NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

September 14, 2021

Attachment 3 –Sitec Aerospace Hydraulic Fire Shut-Off Valves Test Report

POWERPLANTS

DCA18LA163

Engineering Investigation Report

FOR

VALVE, FIRE SHUT-OFF

SITEC AEROSPACE PNR E03A00

SITEC AEROSPACE CAGE CODE C3406

DOC. NO. E03A00-144-02

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REVISION RECORD

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1 INTRODUCTION

1.1 PURPOSE

On April 18th, 2018, at about 18:09 LT (22:09 UTC), a Delta Airlines (DAL) A330-300, MSN 0578, Registration N806NW, powered by Pratt & Whitney PW4168A-1D turbofan engines, performing flight DL-30 from Atlanta International airport ATL/KATL (United States) to London Heathrow LHR/EGLL (United Kingdom) experienced an engine #2 fire during initial climb.

On the affected engine #2, components of the Green and Yellow Hydraulic system have been damaged by the fire. Therefore the hydraulic Fire Shut-Off Valves (FSOVs) were required to be investigated. Furthermore due to the fact that the Reservoir of the Yellow Hydraulic circuit was found empty a special focus was set to investigate the Yellow FSOV in detail.

The French BEA and Airbus S.A.S requested Sitec Aerospace as the manufacturer to assist in performing an investigation of the Fire Shut-Off Valve. The investigation was carried out August 27th.-28th. 2019 at Sitec Aerospace facilities in Bad Tölz, Germany.

Attendees:

- Jean- François Berthier, Safety Investigator, BEA
- Thierry Thoreau, Director of Flight Safety, Airbus S.A.S
- Thorsten Knigge, Airbus Operations GmbH
- Gerhard Triltsch, Chief Engineer, Sitec Aerospace
- Simon Scheel, Dep. Head of Quality, Sitec Aerospace
- Stefan Krös, Sitec Aerospace
- Clive Summers, Director of Sales, Sitec Aerospace

For the investigation Sitec Aerospace prepared an Engineering Test Procedure (see Appendix A) which was distributed and agreed by all parties.

Two FSOVs were returned to Sitec Aerospace:

- Yellow Hydraulic Circuit, P/N E03A00, Amdt. A., Manufacturing Date 07/03 (July 2003), Serial Number 7094. The unit was delivered to Airbus in August 2003 and never returned before.
- Green Hydraulic Circuit, P/N E03A00, Amdt. A, Manufacturing Date 07/03 (July 2003), Serial Number 7095. The unit was delivered to Airbus in August 2003 and never returned before.

List of applicable documents:

- **ATP E03A00-05 Issue 01**
- **Engineering Test Procedure E03A00-056 Issue 01**

Figure 1: Yellow FSOV S/N 7094

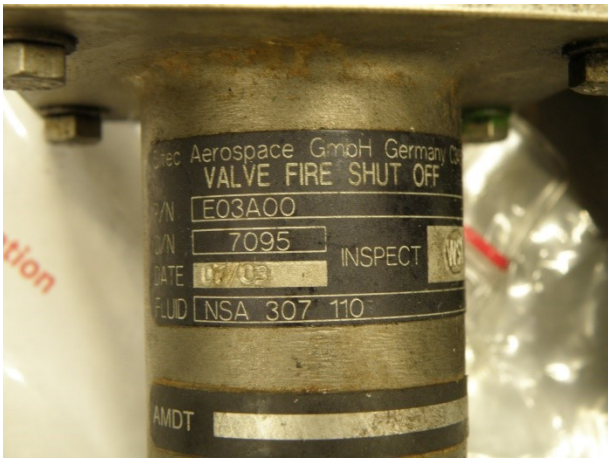

Figure 2: Green FSOV S/N 7095

2 INVESTIGATION OF YELLOW FSOV S/N 7094

The FSOV with serial number 7094 installed in the yellow hydraulic circuit was inspected first since the reservoir of this circuit was found to be empty after the incident.

2.1 VISUAL INSPECTION

The following observations were made at visual inspection as per § 2.1 of the engineering test procedure:

- The general external condition was found to be good.
- No sign of heat damage to be found which would have been indicated for example in a change of colour of the locking paint.
- Imprints were found on the bottom of the mounting holes (Figure 3). These imprints do not interfere with the ball movement or function of the FSOV in general.

Figure 3: Imprints on mounting hole

- Visually the ball appeared to be closed when looking inside the valve. The cavities and the ball seemed to be in good condition. No deposits or other FOD was found. (Figure 4).

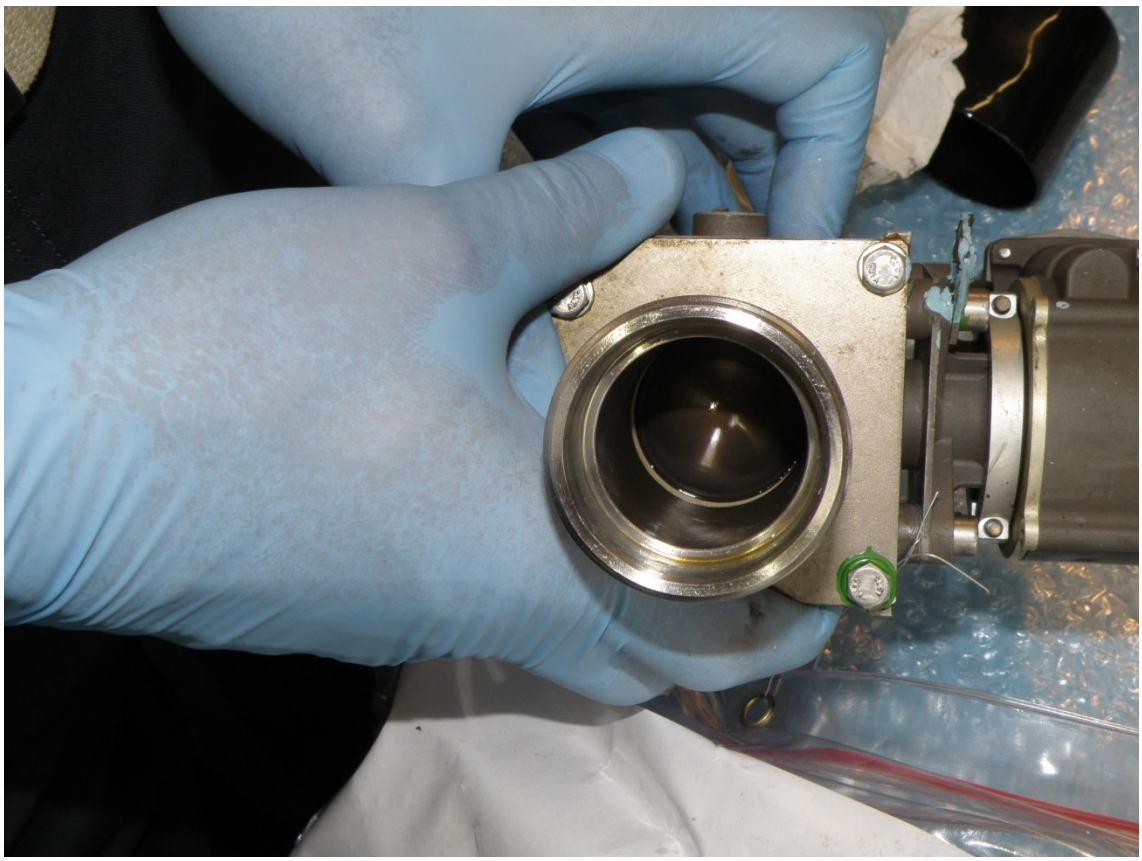

Figure 4: Visual Inspection of Ball Position

- Motor cover of actuator shows dots and/ or dents and deposits (Figure 5 and Figure 6). The impacts marks do not interfere with the actuator function.

