Honeywell

Teardown & Testing Report
Of One Model DP-F2
Part Number 3244896-9
Serial Number C68008

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TOTAL PAGES:

Revision	By	Approved	Date	Pages and /or Paragraphs Affected
New				All (Initial Issue)

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1. INTRODUCTION AND SUMMARY

PURPOSE

This report presents the findings of functional testing and teardown inspection conducted on one Model DP-F2 Main Fuel Control Part Number 3244896-9 Serial Number C68008 at the Honeywell Engines Systems and Services Facility in Montreal, Canada on August 31, 2005.

The testing/teardown was conducted at the request of, and under the cognizance of National Transportation Safety Board (NTSB).

BACKGROUND (as reported by the NTSB or FAA)

On July 1, 2005, at 1357 mountain daylight time, an Agusta A119 helicopter, N403CF, operated by Tri-State Care Flight, LLC, Bullhead, Arizona, as "Care Flight 4" and piloted by a commercial pilot, was substantially damaged when it impacted terrain while approaching to land at a remote landing zone (LZ) approximately 8 miles northeast of Mancos, Colorado. The pilot, nurse, and paramedic were fatally injured. Visual meteorological conditions prevailed, and a company VFR flight plan had been filed and activated for the local medical flight being conducted under Title14 CFR Part 91. The flight originated at Durango, Colorado, at 1242. Preliminary information indicates the helicopter had been dispatched to search for (and eventually located) a 14-year-old drowning victim in the Animas River near Farmington, New Mexico. The helicopter was returning to Durango when it was diverted to the Red Arrow Mines area near Mancos to medivac an injured logger. According to a volunteer fireman, the pilot made a low pass to assess the LZ, and then circled around to make his landing approach. The fireman advised the pilot that the winds were calm and he acknowledged. The fireman said the helicopter, which was above tree level, "dropped straight down." He did not see the impact and reported no unusual engine sounds. The on-scene examination disclosed a ground scar, aligned on an easterly heading, containing slash marks and a separated left skid. The helicopter was at the end and next to the ground scar, and was aligned on a northerly heading. All four rotor blades were still attached to the hub. There were no contact marks on the hydraulic actuators. The swash and pitch link rods were all intact and attached. The tail boom was severed just aft of the engine and was to the right of the helicopter. The tail rotor separated at the gearbox.

2. FINDINGS OF MAIN FUEL CONTROL PART NUMBER 3244896-9 SERIAL NUMBER C68008

NOTES:
1. All observations reported herein are based on visual examinations with the unaided eye, unless otherwise noted.

2.1. RECEIVING INSPECTION AND PRELIMINARY DISASSEMBLY

(a) The MFC was received in a plastic bag wrapped in bubble wrap. The plastic shipping base was absent. The drive coupling (not supplied by Honeywell) was attached to the driveshaft of the MFC. The manual override shield was deformed and the manual override pointer was bent by more than 45 degrees in an upward direction. Movement of the throttle was stiff due to the damage to the manual override shield. The exterior of the MFC was generally clean, however significant blue grease staining was observed at the outer drive shaft bearing.

(b) Lockwire was missing from the drive body mounting screw closest to the assembly date rubber sticker. Lockwire was also missing from the access cover retaining screw for Ng adjustment. The Pg outlet elbow fitting was missing lockwire, along with two of three air regulator body mounting screws. All other lockwire and seals were intact.

(c) The drive body was partially separated from the flow body with a gap between the bodies measuring 0.033” close to the Px/Py face seal o-rings. Opposite this location, on the bellows side, the bodies appeared to be in contact. The drive body mounting screw closest to the P0 face seal o-ring was loose (no torque). The screw was free to move in an axial direction and was retained from falling out of the MFC only by the lockwire still attached. Approximately 1.5 threads were visible between the screw head and the washer.

(d) As a result of the separation in (c) above, the P0 face seal o-ring had partially extruded towards the outside of the MFC. The Px and Py face seal o-rings were also visible, appearing to be seated in their grooves. An air gap was visible between both o-rings and the flow body mating surface, indicating that the pneumatic circuit was no longer sealed.

(e) Due to the body separation, functional testing of the MFC in an as-received condition was not possible. Lack of sealing at the P0 face seal o-ring would have resulted in an external fuel leak from the P0 return circuit and contamination of the pneumatic circuit. Lack of sealing at the Px and Py face seal o-rings would have resulted in the inability to schedule fuel flow higher than min flow

(f) The as-received condition of the screws was established. The screw which had pulled from the body mentioned in (c) was removed for inspection. The threads in the flow body had sheared and remained attached to the removed screw. Based on the amount of pulled threads, it was determined that the thread engagement between the screw and flow body was approximately 2 and one half threads. It was also determined that the wrong screw had been installed in the position found. The required screw for this location is P/N 953504-159, with the remaining three locations shall be P/N 953504-157. Based on a length measurement, screw P/N 953504-157 was actually installed. P/N 953504-159 is 0.125" longer nominally than P/N 953504-157.

(g) The torque on the remaining three screws was measured. The two screws adjacent to the one mentioned in (f) were found snug but with no measurable torque. They were also confirmed to be the correct P/N 953504-157. The screw opposite to that mentioned in (f) was found to have the correct amount of torque applied, but was determined to be P/N 953504-159. Therefore, during the previous shop visit the assembly of the MFC had interchanged P/N 953504-159 for P/N 953504-157.

A subsequent tolerance study demonstrated that the long screw could be properly installed and torqued in any of the three short screw locations.

(h) To allow for flow testing, the pulled screw was replaced and all four mounting screws were re-torqued to specifications. This re-established the proper seal between the flow body and drive body. No gap between the drive body and flow body was observed after the screws were re-torqued.

(i) The P3 pipe was removed as part of normal practice prior to mounting the unit to the test stand. Fuel residue was observed within the pipe fitting, accompanied by a strong fuel odor. Removal of the air adapter shipping caps found the threads of the adapter wet with fuel.

2.2. FUNCTIONAL TESTING

(a) The unit was installed on the test bench and tested per the audit specification AETS 71060. In addition to the audit specification, the air regulator set point adjustment was verified as described in the calibration specification AETS 71059, paragraphs 11.01 & 11.02.
(b) The relief and pressurizing valve opening pressures were within limits.
(c) The metering valve and bypass head settings were verified next as part of paragraph 2 and also found to be within limits. This verifies the basic functioning of the metering valve/torsion shaft/bellows system, as well as proper functioning of the bypass valve. The Px-Py leakage was measured as 0.0 in. Hg, which confirms that the pneumatic circuit, is properly sealed, including the Py flapper orifice.
(d) The minimum flow was checked and found to be nominal within limits.
(e) The enrichment spring setting was checked and test point 4.03 was found slightly high at 157 pph compared to limits of 141 – 154 pph. All other enrichment spring setting test points were within limits.
(f) The maximum governor spring setting was checked and the governor break point was occurring 250 rpm late, and the governor slope was found to be shallow. The limits for the slope are 1.9 – 1.63 pph/rpm and the actual slope measured 0.62 pph/rpm.
(g) The idle flow was found slightly high at 162 pph, compared to limits of 138 – 159 pph. The pick up angle was early at 16 degrees, compared to limits of 19 – 25 degrees. Both the idle flow and pick-up angle are influenced by changes to the maximum governor spring setting. Field adjustment mentioned in Analysis paragraph (f) below will cause the idle flow and pick-up angles to change in the directions observed.
(h) The low end acceleration and throttle movement effect test points were within limits.
(i) The bellows stop nut adjustment fuel flow was slightly low at 177 pph, compared to limits of 180 – 200 pph.
(j) The Manual override test points were all within limits.
(k) The governor reset test points were all within limits. The governor reset functions to control metered fuel based on inputs from the power turbine governor by varying the tension on the governor spring. The set point for the air regulator was also verified per paragraph 11.01 & 11.02 in the test specification AETS71059. The air regulator set point was slightly high at 37.5 in. Hg, compared to limits of 35 – 37 in. Hg. The set point droop was well within limits.
(l) The deceleration schedule was within limits.
(m) The cut-off modulation was found slightly high with a nozzle flow change of 5 pph, compared to 4 pph maximum. The cut-off angle was achieved at 2 degrees compared to limits of 4 - 6 degrees. With the cut-off angle set to 5 degrees, leakage was measured at 25.0 cc/min, compared to maximum limit of 3.0 cc/min.

2.3. DISASSEMBLY INSPECTION

(a) The manual override shield was removed and found generally deformed. A sharp dent on one of the edges was also observed.
(b) The air adapter was removed and the internal cavities inspected. The gasket mating surface and all cavities were heavily fuel contaminated. The drive body mating surface was also wet with fuel and a dark blue ring was visible, following the contour of the air adapter when mounted. The dark blue ring is believed to be grease used to lubricate MFC bearings that had become diluted as a result of the fuel contamination.
(c) The drive body and flow body were split for examination of the governor cavity and related parts.
(d) The spool bearing assembly was removed from the driveshaft. The top of the assembly was covered in diluted blue grease that had leaked out of the follower bearing in the enrichment lever. This was attributed to fuel entering the governor cavity and diluting the grease. This grease was observed leaking from the follower bearing.
(e) The governor lever and enrichment lever were removed from the drive body as an assembly. The governor lever-sealing pad was covered in a brown powdery debris deposited from the Py flapper orifice. The debris is typical of a unit with service time. The side opposite of the sealing pad had a thick ribbon of blue grease across the pivot axis. This blue grease originated from the spool bearings and was thrown against the lever assembly due to the rotation of the driveshaft. The excessive blue grease is believed to have been liberated as a result of fuel contamination diluting bearing grease. During normal operation, the blue grease should not be excessively liberated from the bearings.
(f) A similar ribbon of blue grease was observed on the inner wall of the drive body all the way around, as well as on the flyweights and driveshaft. The source of the blue grease is as described in (e) above.
(g) The driveshaft bearing retainer plate was removed and blue tinted fuel was found to pool within the recess of the drive body. The driveshaft bearings were covered in diluted blue grease that had leaked out as a result of the fuel contamination.
(h) The air regulator assembly was disassembled and all components were found to be extremely clean. The Pr regulator components were found to have very little wear.
(i) The manual override access cover was removed for inspection. Brown powdery debris was found lightly coating the bellows stop nut, wave spring, follower and housing. The debris is typical of some normal wear in this area.

(j) The surface of the drive body housing that mates with the flow body was inspected by laying it on a marble table. While holding one corner of the body against the table, the body was found to be warped with the largest gap between the table and body measuring approximately 0.033".
(k) Additional inspections completed at Honeywell South Bend confirmed the warpage of drive body as noted above. The mounting surface of the drive body was checked and no significant (.002" max) warpage found. Also, the mating surface of the flow body was checked and no significant (.0015" max) warpage noted. Fluorescent penetrate inspection (FPI) of both the drive body and the flow failed to identify any cracks. The depth of the Px, Py and Po face seal o-ring cavities were measured to have a depth of .053", the print requirement is .051" -.055". The o-ring cross sections were measured at approximately .067", the print requirement is .067"-.073" for new o-rings.

3. ANALYSIS AND CONCLUSIONS

ANALYSIS

a) The exterior of the MFC suffered damage most likely as a result of a heavy impact. This was evidenced by the damage and distortion suffered by the MOR shield. Further evidence is provided by the sheared threads in the flow body (drive body mounting screw) and the drive body deformation. In addition, thread imprints are evident on the inside diameter on three of the four mounting holes in the drive body.
b) Interchanging the screws could result in a loss of clamping load due to lack of thread engagement or due to interference (bottoming). The clamping load applied by each screw is proportional to the applied torque. The specified torque value for each of the four screws is 20 - 25 in-lbs. Visual examination of the "pulled" screw determined that approximately 2.5 threads were engaged. A test was conducted using two P/N 953504 -157 screws, another flow body and fixturing to duplicate the 2.5 thread engagement. Both screws were successfully torqued to 25 in-lbs, with failure occurring at 34 and 38 in-lbs. In addition a stress analysis, reference Appendix III verified that a thread engagement of 2.5 threads would allow for proper torqueing of the screws. A tolerance study was completed using worse case tolerance stack ups and the actual manufacturing process to determine if a long screw installed in a short screw position would result in an interference condition. Loss of clamping load could result if the screw bottomed prior to the specified torque value being applied. The study indicated that the long screw would not bottom; therefore the clamping load is retained.

c) An investigation was completed in the South Bend Materials Technology Center, see report in Appendix II to examine the fracture surface of the "pulled" threads and the drive body to flow body mating surfaces. The report concluded the pull out of the bolt from the flow body was caused by a overload condition. In addition there was no fretting wear between the mating surfaces of the drive body and the flow body. This indicates the two bodies had been tightly clamped together. These findings are consistent with damage resulting from a heavy impact.

d) The partially extruded P0 face seal o-ring produced a leak allowing fuel to contaminate the governor cavity as well as the Px and Py channels in the drive body. The heavy ribbon of diluted blue grease found within the governor cavity indicates that fuel contaminated the governor section while the MFC was in operation. However, as the test as received was conducted prior to the disassembly, it cannot be determined whether the ribbon of blue grease was a pre-existing condition or was produced as a result of the test.

e) Fuel was also observed in the air adapter and P3 pipe prior to the test as received. The amount of fuel observed in the various areas and the extent of the blue grease dilution is considered non-typical. Previous bearing washout investigations from failed fuel pump seals did not reveal fuel contamination to the extent observed during this investigation.

f) Receiving inspection found lockwire missing on the access cover retaining screw mentioned in 2.1 (b). The governor break point can be field adjusted by removing the access cover and turning the Ng adjuster screw. Increasing the tension on the governor spring will cause the break point to occur late. As a result of the missing lockwire, no conclusion can be drawn between the as-received and as-shipped position of the Ng adjuster.

g) The basic accel test points had no significant deviations. The governing test points were deviating more significantly. There are three potential causes for the governing deviations. The first and most likely primary cause is the distortion and loss of torque on the drive body mounting screws as a result of the impact. Governing is significantly impacted by un-torquing and re-torquing the drive body mounting screws as the scheduling cam and the cam follower lever are installed in two separate bodies. These are the drive body and flow body respectively. The smallest movement between these two bodies results in a change of relationship between the scheduling cam and the cam follower lever and has a direct impact on governing. Secondary causes include field adjustment of the Ng adjuster screw and the fuel ingress in the air adapter which will alter the flow characteristics of the bleeds. The deviations of the governor section would not cause a reduction in fuel flow, and the MFC would still be able to govern speed, albeit at a slightly different speed for a given throttle input. The rest of the deviations are considered minor and typical of a unit with service time.

CONCLUSIONS

a) The MFC was received in a damaged condition externally and structurally. The damage caused a loss of sealing at the three face seal o-rings between the drive and flow bodies. These face seal o-rings normally seal P0 return pressure, Px pressure, and Py pressure. The loss of these seals would result in an external fuel leak of Po return flow as well as a reduction in fuel flow to minimum flow due to the loss of pneumatic pressure.
b) Based on the results of the as received test, it can be concluded that the MFC was in a serviceable state before the impact damage. Aside from the heavy fuel ingress and subsequent blue grease dilution, the condition of the MFC components is considered typical of a unit with service time.

