0 MPa and the FP was within acceptable new factory limits.

D.2.3.4 Fuel Pump Disassembly

One O-ring on the torch ignitor flow restrictor transfer tube was deformed and cut during the last assembly (Photo 35). The inspection for this part is every 300 hours.

Dis-assembly of the FP did not present any technical difficulties (Photo 36). The needle bearings of both gear shafts were undamaged. The gear shaft assemblies and involute teeth surfaces were undamaged (Photo 37). The side-sealing plates exhibited burnishing and very slight scoring but were otherwise undamaged (Photo 38). the gear cavity of the aluminum pump housing was undamaged (Photo 39).

D.2.4 Propeller Governor

D.2.4.1 General Notes Regarding the Propeller and Propeller Control System

Overview

The propeller converts the rotational energy of the engine output shaft into useable thrust to move the airplane.

A fixed pitch propeller is the simplest of propeller designs and is used in light, piston engine aircraft. The hub and blades are typically a one-piece component in which angle of attack of the propeller blades are a fixed pitch and cannot be changed during aircraft operation. The fixed blade angle is a compromise between the optimum pitch for takeoff, climb and cruise. In these installations, the rotational speed is controlled only by the engine speed.

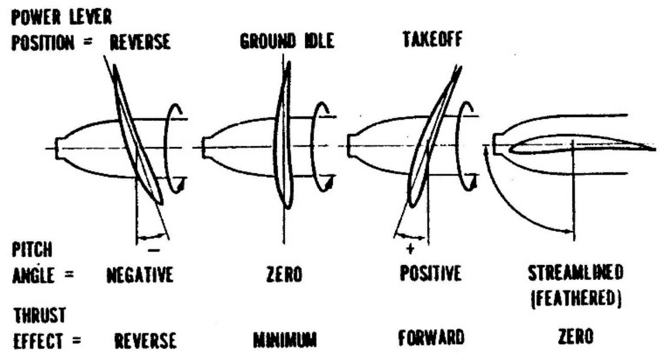


Figure 5 - Propeller Blade Angle Ranges

A constant-speed (or variable pitch) propeller (Ref. Figure 5) is one in which the blade pitch or angle can be adjusted during flight in order to obtain an optimum value for all phases of flight, such as takeoff, climb or cruise. It is also possible to feather the blades after an engine failure, which is necessary so that the streamlined blades produce the least aerodynamic drag to flight.

If not controlled, the propeller RPM would vary greatly as a function of engine power, blade pitch angle and airspeed, therefore, a propeller speed control unit (PCU) is added to the system to make the propeller behave in a constant speed manner, irrespective of engine power selected or airspeed by automatically varying the blade pitch angle to absorb the pilot-selected engine power. The propeller pitch is controlled by using engine oil pressure to move an internal piston in the propeller hub. The piston moves internal linkage which moves the blades to their appropriate angle. If the pilot commands a change in engine power, or if the airspeed changes, the PCU adjusts the oil pressure, changing the pitch of the blades to maintain the set speed of the propeller. If the propeller is turning too quickly, the blade pitch is automatically changed to take a bigger bite out of the air, creating more thrust and torque, thus slowing the propeller RPM. If the prop is turning too slowly, the blade angle is decreased to take smaller bites, producing less torque and thrust, allowing propeller RPM to speed up. The speed-sensing governor continually adjusts the oil pressure to keep the propeller RPM at constant speed.

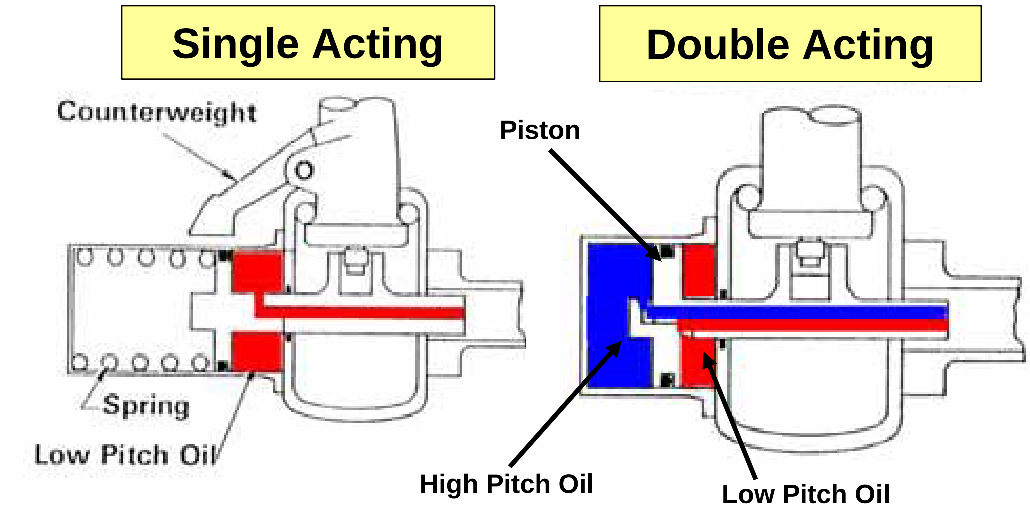


Figure 6 - Schematic Comparing Single and Double Acting Propeller Systems

There are two different internal control systems in propellers (Ref. Figure 6):

Single acting system, which features counterweighted blades and internal large feather springs that constantly push the blades toward high pitch (feather). Since the blades are always being driven to coarse pitch or feather, the propeller only needs a piston with pressure on one side to push back against the counterweights and spring. When the piston pressure is increased, the blades go toward low (flat) pitch. When the piston pressure is decreased, the counterweights and springs drive the propeller back toward high pitch. The counterweights do most of the work to drive the blades to high pitch. The springs help feather when the propeller RPM is low and the centrifugal loads acting on the counterweights do not have enough force to drive the blades completely to feather.

Double acting system, which features a piston that provides force, via engine oil pressure, in both directions to control the propeller RPM. The governor controls the oil pressure on both sides of the piston to increase or decrease the pitch as required. A double-acting propeller normally uses oil pressure from the engine main oil pump or, in the event of an engine failure, requires an emergency electric auxiliary oil pump, to completely feather the blades. Although counterweights help to increase pitch in the event of oil system failure, they are ineffective in feathering the blades when the propeller is spinning at low RPM since there is insufficient centrifugal force generated to drive the propeller blades to feather. In this event, the propeller blades will remain in the last position they were in before the loss of oil pressure.

According to the Avia propeller manual, E-1500, dual acting propellers require an electric feathering pump for emergency conditions:

"D. Feathering

If an engine fails in flight, it is necessary to feather the propeller. Installations using dual acting propellers are usually equipped with feathering system with feathering valve and an electric feathering pump. The system is initialized by a cockpit button or automatically.

a) Manual Feathering

The pilot activates auto feathering by pushing the appropriate cockpit button the feathering pump (LUN7840) and feathering valve (LUN7880). Oil from electric pump is directed to the high pitch channel, feathering the propeller.

b) Automatic Feathering

This action is similar to manual feathering only the activation is automatic based on engine torque evaluation. Usually the automatic system is limited to some engine condition lever range.

c) Emergency Feathering

It is used when the feathering pump is out of operation or it is not installed. Emergency feathering is activated by moving the propeller condition lever onto feather stop. Blades are forced into feather position by counterweights moment and eventually by oil pressure.

Feathering time is about three times longer than manual and automatic feathering.

Emergency feathering can be used at engine stop."

The event airplane was not equipped with an electric feathering pump.

Notes on Emergency Propeller Feathering with Dual Acting Propellers

The Diemech M601D engine is intended to be installed into a LET410 airplane, a Czech built twin-engine installation that features an Avia model V508E-AG/84/A dual acting propeller, identical to the event propeller. The LET410 design incorporates the Avia propeller manual guidance which requires an emergency electric propeller feather pump and appropriate hardware to direct pressure oil to the high-pitched channel, feathering the propeller in a timely manner. The Lancair is a kit airplane, and although it is powered by the same Walters M601D turbine engine and Avia model V508E-AG/84/A propeller combination is significantly different from the LET410 in that it is a single engine propeller airplane that does not incorporate an emergency electric propeller feather pump.

A review of the accident Lancair airplane systems revealed that there was no emergency electric propeller feather pump installed in the airplane. According to Lancair, there is no requirements or engine installation guidance to have such a system installed

Emergency feathering, without an emergency electric propeller feather pump, can also be activated by moving the propeller conditioning lever onto the feather stop; however, this requires the gas generator portion of the engine to still be operating since it drives the engine main oil pump and provides oil pressure to the propeller that is used for pitch control and emergency feathering. If the main oil pump no longer operates, then the only way the blades can be driven into the feather position is by the moment of the counterweights, however this requires the propeller to be rotating quickly for the counterweights to be effective. Additionally, the aerodynamic loads on the propeller blades, which drive the propeller into the feather position, are also very low when the propeller is rotating slowly.

In an installation without an emergency electric propeller feather pump: when an engine loses power for any reason, the gas generator section quickly stops rotating and there is no engine oil pressure available to feather the propeller. With no engine power to turn the propeller, it will quickly stop rotating, making the counterweights and aerodynamic pressure on the rotating blades the only driving force to feather the propeller; however, unless the pilot immediately moves the propeller conditioning lever into feather stop, the propeller RPM will be too slow for the counterweights and aerodynamic loads on the blades to feather the blades in a timely manner, thus effectively locking the propeller pitch into the last selected position at the time of engine failure.

Installation of the dual acting propeller and engine into the Lancair installation without the addition of an emergency electric propeller feather pump presents a latent failure mode. Only under the conditions of a failed gas generator and a pilot who is slow to react to a sudden loss of power, will this no-feather condition arise. A pilot can practice an engine failure by reducing the engine power to idle and simulating a loss of power event; however, an idling gas generator will still supply enough oil flow and pressure to the propeller to feather it normally.

FAA Amateur Built Aircraft Regulations and Policies

For a person to build, obtain an experimental airworthiness certificate, register the aircraft, and operate an amateur built aircraft, the applicant must follow the rules of the Title 14 Code of Federal Regulations Section 21-191 (§ 21.191) entitled 'Experimental Certificates'. The FAA provides guidance to the applicant on how to meet the requirements of an experimental certificate by providing Advisory Circulars (ACs), Orders, and Forms. See Table 1 for a full list of all the regulations and policies. Finally, to obtain an airworthiness certificate, the applicant must fill out various forms and documents and submit them to the FAA before approval for flight is granted.

Title 14 Code of Federal Regulations
- Section 21.191, Experimental Certificates

Advisory Circulars (AC)
- 20-27, Certification and Operation of Amateur-Built Aircraft.
- 21-12, Application for U.S. Airworthiness Certificate, Form 8130-6.
- 39-7, Airworthiness Directives.
- 65-23, Certification of Repairpersons (Experimental Aircraft Builders).
- 90-89, Amateur-Built Aircraft and Ultralight Flight Testing Handbook.
- 90-109, Airmen Transition to Experimental or Unfamiliar Airplanes

Orders
- 8130.2, Airworthiness Certification of Aircraft and Related Products.
- 8130.33, Designated Airworthiness Representatives: Amateur-Built and Light-Sport Aircraft Certification Functions.

Forms
- 8050.88 Affidavit of Ownership
- 8000-38, Fabrication/Assembly Operation Checklist.
- 8130-6, Application for U.S. Airworthiness Certificate.
- 8130-12, Eligibility Statement: Amateur-Built Aircraft.
- 8610-2, Airman Certification and/or Rating Application.

Table 1 – Relevant FAA Documentation

14 CFR § 21.191(g), defines an amateur-built aircraft as "an aircraft of which the major portion (more than 51%) has been fabricated and assembled by a person(s) who undertook the construction project solely for their own education or recreation.

a. Amateur-built aircraft may be constructed from—

(1) An amateur builder's original design, or

(2) Purchased plans or kits."

The FAA purposely gives great latitude to experimental aircraft home builders, and therefore offers no airworthiness standards or technical restrictions in the documentation. 14 CFR § 21.191 does not supply technical design guidance to the constructor. In fact, FAA Order 8130.2H states "The FAA should be reasonable in its requests for design data from amateur builders, keeping in mind that in most instances only one aircraft is involved. Accordingly, the amateur builder(s) are not required to have the detailed design data, quality systems, and procedures that holders of TCs and PCs are required to have for the serial production of duplicate aircraft. Often, the amateur builder will only have the information provided with the kit."

With respect to the documentation for kit-built airplanes, the FAA makes clear that "It is important to remember that the FAA does not approve or certify aircraft kits or kit manufacturers…. an applicant (builder) may still apply for airworthiness certification upon completion of an aircraft built from this kit.". In contrast, Title 14, CFR Part 25, Airworthiness Standards: Transport Category Airplanes or Title 14, CFR Part 29, Airworthiness Standards: Transport Category Rotorcraft control most aspects of the design and safety features that must be incorporated into the qualifying aircraft.

Most of the FAA supplied technical information and guidance for experimental aircraft home builders to help in the design, fabrication and operation of their aircraft is available in AC 20-27G titled Certification and Operation of Amateur-Built Aircraft issued September 30, 2009 and AC 90-89B titled Amateur-Built Aircraft and Ultralight Flight Testing Handbook, issued April 27, 2015; however, in a review of these ACs, the NTSB found no references to turbine engine installation considerations.