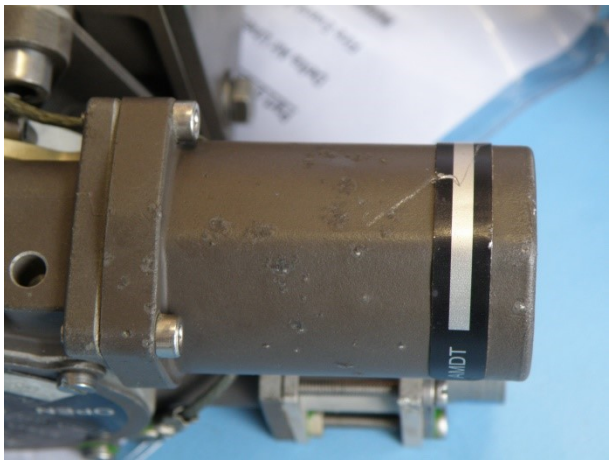

Figure 5: Dents/ Deposits on motor cover 1

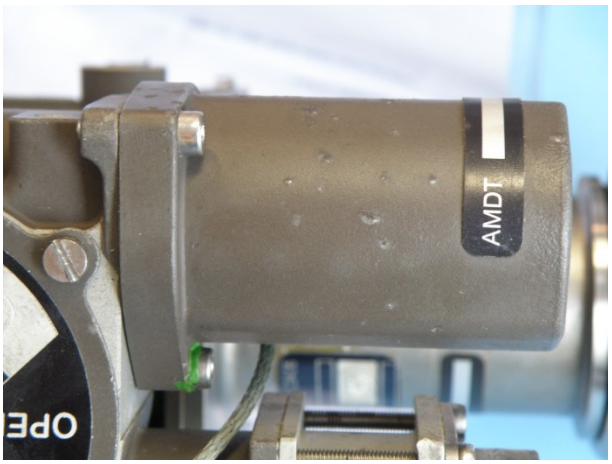

Figure 6: Dents/ Deposits on motor cover 2

- Connector of actuator seemed to be in good condition, no bent or missing pins, no FOD inside connector that could cause short circuit (Figure 7).

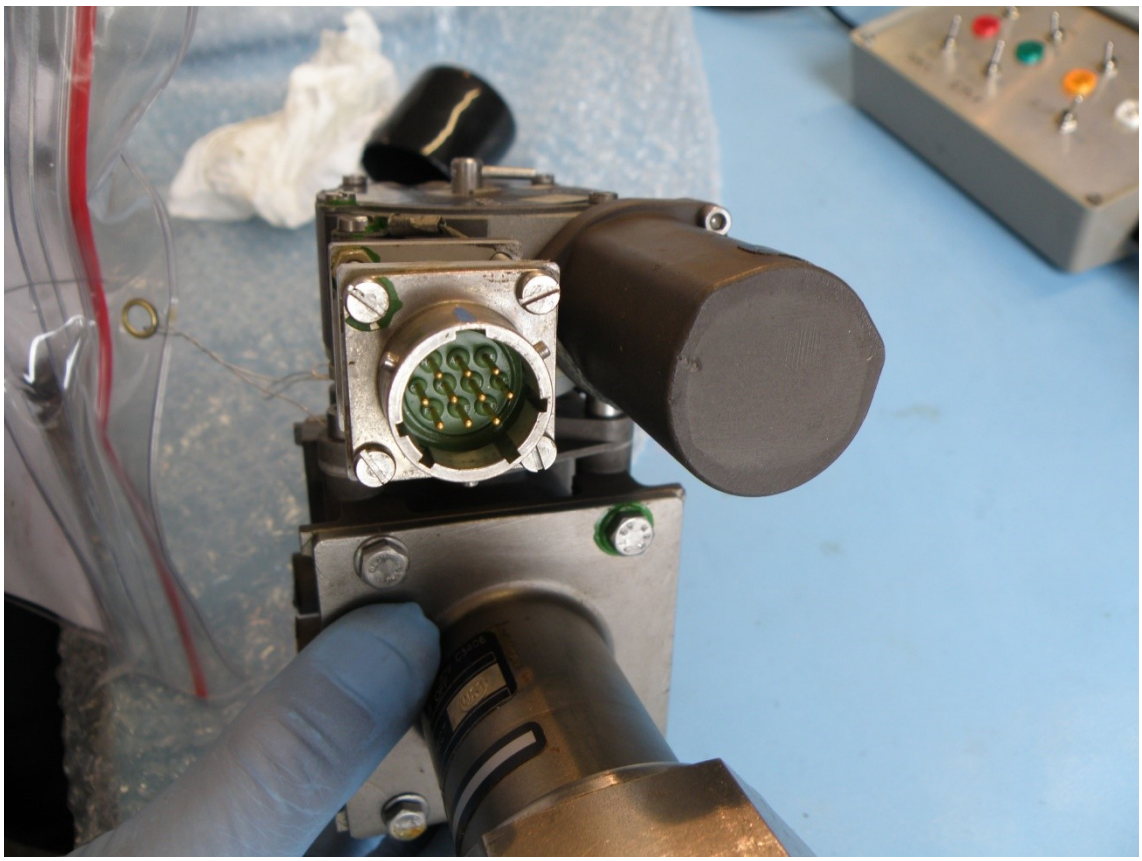

Figure 7: Connector pins

- On actuator housing and cover several impact marks were found (Figure 8 and Figure 9).