4. ATTENDEES

Mr. Paul Frechette	Transportation Safety Board of Canada
Mr. Luigi Candiani	Agusta, Italy
Mr. Paolo Ferreri	Agusta, Italy
Mr. Marc Hemmings	Pratt & Whitney Canada, Longueuil Quebec
Mr. David Barnard	Pratt & Whitney Canada, Longueuil Quebec
Mr. Ken Miller	Honeywell South Bend
Mr. Hytham Mokhtar	Honeywell Montreal
Ms. Sylvie Robin	Honeywell Montreal

5. LIST OF PHOTOGRAPHS

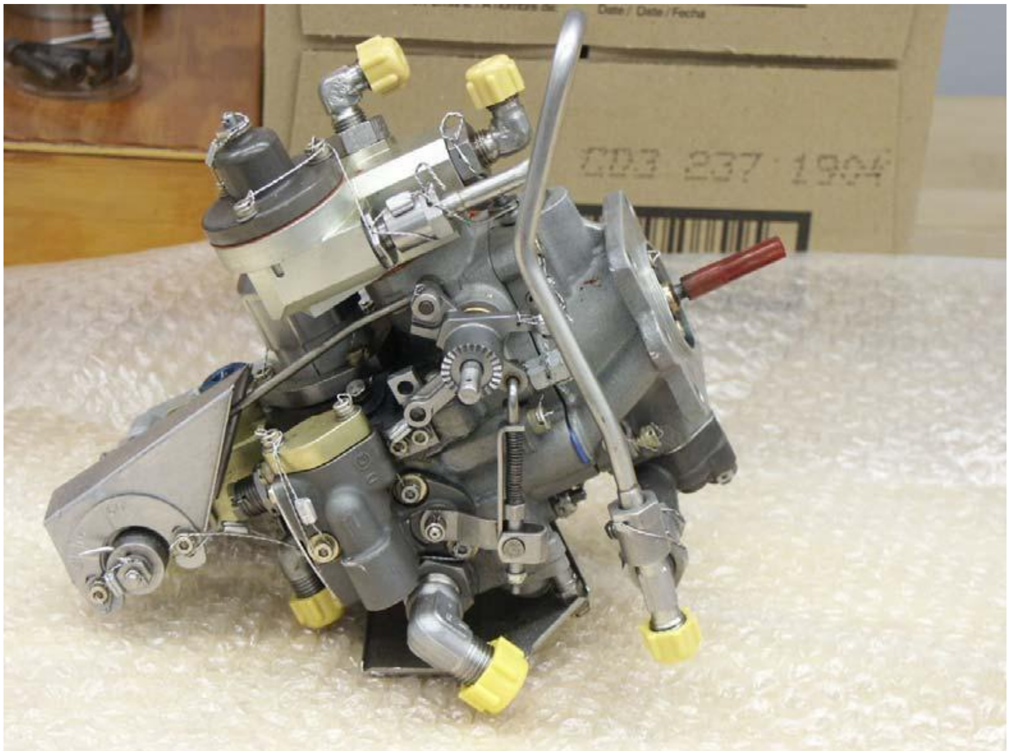


Figure 1 as received

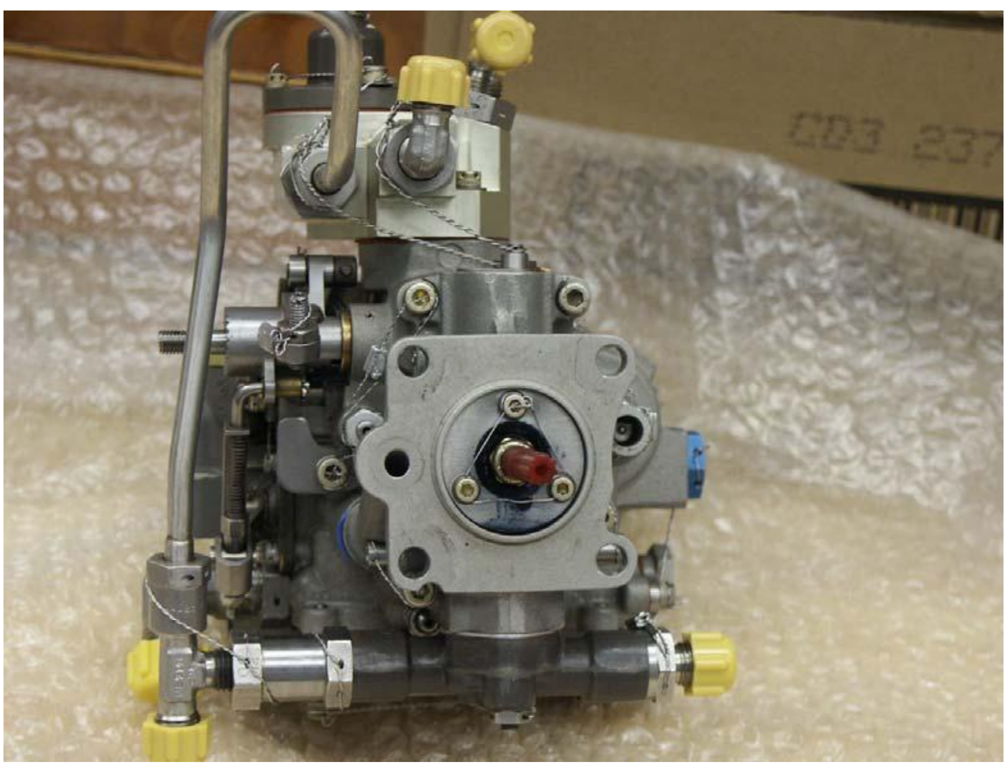


Figure 2 as received

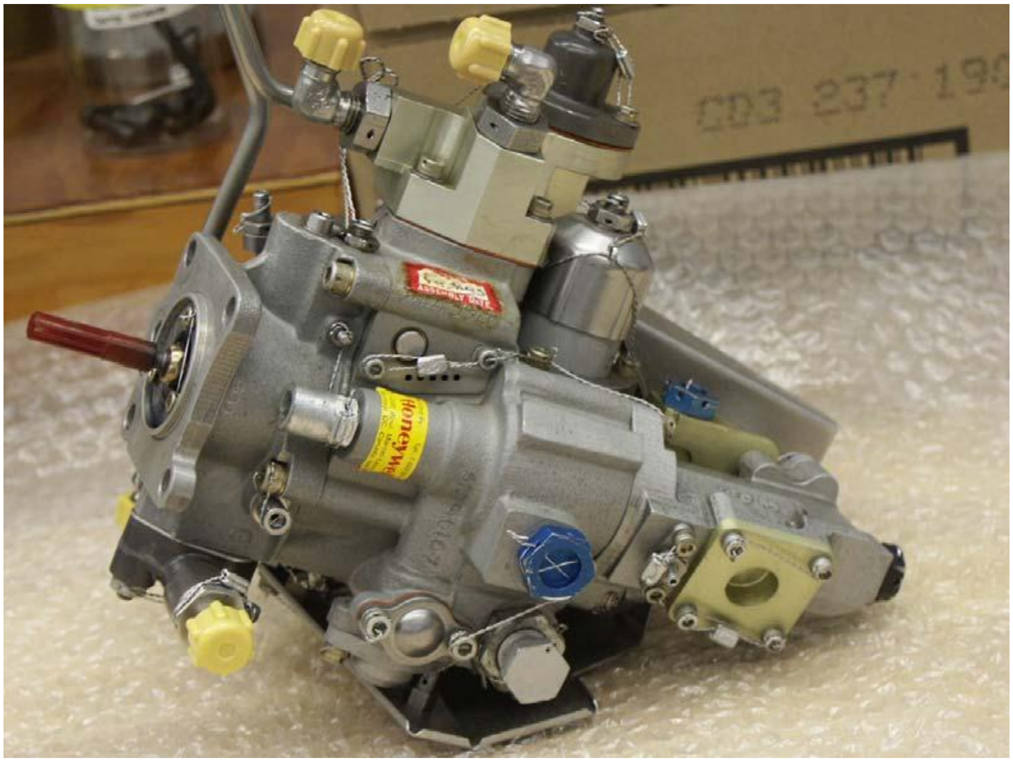


Figure 3 as received

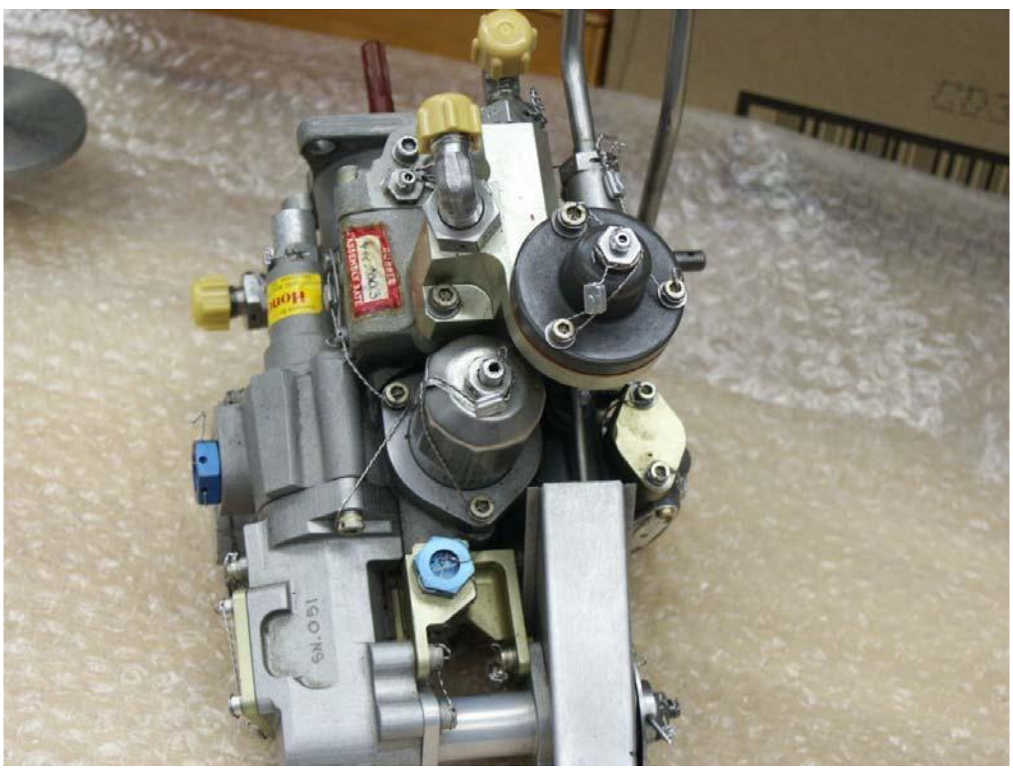


Figure 4 as received

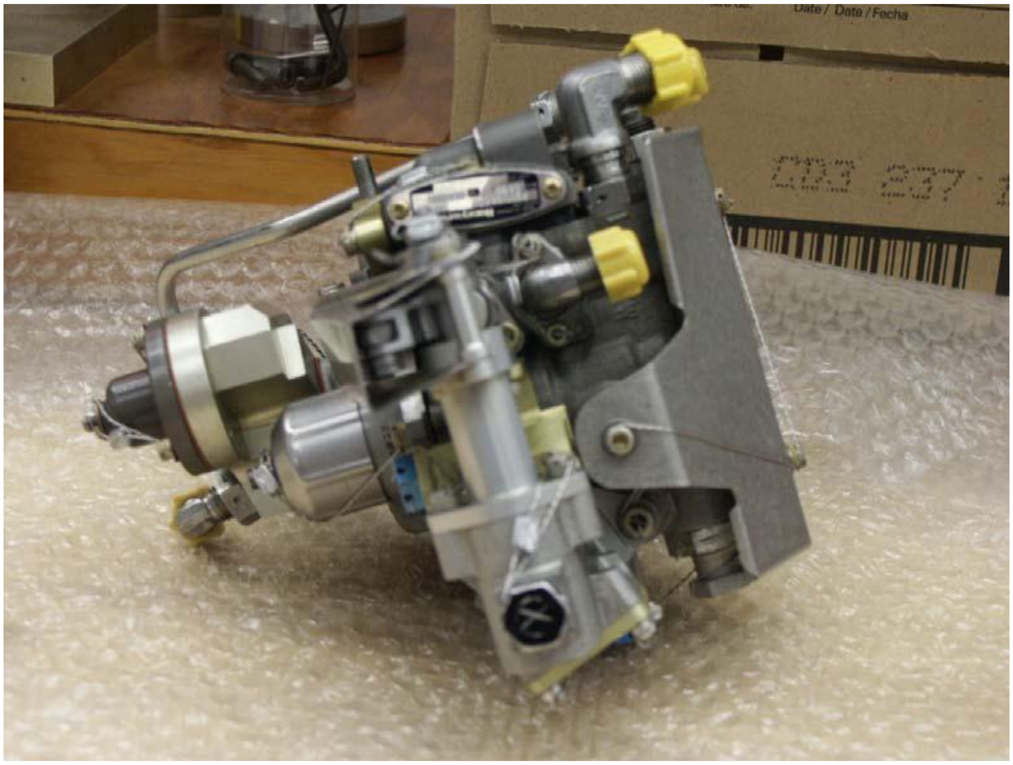


Figure 5 as received

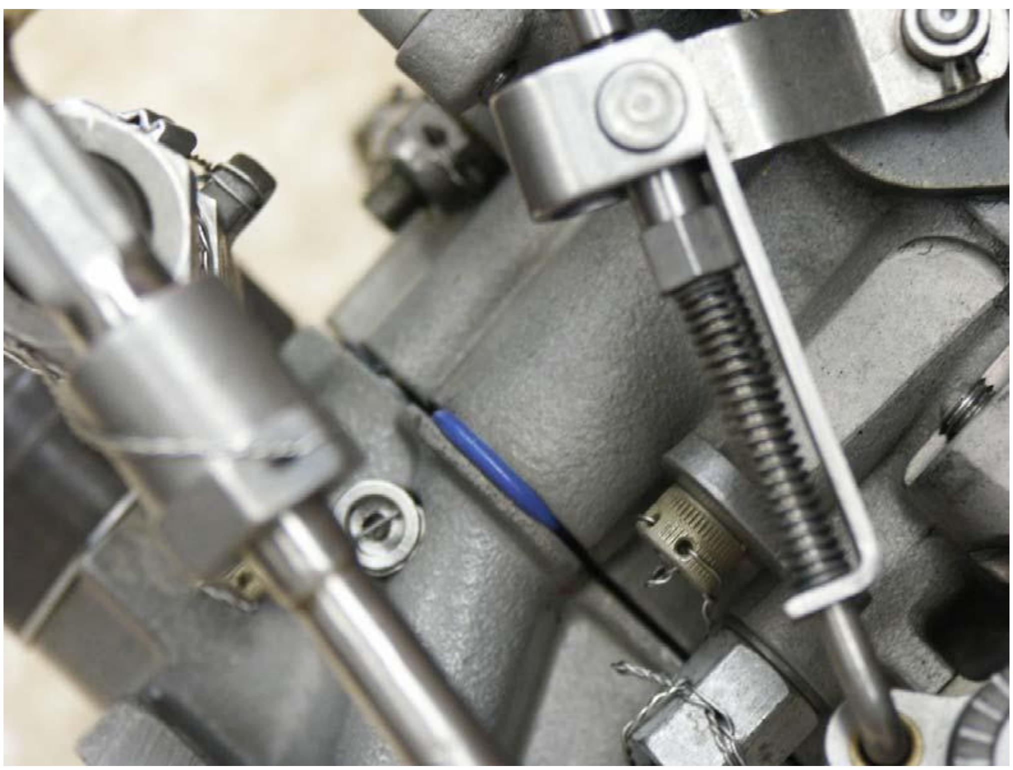


Figure 6 separation of bodies and extrusion of P0 o-ring

Figure 7 mounting screw loose

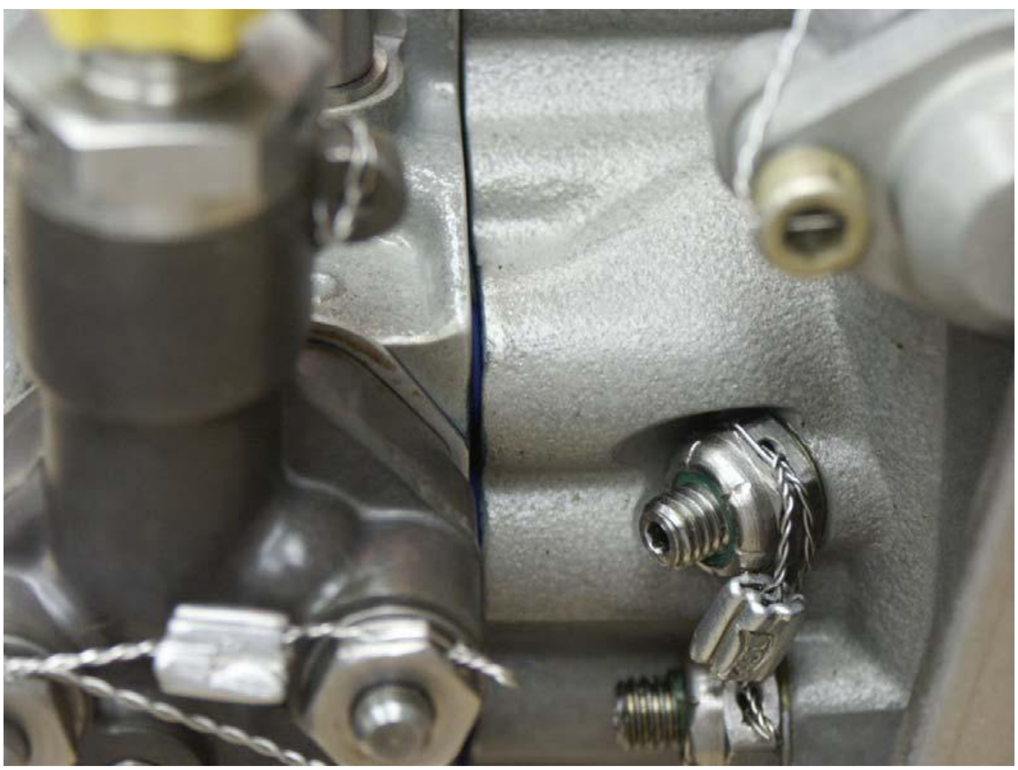


Figure 8 separation of bodies and lack of seal at Px and Py o-rings

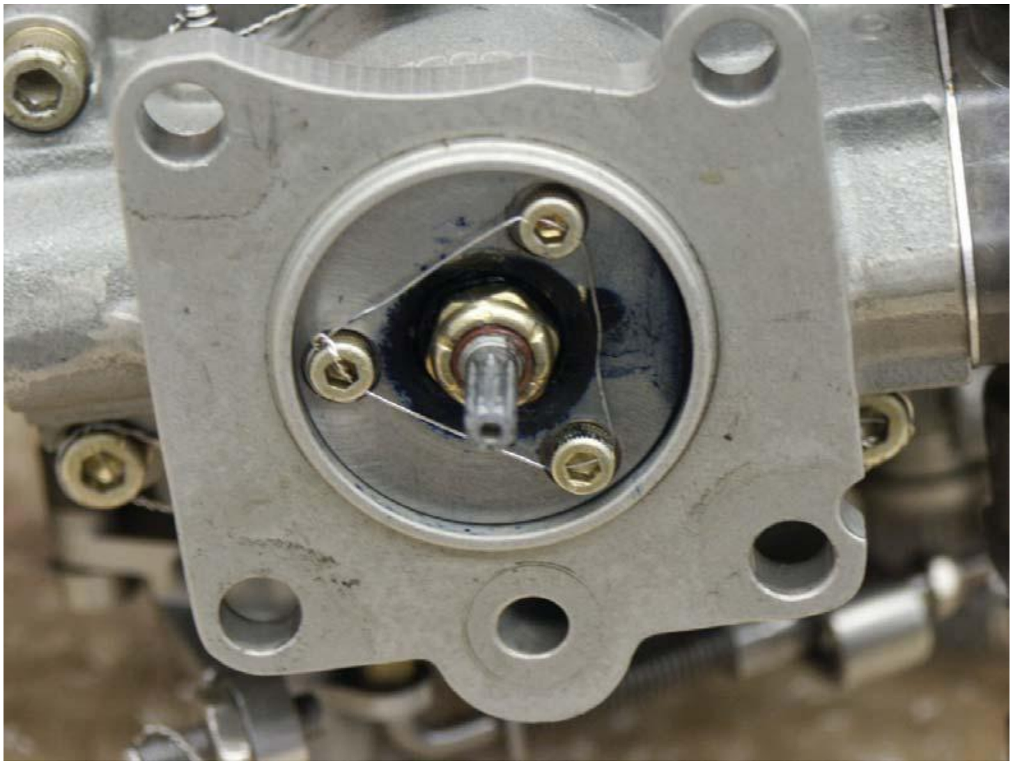


Figure 9 drive pad blue grease dilution

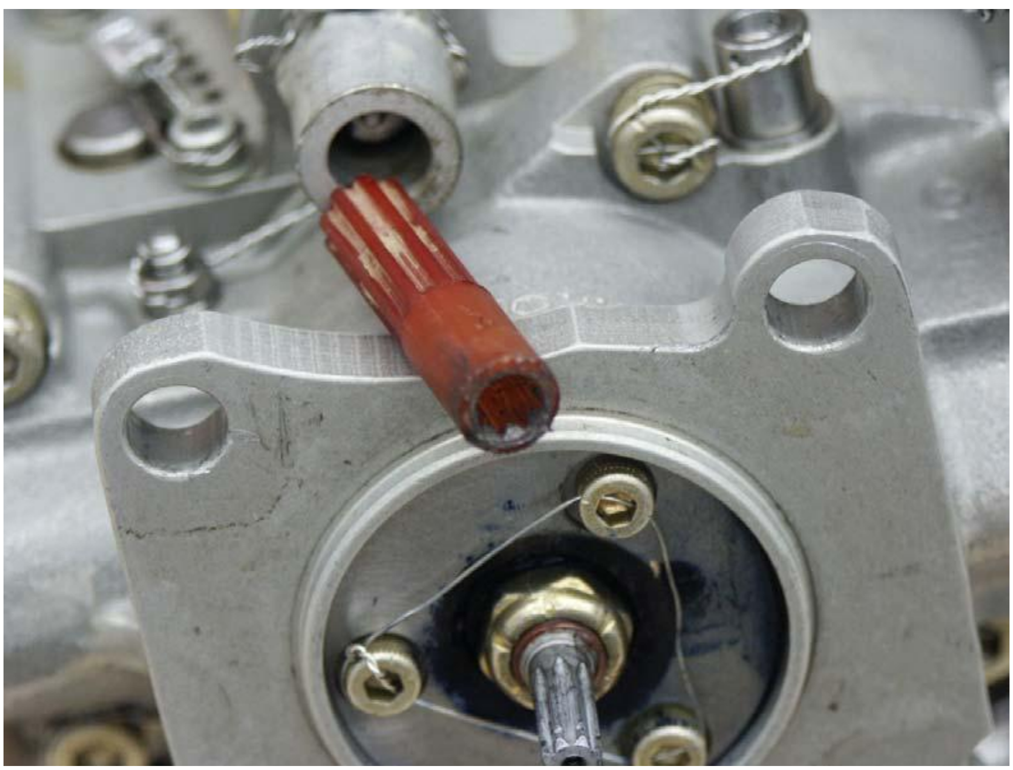


Figure 10 drive coupling and drive pad

Figure 11 deformation of manual override shield

Figure 12 deformation of shield and sharp dent

Figure 13 air adapter cavity and gasket wet with fuel

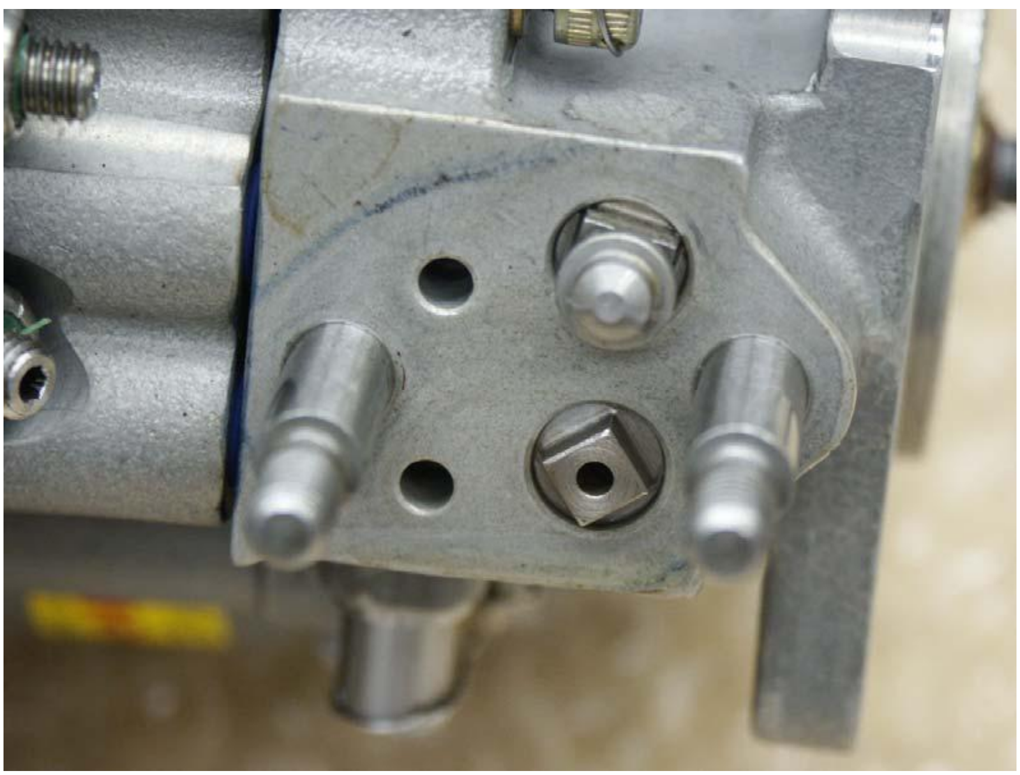


Figure 14 drive body adapter mating surface with ring of blue grease

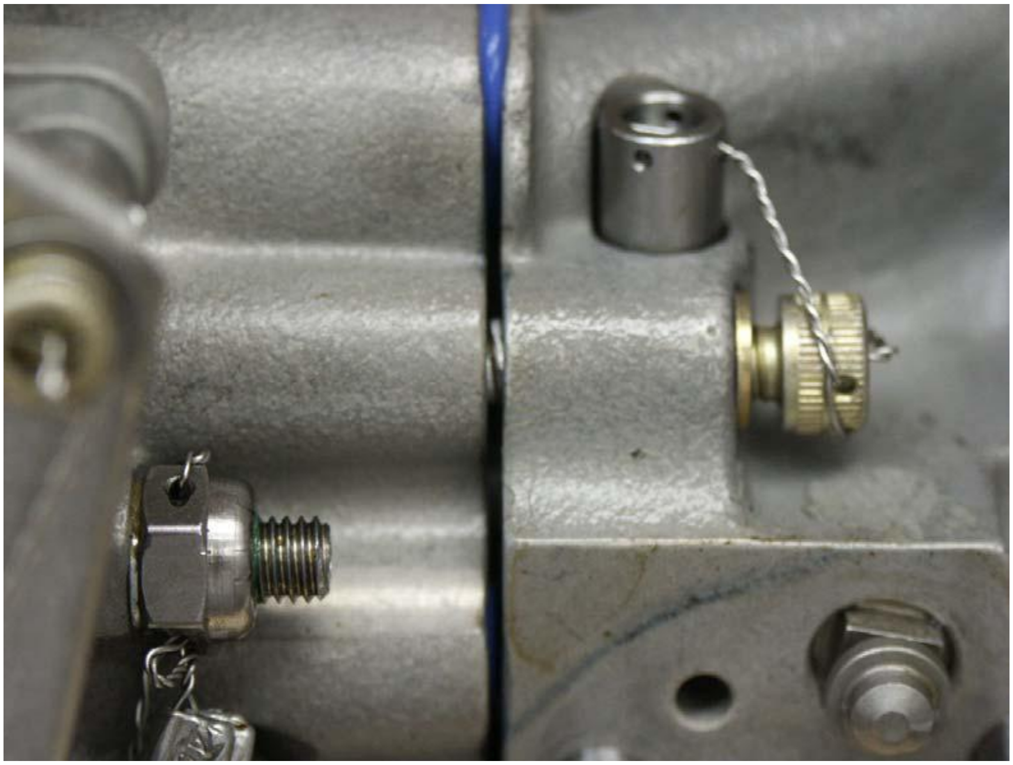


Figure 15 extruded Po o-ring and pulled flow body threads

Figure 16 Pc inlet fitting wet with fuel

Figure 17 air adapter Pc inlet wet with fuel

Figure 18 pulled drive body mounting screw

Figure 19 diluted blue grease on spool bearing assembly

Figure 20 sealing surface of governor lever

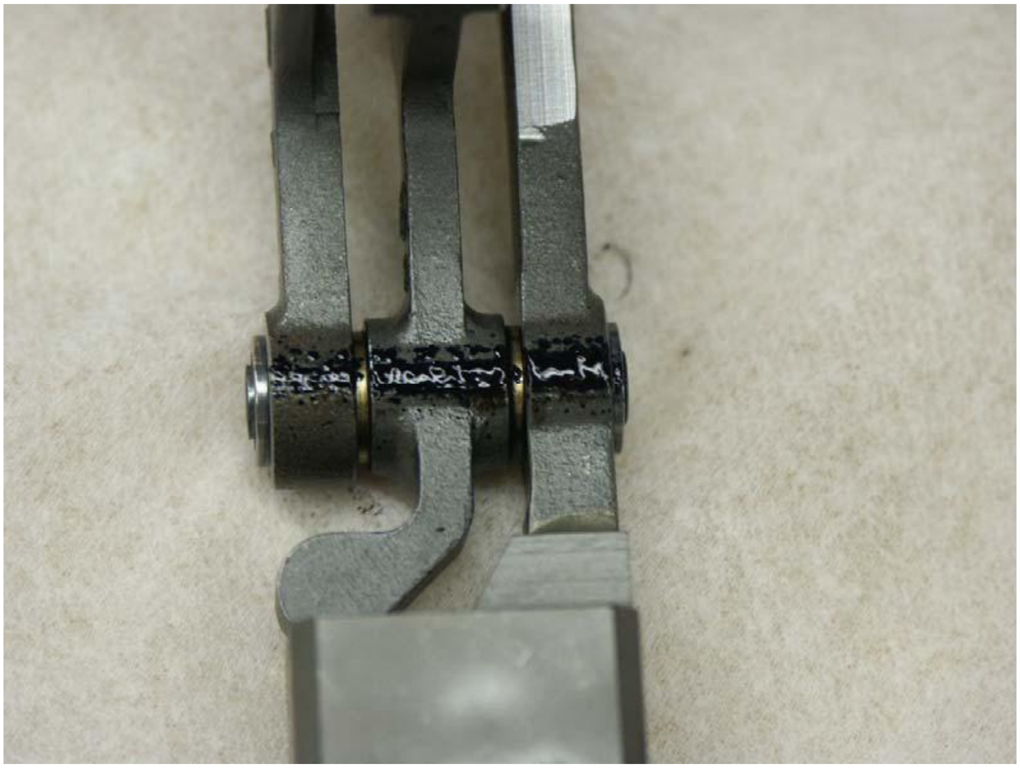


Figure 21 lever assembly contaminated with ribbon of blue grease

Figure 22 ribbon of blue grease on flyweight

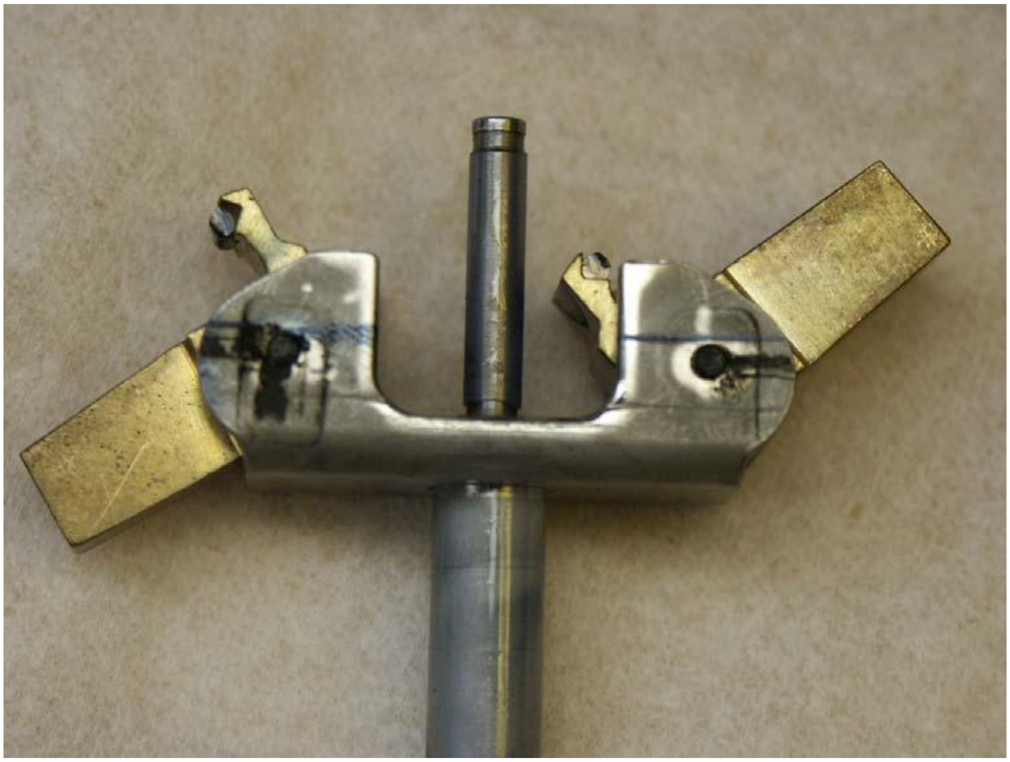


Figure 23 side view of driveshaft assembly with weights

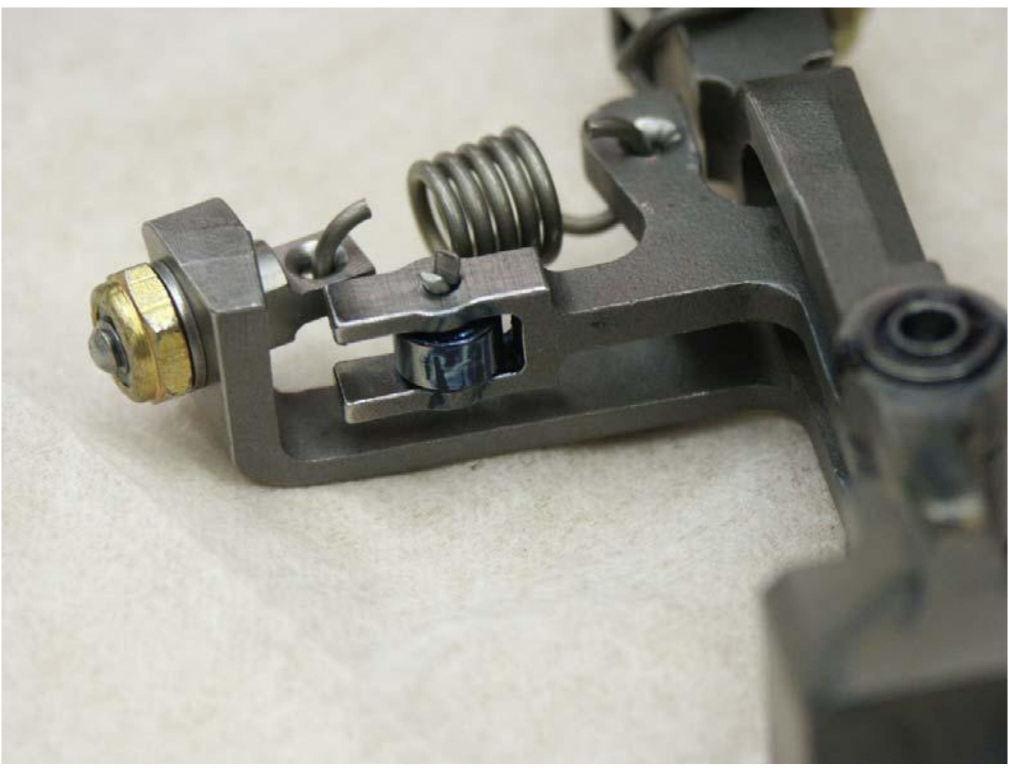


Figure 24 view of enrichment lever bearing leaking blue grease

Figure 25 drive pad with driveshaft removed

Figure 26 fuel found underneath drive bearing retaining plate

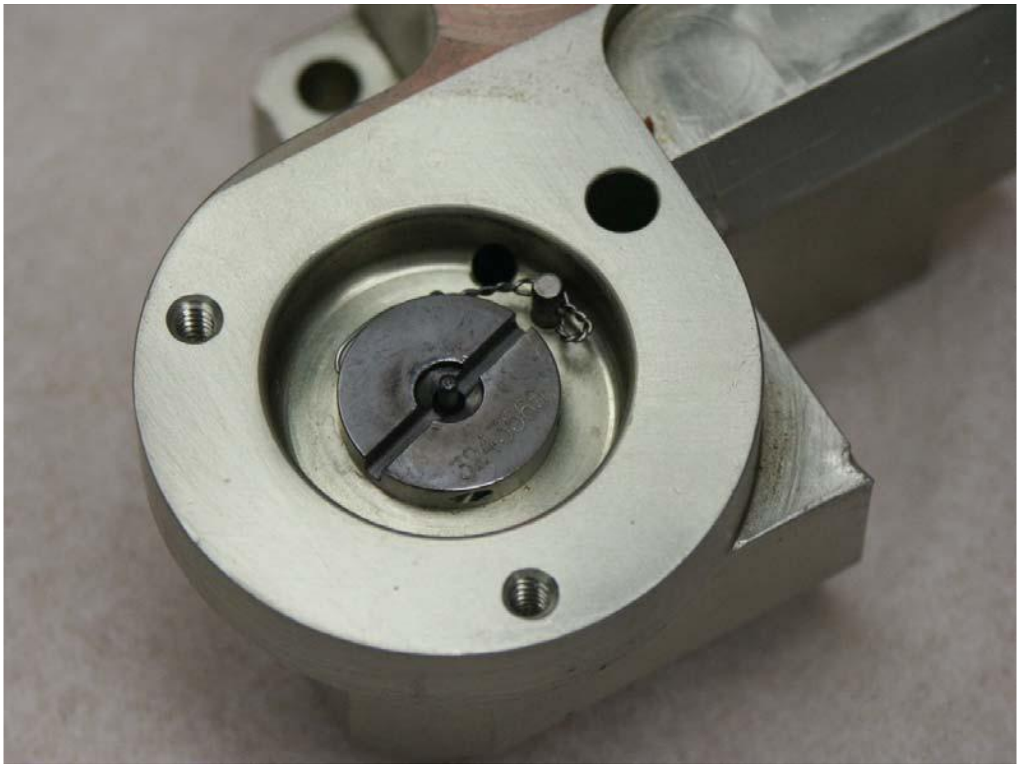


Figure 27 Pr regulator installed in air regulator body

Figure 28 Pr side of air regulator diaphragm

Figure 29 Pg reset diaphragm

Figure 30 spool bearing

Figure 31 spool bearing assembly

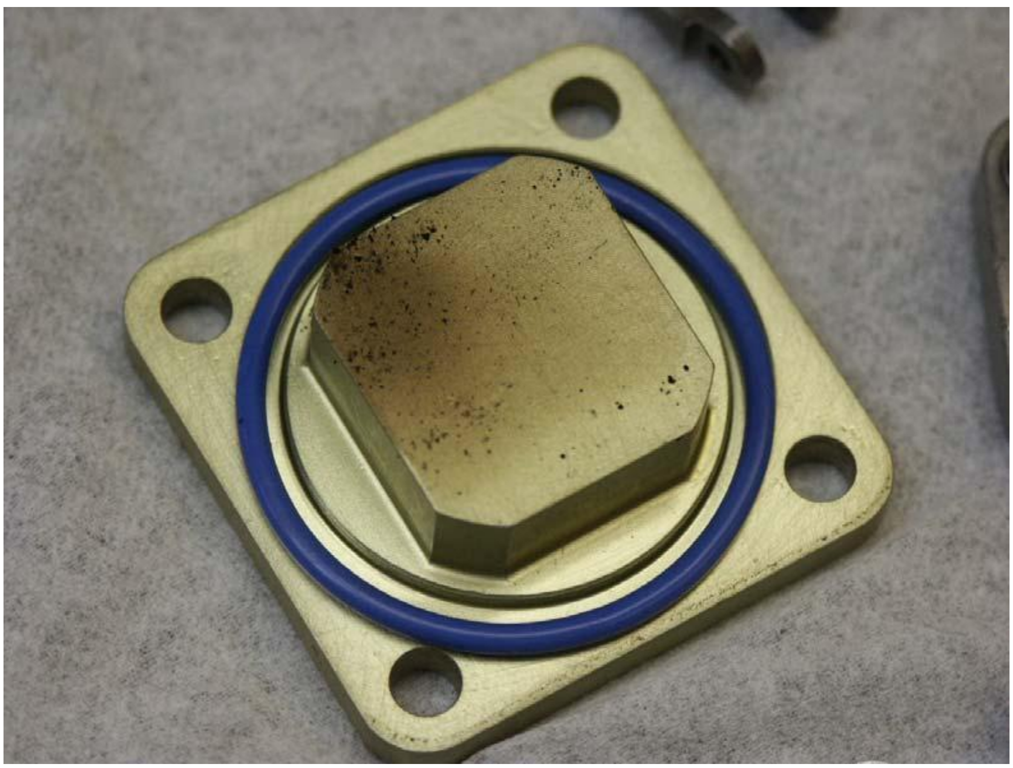


Figure 32 inside of bellows MOR cover

Figure 33 wear debris in bellows MOR cavity

Figure 34 bellows decel stop nut

Figure 35 accel bellows

Appendix I - Test as received

AlliedSignal AEROSPACE CODE IDENT 07213	TEST SPECIFICATION	Number AETS 71060	Rev. E
		Sheet 1 of 7	

Orig By: G. Chan	Chk By: W.H. Foster WHF	Project Leader: W.H. Foster	MFG Approval:
Date: 31/08/05	Test Stand No. FF14A	Operator: 4665	S/N: C68008
Unit: Automatic Fuel Control		Model: DP-F2	P/N: 3244896 -9

REV.	A	B	C	D	E
REL. DATE	27 MAY97	3 JUL97	14 DEC98	22 MAR99	18 MAY99

SHT REV STATUS

SHT REV	E	E	E	E	E	E	E					
SHT	1	2	3	4	5	6	7	8	9	10	11	12
SHT REV												
SHT	13	14	15	16	17	18	19	20	21	22	23	24

Audit Specification

A. See AEEI 68923 for location of adjustments and pressure taps.

B. Index throttle quadrant to 60° T.A. by inserting alignment pin thru throttle lever and throttle rig. Torque throttle quadrant fixture to 40-45 in.lb.

C. Control rotation CW as viewed from control shaft end.

D. Maintain Po pressure to 60 - 90 PSIG at control by-pass tap.

E. Pn pressure shall be set within ± 10 PSI of specified value at pressure below 200 PSIG and ± 25 PSI of specified value at pressure above 200 PSIG.

F. Set test conditions (RPM, Supply, & Pc) in the sequence indicated by numbers 1, 2, 3, etc.

(1) When two numbers are listed, set and then trim test condition in the sequence indicated.

(2) Approach all speeds, total fuel supplies, and Pc settings from a lower value, except at hysteresis points.