D.2.4.2 Propeller Governor Description

The PG is a double-acting type which regulates propeller speed by transferring oil to either side of the hub internal piston which in-turn varies the pitch of the propeller blade to maintain the governing speed. The PG internal flyweights, actuated by the centrifugal force developed by the speed of the rotation, positions a pilot valve which covering or uncovering ports in the drive gear shaft thus controlling the flow of oil to either side of the piston of the propeller. The centrifugal force exerted by the flyweights is opposed by the force of an adjustable speeder spring. The load exerted by the flyweight speeder spring determines the engine RPM required to develop enough centrifugal force in the flyweights to center the pilot valve. Oil to operate the propeller's pitch changing mechanism is supplied by a gear-type oil pump at a pressure value limited by a relief valve. The governor is double-acting type, intended to be used only with double-acting propellers, using oil pressure to decrease and increase propeller blade pitch.

The dual acting propeller does not have an internal feathering spring.

Propeller Governor As-Received Condition

The PG was P/N LUN7815.02-8, S/N 862033. An external visual examination revealed that the propeller governor was undamaged (Photo 40). Oil was seen to exit the mounting flange passages. The propeller governor features an oil pressure port which is intended to allow oil pressure from the emergency electric feathering pump to feather the propeller in the event of an engine failure. This port was intentionally blocked as part of the engine installation design (Photo 41).

Propeller Governor Teardown

All the internal cavities and components were oil wetted. The pump involute gear teeth (Photo 42) and the side sealing faces of gear pump were undamaged as were the brass side seals. The rotating main shaft with the pilot valve, the speeder spring (Photo 43) and the flyweights (Photo 44) were oil wetted, undamaged and free to operate. The beta valve was undamaged and free to rotate.

D.2.4.3 Control System Findings Summary

Functional testing of the FCU and hydromechanical system did not reveal any performance discrepancies that would have caused the engine to fail to maintain speed or to accelerate or decelerate. No fault was found in the EOR circuit that would have prevented normal operation. No pre-existing condition was found in the FCU that would have prevented normal operation

The FP passed the new part functional test procedure. No pre-existing condition was found in the FP that would have prevented normal operation

No pre-existing condition was found in the PG that would have prevented normal operation.

D.3 Propeller Examination & Teardown

The propeller was examined on August 7-8, 2018 at the Plain Parts facility in Pleasant Valley, California where it had been stored since the accident.

D.3.1 AVIA Propeller – General Description (Ref. Figure 7)

The propeller was an Avia model V508E/84/B2, serial number 140651237, a 3-bladed, double-acting, hydraulically controlled, constant speed (variable pitch) propeller which is fully reversible and featherable.

The propeller 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 (1) and blade bushings (5) is steel, while the propeller blades are of aluminum. The blades are screwed into the blade bushings and secured by the counterweight clamps. Each propeller blade is supported by two ball bearing races (4) at the root. The blade pitch is controlled by a double acting hydraulically actuated piston (6) within a cylinder (7) mounted to the hub.

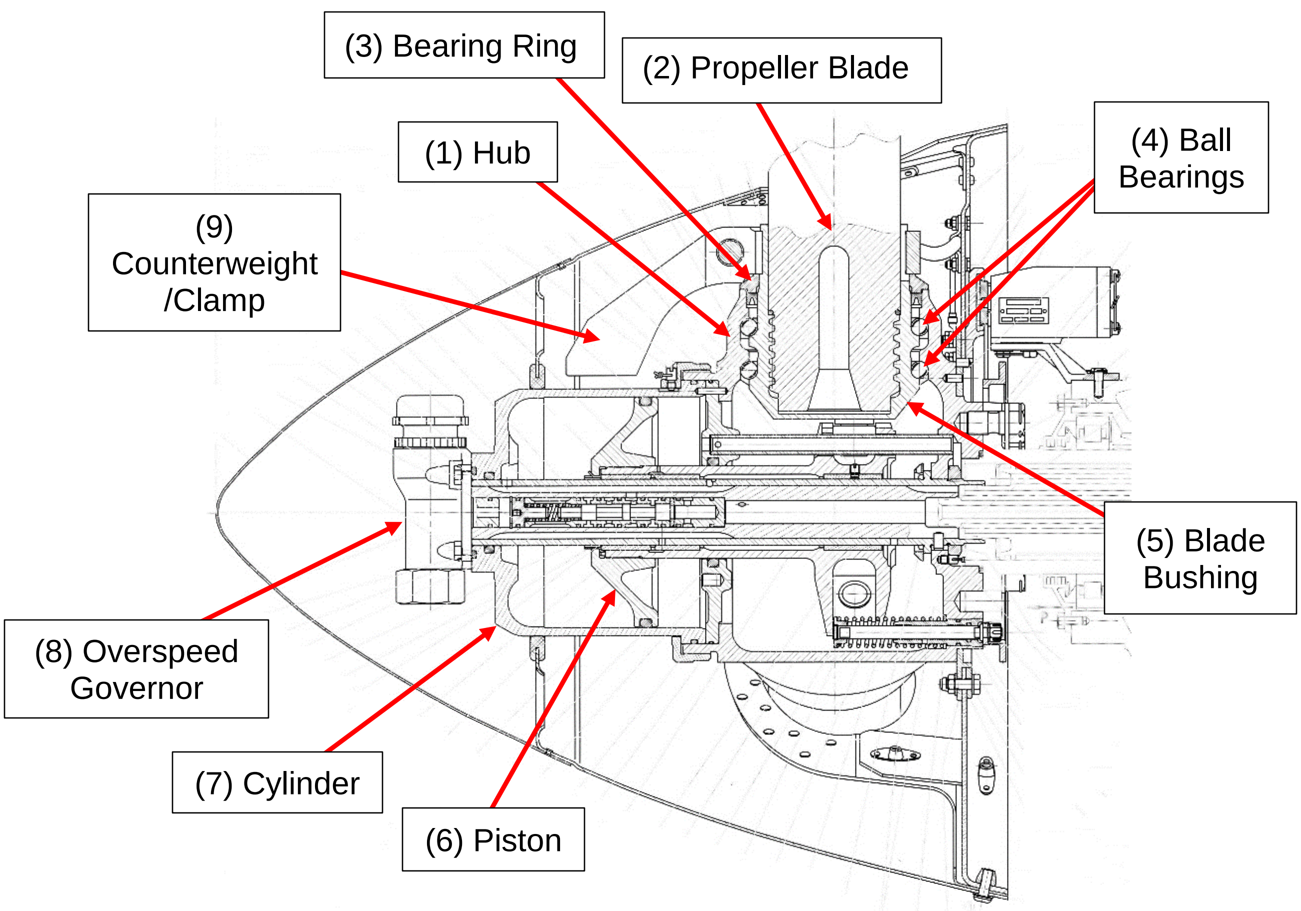


Figure 7 - AVIA Propeller Cross Section

The propeller is equipped with an overspeed governor (8) on the cylinder front face, which features an internal spring-loaded weighted valve. Centrifugal forces of the propeller RPM act on the weighted valve and once the spring pressure is overcome, the valve opens, allowing oil from the low pitch area in the hub to the drain till the RPM decreases to correspond with speed setting.

D.3.2 Details of the Examination

General

The propeller was generally intact and clean (Photo 45). The spinner was not present. Oil was seen to exit the aft center port. When one blade was rotated around the span axis, all other blades rotated in unison, consistent with internal mechanical integrity.

Blades

The face side of the blades had been previously marked with the numbers 1,2 and 3 so this numbering system was used. All the blades had a single, large radius bend at the mid-span in the chord axis; blades #1 and #3 were slightly bent backwards while #2 was bent backwards to approximately 75 degrees (Photo 46). There was no evidence of positive blade twisting along the span axis, which is normally observed when the propeller is being driven with engine power at impact. The leading edges of all the blades, although abraded from normal use, displayed no evidence of soft or hard body impact damage (Photo 47). The trailing edges of blades #2 and #3 were deformed. There were no rotational score marks on the face or camber sides of the blades, which are usually present if the propeller is turning under power during impact. The camber side of all the blades exhibited thin red lines in the chord direction approximately 10 -1/8 inches in from the tips (Photo 48).

Blade & Blade Bushing Mounting

(Ref. Figure 7) During assembly, the blades are screwed into the blade bushings (5), indexed to the bearing ring (3) for unison and retained by a counterweight/clamp (9). During normal operation, the friction of the clamps is enough to prevent the blades from rotating or un-screwing from the blade bushings; however, if the blades encounter impact during operation that causes a high torque in the span axis, then the clamp friction can be overcome, and the blades will rotate in their bushing.

The original blade location in the bushing can be determined by observing a factory scribed mark on beveled surface on the lip of the blade bushing and a factory scribe mark on the blade. These two scribe marks are in alignment during assembly. Blade #1 was rotated in its bushing by approximately 1 inch along the circumference (Photo 49). Blade #2 was rotated in its bushing by approximately 1- ¾ inch along the circumference (Photo 50). Blade #3 was aligned to the original location (Photo 51).

Bearing Ring Indications

The outer flange of the bearing ring (3) (Ref. Figure 1) becomes sheared when the moment on the propeller blade bushing is forced beyond its structural limits during impact with an object (Photo 52). Analysis of the damage to the bearing ring can therefore be used to determine the location of the blade during impact because the bearing ring has a known alignment with the propeller. The alignment is established with a notch on the bearing ring (3) (Photo 53), which is indexed to a mating pin on the counterweight/clamp (9) (Photo 54). Via a slot, the counterweight/clamp is, in turn, indexed to the blade bushing (5) key (Photo 55).

A geometric analysis of shear damage to the bearing ring (2) (Photo 56) by the manufacturer concluded that the blades were at the minimum flight angle (low pitch stop) of approximately 18 - 20 degrees or fine pitch.

Cylinder & Piston

The overspeed governor was intact and undamaged. When removed from the cylinder, oil was seen to exit the cavity and all the O-rings were found to be intact (Photo 57).

The cylinder mounting nut was still retained by the locking screw (Photo 58) and once removed, the nut was unscrewed from the hub with normal torque. The cylinder inner surface was undamaged, with only slight witness marks visible (Photo 59). The piston and elastomeric piston ring were undamaged (Photo 60 & Photo 61).

Hub & Internal Control Mechanism

The center tube (Photo 62) and its secondary pitch lock components were undamaged (Photo 63), however the front O-ring of the aft spacer of the slide valve assembly was sheared, consistent with an incorrect installation practice (Photo 64). According to the manufacturer, if the O-ring is missing, then the propeller would not achieve maximum reverse position. The O-ring damage observed would not influence the forward mode of the propeller.

The three fork guides were straight and undamaged (Photo 65). The fork and center tube (Photo 62) were oil wetted and fork slid smoothly along the center tube, without unusual resistance. Sliding wear from the pitch change blocks was observed on the aft inner surfaces of the fork flanges (Photo 66 & Photo 67). The front surfaces of the flanges for blades #1 and #2 were dented, consistent with contact against the cornered edges of the blade bushings (Photo 68) near the pitch change block. A width measurement of the fork flanges was made across the pitch change block span (Photo 69) and the two surfaces were found to be non-parallel, consistent with deformation caused by a high separation load exerted by the pitch change block during impact.

The blade bushing ball bearings were all present and undamaged (Photo 70). The blade bushings were intact, however they had impact marks, consistent with contact against the fork front surface (Photo 71).

The hub was intact and undamaged (Photo 72).

D.3.3 Propeller Findings & Summary

1) The blades were at the minimum flight angle (low pitch stop) of approximately 18 - 20 degrees or fine pitch. The emergency condition of the blades during an engine problem should be feather, or 90 degrees.
2) No evidence of blade twisting, leading edge nicks or dents or rotational scoring on the blades are all evidence of low RPM and power condition.
3) No pre-existing internal condition was found in the propeller that would have prevented normal operation.