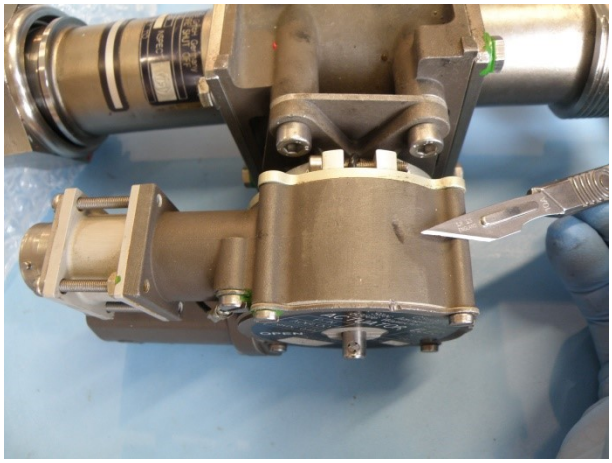

Figure 8: Impact mark on actuator housing

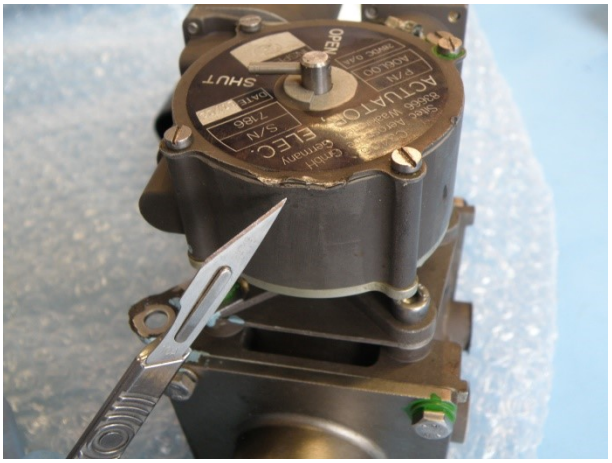

Figure 9: Impact mark on actuator cover

- Two surfaces of the actuator housing seem to be refurbished. This doesn’t interfere with the function of the valve (Figure 10).

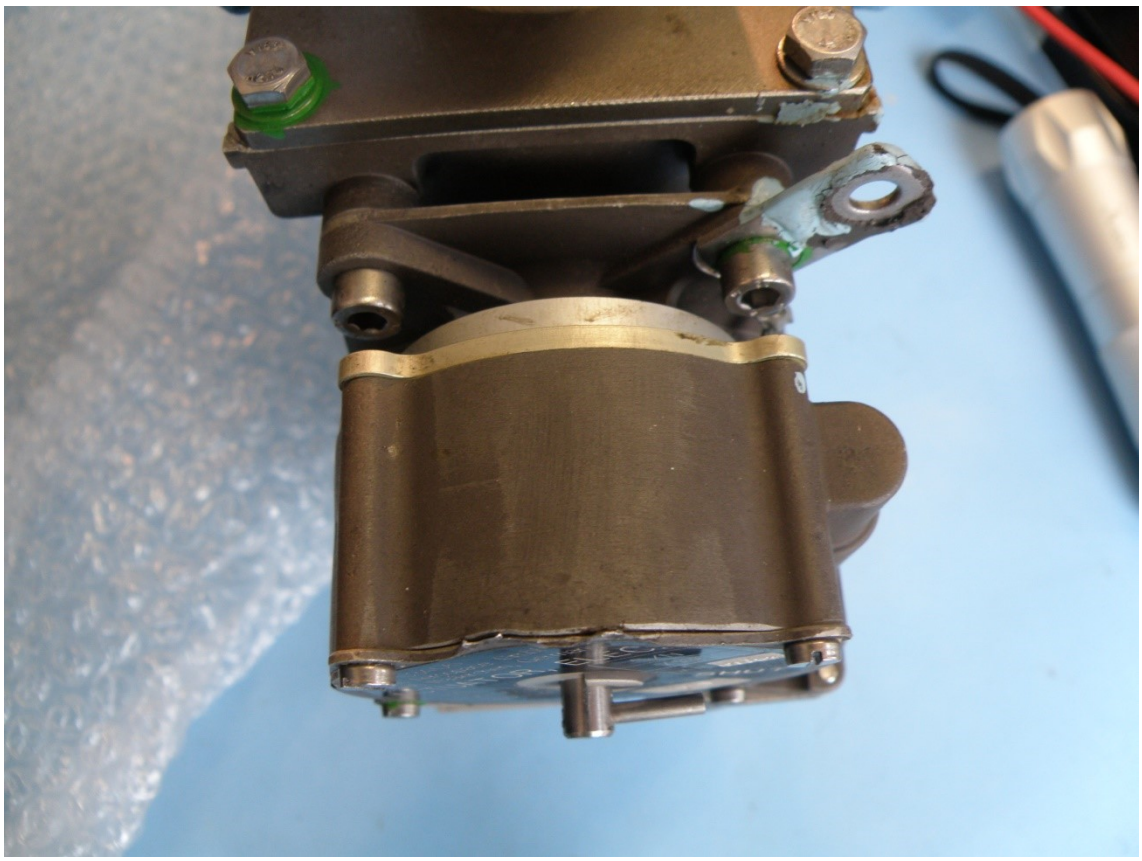

Figure 10: Refurbished actuator surface

- Extremity of both bonding leads were in original condition. The locking paint was untouched. This indicates that the valve wasn’t disassembled from the actuator before.

2.2 ELECTRICAL INDICATION TEST

The electrical indication was checked without operating the valve. An Ohm- meter was connected to the unit as per engineering test procedure §2.2. The resistance was measured at 0.5 Ohm indicating that the valve is in closed position.

Additionally the Ohm- meter was connected to the unit to check if the signal for the valve to be open is present which should not be the case. The measured resistance was infinite which proofs that the electric indication is functional and indicates that the valve is in closed position.

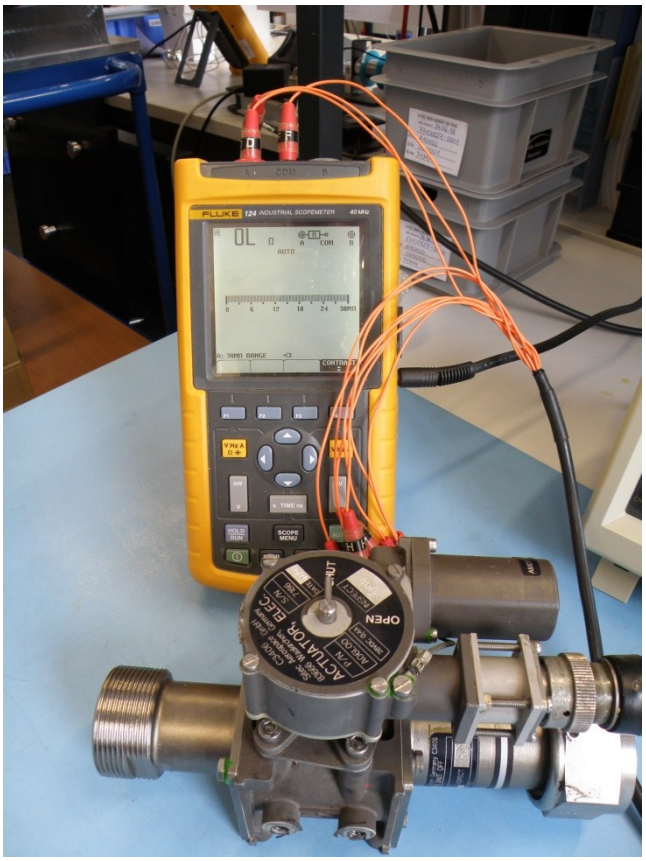

Figure 11: Electrical Indication Test, infinite resistance

2.3 LEAKAGE TEST

The unit was connected to the ATP test stand KA6360-M064 SN1 and the pressure was manually increased to 2 bars, 3.5 bars and 5.2 bars. For each pressure setting the leakage was measured.

On the ATP test stand the pressure is applied with a cylinder which is forced towards the valve and compresses the skydrol inside the system. Once the required pressure level is reached the leakage of the valve results in a further movement of the cylinder. Therefore leakage rate is not measured directly but calculated from movement of the cylinder.