G. Speed for Tests Points indicated by (#) is to be set to ± 2 RPM of specified value. All other points are to be set within ± 20 RPM of specified value.

H. Total supply is to be set to ± 20 PPH of the specified value or within limits when shown.

I. Removing Py port fitting P/N 3244137 prior to auditing.

APPROVED BY PRODUCTION CONTROL FOR USE ON
WO/MOR/OD. NO.______________ SIGNED [redacted]

REFERENCE PRINT - NOT REPLACED AUTOMATICALLY

TEST POINT	SPEED RPM	SUPPLY PPH	THRO DEG.	COND DEG.	Pc psia	NOZZLE FLOW, PPH MIN	REC	MAX	P1 - P2 "Hg	Pn psi

CHECK RELIEF VALVE OPENING

(a) Cap outlet port.

(b) Increase P1 pressure until fuel supply is within supply limits specified and observe P1-Po differential.

TEST POINT	SPEED RPM	SUPPLY PPH	THRO DEG.	COND DEG.	Pc psia
1.01	1 0	4 200-275	2 60		3 85.0

Relief valve opening P1-Po 950 [999] 1000 psig

CHECK PRESSURIZING VALVE OPENING

(a) Open outlet port.

(b) Increase P1 pressure and observe start of nozzle flow.

TEST POINT	SPEED RPM	SUPPLY PPH	THRO DEG.	COND DEG.	Pc psia
1.02	1 A.R.	4 A.R.	2 60		3 85.0

Pressurizing valve opening P1 - Po 52 [54] 70 psig

METERING VALVE ORIFICE AND BY-PASS HEAD (P1-P2) SETTING

TEST POINT	SPEED RPM	SUPPLY PPH	THRO DEG.	COND DEG.	Pc psia	MIN	REC	MAX	P1 - P2 "Hg	Pn psi
2.01	2 5800	3-5 1750	1 60		4 40	288	293	304	47.0	6 180
	P1 - P2 = 26-46 in. Hg.									
2.02	5800	1750	60		70	504	518	532	46.0	360
	Px-Py	0	1.2 in. Hg. max.							
2.03	4500	1360	60		55.0	396	402	407	46.5	260
	→**Note: Ng = 4500RPM**									
2.04	5800	1750	60		100	620	626	640	45.0	450
2.05	5800	1750	60		40	-10	+1	+10	47.0	180

Hysteresis of T.P. 2.01

REFERENCE PRINT - NOT REPLACED AUTOMATICALLY

AlliedSignal AEROSPACE CODE IDENT 07213	TEST SPECIFICATION	AETS 71060 SHEET 3 OF SHEETS 7	REV. E

TEST POINT	SPEED RPM	SUPPLY PPH	THRO DEG.	COND DEG.	Pc psia	NOZZLE FLOW, PPH MIN	REC	MAX	P1 - P2 "Hg	Pn psi

MINIMUM FLOW ADJUSTMENT

Connect Pc gauge to Py line and apply 8 psia to Py.

TEST POINT	SPEED RPM	SUPPLY PPH	THRO DEG.	COND DEG.	Pc psia	MIN	REC	MAX	P1 - P2 "Hg	Pn psi
	2	3-5	1		4					6
3.01	2900	900	60		amb	62	65	68		42

ENRICHMENT SPRING SETTING

TEST POINT	SPEED RPM	SUPPLY PPH	THRO DEG.	COND DEG.	Pc psia	MIN	REC	MAX	P1 - P2 "Hg	Pn psi
	2	3-5	1		4					6
4.01	4500	1360	60		30.0	211	216	227	Pc-Px 3.5 In.Hg	140
4.02#	3600	1100	60		30.0	-16	-16	-24	Pc-Px= 8.6 In.Hg	140

Approach enrichment speed from 3100 RPM, fuel flow must be 16 to 24 less than 4.01.

TEST POINT	SPEED RPM	SUPPLY PPH	THRO DEG.	COND DEG.	Pc psia	MIN	REC	MAX	P1 - P2 "Hg	Pn psi
4.03	3125	1000	60		25.0	141	157	154	Pc-Px= 11.2 In.Hg	105
4.04	3800	1150	60		34.0	240	245	255	Pc-Px= 4.2 In.Hg	150
4.05	2500	800	60		22.0	130	138	145	Pc-Px= 9.2 In.Hg	100

MAX. GOVERNOR SPRING SETTING

250 RPM LATE

TEST POINT	SPEED RPM	SUPPLY PPH	THRO DEG.	COND DEG.	Pc psia	MIN	REC	MAX	P1 - P2 "Hg	Pn psi
	4 6638	3-6	1		2-5					7
5.01#	6585	1950	60		100.0	514		546		365
5.02	~~6878~~	1950	60	6963	"		515			350

Record speed.

TEST POINT	SPEED RPM	SUPPLY PPH	THRO DEG.	COND DEG.	Pc psia	MIN	REC	MAX	P1 - P2 "Hg	Pn psi
5.03#		1950	60		"	230	~~422~~	270		150
5.04		1950	60		"		515			350

X [ ] X Hysteresis 50 RPM max. of T.P. 5.02.

REFERENCE PRINT - NOT REPLACED AUTOMATICALLY

AlliedSignal AEROSPACE CODE IDENT 07213	TEST SPECIFICATION	AETS 71060 SHEET 4 OF 7 SHEETS	REV. E

TEST POINT	SPEED RPM	SUPPLY PPH	THRO DEG.	COND DEG.	Pc psia	NOZZLE FLOW, PPH MIN	NOZZLE FLOW, PPH REC	NOZZLE FLOW, PPH MAX	P1 - P2 "Hg	Pn psi
IDLE SPEED STOP SETTING AND PICK-UP ANGLE										
At T.P. 6.02, increase T.A. until 4 pph max. fuel flow from 6.01 is observed.										
	3	1-6	4		2-5					7
6.01 #	3875	1200	14-16	-	38.0	138	162	159		100
6.02 #	3875	1200		-	38.0					
					Pick-up angle	19°	16°	25°		100
LOW END OF ACCELERATION CURVE AND THROTTLE MOVEMENT EFFECT										
	2	3-5	1		4					6
7.01	815	230	22		Local	60	115	X		80
7.02	2100	650	22		25.0	124	140	152		100