Harald Reichel
Aerospace Engineer – Powerplants

Photo 1 – Walter M601D Engine, S/N 871020 159/03/03 - As Received

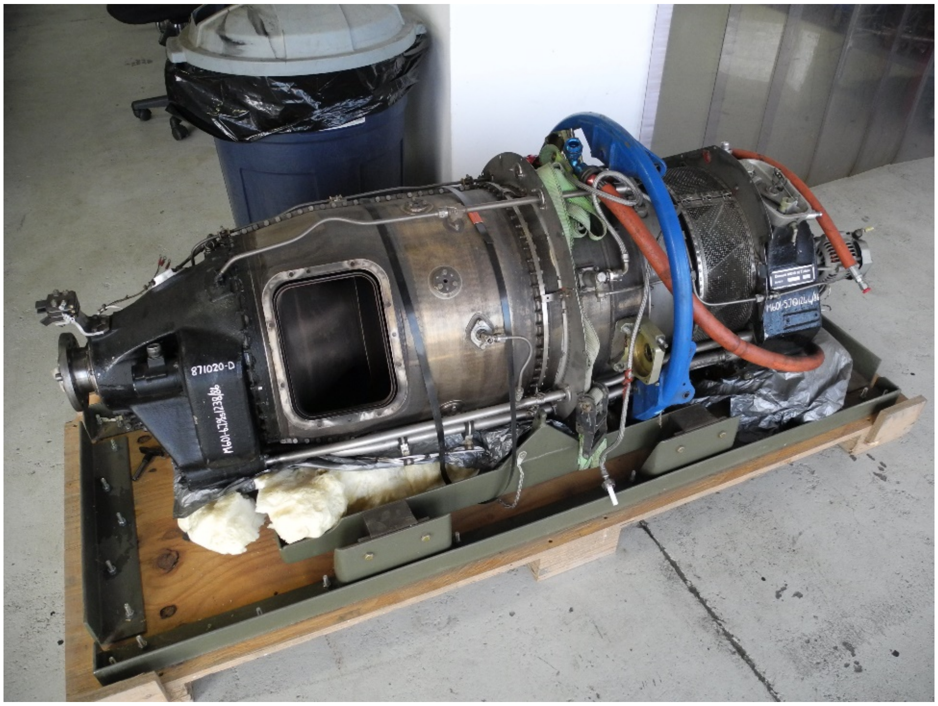


Photo 2 – Oil Transfer Tube – Bent and Buckled

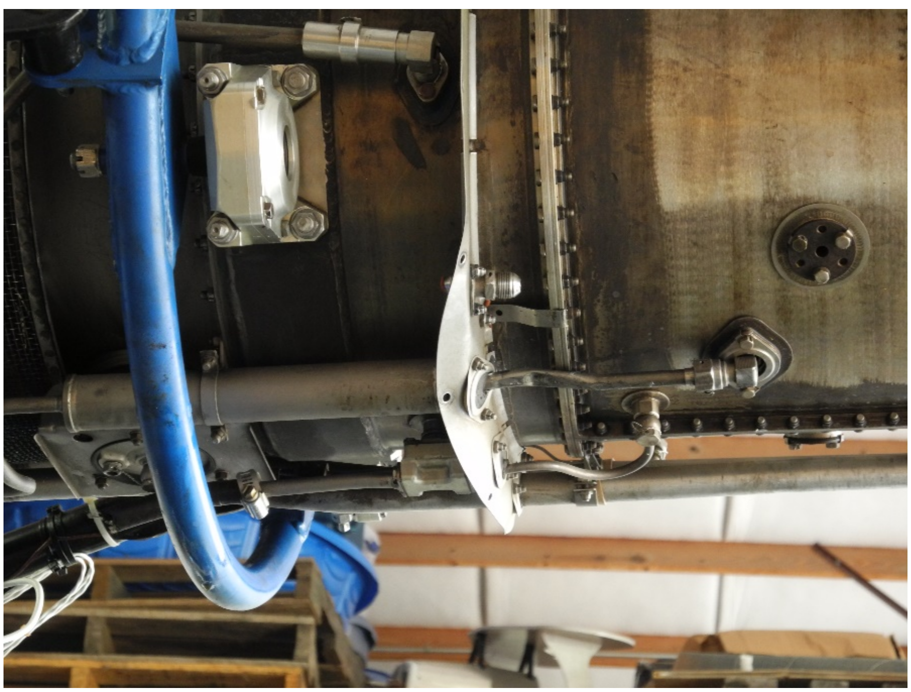


Photo 3 – Power Turbine Blades - Undamaged

Photo 4 – Propeller Shaft Flange - Undamaged

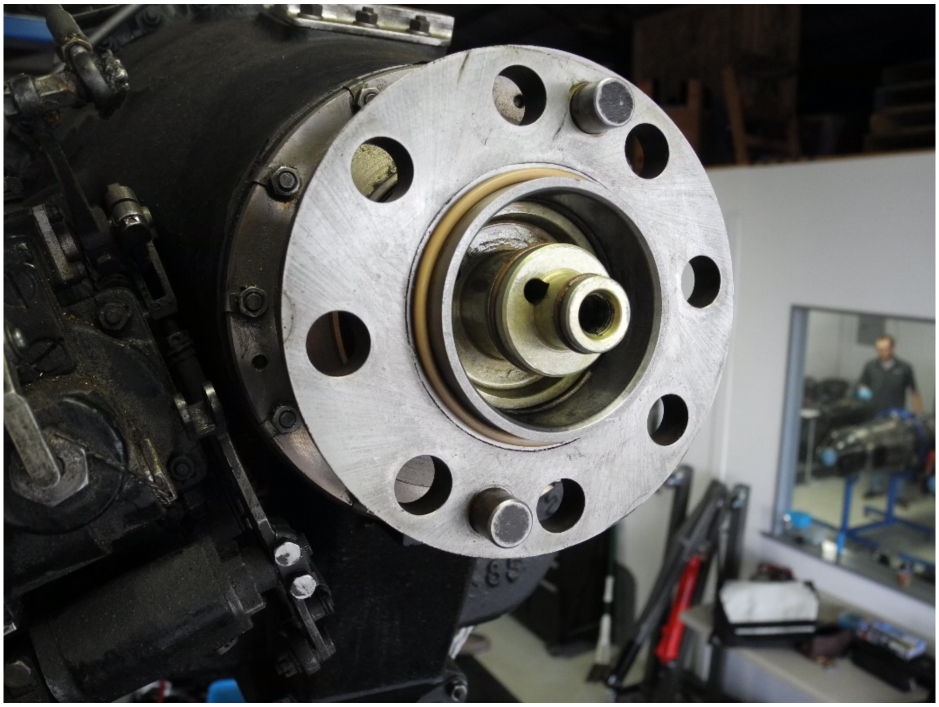


Photo 5 – Gas Generator (GG) Case and Inlet Screen - Undamaged

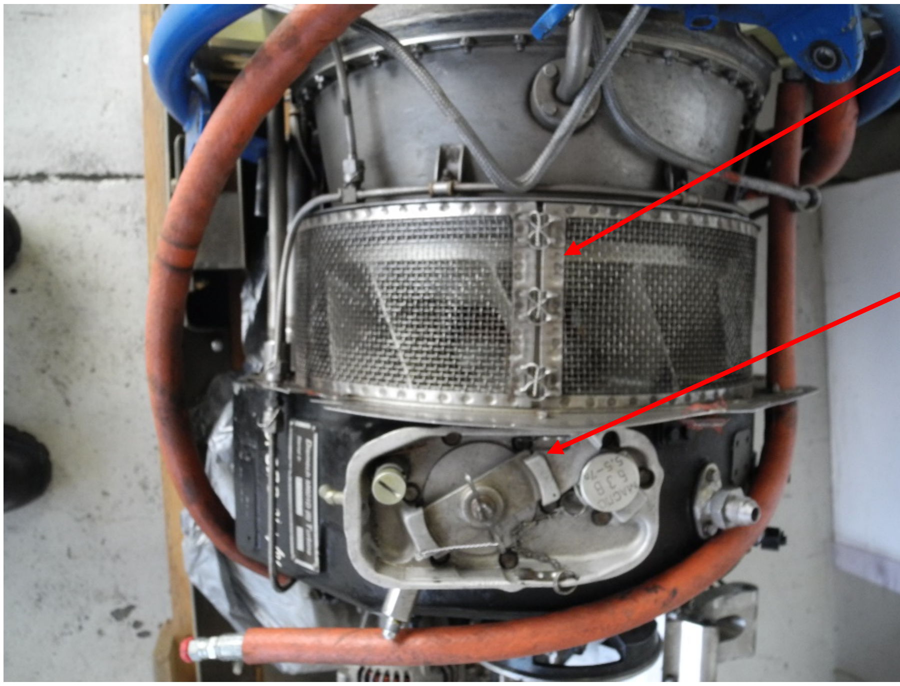


Photo 6 – Reduced Gearbox (RGB) - Undamaged

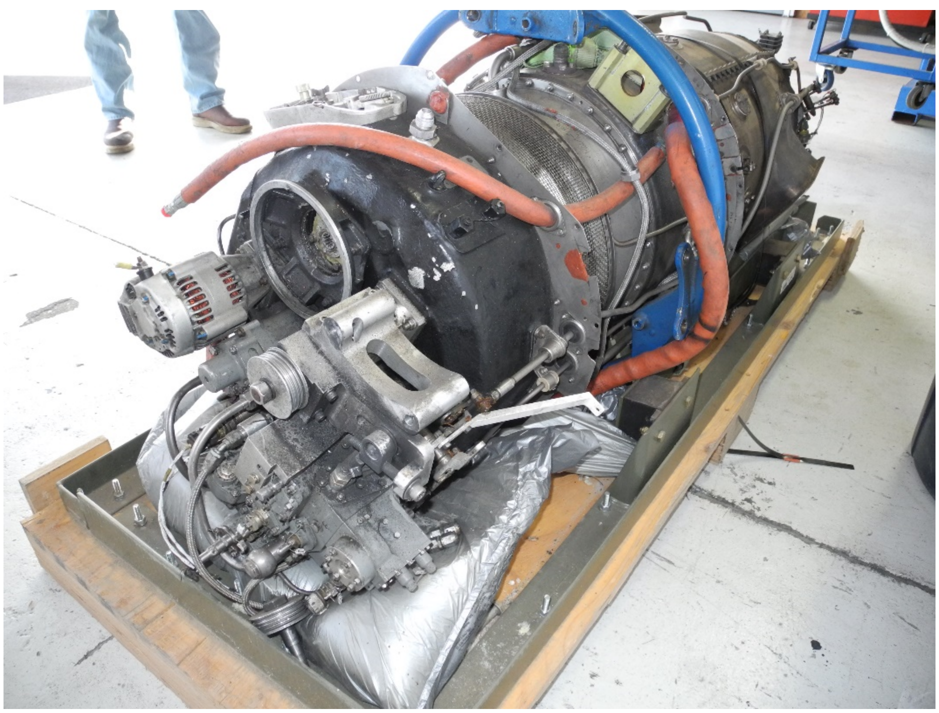


Photo 7 – Engine Mounts – Two Fractured and Without Elastomer

Photo 8 – TPT Truck Frame Mounted Test Cell

Photo 9 – TPT Truck Frame Mounted Test Cell – Control Panel

Photo 10 – Mounting Slave Propeller

Photo 11 – Engine Being Tested

Photo 12 - FCU, FP & Prop Governor - Received at Jihostroj

Photo 13 - FCU - As-Received

Lower Aft Outer Quadrant

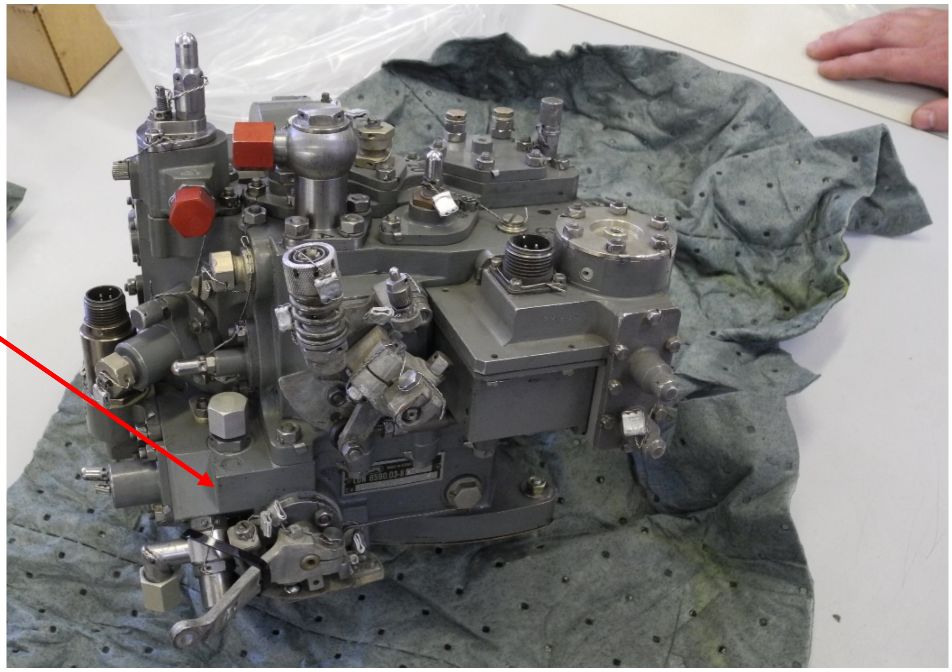


Photo 14 - Ball-and-Spring Stop Mechanism of the Cutoff & EOR Lever - Deformed and Not Functional