Figure 12: ATP Test Stand with FSOV

The measured values can be found in Table 1.

Table 1: Leakage test prior to valve operation

Applied pressure [bar]	2.0	3.5	5.2
Position, Start [mm]	78.900	79.940	80.478
Position, End [mm]	79.450	80.156	80.538
Movement of cylinder [mm]	0.55	0.216	0.06
Total Leakage [cm³]	0.847	0.33	0.092
Leakage rate [cm³/min]	**0.4235**	**0.166**	**0.046**

$$Leakage\ rate = \frac{cylinder\ movement\ \times\ sqaure\ cross\ sectional\ area}{2\ minutes}$$

The square cross sectional area of the cylinder is 15.4064 cm².

It can be noticed that a higher pressure level results in a lower leakage rate due to the fact that the higher the pressure the higher the force on the ball forcing it into the sealing ring which further reduces the leakage. This is a typical static sealing behavior of valves.

As per ATP E03A00-05 Issue 01 §3.3 of the FSOV (Appendix B) the internal leakage rate (ball in closed position) should be below 0.7 cm^3/min. Therefore all measurements are within specification and indicate that the valve is fully closed.

2.4 FUNCTIONAL TESTS

2.4.1 FIRST MOVEMENT

The unit was connected to power supply with 28VDC and it was checked if the ball moves when the command to close is given which would indicate that the unit was not fully closed. When power was connected to the unit the ball did not move which indicates that the valve was in fully closed position.

2.4.2 NORMAL OPERATION

The unit was connected to power supply and operated from fully closed to fully open position. The travel time for this movement was 1.54 seconds. Afterwards the unit was moved from fully closed to fully open position. The travel time was 1.52 seconds. The current for both movements was 176 mA (without lamp indication).

As per ATP the operating time at open and closed position is 1.8 seconds maximum. The Nominal current at open and closed position is 400 mA maximum. Therefore all measurements were within specification limits.

2.4.3 LEAKAGE TEST

The test as described in chapter 2.3 was repeated. The measured values can be found in Table 2.

Table 2: Leakage test after valve operation

Applied pressure [bar]	2.0	3.5	5.2
Position, Start [mm]	72.200	73.240	73.760
Position, End [mm]	72.628	73.466	73.830
Movement of cylinder [mm]	0.428	0.226	0.070
Total Leakage [cm^3]	0.659	0.348	0.108
Leakage rate [cm^3/min]	**0.330**	**0.174**	**0.054**

All values are within specification limits. No increased leakage rate was detected.

2.4.4 TORQUE TESTS

In addition to the test procedures the torque of the valve ball was measured. For this the actuator was disassembled from the valve. Afterwards the torque to move the ball was measured as 0.7 ± 0.05 Nm for both directions of ball movement.

As per drawing of the valve the torque should be between 0.7 Nm and 1.2 Nm. Therefore the measured values are within specification.

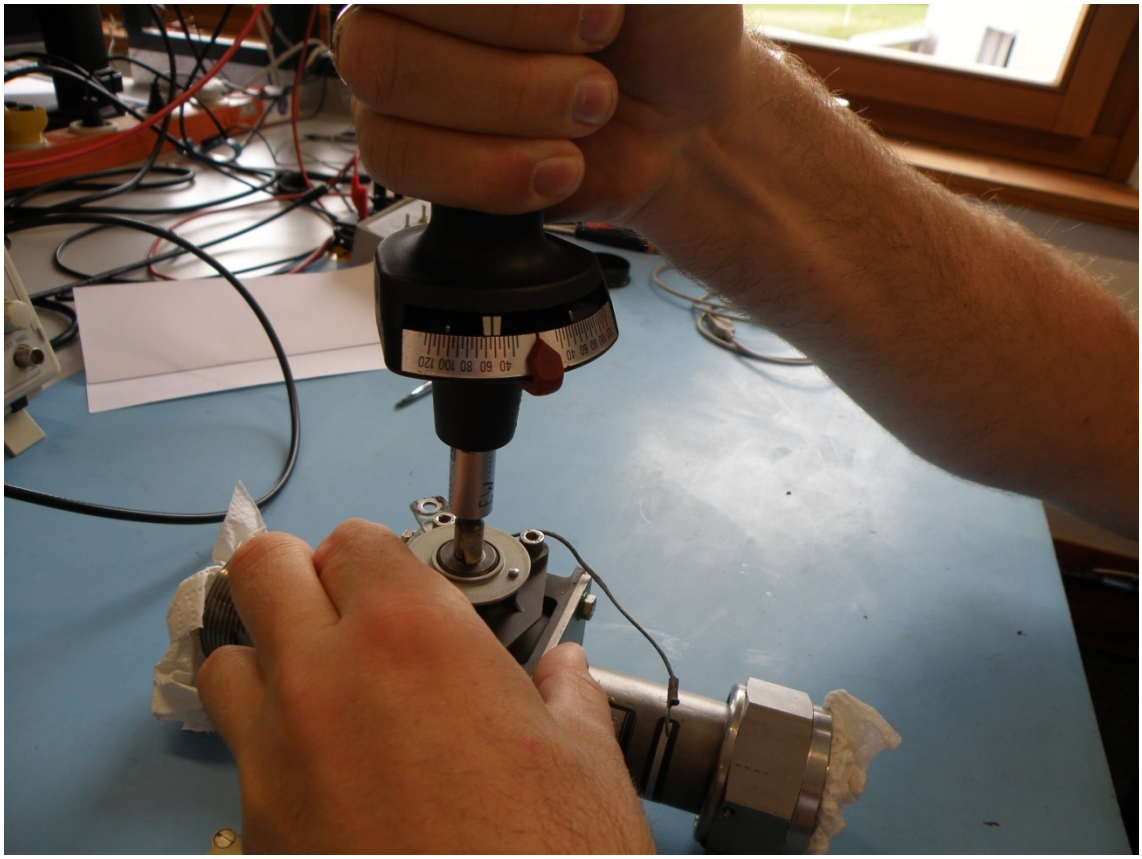

Figure 13: Torque measurement of valve ball

Additionally a load of 1.2 Nm and 2.5 Nm was applied to the actuator and the travel time under these loads was measured. The travel times were measured as 1.58 seconds and 1.74 seconds (Figure 14 and Figure 15). This shows that the actuator is able to move the ball from open to closed position in less than the required 1.8 seconds even with a load that is three times higher than the actual torque of the ball.