BELLOWS STOP NUT ADJUSTMENT										
	1	3-5	2-7		4					6
8.01	2900	900	14-16		80	180	177	200		115
Rotate T.A. to 60° and back to 14° to 16° prior to recording fuel flow.										
MANUAL OVERRIDE CHECK										
	1	3-5	2		4					6
9.01	5800	1750	60		100	620	625	640		450
9.02	5800	1750			100					
Decrease T.A. until 4 pph fuel flow drop from T.P. 10.01 is observed. Record T.A.										
					T.A.	50	49.8°	57.5		450
9.03	5800	1750	110		100	620	626	640		450
9.04	2900	900	10		100	78	105	160		110
At T.P. 9.05 to 9.09, connect Pc gauge to Py line and apply 8 psia.										
9.05	2900	900	60		atm	62	65	68		42

AlliedSignal AEROSPACE CODE IDENT 07213	TEST SPECIFICATION	AETS 71060		
		SHEET 5	OF SHEETS 7	REV. E

TEST POINT	SPEED RPM	SUPPLY PPH	THRO DEG.	COND DEG.	Pc psia	NOZZLE FLOW, PPH MIN	REC	MAX	P1 - P2 "Hg	Pn psi
9.06	2900	900	60		atm					

Increase T.A. until 4 pph fuel flow increase from T.P. 9.05 is observed. Record T.A.

TEST POINT	SPEED RPM	SUPPLY PPH	THRO DEG.	COND DEG.	Pc psia	MIN	REC	MAX	P1 - P2 "Hg	Pn psi
					T.A.	60	68°	68		42
9.07	5000	1500	105		atm	590	617	640		450
9.08	5000	1500	110		atm	590	623	640		450
9.09	2900	900	10		atm	62	65	68		42

GOVERNOR RESET CHECK

Note : Place calibrated 2529539-70X Pg bleed in control.
Connect Pg port (side) to Pg port (top) during the Governor Reset Check.

a) At T.P. 10.01 to 10.03, place calibrated 2529539-70X bleed fixture at the end of a pipe connected to the Pg port (side). Connect the high pressure side of the manometer to a tee in this pipe. Connect a ¼" needle valve downstream of the bleed fixture. Connect the low pressure side of the manometer to a tee between the bleed fixture and the valve. The pressure at this point is designated Ps. The speed at T.P. 10.03 must be gradually increased above 6,585 RPM until required flow is obtained. Maintain this speed setting within ± 2 RPM for T.P. 10.02 and 10.03. Pg-Ps at T.P. 10.02 and 10.03 is to be approached from lower Pg-Ps value only.

b) At T.P. 10.04, connect pipe with needle valve and tee to Pg port (side). Connect manometer to tee.

TEST POINT	SPEED RPM	SUPPLY PPH	THRO DEG.	COND DEG.	Pc psia	MIN	REC	MAX	P1 - P2 "Hg	Pn psi
	4	3	1		2-5					6
10.01	X	2000	60		100.0		485			325
Needle valve closed.										
10.02	X	2000	60		100.0		461			305
					Pg - Ps	2.2	3.4	3.4 in. Hg.		
10.03	X	2000	60		100.0		349			220
Difference from T.P. 10.02					Pg - Ps	.30	0.9	1.0 in. Hg.		
10.04#	4000	1210	60		35.0	114	120	130		90
					Pg - Pa	11.0	12.6	14.4 in. Hg.		

Note: Open needle valve fully. Adjust valve to meet the flow requirement of T.P. 10.04 as required (nozzle flow must be seen to increase a minimum of 1 PPH during this adjustment before recording actual PPH and Pg-Pa values).

TEST POINT	SPEED RPM	SUPPLY PPH	THRO DEG.	COND DEG.	Pc psia	NOZZLE FLOW, PPH MIN	REC	MAX	P1 - P2 "Hg	Pn psi

DECELERATION SCHEDULE

Set-up test condition as per T.P. 10.04 and do not alter needle valve.

	4	3	1		2-5					6
11.01*	5800	1750	60		100	170	177	180		120
11.02	5800	1750	60		60	82	108	108		70
11.03	5800	1750	60		40	62	79	81		50

Note: Disconnect Gov. Reset pipings & remove 2529539-70X Pg bleed from control after test.

Check box to indicate Pg bleed removed. [OK]

CUT-OFF MODULATION AND CUT-OFF LEAKAGE

At T.P. 12.01, set test condition with 20° T.A.

a) Move T.A. to 30° and observe nozzle flow change.

	2	3-5	1		4					6
12.01	2000	600	20		A.R.	160	166	170		110

Nozzle flow change [5] 4 PPH max.

At T.P. 12.02, check cut-off leakage.

a) Remove nozzle outlet line from control.
b) Set total supply with T.A. in cut-off position. (Highest T.A. position where no leakage is observed at outlet fitting).
c) Increase T.A. to permit flow out the outlet fitting.
d) Decrease T.A. as required until no leakage is observed at outlet fitting (Observe T.A.).
e) Same Pc as established for T.P. 12.01.

12.02 2000 600 4-6 C.O. leakage 0 [25.0] 3.0 cc/min

2° ____ 0.5 P1 [185] 250 psig max.