Non-Original Tapped Holes

Fuel Cutoff & EOR Lever

Ball & Spring Stop Mechanism - not Functioning

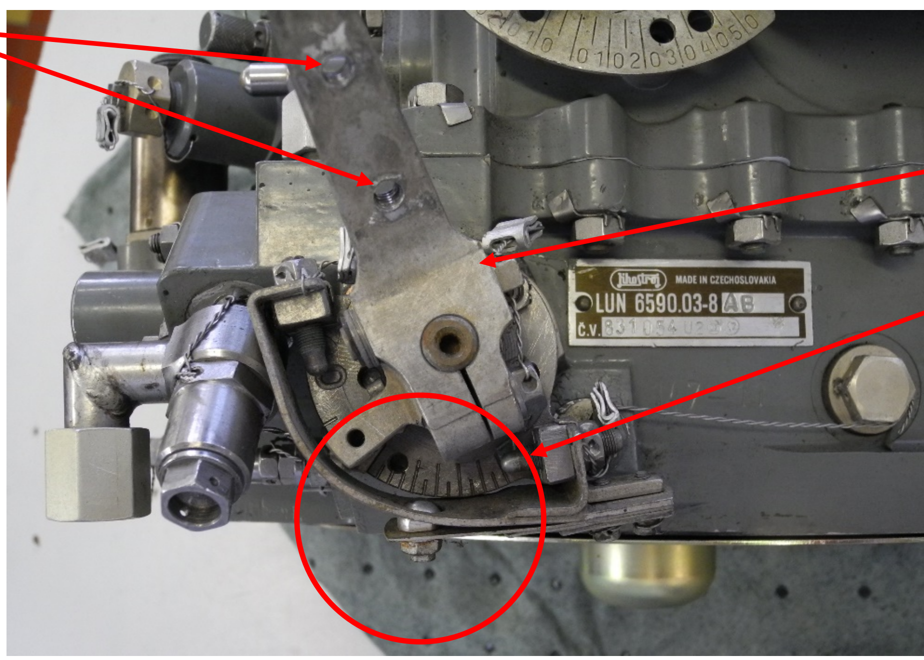


Photo 15 - Engine Power Lever (EPL) & Emergency Power Spring-Loaded Detent

Emergency Power Spring Detent

Engine Power Lever

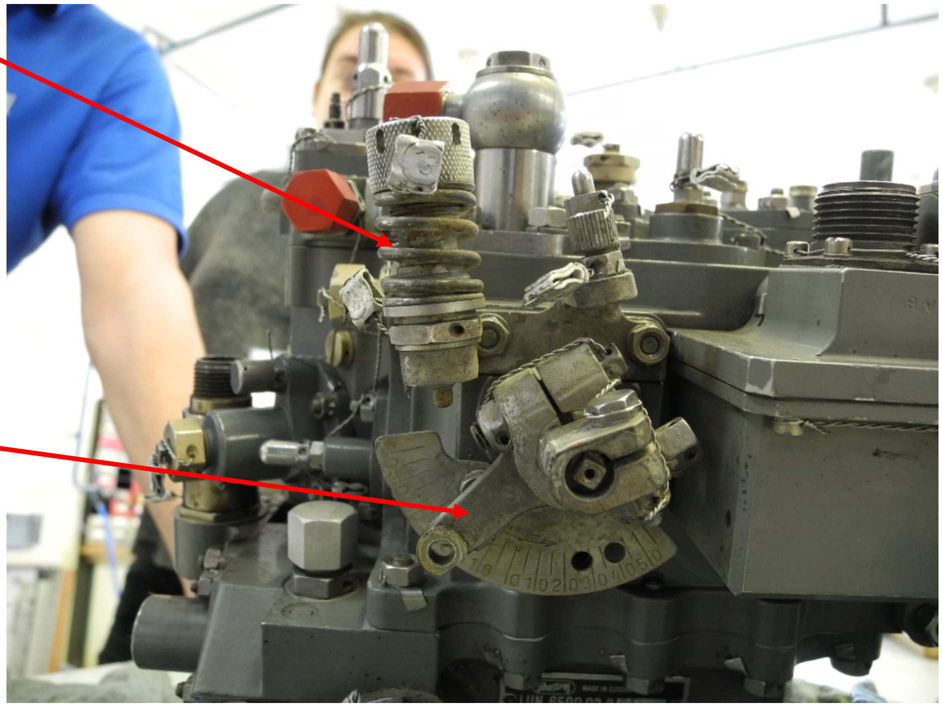


Photo 16 – Witness Cap - Missing

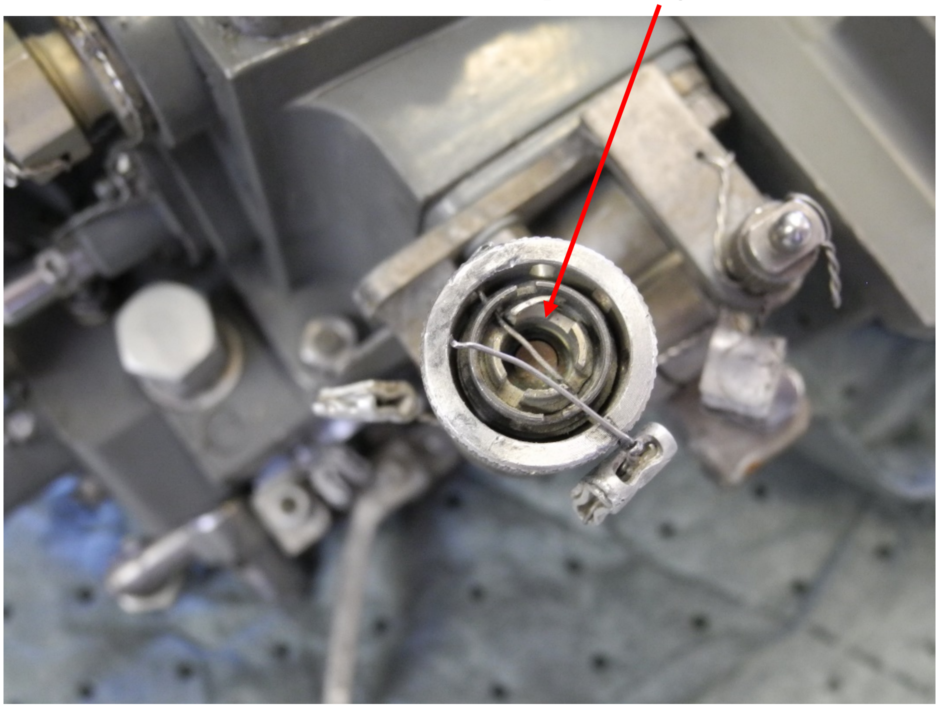


Photo 17 - FCU Input Drive Splined Drive - Undamaged

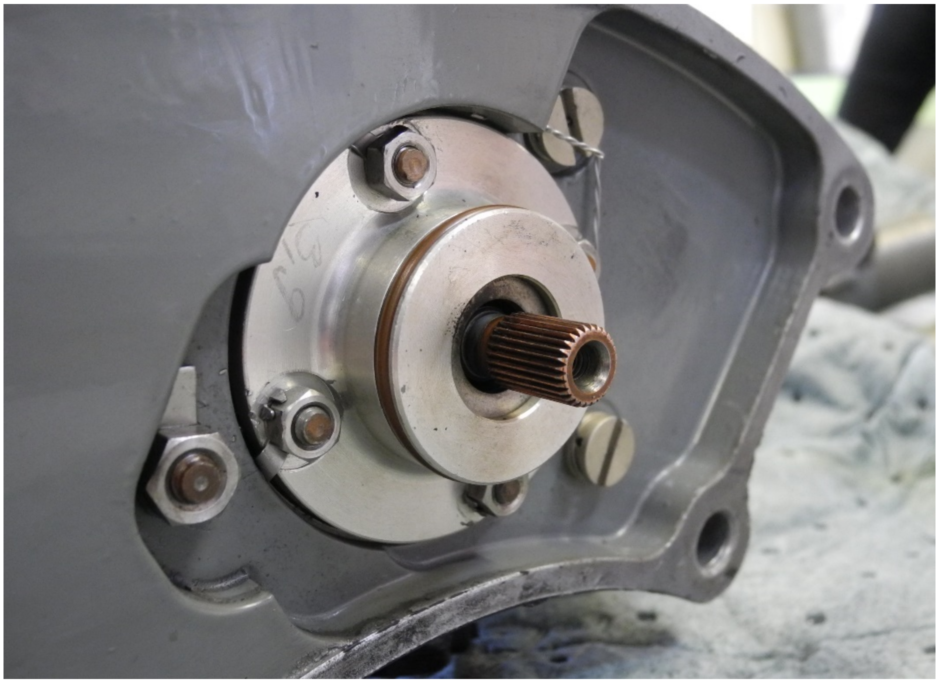


Photo 18 - Non-standard Fasteners. Hex Bolts Instead of Studs & Nuts

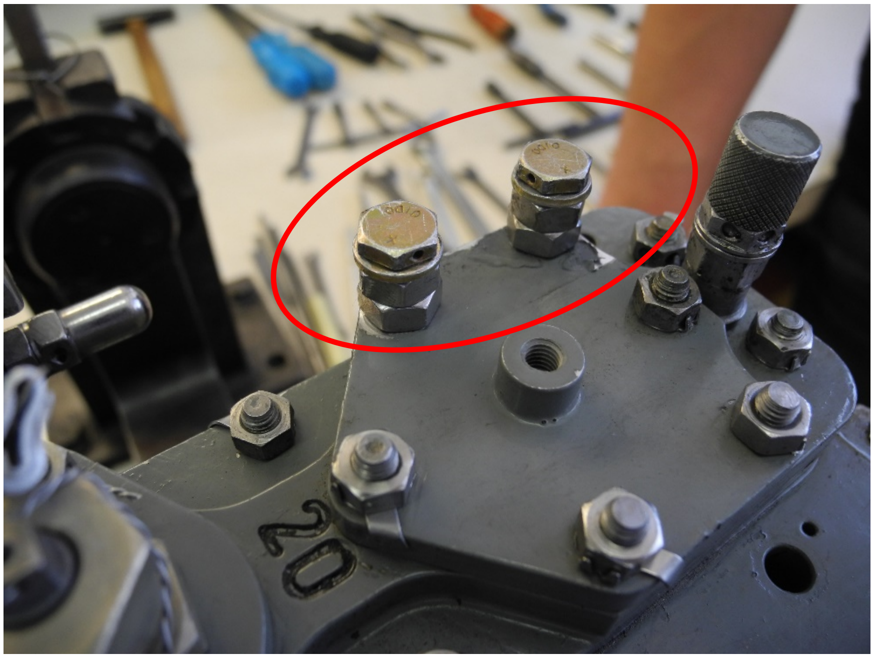


Photo 19 - Lock Wire at adjustment Screw 33

Photo 20 - Lock Wire on Adjusters 40, 41 & 50

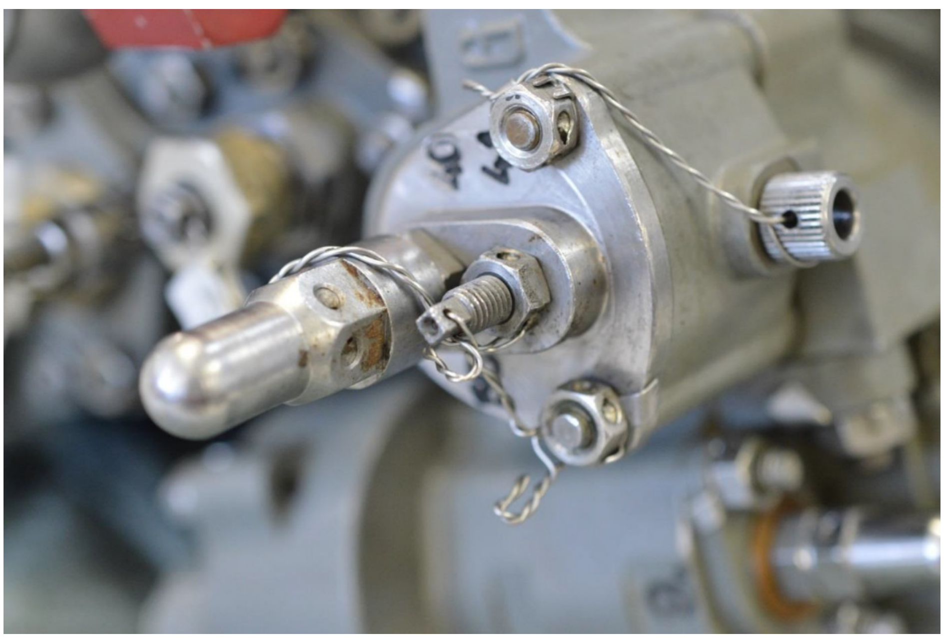


Photo 21 - FCU & Fuel Pump Mounted in Test Bench

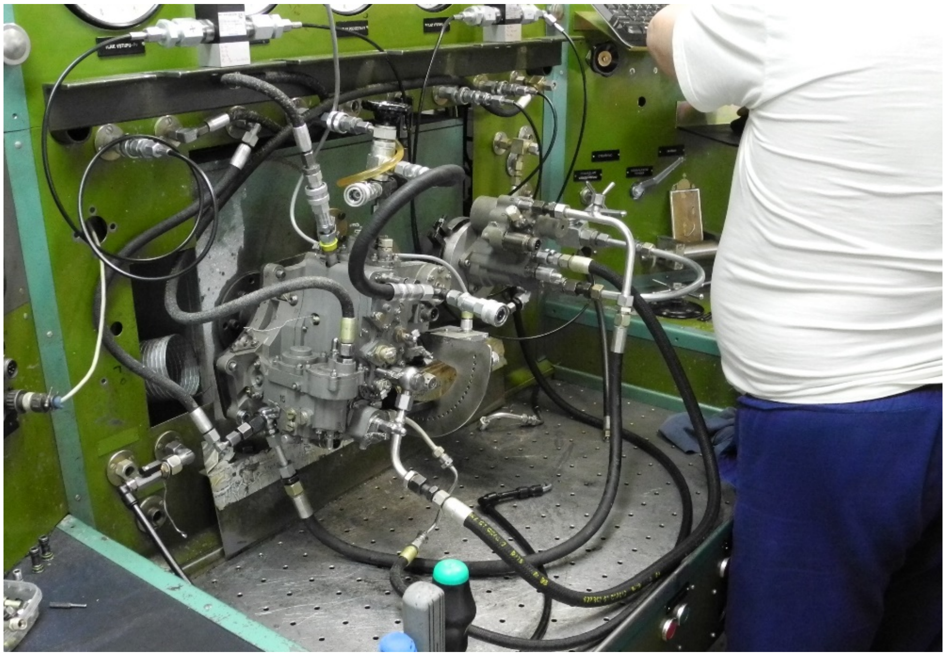