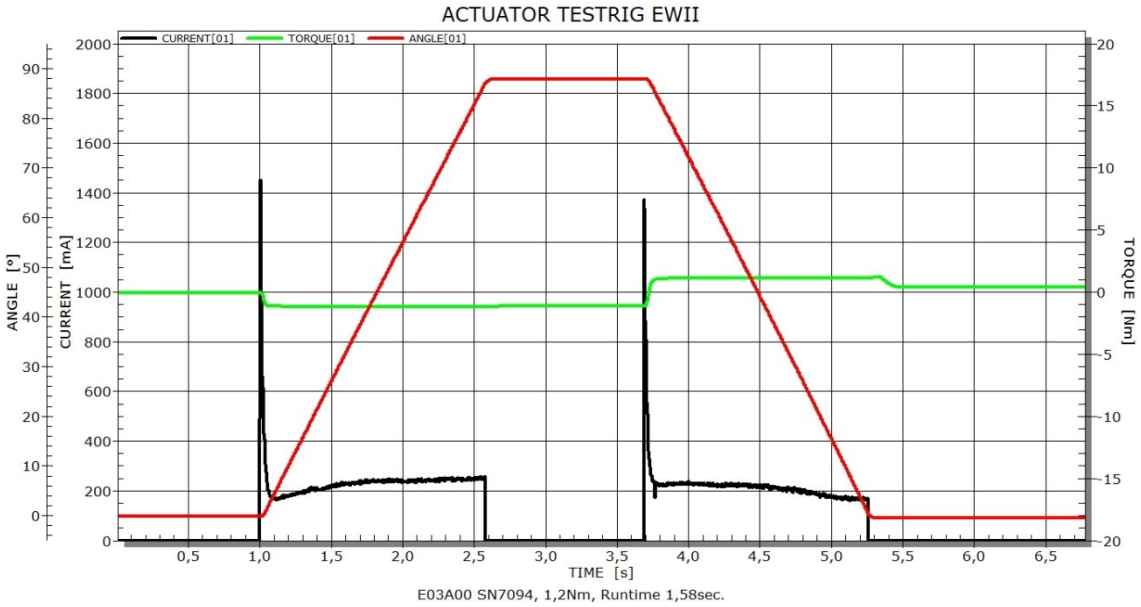

Figure 14: Actuator travel time under 1.2 Nm load

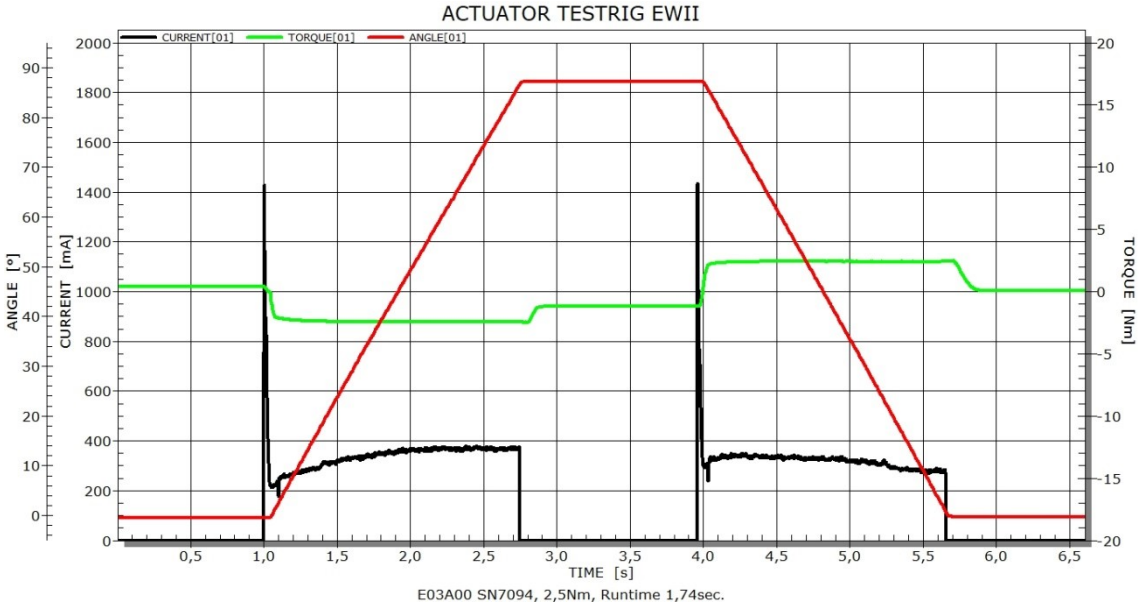

Figure 15: Actuator travel time under 2.5 Nm load

Afterwards a load of 8 Nm was applied to the actuator which is more than 10 times higher than the torque needed to turn the ball. Even if the maximum travel time was exceeded (2.92 seconds) the actuator was still able to perform a 90° turn (Figure 16). Therefore it can be concluded that the actuator was operational and was not on the edge of its performance when command to close was given.

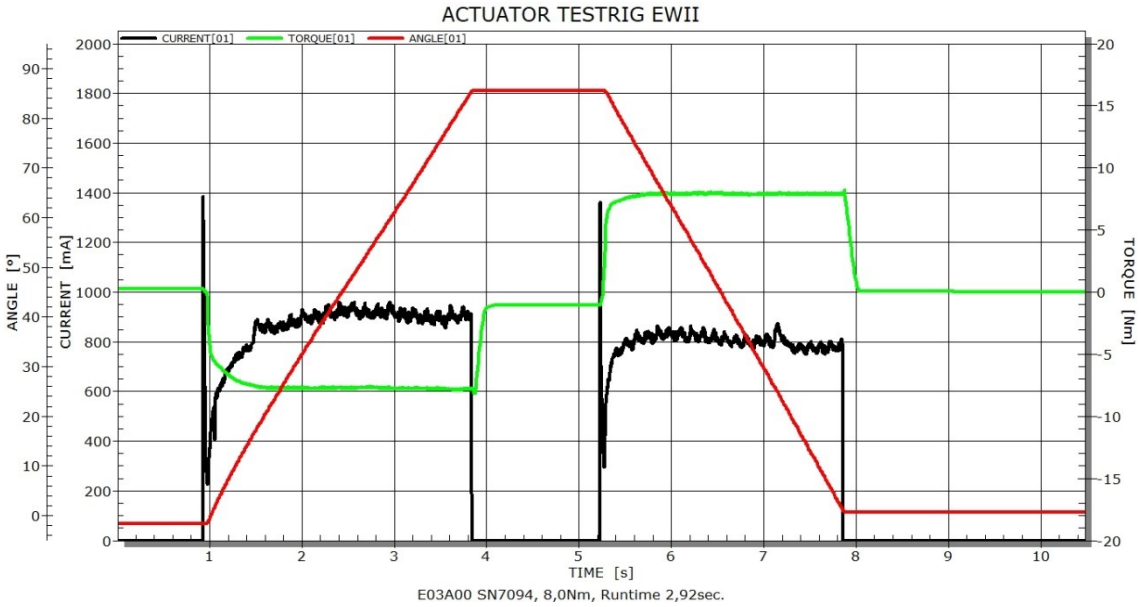

Figure 16: Actuator travel time under 8.0 Nm load

2.5 STRIP DOWN INSPECTION

2.5.1 STRIP DOWN INSPECTION – ACTUATOR

While performing the strip down inspection of the actuator the following observations were made:

- When the actuator cover was opened all screws were tight still glued with Loctite. No sign of previous opening was found.
- No humidity, excessive dirt or other FOD was found inside the actuator.
- No obvious sign of heat was found, no colour change on the sealant of the screws which would indicate intense heat.