REFERENCE PRINT - NOT REPLACED AUTOMATICALLY

TEST POINT	SPEED RPM	SUPPLY PPH	THRO DEG.	COND DEG.	Pc psia	NOZZLE FLOW, PPH MIN	REC	MAX	P1 - P2 "Hg	Pn psi

At T.P. 12.03 (-5° T.A.)

a) Observe P1 pressure.
b) At 0° T.A. lower C.O. lever to be within ± 5° of horizontal.

12.03 2000 600 -5 A.R. P1 [185] PSIG max

Pc same as T.P. 12.01, P1 same or less than T.P. 12.02

12.04 -5 to 110 Local

Operate T.A. lever over full range. T.A. torque [8.0] 20 in-lb. max.

Re-install Py port fitting P/N 3244137 after auditing. Torque fitting per AEEI-15078.

EXTERNAL LEAKAGE CHECK

A. Cap Po at drive flange by-pass tap.
B. Remove Po line to control and install Po plug.
C. Cap outlet port.
D. Set P1 pressure to 1000 psig.
E. Observe leakage for 2-3 minutes.
F. No leakage permitted.

13.01 OK [ ] REJ.

13.02 Record shipping weight X [ ] 7.0 lbs. max.

Checked [4665]

Inspected By: [ ]

TEST POINT	SPEED RPM	SUPPLY PPH	THRO DEG.	COND DEG.	Pc psia	NOZZLE FLOW, PPH MIN	REC	MAX	P1 - P2 "Hg	Pn psi

GOVERNOR RESET CHECK

a) At T.P. 11.01 and 11.02, place calibrated 2529539-70X bleed fixture at the end of a pipe connected to the Pg port (side). Connect the (+) side of differential gauge to a tee in this pipe.

Note : Connect Pg port (side) to Pg port (top) during the Governor Reset Check.

b) At T.P. 11.03 to 11.05, place calibrated 2529539-70X Pg bleed in control. Connect a ¼" needle valve downstream of the 2529539-70X bleed fixture referred to in "a" above. Connect the (-) side of differential gauge to a tee between the bleed fixture and the valve. The pressure at this point is designated Ps. The speed at T.P. 11.03 must be gradually increased above 6,585 RPM until required flow is obtained. Maintain this speed setting within ± 2 RPM for T.P. 11.04 and 11.05. Pg-Ps at T.P. 11.04 and 11.05 is to be approached from lower Pg-Ps value only.

c) If unable to meet T.P. 11.04, replace reset spring.
   1) Use shorter spring (unmarked) to decrease Pg-Ps.
   2) Use longer spring (two stripes) to increase Pg-Ps.

d) At T.P.11.06, connect pipe with needle valve and tee to Pg port (side). Connect (+) side of differential gauge to tee.

e) If unable to meet T.P. 11.06, readjust T.P. 11.01. Higher value Pr-Pa increases Pg-Pa. If T.P. 11.01 has been readjusted, recheck T.P. 11.02 to 11.06 inclusive.

11.01*	Adjust air regulator			85.0	Pr-Pa	35	37.5	37 in. Hg.	
11.02				40.0	Pr-Pa	X	37.2	X in. Hg.	
	Difference from T.P. 11.01					X	0.3	2.0 in Hg max.	
	4	3	1	2-5					6
11.03	X	2000	60	100.0			485		325
	Needle valve closed.								
11.04*	X	2000	60	100.0			461		305
					Pg - Ps	2.3		3.3 in. Hg.	
11.05	X	2000	60	100.0			349		220
	Difference from T.P. 11.04				Pg - Ps	.40		.90 in. Hg.	

Appendix II – Materials laboratory report

South Bend Materials Technology Center
Project Report

SUBJECT:	Investigation of B-37 Fuel Control, S/N C68008						
REQUESTED BY:	K. Miller		**S/N**	C68008	**PART NO.**	3244896-9	
DEPARTMENT	861	**EXTENSION**	4280	**PART NAME**	Fuel Control, B-37		
CHARGE NO.	7000000258-0050		**CUSTOMER**	PWC		**MODEL**	DP-F
ATLAS NO.			**PROJECT ENG.**	K. Miller			

BACKGROUND:

This fuel control is being investigated as a result of the Tristate Careflite (PT6B-37A Augusta Helicopter) incident. The incident occurred in Colorado several weeks ago. The helicopter crashed attempting to rescue an injured logger.

Visual examination of the control indicated the drive body had separated from the flow body. The gap was measured at .033" and the Po (pump return) O-ring was extruded and visible in the gap (PICT0006). The drive body is attached with four screws one of which had pulled out of the flow body allowing the gap. Of the four screws one is approximately .100" longer than the other three. Investigation found a short screw had been switched with a long one. Since a short screw was placed in the position intended for a long screw the thread engagement was reduced to approximately two and one half threads.

REFERENCES

REQUEST:	**REPORT TO:**
Analysis requested: One of four screws holding the drive body to the flow body has pulled out of the flow body. Examine the material remaining in the screw threads to determine the fracture mode. Also, examine the mating surfaces of the flow body for indications of differential movement (loss of clamping load).	Ken Miller Alison Dekoschak Hytham Mokhtar Lee Fisher Sylvie Robin Brad McRoberts Greg Lafferty

WRITTEN BY:	Martin Day	**REVIEWED BY:**	D. Steinke	**DATE:**	11/11/2005

Conclusions:

1) The pullout of the bolt from the flow body was caused by a shear overload condition. See Figure 11, page 13. The direction of the shearing was along the bolt axis.

2) The lack of any fretting wear between the mating surfaces the the drive body and flow body indicated that the two bodies had been tightly clamped together.

Investigation:

The bolt holes and mating surfaces between the the drive body and flow body of the fuel control were documented in Figures 1 - 6 , pages 3 - 8. The bolt holes were labeled #1 through #4, hole #3 being the hole from which the bolt had pulled out. Except for a slight witness mark around one of the bolt holes (not the one in which the bolt had pulled out), the mating surfaces were unworn. There was no evidence of fretting wear to indicate that relative motion between the surfaces had occurred. It was also noted that in addition to the damaged ID threads of bolt hole #3 in the flow body, three of the four holes in the drive body had been damaged by the threads of the bolts.

Fluorescent penetrant inspection was performed on the flow body to determine if any cracks were present around bolt hole #3. No indications were found.

A scanning electron microscope / energy dispersive (SEM/EDS) system was used to examine the material remaining between the threads of the bolt that pulled out of the flow body. Results from the EDS elemental analysis of this material concluded it was the flow body alloy. A typical spectrum of the analysis is shown in Figure 7, page 9. The material between the bolt threads showed smearing in approximately the axial direction of the bolt. Apparently, the ID threads of the flow body had been sheared off, Figures 8 – 10, pages 10 - 12. Much of the original fracture morphology of this sheared material had been obliterated by smearing. However, isolated regions of shear dimples were found indicating the fracture was due to a shear overload condition, Figure 11, page 13.

For comparison purposes, a test was performed to simulate a condition in which the ID threads in a flow body were sheared by over torquing a bolt with an approximately two and one half thread engagement. SEM analysis of the sheared material between the bolts revealed a morphology much like that observed in the incident bolt. Shear dimples were readily apparent, but the orientation of the smearing appeared to be more canted from the axial direction, Figures 12 - 13, pages 14 - 15.

Additionally, when the thread engagement surfaces between the sheared material and the threads of the above bolts were examined, significant differences were noted. The sheared material was “unscrewed” from both the incident bolt and from a test bolt for examination under the SEM. The contact surfaces of the sheared material from the incident bolt showed that deformation of the ID thread of the flow body by the bolt thread was in the axial direction as evidenced by axial score marks. The bolt thread had also deformed the ID thread, creating a groove and splitting the thread.
Very little circumferential scoring from the bolt threads were observed, Figures 14 – 17, pages 16 - 17. In contrast, there was significant scoring of the ID thread of the flow body by over torquing the bolt, Figures 18 - 20, pages 18 - 19.

It is concluded that the pullout of the incident bolt was not due to over torquing, but likely to an axial overload condition. It is recommended that a test be performed to pull a bolt out of a flow body in an axial direction. The bolt should be pulled out suddenly to simulate an axial overload condition that may have existed at the time of the crash. The fracture surfaces and the thread engagement surfaces should then be examined and compared to the incident bolt.

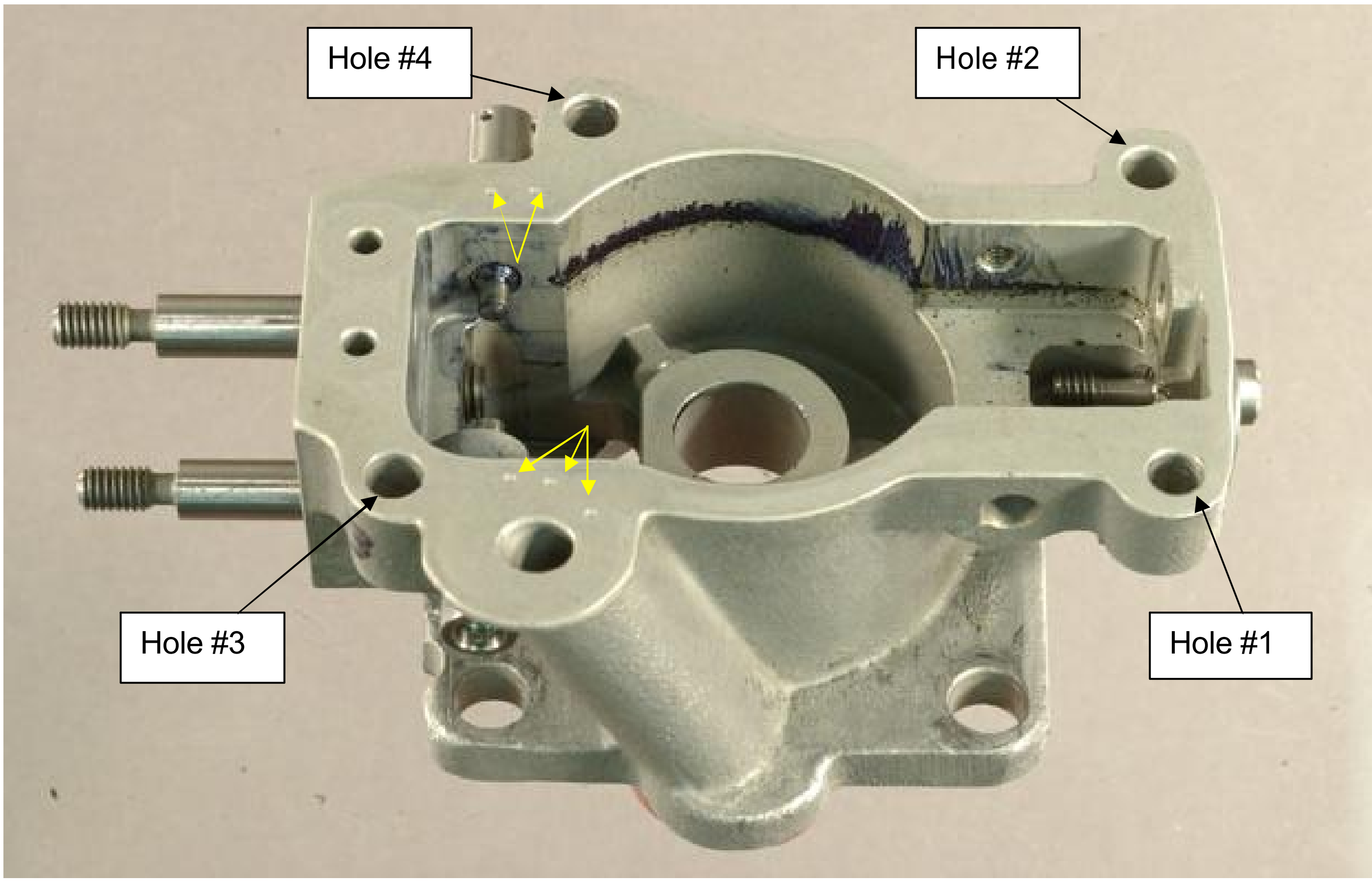


Figure 1.
The drive body half of the fuel control showing the bolt holes and the surface that mates to the flow body. The five shallow dimples in the surface were from hardness measurements made at the time of this investigation (yellows arrows).

A) Face-on view.

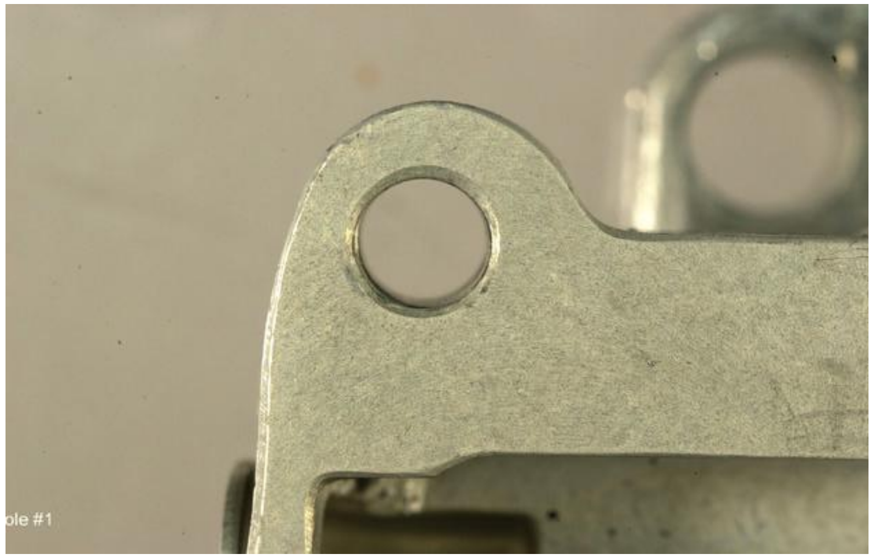
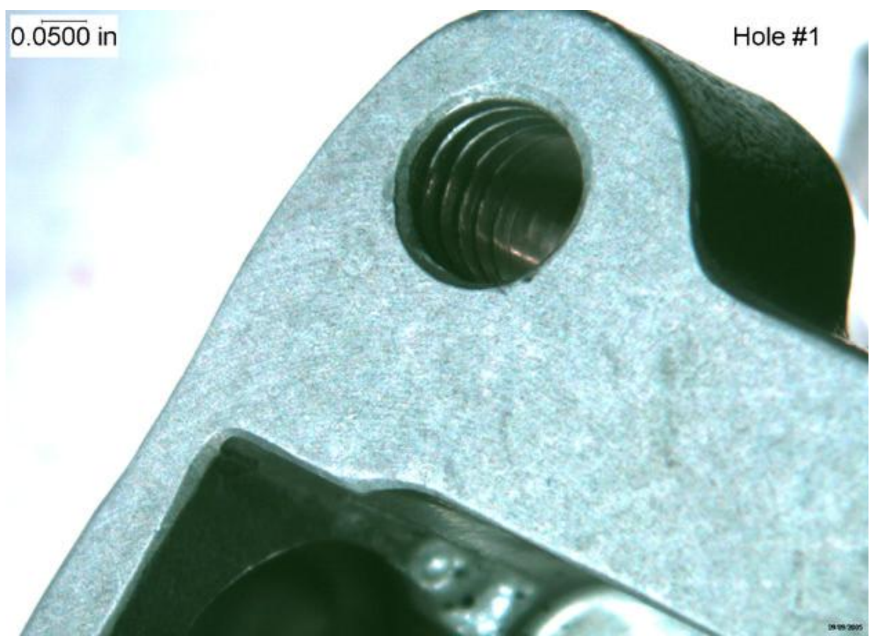


Figure 2.
Close up views of bolt hole #1 and the surrounding interface on the drive body. Thread marks from the bolt are seen in the hole ID.

B) Angled view.



A) Face-on view.

Figure 3.
Close up views of bolt hole #3 and the surrounding interface on the drive body. Thread marks from the bolt are seen in the hole ID.

B) Angled view.

A) Face-on view.

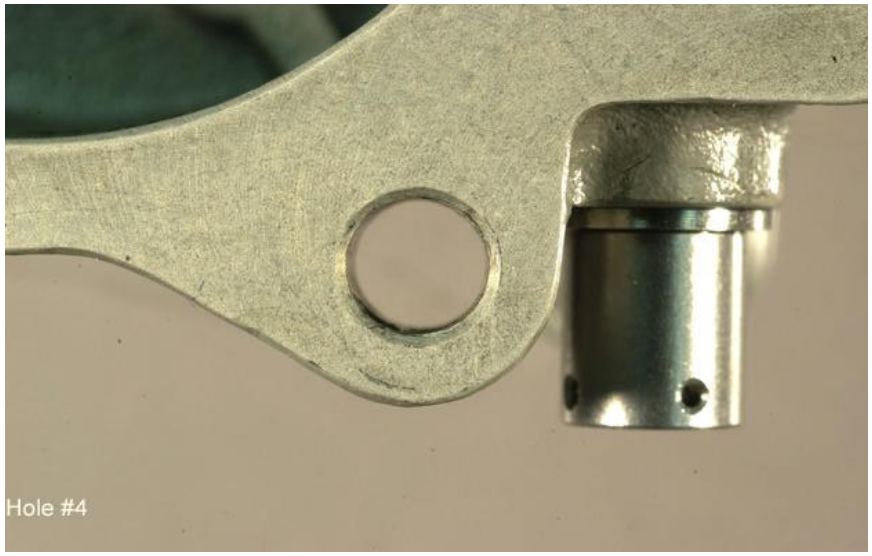
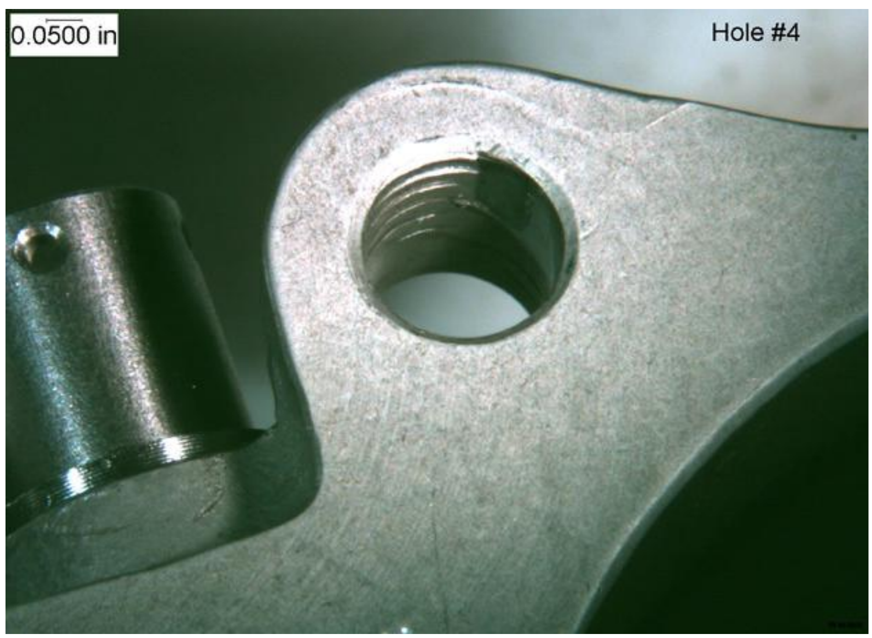


Figure 4.
Close up views of bolt hole #4 and the surrounding interface on the drive body. Thread marks from the bolt are seen in the hole ID.