Photo 22 – Alpha Shaft Housing – Reworked Retain to Non-Standard Seal

Photo 23 - Rubber Diaphragm and Spring - Corroded

Photo 24 - Acceleration and Deceleration Orifice Assemblies – Clean

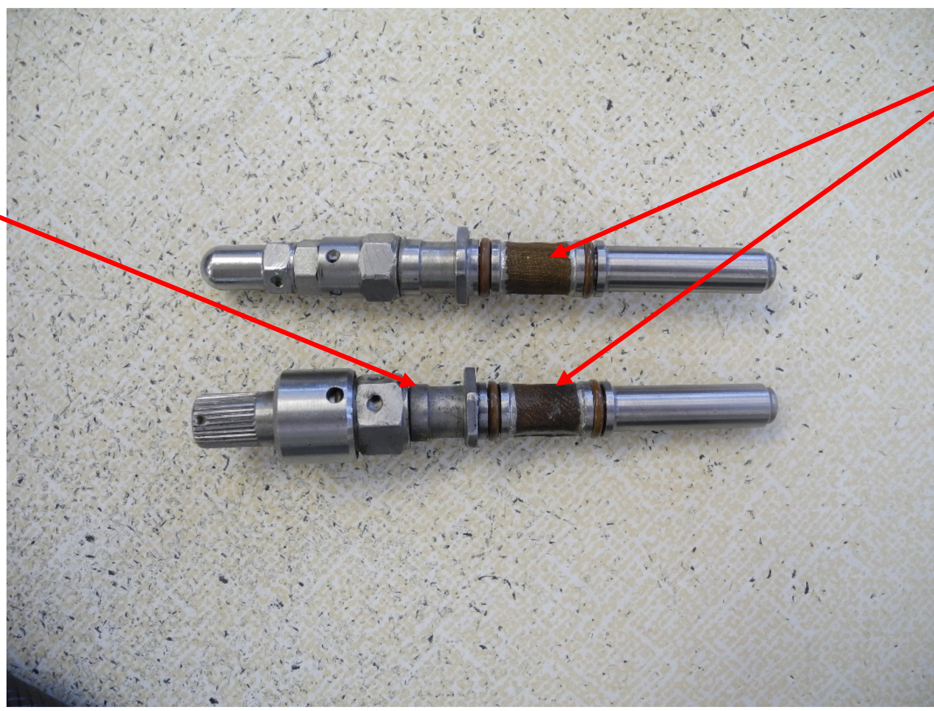


Photo 25 - Main Fuel Valve – Intact & Undamaged

Photo 26 - Emergency Metering Valve Assembly

Photo 27 - Pressure Regulating Valve of the Emergency Circuit – Minor Corrosion

Photo 28 - Fuel Cutoff Valve

Minor Corrosion

Photo 29 - Emergency Circuit Solenoid

Photo 30 - Emergency Poppet Valve

Photo 31 - Fuel Pump – As Received

Photo 32 - Fuel Pump - Input Shaft Splines – Undamaged

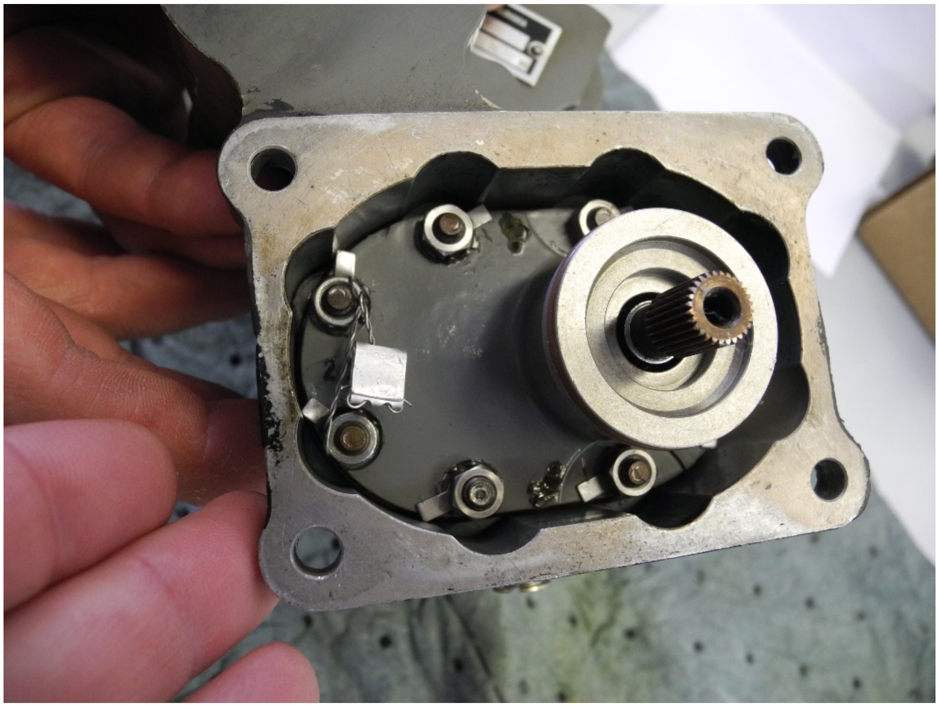


Photo 33 - Fuel Filter Element - Clean

Photo 34 - Fuel Filter cavity in Fuel Pump - Clean

Photo 35 - Torch Ignitor Flow Restrictor Transfer Tube – Torn O-ring

Photo 36 - Fuel Pump - Disassembled