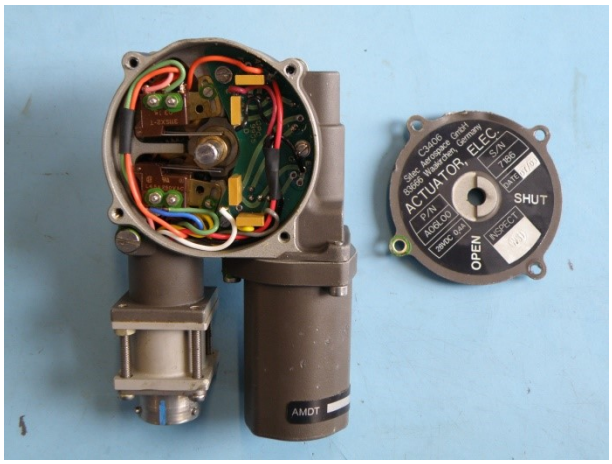

Figure 17: Opened actuator

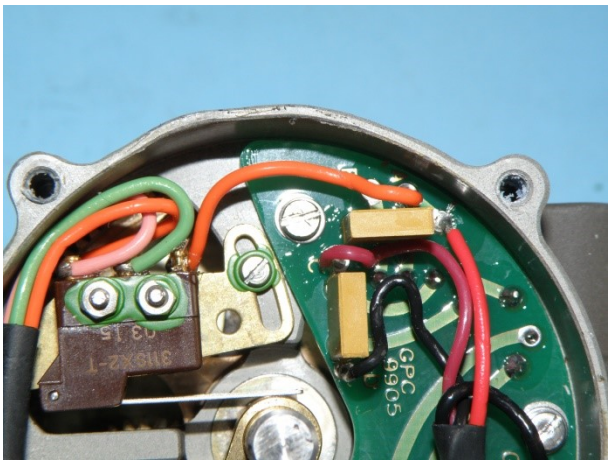

Figure 18: Opened actuator - detail

- Soldering points were still in shape. A flattening of these points would have indicated heat exposure.
- The lid of the actuator cover showed signs of impact. A crack that went through the cover into the o- ring groove was found (Figure 19 and Figure 20)

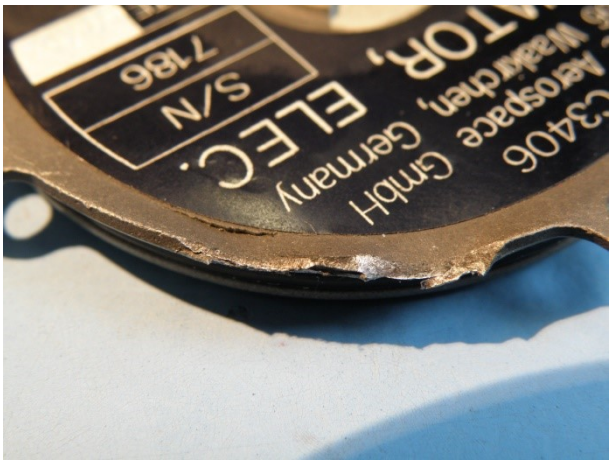

Figure 19: Crack on actuator cover

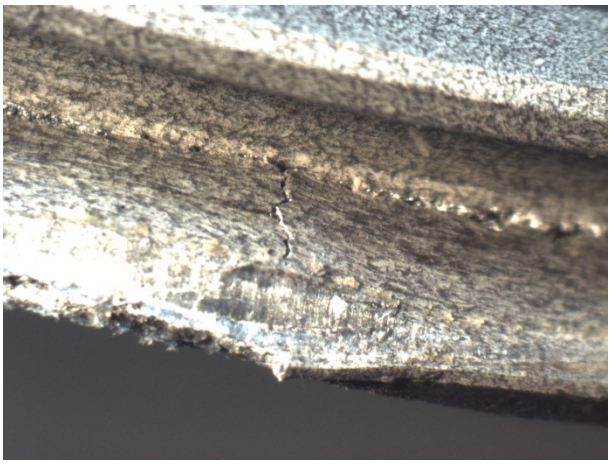

Figure 20: Crack in o- ring groove

The o- ring inside the groove of the cover was dried and cracked (Figure 21)

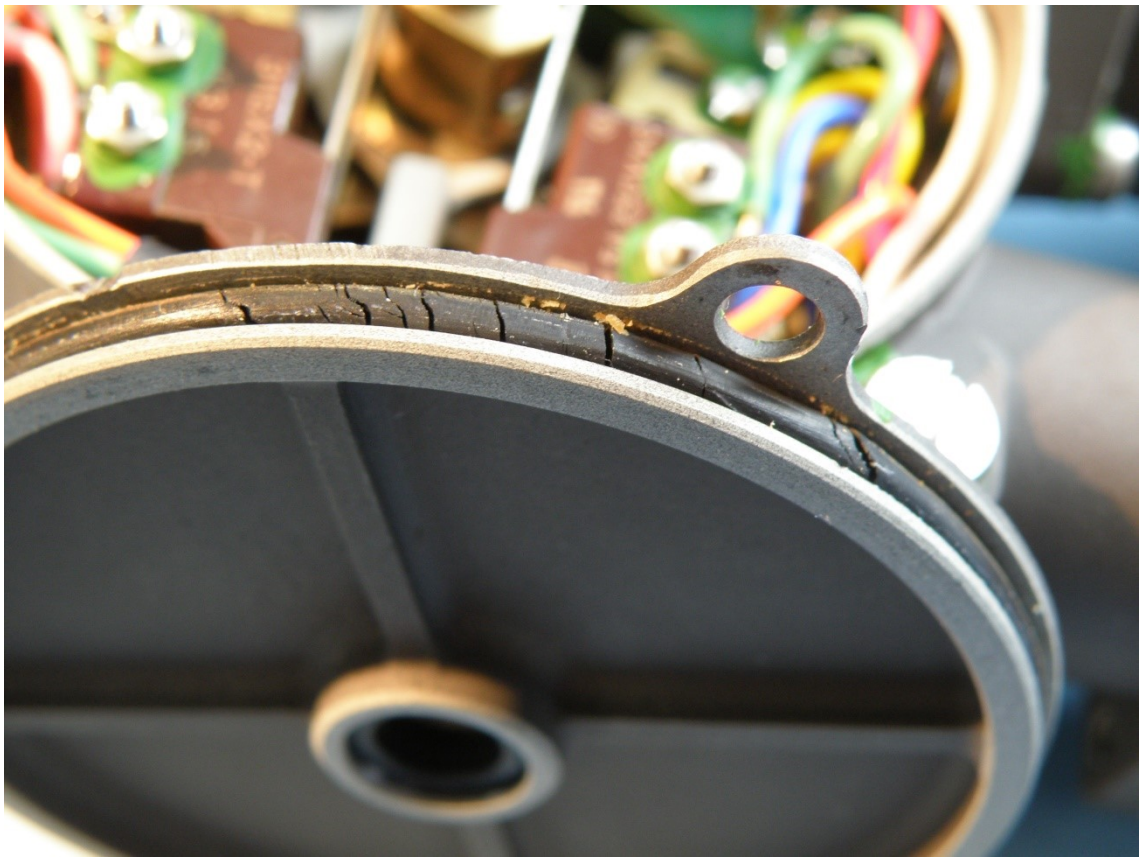

Figure 21: Cracked o- ring

- All wires were still in place and soldered. No damage of the wires was detected.