B) Angled view.



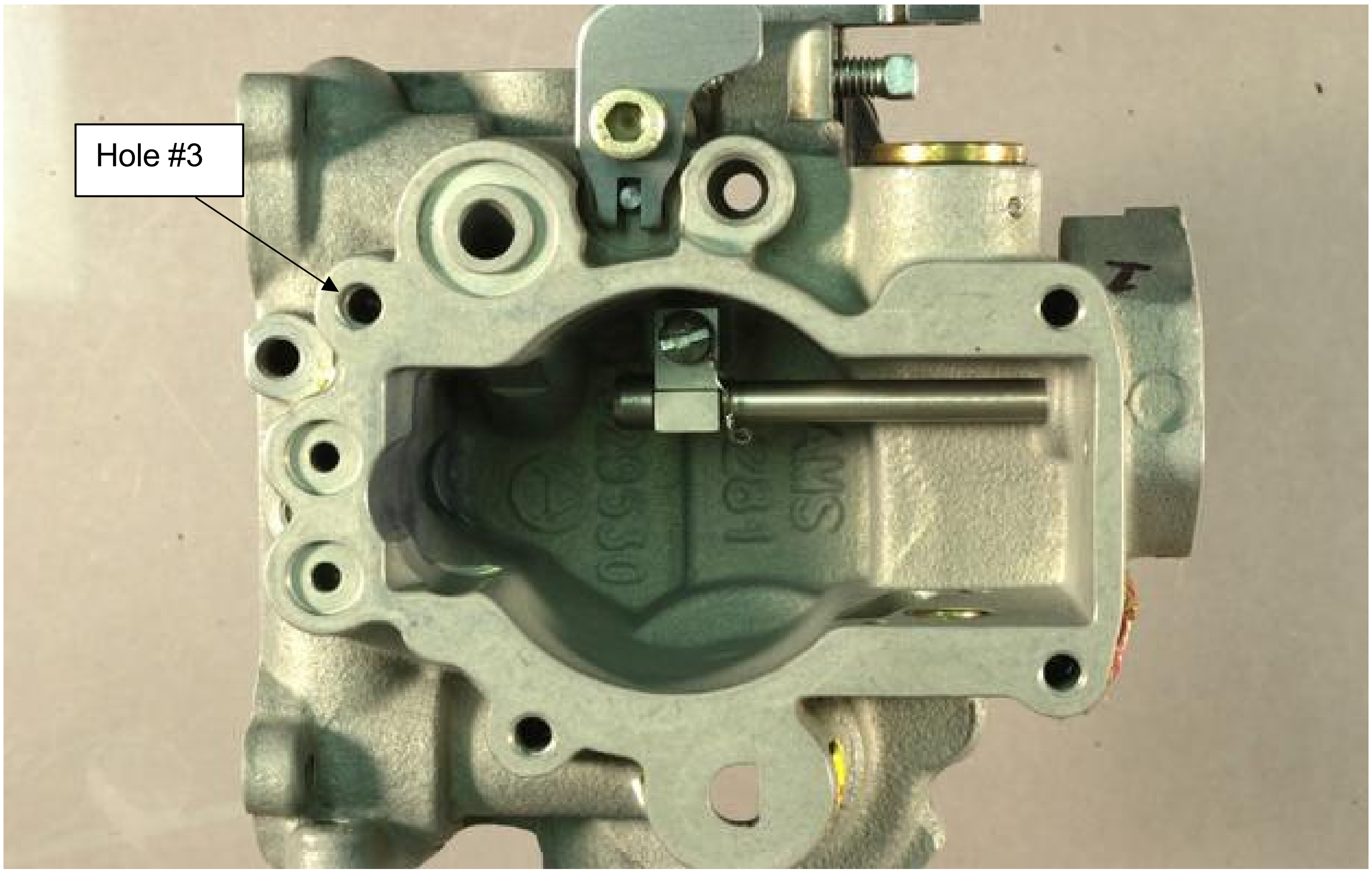


Figure 5.
The flow body half of the fuel control showing the bolt holes and the surface that mates to the drive body.

A) Top view.

Figure 6.
Close up views of bolt hole #3 from which the bolt had been pulled out. Note the damage to the ID threads.

B) Side view.

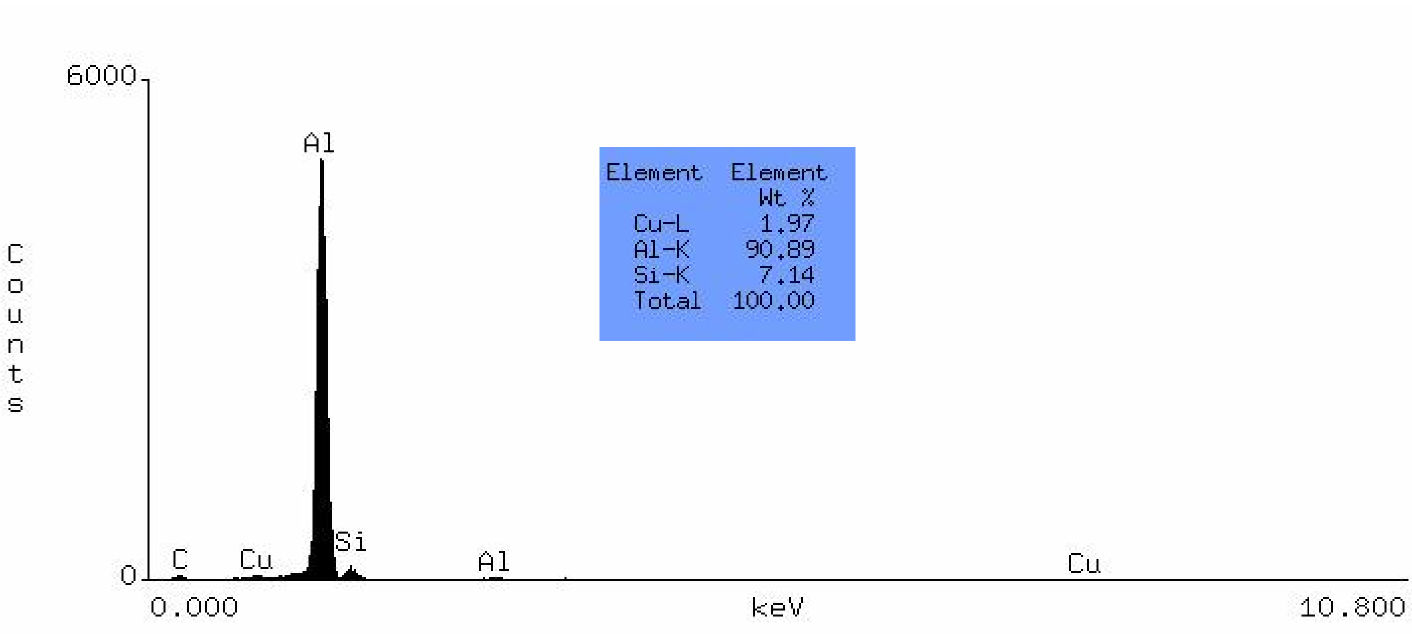


Figure 7.
EDS spectrum of the material between the threads of the bolt that had pulled from bolt hole #3 of the flow body. The composition was consistent for flow body material.

A) 0^0 orientation.

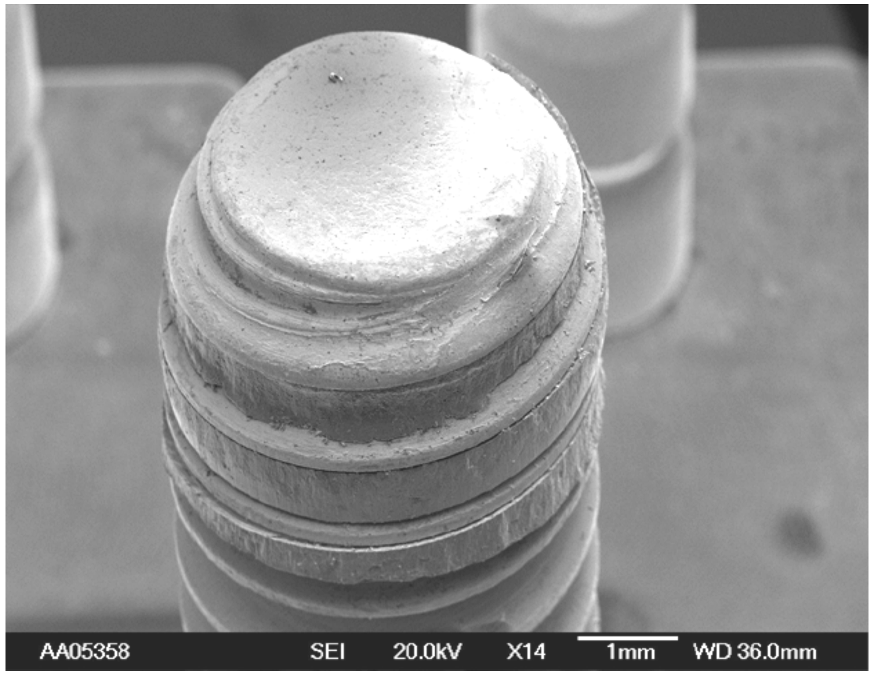
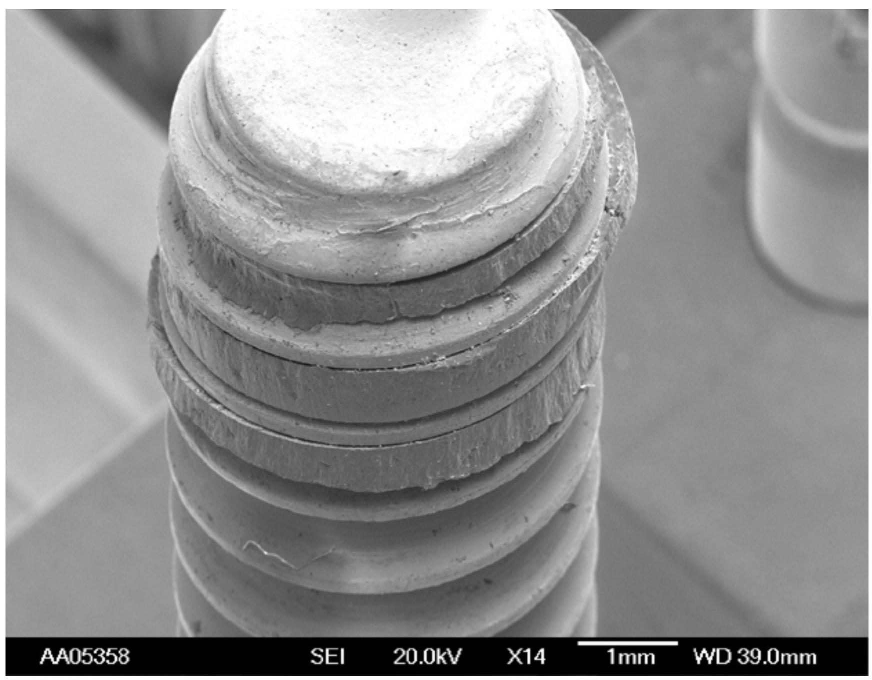


Figure 8.
SEM photomicrographs of the material between the threads of the bolt that pulled out of hole #3 in the flow body.

B) 90^0 orientation.



A) 180^0 orientation.

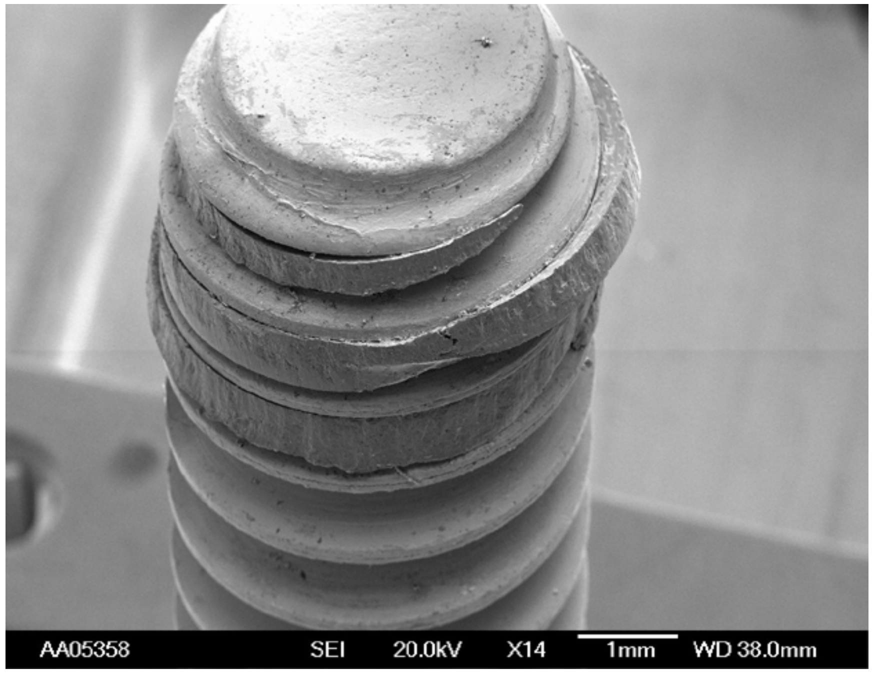
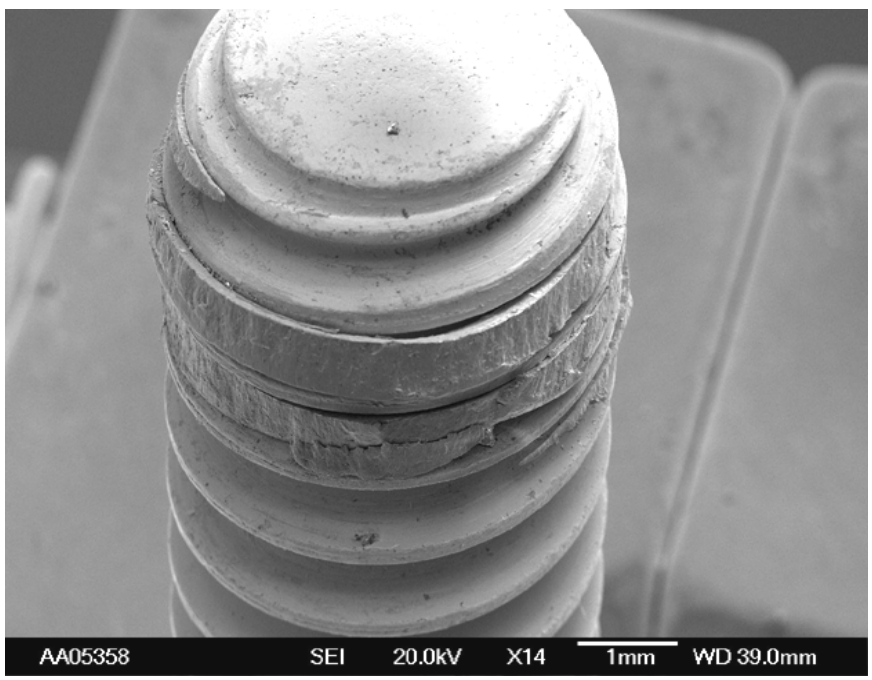


Figure 9.
SEM photomicrographs of the material between the threads of the bolt that pulled out of hole #3 in the flow body.

B) 270^0 orientation.