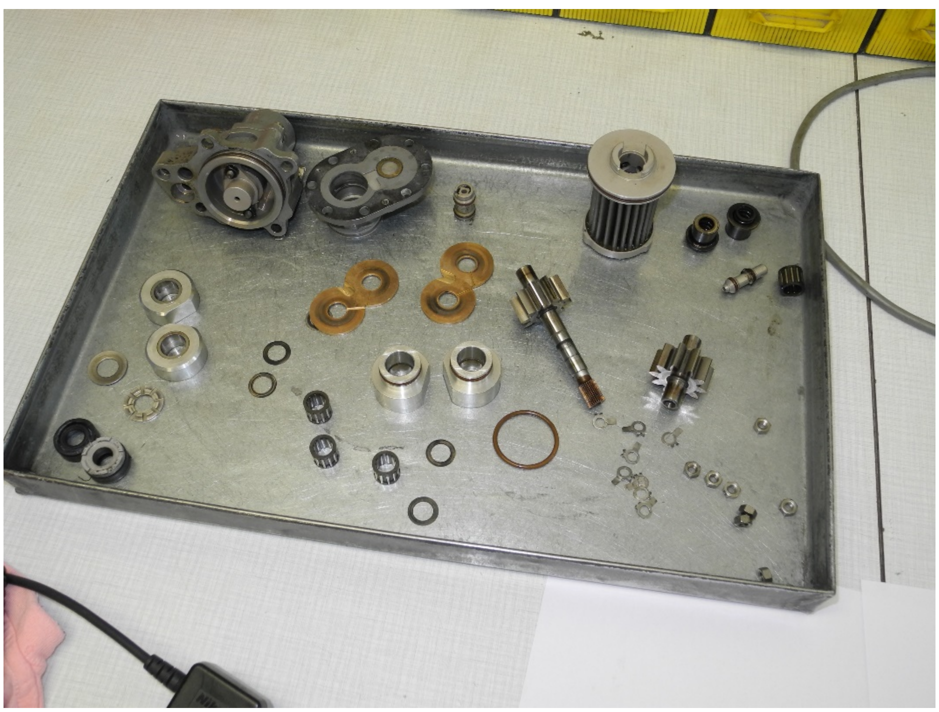


Photo 37 - Gear Pump Assembly – Intact

Photo 38 - Brass Side Sealing Plates - Undamaged

Photo 39 – Gear Pump Cavity

Photo 40 - Propeller Governor P/N LUN7815.02-8, S/N 862033

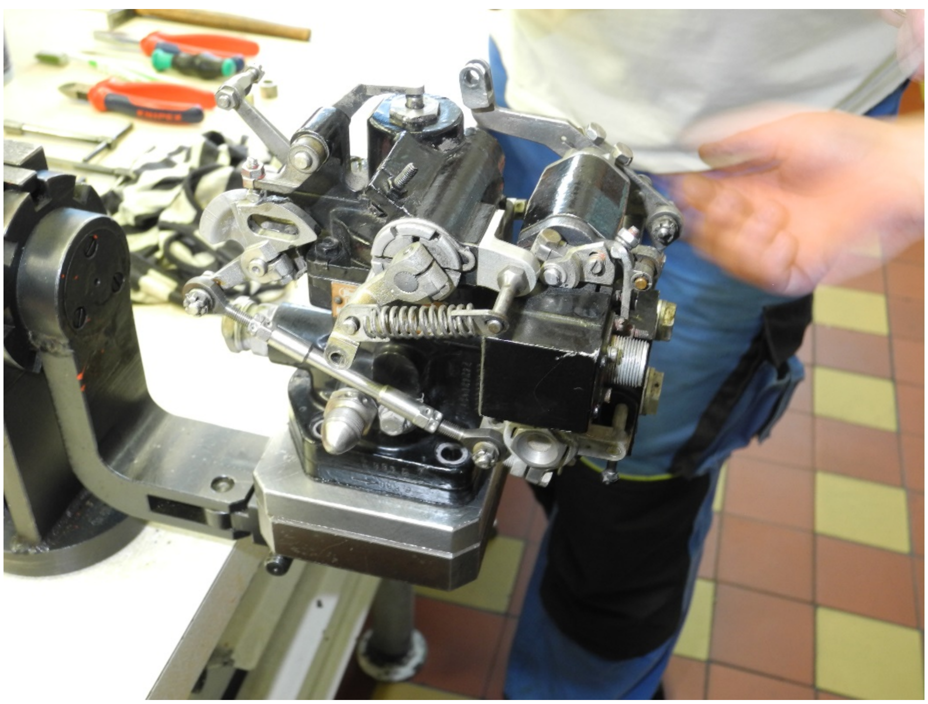


Photo 41 - Emergency Feather Fitting Blanked-off

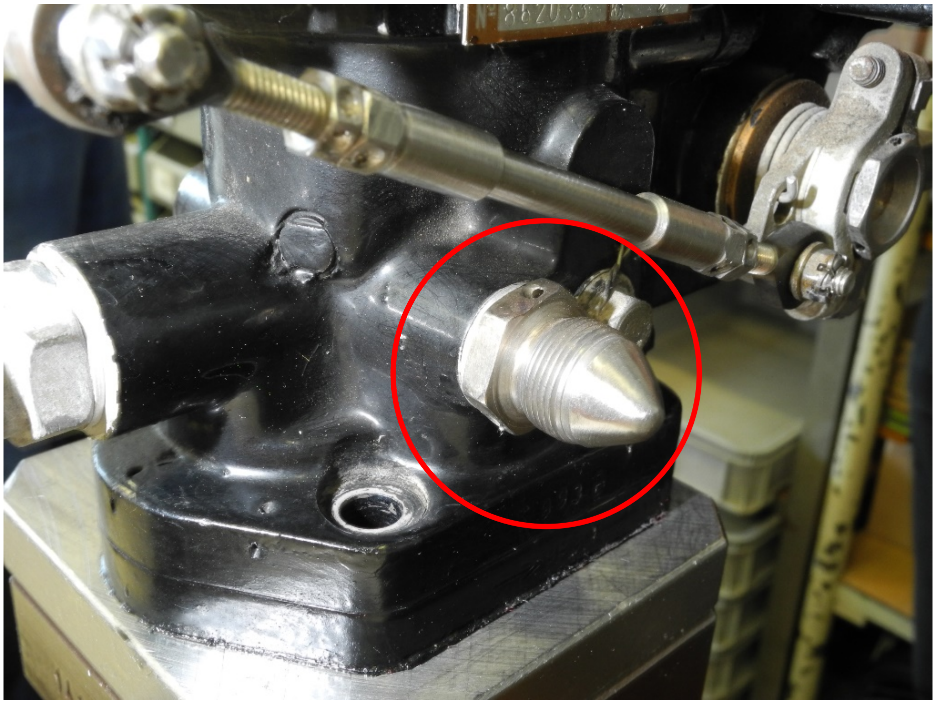


Photo 42 - Oil Pump Involute Gear Teeth - Undamaged

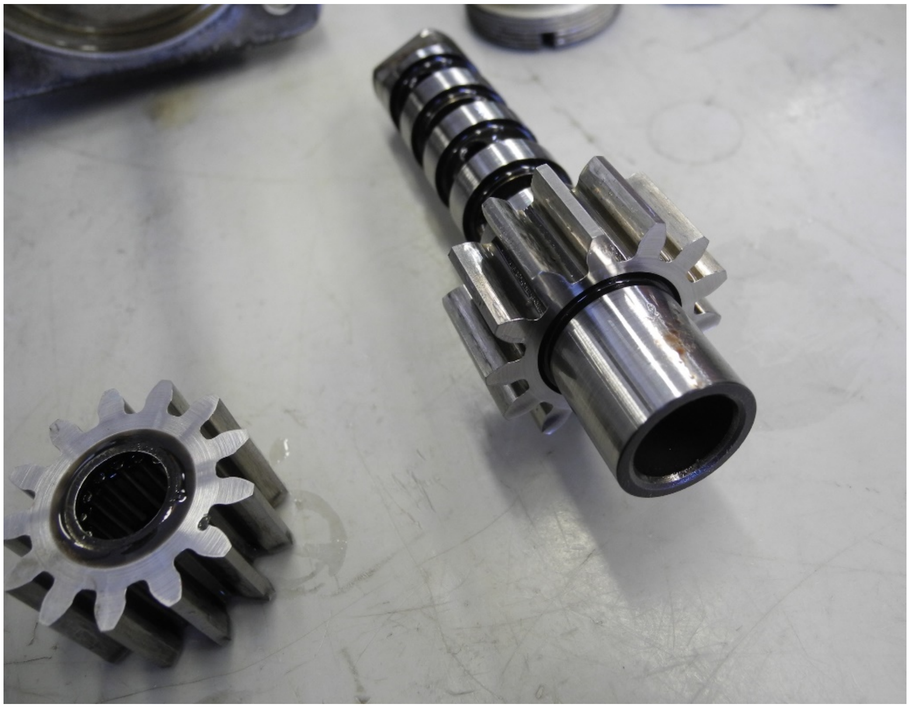


Photo 43 - Rotating Main Shaft, Pilot Valve and Speeder Spring

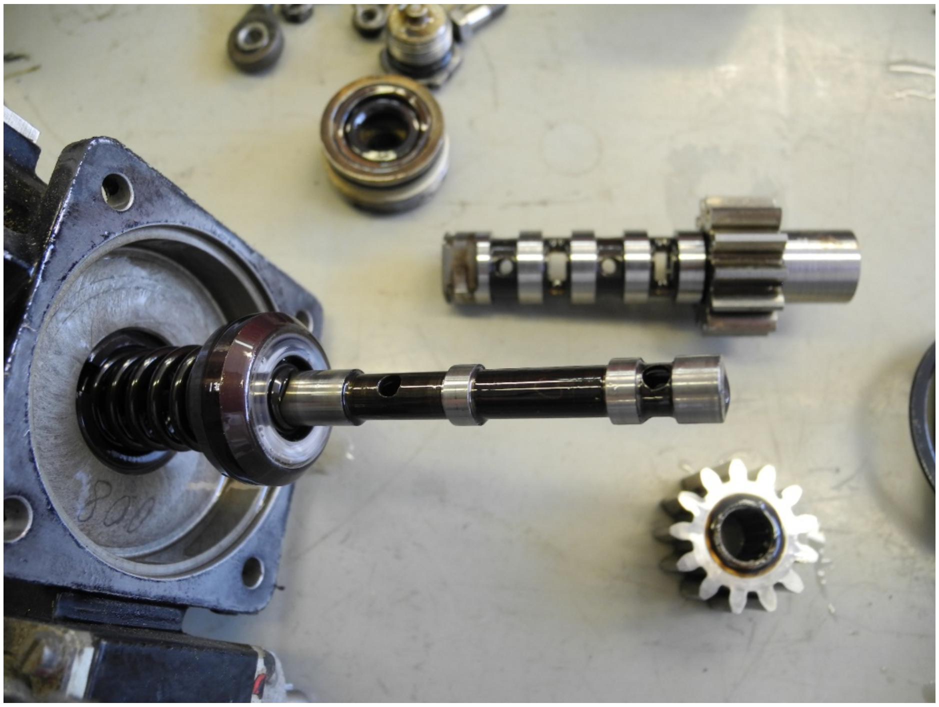


Photo 44 - Flyweights - Undamaged

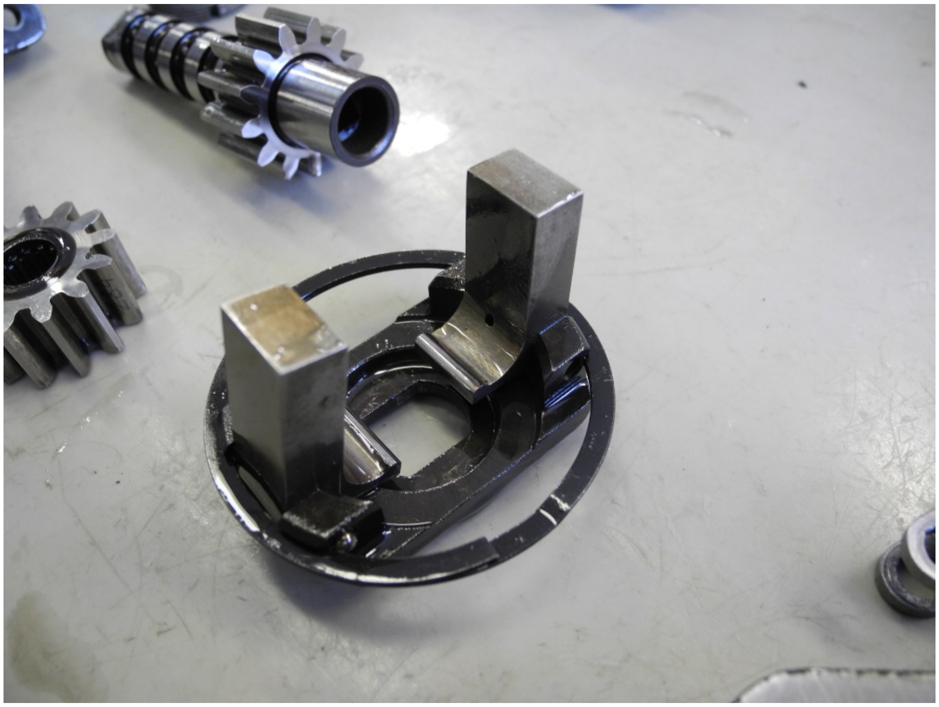


Photo 45 – AVIA Propeller - V508E/84/B2, S/N 140651237

Photo 46 - Propeller Blades – General Damage

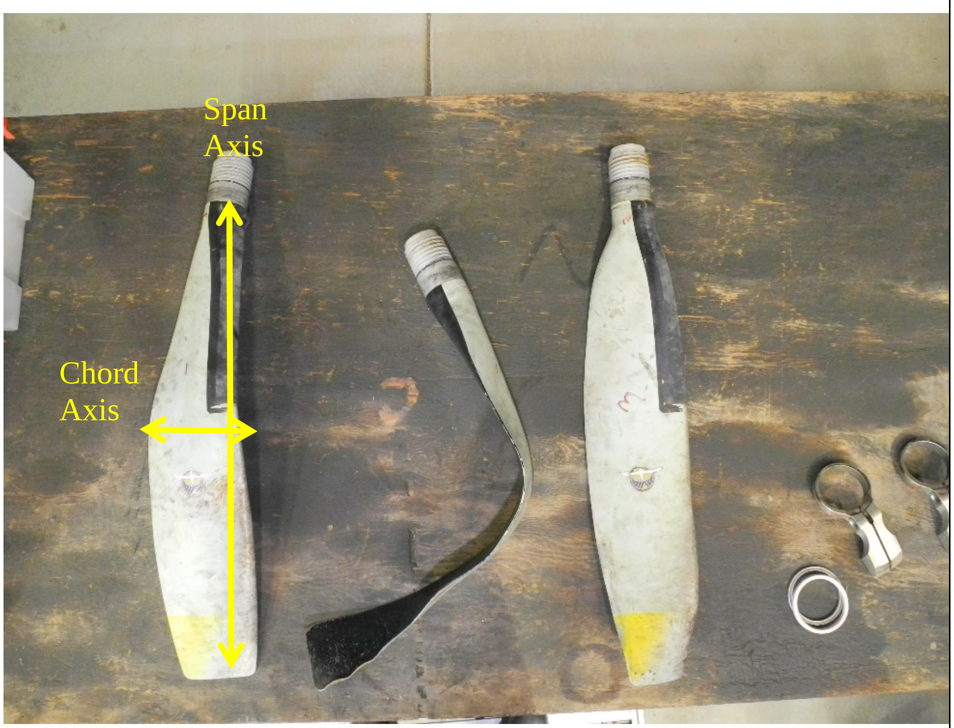


Photo 47 – Typical Damage to Blades