- No damage on the PCB was detected (Figure 22 and Figure 23)

Figure 22: PCB - top

Figure 23: PCB- bottom

- After removal of the PCB the gear was found in good condition. No signs of obvious wear. No dirt or other FOD was found. Grease was still present and clean. All teeth of the gearwheels were present and in good condition. No wear excessive wear was found.

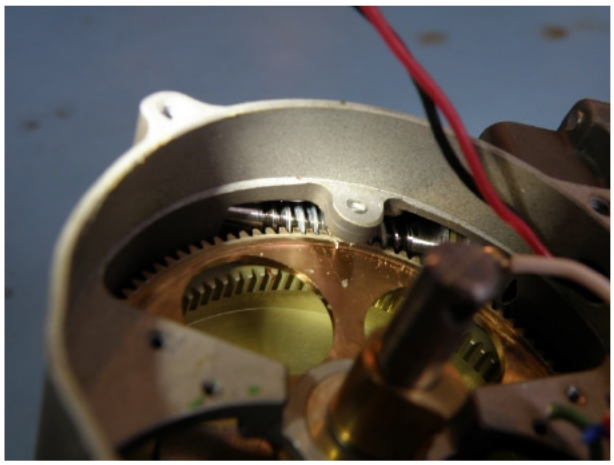

Figure 24: Gear and worm

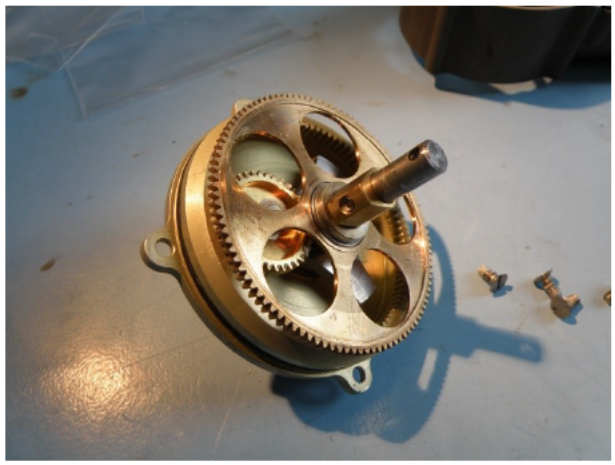

Figure 25: Planetary gear

- All screws on the output flange were tight and locked. No sign of previous opening was found.
- The o- ring of the output flange was found in good condition. All teeth were present and in good condition (Figure 26 and Figure 27)
- When motor assembly was opened motor and gear were found in good condition. No dirt or other FOD was found. (Figure 28)
- Lightning protection was found in good condition. All soldering points were still in shape. No sign of heat exposure (Figure 29)

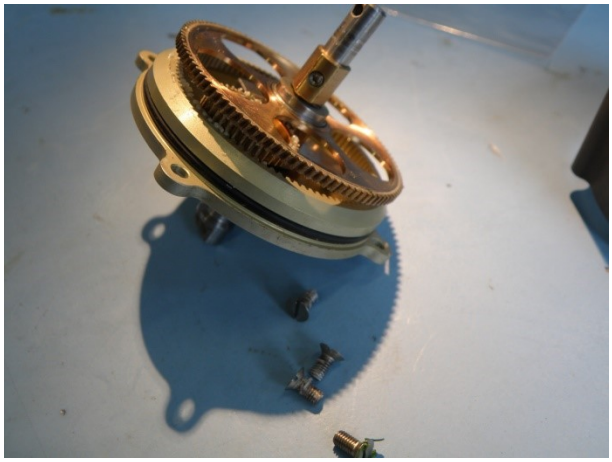

Figure 26: Gear and output flange

Figure 27: Output flange - teeth

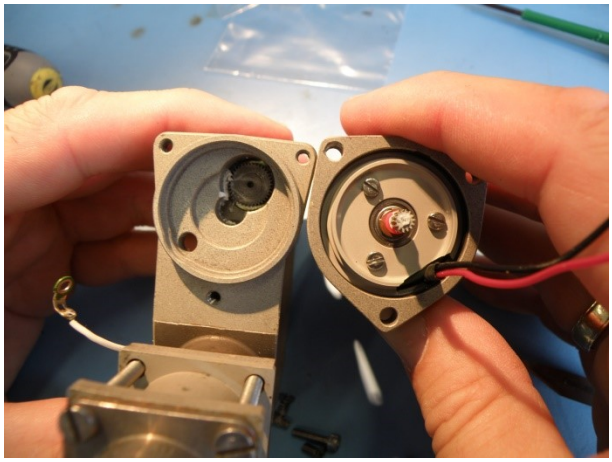

Figure 28: Motor assembly with gear

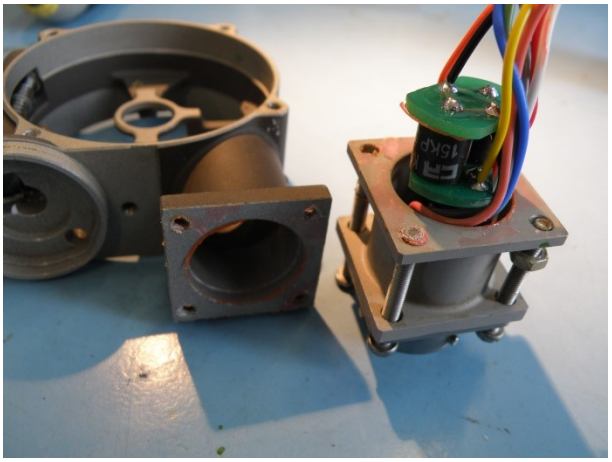

Figure 29: Lightning protection pack

2.5.2 STRIP DOWN INSPECTION - VALVE

During the stripping of the valve the following observations were made:

- When the flanges were disassembled from the valve body all screws were still tight.
- The o- rings were found to be in good condition. No scratches or dents could be detected on either body or flanges.
- No imperfections of neither ball nor sealings were found. No dirt or other FOD was detected (Figure 31).