A) Micron bar = 100 microns

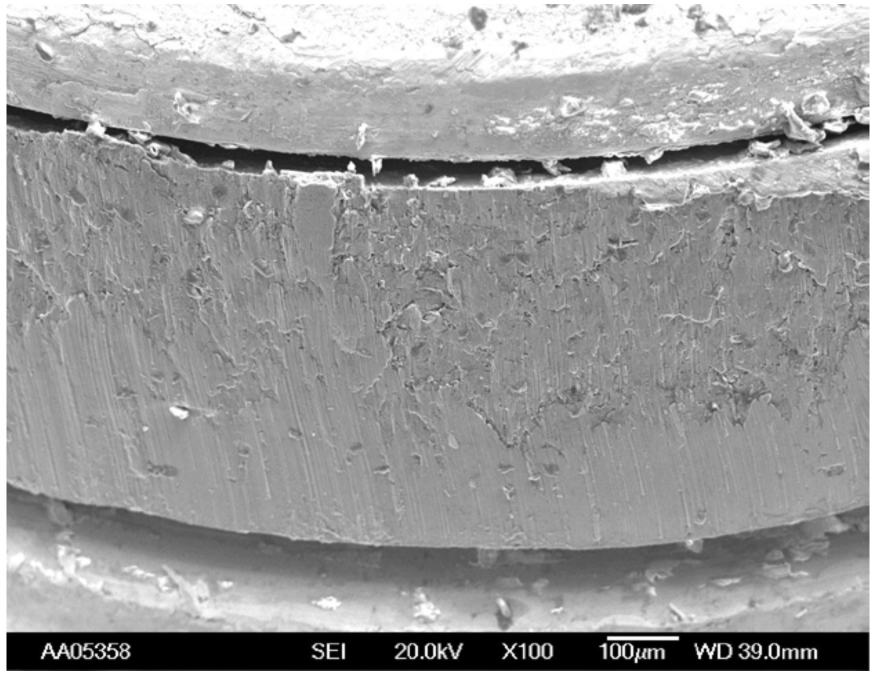
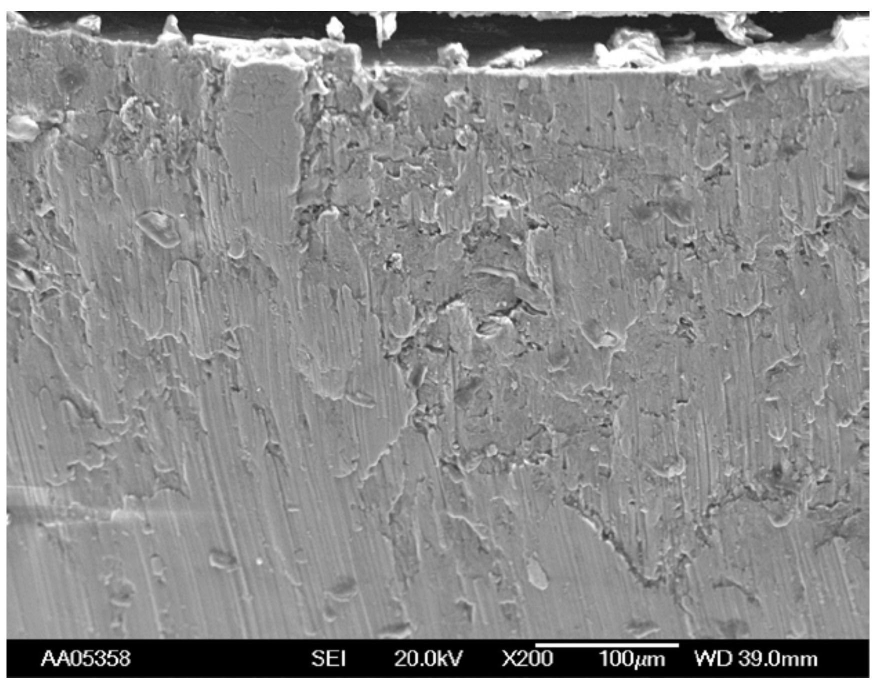


Figure 10.
SEM photomicrographs of the sheared surfaces of the material between the threads of the bolt that pulled out of hole #3 in the flow body.

B) Micron bar = 100 microns



A) Micron bar = 10 microns

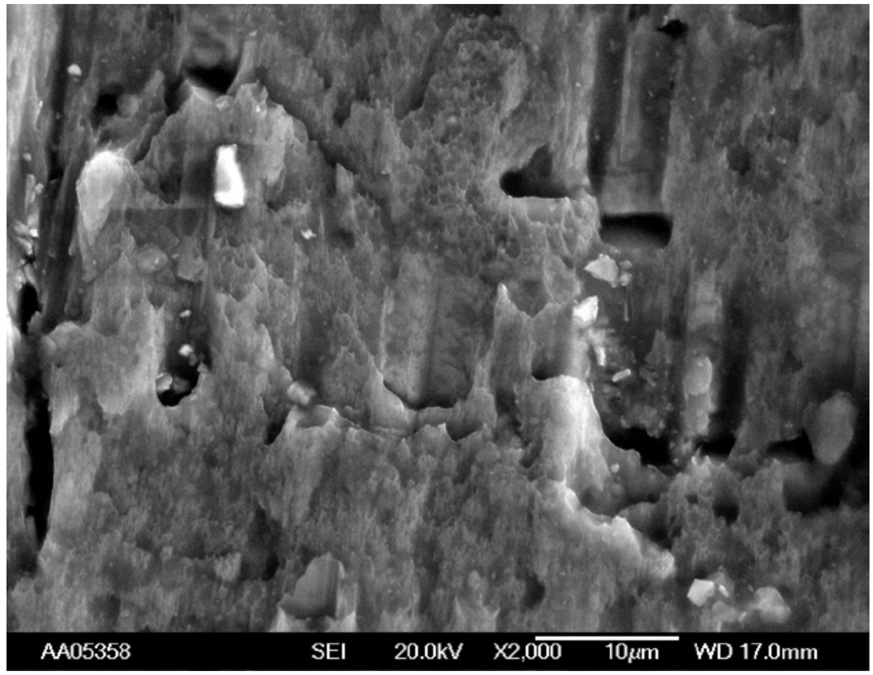
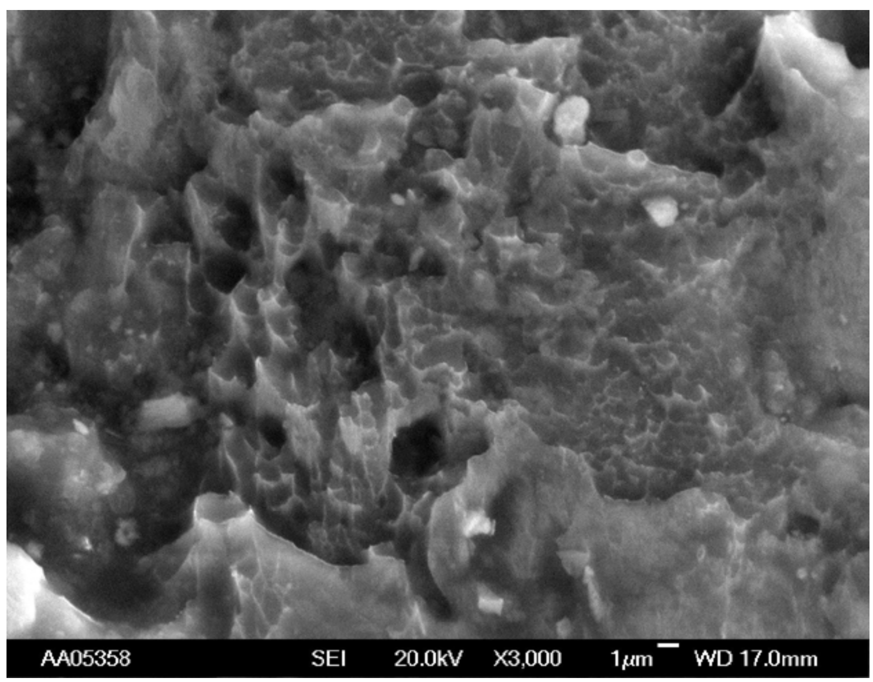


Figure 11.
SEM photomicrographs of the sheared surfaces of the material between the threads of the bolt that pulled out of hole #3 in the flow body. A shear dimple rupture morphology is evident.

B) Micron bar = 1 microns



A) 0^0 orientation.

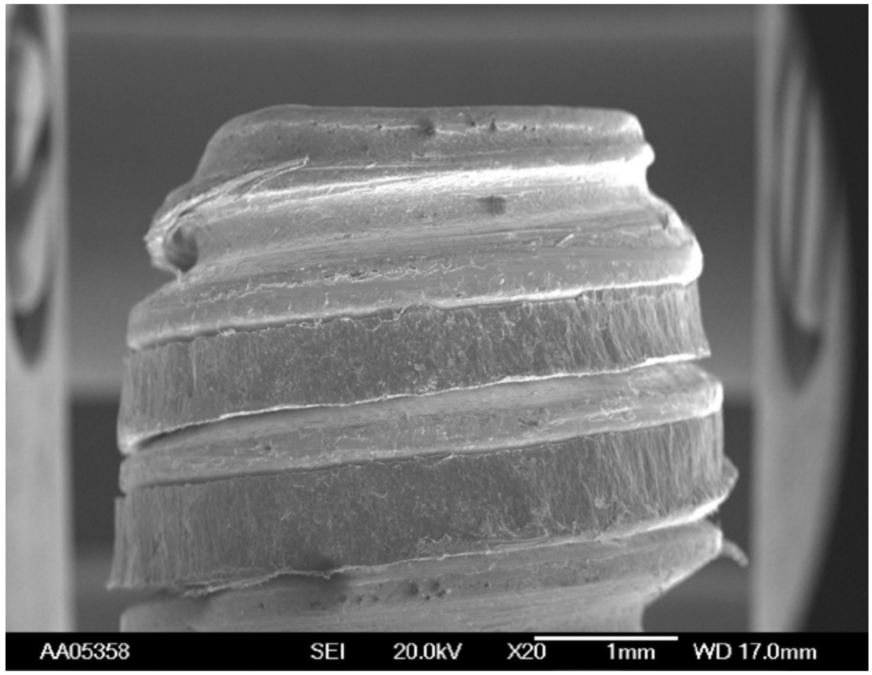
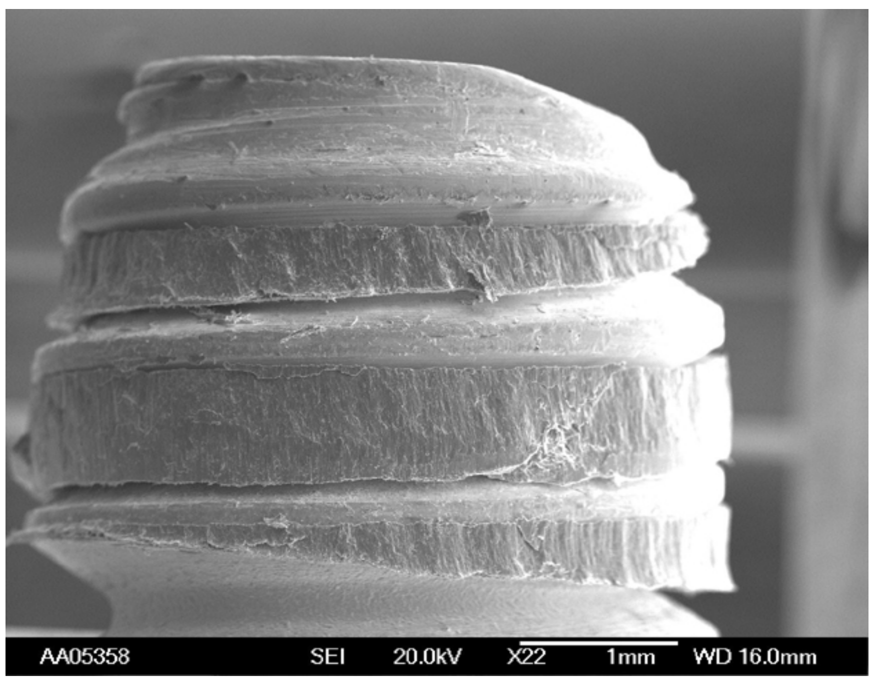


Figure 12.
SEM photomicrographs of the material between the threads of the bolt that simulated shearing of the ID threads by over torquing a bolt with an approximately two and one half thread engagement.

B) 180^0 orientation.



A) Micron bar = 100 microns

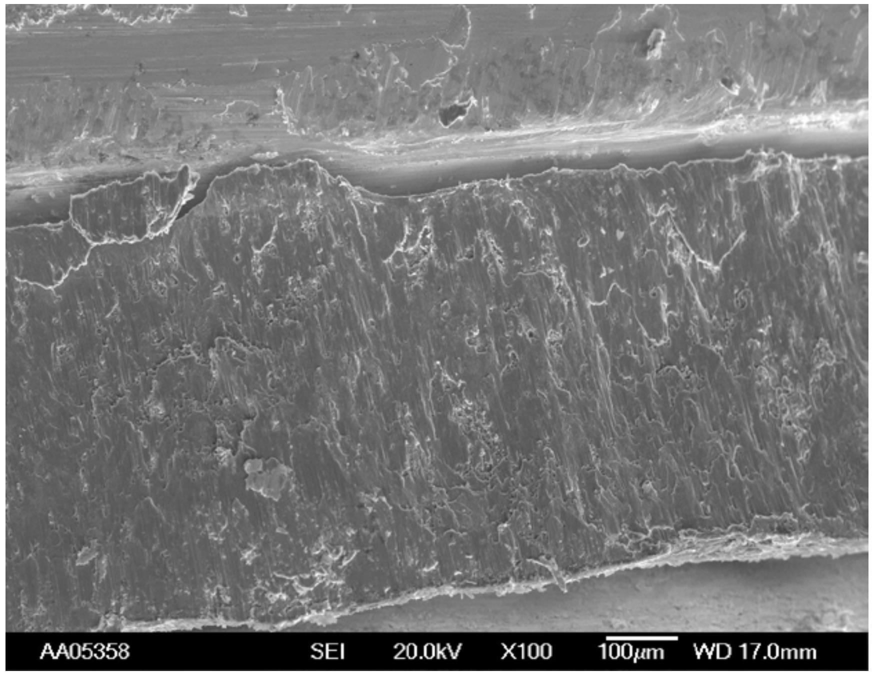


Figure 13.
SEM photomicrographs of the material between the threads of the bolt that simulated shearing of the ID threads by over torquing a bolt with an approximately two and one half thread engagement. A shear dimple rupture morphology is evident.

B) Micron bar = 100 microns

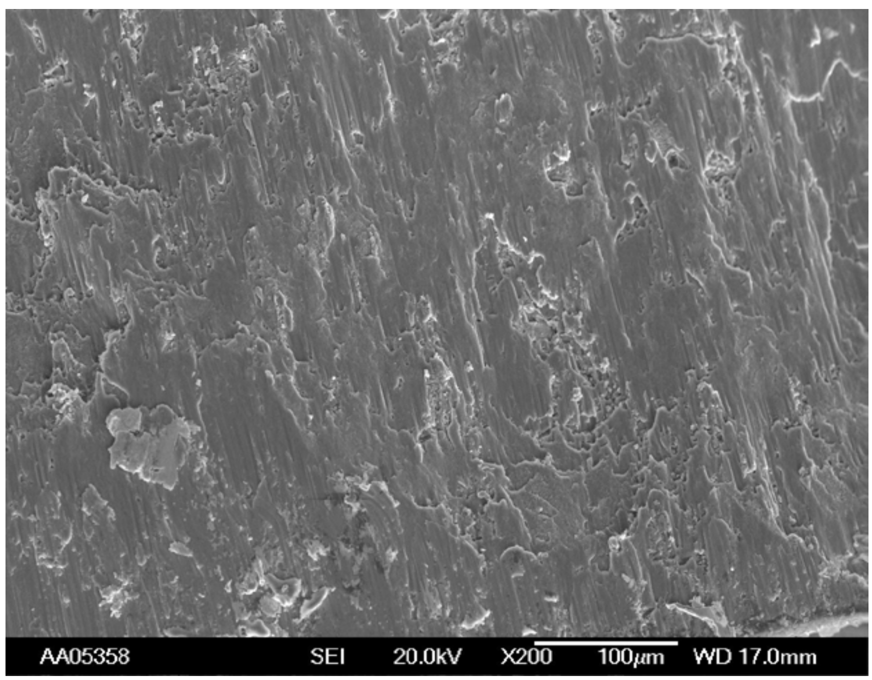


Figure 14.
SEM photomicrograph of the sheared material “unscrewed” from the bolt that pulled out of the hole #3 in the flow body. The three regions identified are shown in the subsequent photographs.