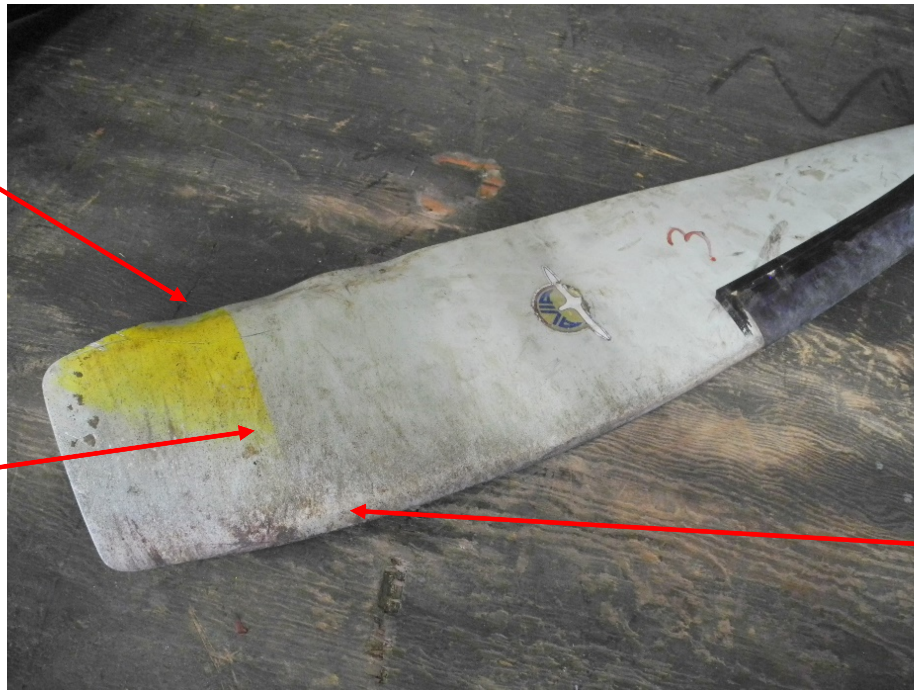


Photo 48 - Camber Side of the Propeller Blade #3

Photo 49 - Blade #1 – Alignment Scribe Marks – Mis-aligned

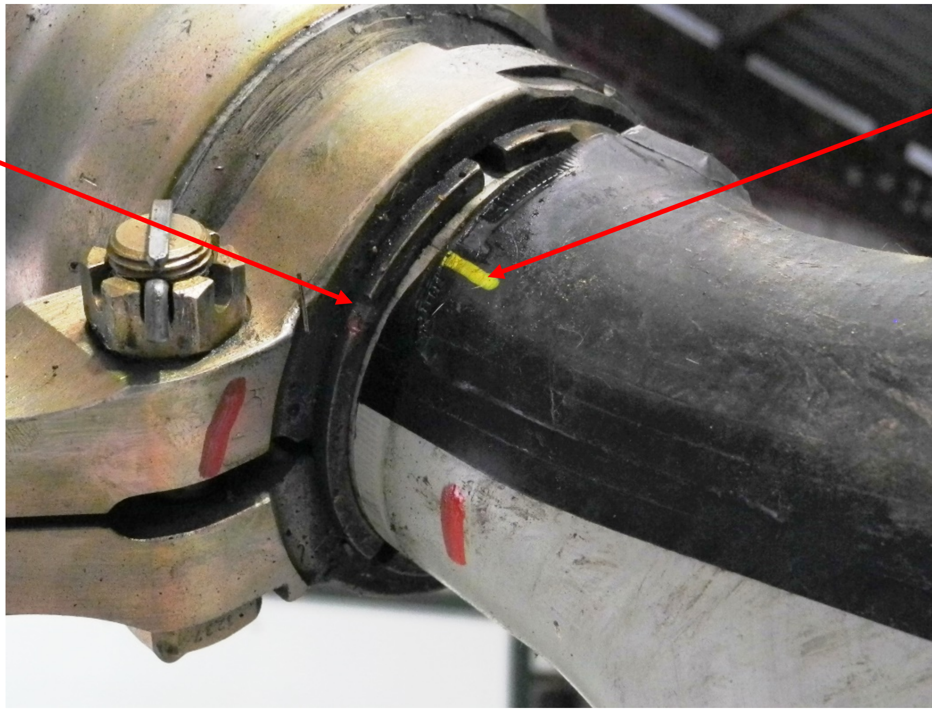


Photo 50 - Blade #2 – Alignment Scribe Marks – Mis-aligned

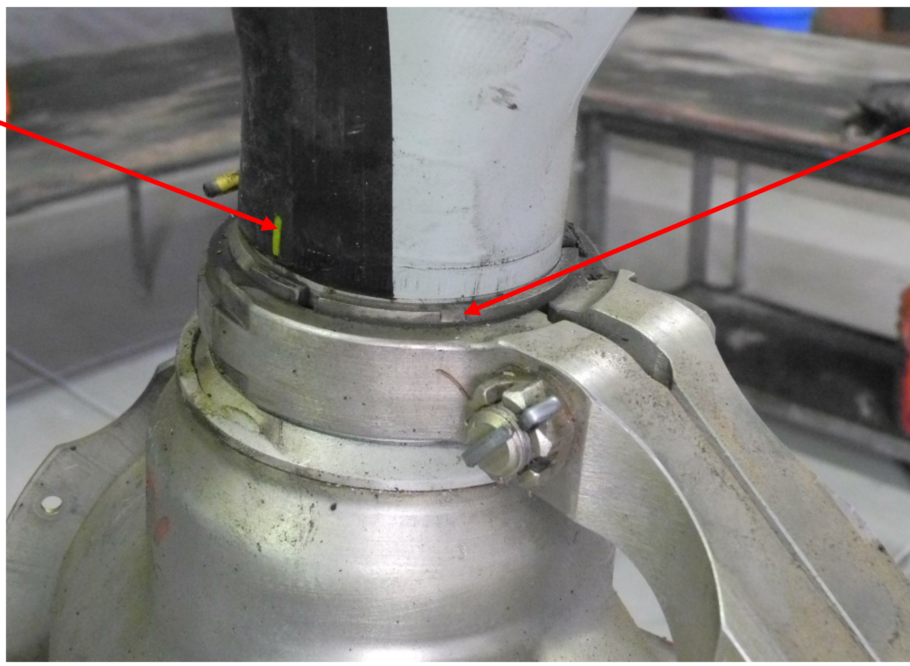


Photo 51 - Blade #3 – Alignment Scribe Marks - Aligned

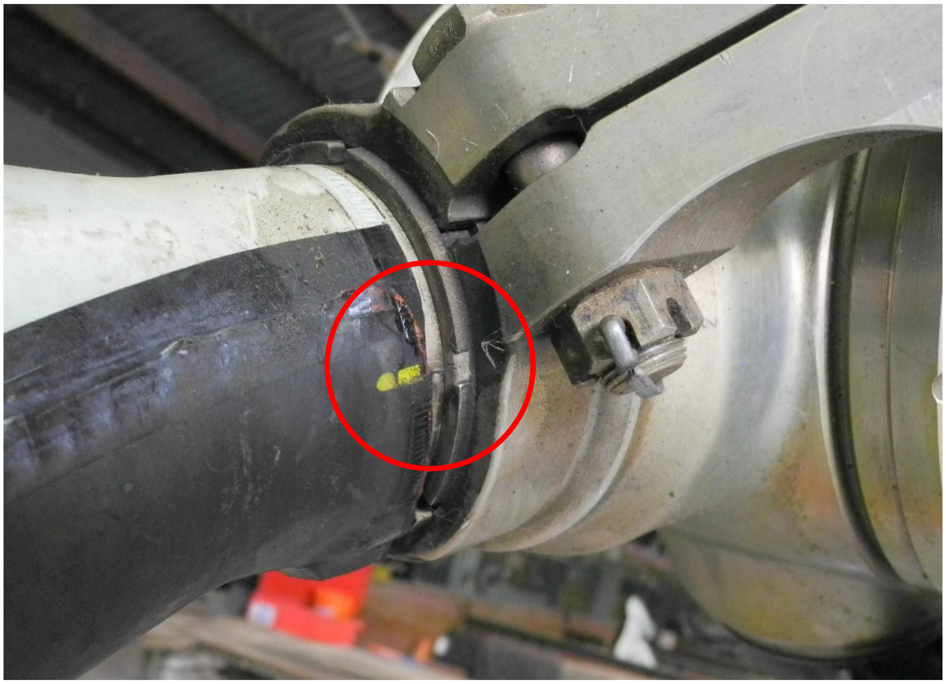


Photo 52 - Bearing Ring Blade #2 – Flange is Sheared

Bearing Ring
Flange - Sheared

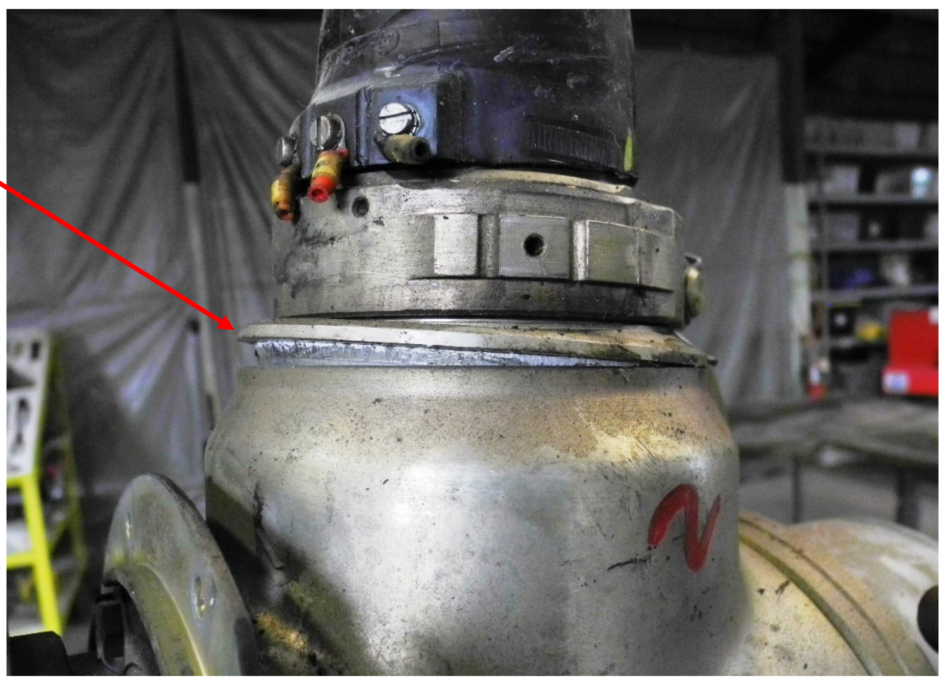
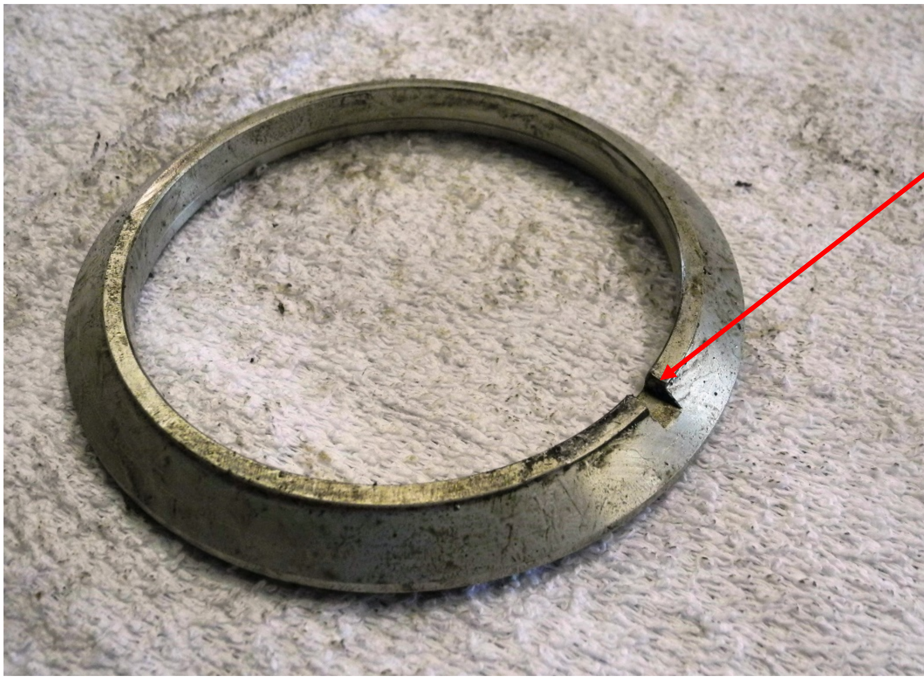
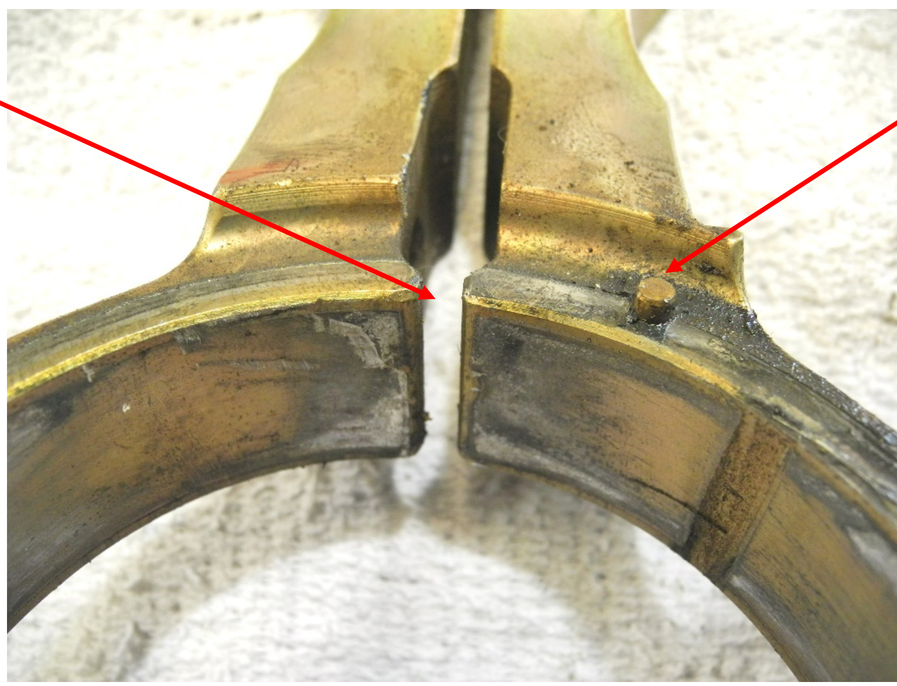


Photo 53 - Bearing Ring of Blade #3 - Undamaged



Indexing Slot for Counterweight / Clamp (Ref. Photo 54)

Photo 54 – Counterweight / Clamp



Alignment Slot for Blade Bushing Key (Ref. Photo 55)

Indexing Pin for Bearing Ring Slot (Ref. Photo 53)