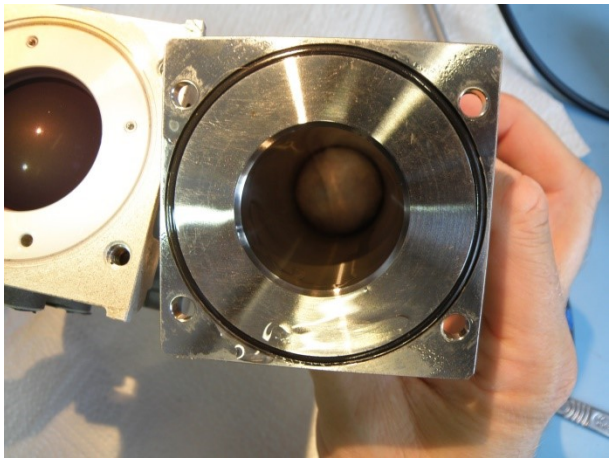

Figure 30: O- ring seal of valve flange

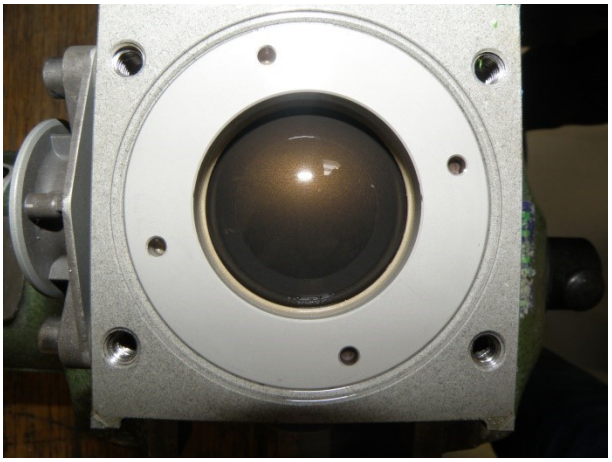

Figure 31: Valve body with ball

- When sealing ring was removed no dirt or other FOD was detected. No nicks or dents were found on sealing ring (Figure 32).
- Ball was found in good condition. No scratches or similar was detected. Marks from surface treatment were found inside the ball. These marks have no impact on function of the ball (Figure 33).

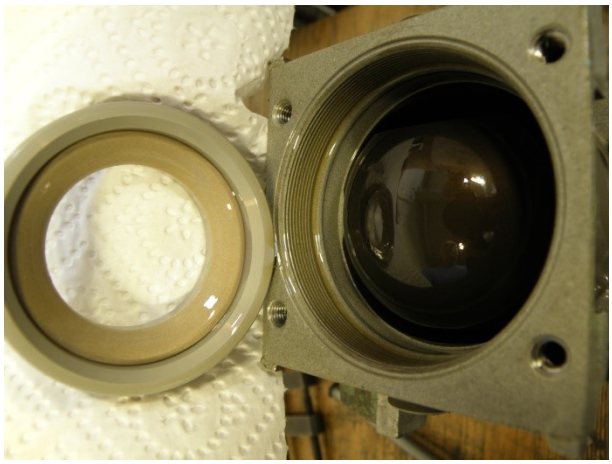

Figure 32: Valve sealing ring

Figure 33: Valve ball with manufacturing marks inside

2.6 CONCLUSION FSOV S/N7094

While inspecting the FSOV with serial number 7094 removed from yellow hydraulic system no evidence was found that the unit was not performing as required. The unit was found in closed position and in fully serviceable condition which is supported by all tests and inspections performed.

3 INSPECTION OF GREEN FSOV S/N7095

Due to the fact that no evidence for malfunction was found while conducting the inspection of FSOV S/N7094 and no visual damages could be detected on S/N7095 it was agreed to only perform an ATP for this unit.

3.1 VISUAL INSPECTION

While visual inspection the unit was found in closed position. No obvious sings of heat or damage could be found. The bonding strap of the valve was missing and the screw holding the bonding lead and strap was found loose. Probably the bonding leash was disassembled by Delta Airlines when removing the FSOV from the hydraulic system.

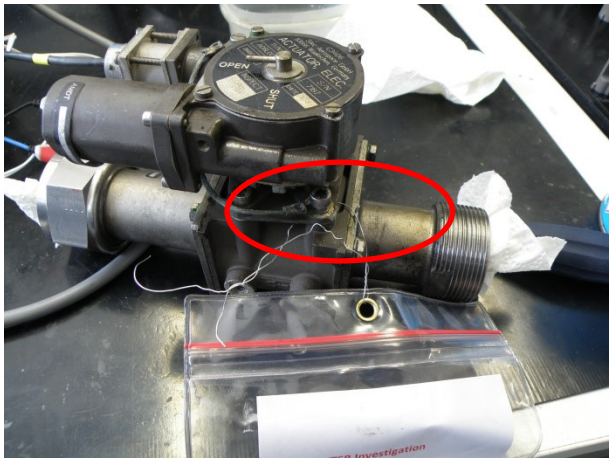

Figure 34: Green FSOV with missing bonding strap

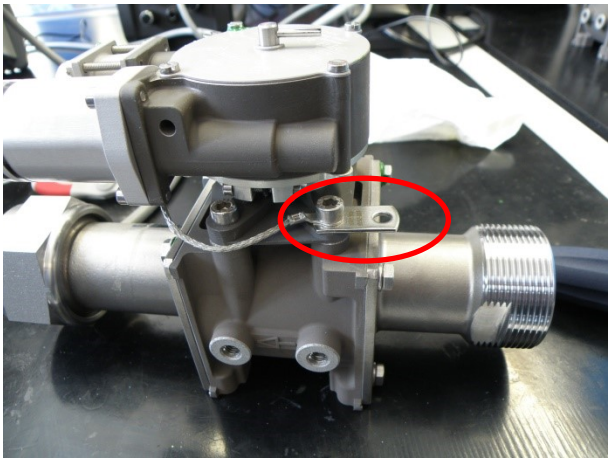

Figure 35: New FSOV with bonding strap assembled

3.2 EXECUTION OF ACCEPTANCE TEST PROCEDURE

The acceptance test procedure was carried out in accordance with E03A00-05 issue 01 on the ATP test stand. All electrical values and leakage rates were in tolerance. The travel time was in tolerance. The bonding measurement failed due to the loose screw holding the bonding leash. The ATR can be found in Appendix C.

Figure 36: Green FSOV S/N7095 on ATP test stand

3.3 CONCLUSION FSOV S/N7095

While inspection of green FSOV S/N7095 no sign of malfunction could be detected. All test values were in tolerance. After replacing the missing bonding leash the unit is serviceable.

4 CONCLUSION

The focus of the investigation performed was on the FSOV S/N 7094 installed in the yellow hydraulic circuit. This unit was found in closed position which was proven by several tests performed.

An intense visual inspection was performed which showed several imperfections but none of them had any influence on the functionality of the device. Several tests were performed to check functionality of actuator and valve. No signs of malfunction were found. Instead the actuator exceeded the requirements concerning its performance.

The strip down investigation of actuator and valve showed no evidence of excessive wear or FOD which could have influenced the functionality of the unit.

Both actuator and valve were found in serviceable condition.

With FSOV S/N 7095 which was installed in the green hydraulic circuit a visual inspection was performed. The unit was found in good condition but with missing bonding strap. To check the functionality of this unit a full ATP was performed. Except bonding measurement (due to loose bonding screw) all values were in tolerance. The unit was found in serviceable condition.

The investigation performed on both units delivered to Sitec Aerospace lead to the conclusion that both units were in serviceable condition and performed as required when the flight incident occurred. No evidence of any potential intermittend operation or unintended operation for any of the two units was found.

APPENDIX A ENGINEERING TEST PROCEDURE E03A00-56 ISSUE 01

APPENDIX B ACCEPTANCE TEST PROCEDURE E03A00-05 ISSUE 01

APPENDIX C ATR E03A00 S/N7095