Photo 55 – Blade Bushing

Photo 56 - #2 Propeller Bearing Ring

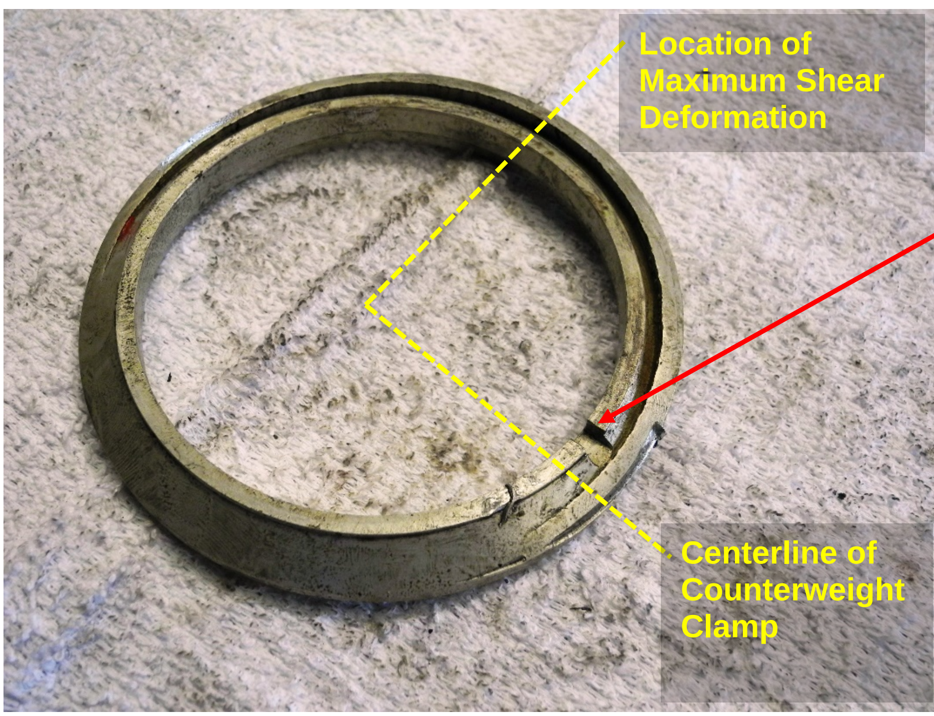


Photo 57 - Overspeed Governor Being Removed from Cylinder

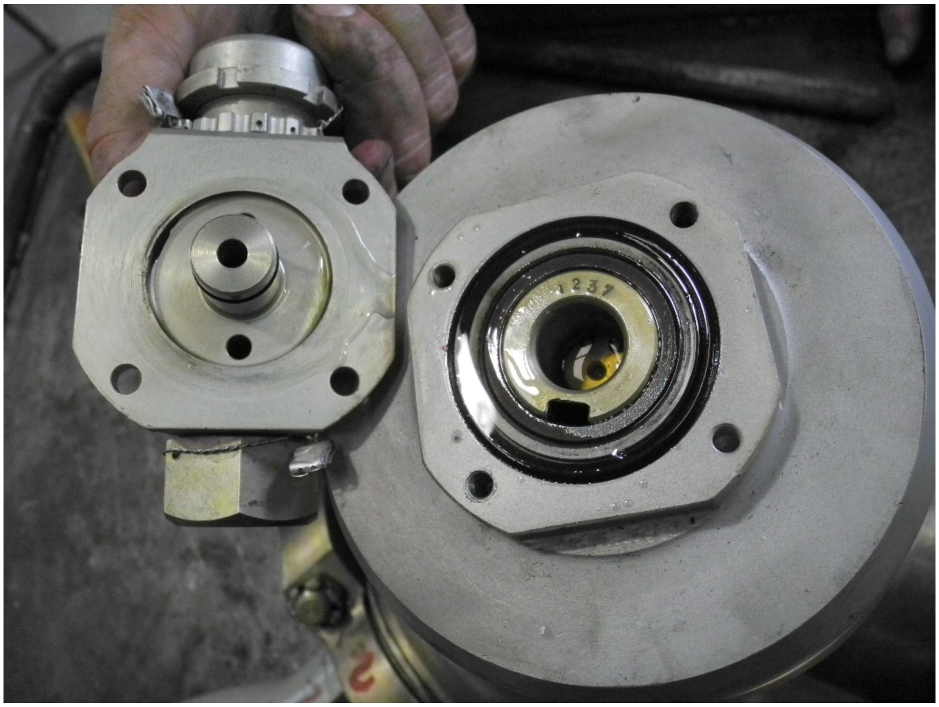


Photo 58 - Cylinder Lock Screw – Lockwire Removed

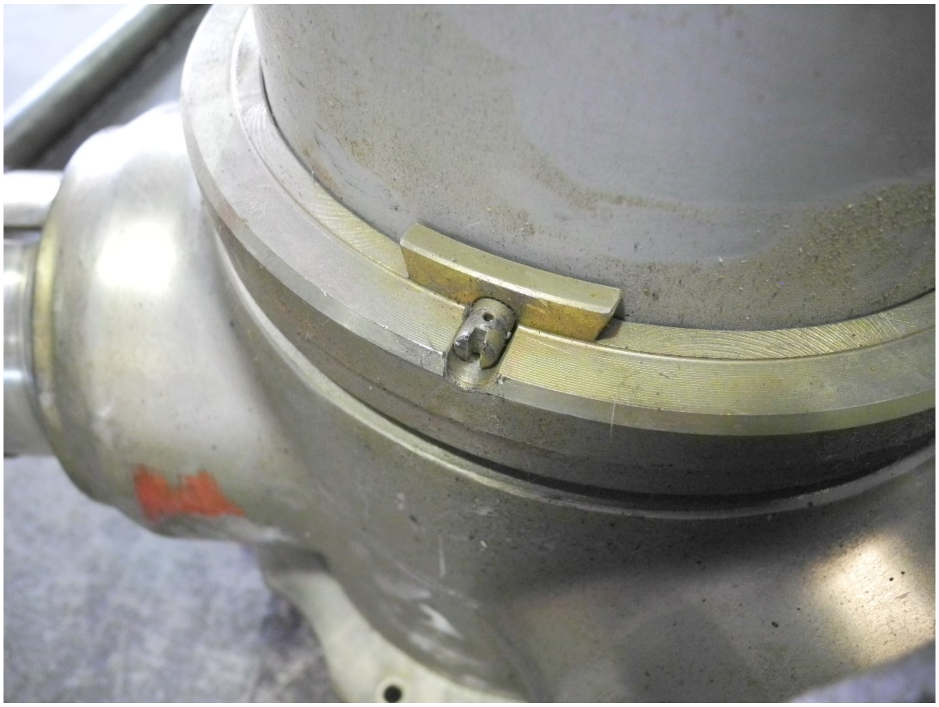


Photo 59 - Inner Surface of Cylinder - Undamaged

Photo 60 - Piston & Elastomeric Piston Ring - Installed

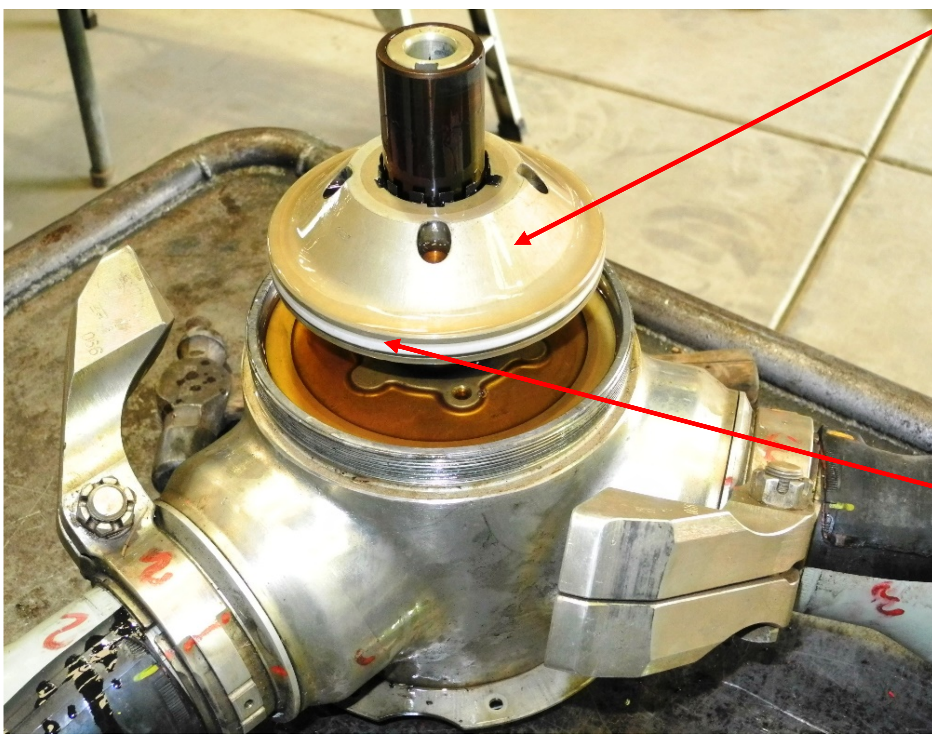


Photo 61 - Piston & Elastomeric Ring - Undamaged

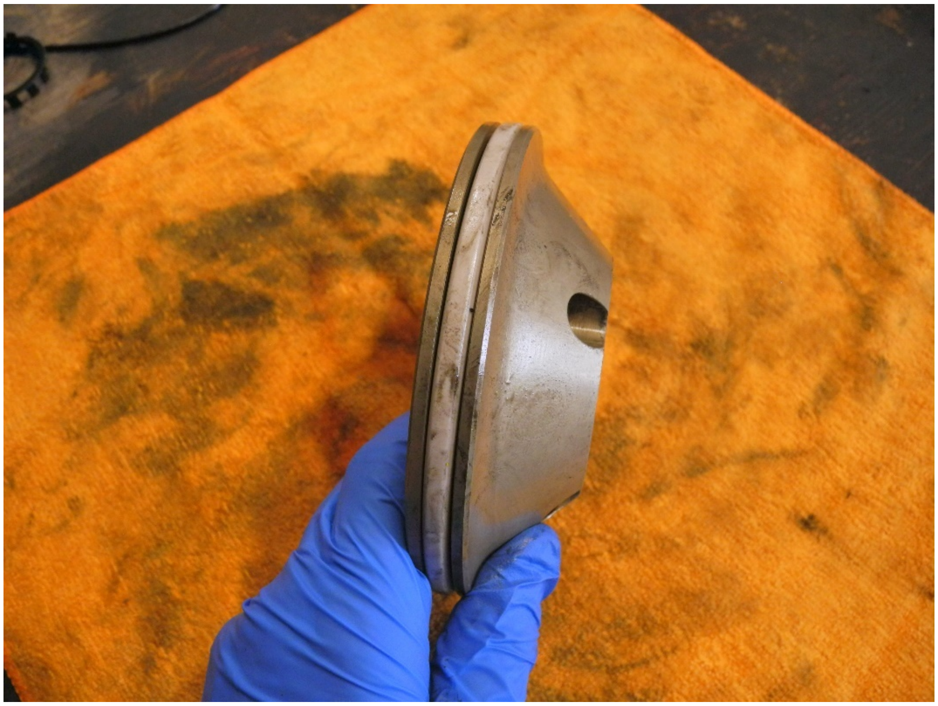


Photo 62 - Center Tube (top) and Fork (bottom) - Intact

Photo 63 - Secondary Pitch Lock Components - Intact

Aft Spacer
See Detail
(Photo 64)

Photo 64 - Aft Spacer of the Pitch Lock Components

Sheared O-Ring

Photo 65 - Fork Guides - Undamaged

Photo 66 - Fork – Wear from Pitch Change Blocks

Detail of Wear
(Ref. Photo 67)

Photo 67 - Detail of Fork Flange Wear from Pitch Change Blocks

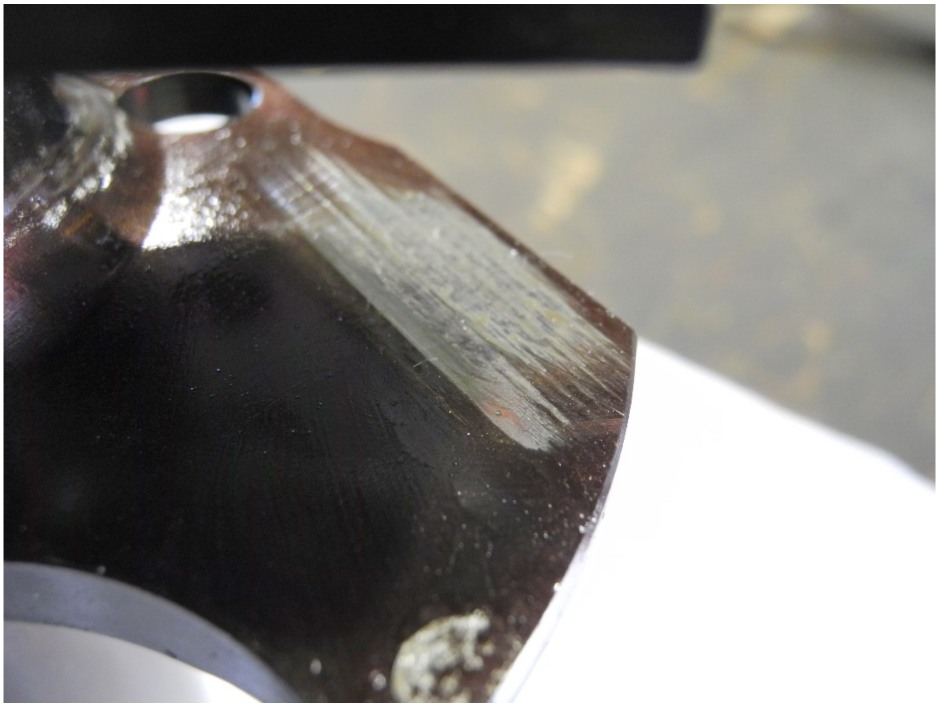


Photo 68 - Fork Front Surface - Dented

Photo 69 - Pitch Change Block Span Measurement

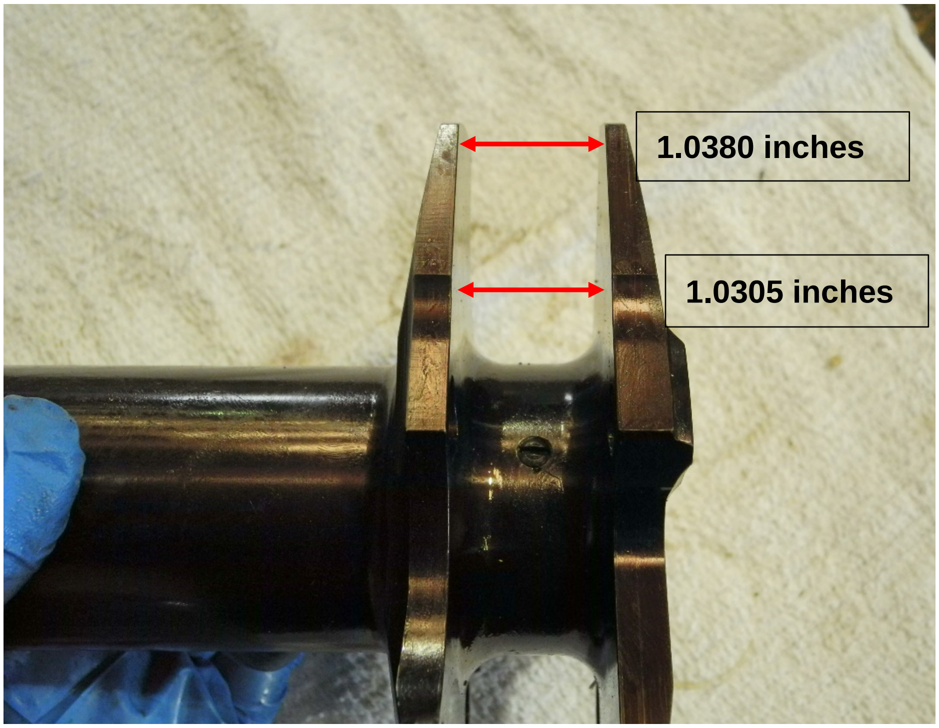


Photo 70 - Blade Bushing Ball Bearings - Undamaged

Photo 71 - Blade Bushing – Impact Marks

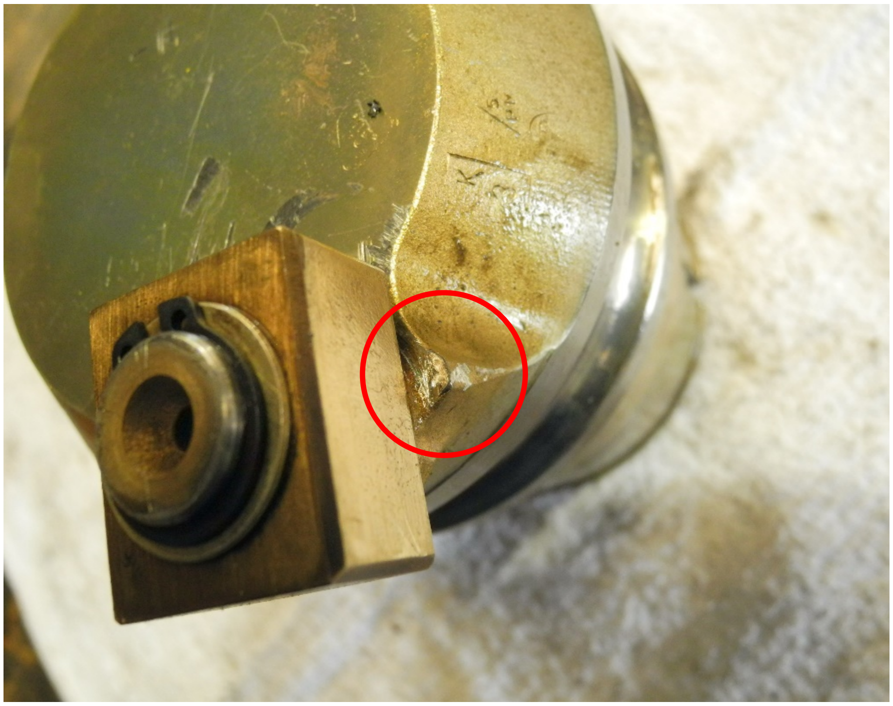


Photo 72 - Hub - Undamaged