Micron bar = 1 mm

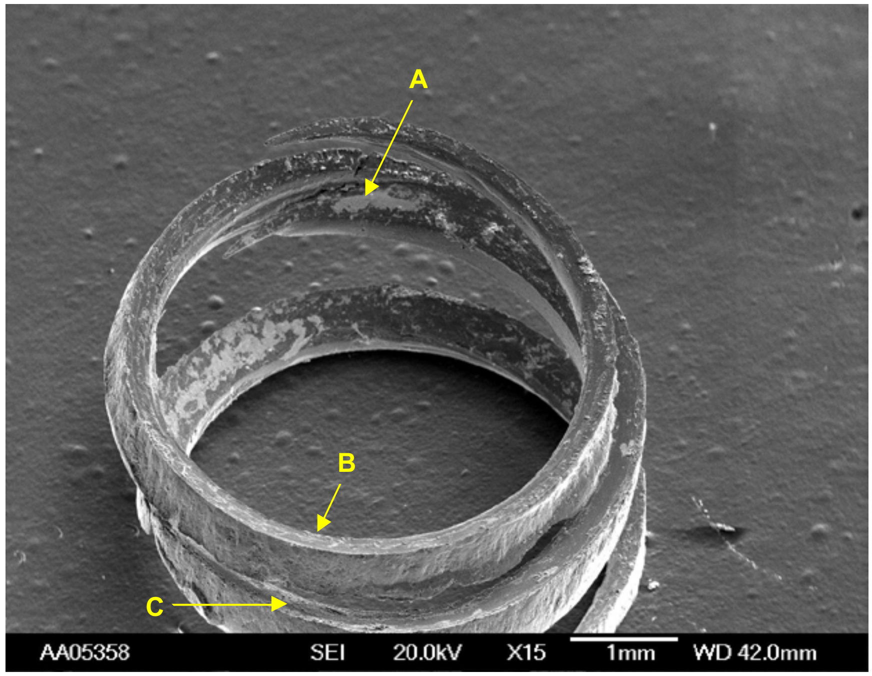
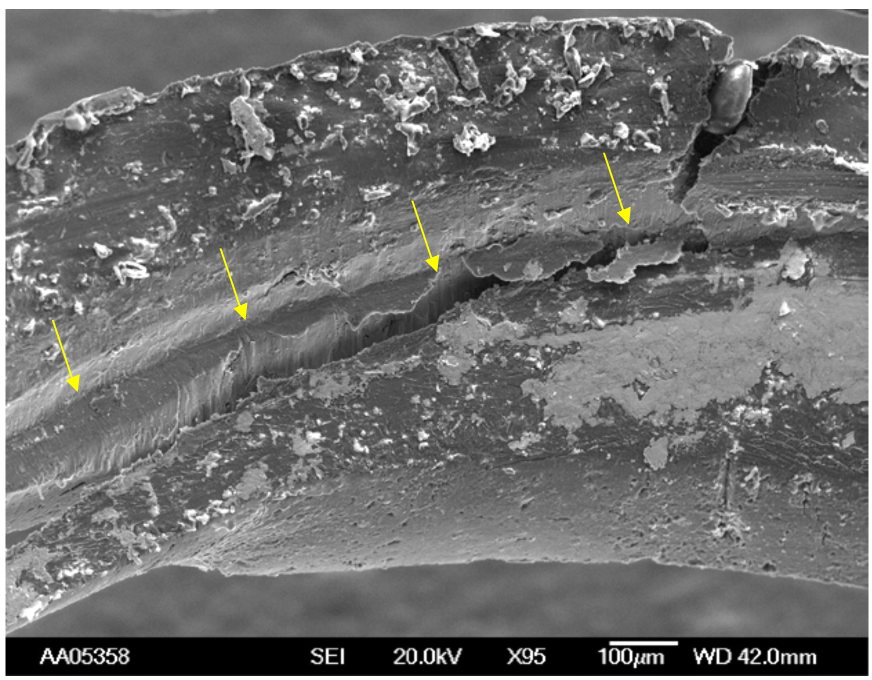


Figure 15.
SEM photomicrograph of region “A” of Figure 14. Deformation of the ID thread of the flow body by the bolt thread was in the axial direction as evidenced by the axial score marks. The bolt thread deformed this region creating a groove and splitting the thread (arrows).

Micron bar = 100 microns



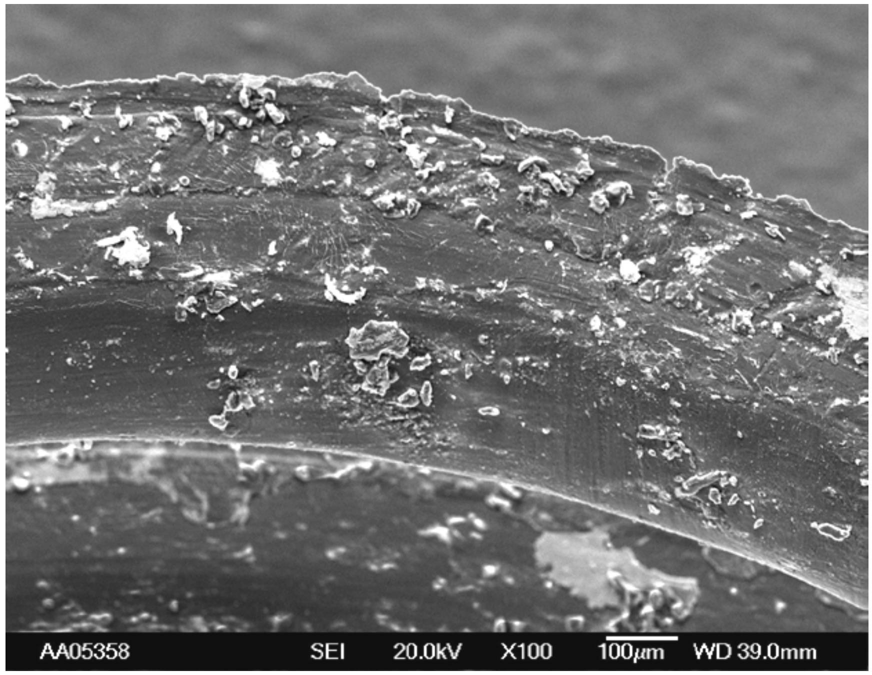


Figure 16.
SEM photomicrograph of region "B" of Figure 14. No significant circumferential scoring of the ID thread of the flow body by the bolt thread. Compare with the scoring found on the over torqued bolt test, Figures 18 - 21.

Micron bar = 100 microns

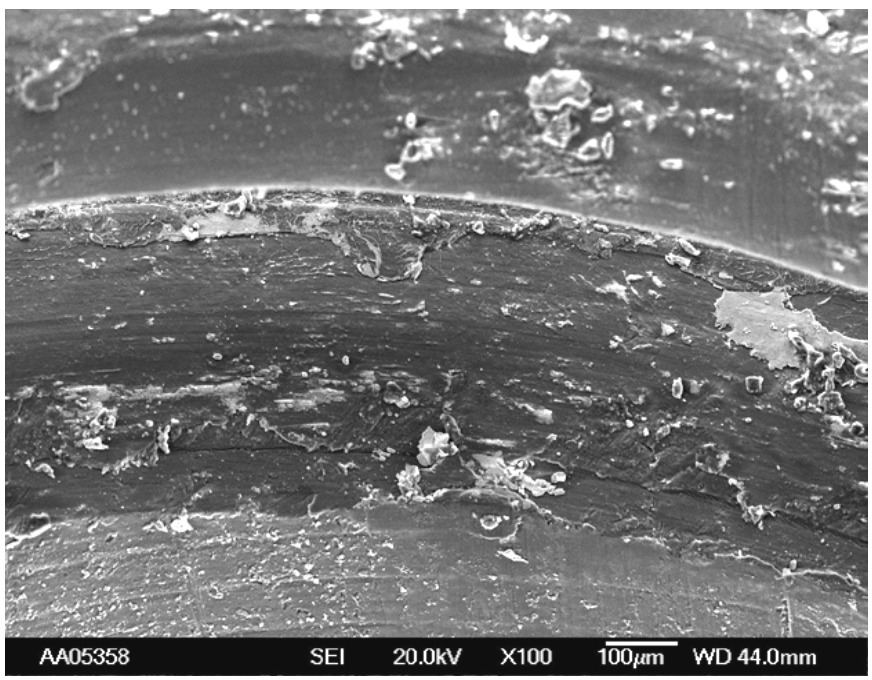


Figure 17.
SEM photomicrograph of region "C" of Figure 14. No significant circumferential scoring of the ID thread of the flow body by the bolt thread. Compare with the scoring found on the over torqued bolt test, Figures 18 - 20.

Micron bar = 100 microns

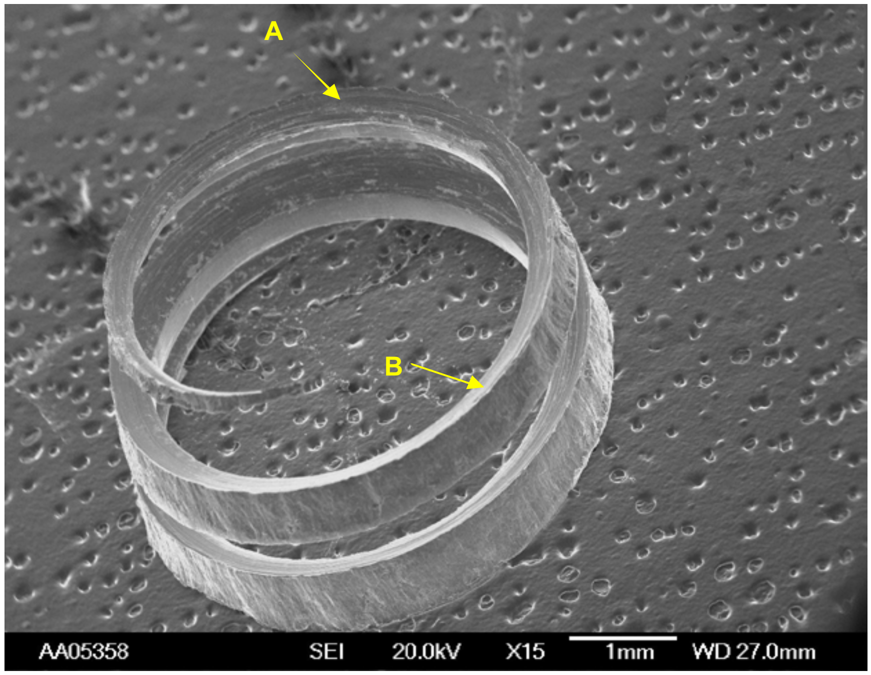


Figure 18.
SEM photomicrograph of the sheared material “unscrewed” from the over torqued bolt test the three regions identified are shown in the subsequent photographs.

Micron bar = 1 mm

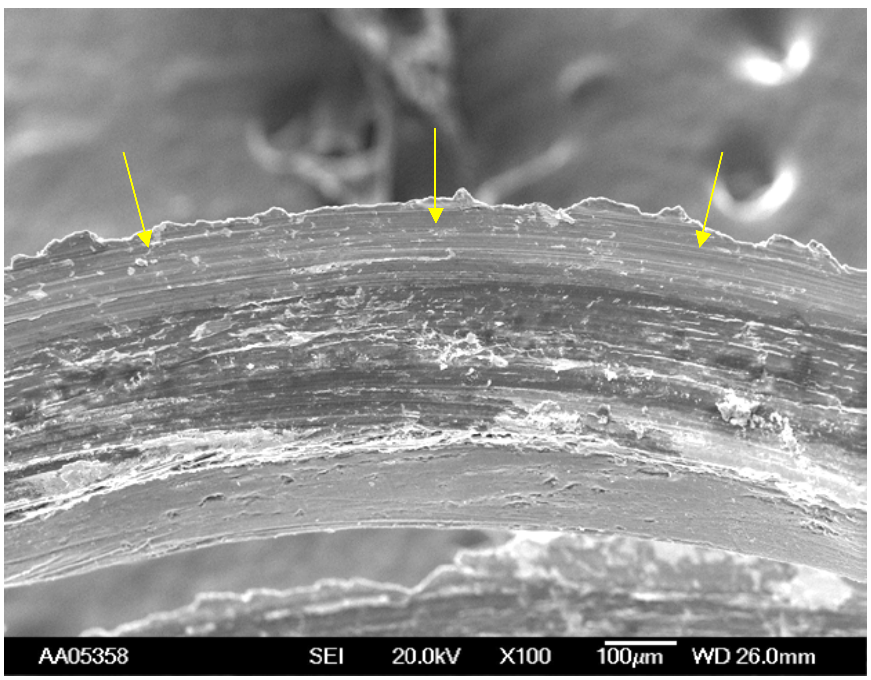


Figure 19.
SEM photomicrograph of region “A” of Figure 18. Over torquing of the bolt caused significant circumferential scoring of the ID thread of the flow body (arrows).

Micron bar = 100 microns

A) Micron bar = 100 microns

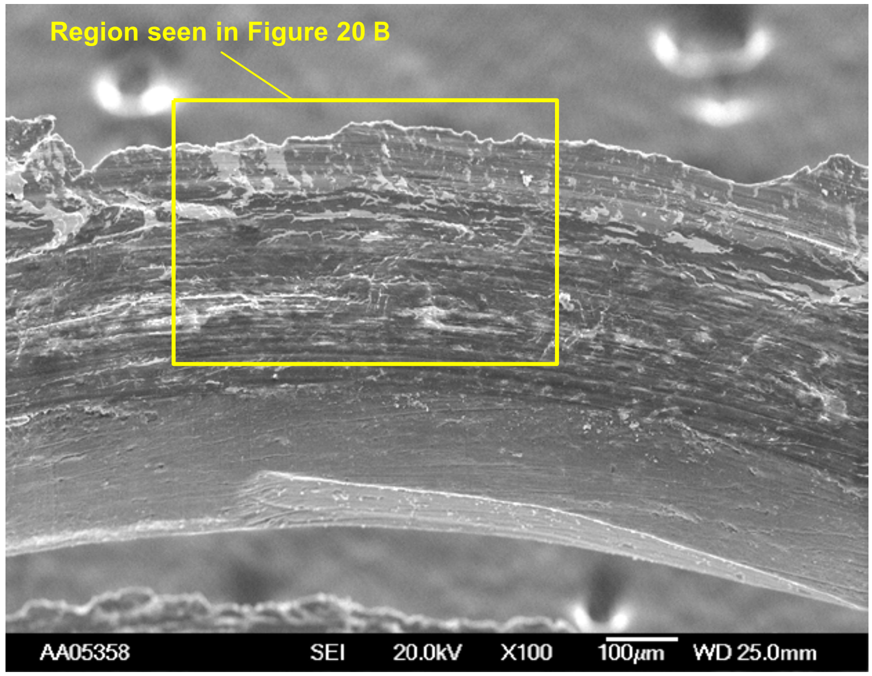
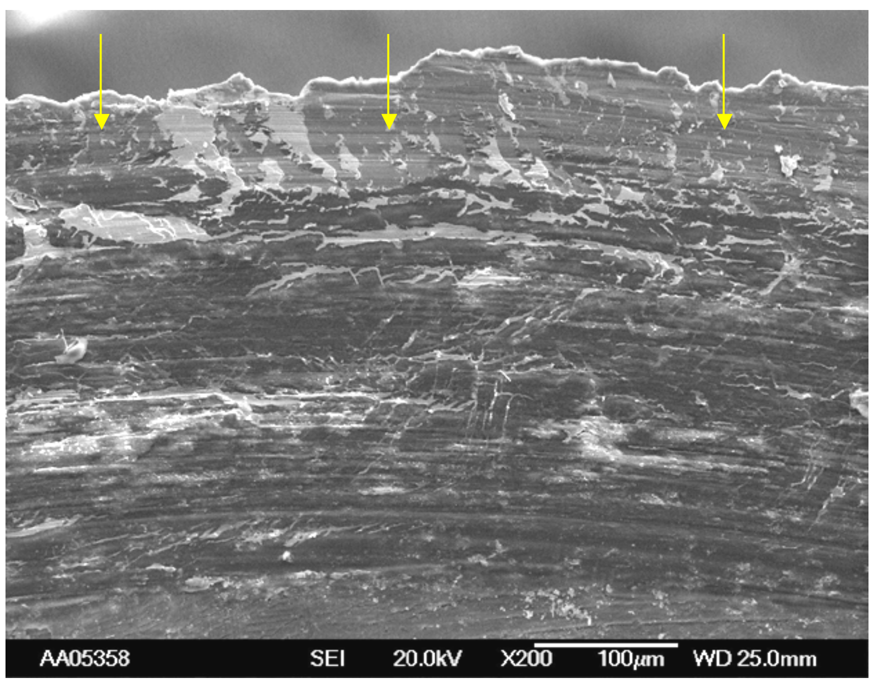


Figure 20.
SEM photomicrographs of region "B" of Figure 18. Over torquing of the bolt caused significant circumferential scoring of the ID thread of the flow body (arrows).

B) Micron bar = 100 microns



Appendix III – Stress analysis report

Honeywell

Interoffice Correspondence

Engineering Sciences and Services
Engine Systems and Services
717 N. Bendix Dr., South Bend, IN 46628

Date: September 15, 2005
To: Ken Miller
Alison Dekoschak
cc: Department 868 Files
Kerri McCool
Subject: Thread Pull-out Failure Analysis
References: PI Investigation B-37 Fuel Control
Attachments: Analysis & Equation summary

Memo: 868-DAH-1057
From: Doug Hall
Department: 868
[redacted]

I have analyzed Socket Head Screw, PN953504, used in the B-37 Main Fuel Control Unit, PN3244896. A control was returned from the field with stripped housing threads. Analysis considers the evidence and consequences for units in the field. With worst case loads and material properties, a short screw installed through a thick lug would yield the threads enough to reduce or eliminate the clamping load. The interface can survive with one screw missing.

Four screws secure Flow Body, PN2690233, to the Drive Body, PN3243988. The interface uses three PN953504-157 and one PN953504-159, #10-24 socket head screws. The -159 is longer. Holes in the Flow Body are deep enough to accept the long screw into any hole at this interface.

All screws are installed to 20-25 in-lbs, exceeding the standard torque reported in EI-1153. Temperature ranges from -40F to + 250F. Vibration loads assume 20G's in the vertical direction, a transmissibility factor 5.0 and 5 lbs of overhanging weight. Fatigue analysis assumes that each flight starts cold and reaches maximum temperature with a design life of 100,000 flights. Fatigue properties for 355.0-T6, permanent mold cast aluminum per AMS 4281, are estimated from design minimum values for static strengths.

The returned unit mixed a long and short screw, significantly reducing the number of engaged threads from 5.04 to 2.16. Including thermal, installation preload and vibration loads, the short screw installed in a thick lug can be expected to cause structural failures due to shear tearout of the housing threads. The shear stresses in the aluminum threads exceed the ultimate shear strength of the material. The assembly stresses are not necessarily high enough to cause failure to occur prior to high temperature operation on an engine.

If the improperly installed short screw fails, the neighboring screw reacts twice the vibration load. However, the remaining screws must necessarily have at least 5.04 threads engaged in the aluminum, significantly increasing the thread shear area. These controls can survive for 100,000 flights. Vibration stresses are not expected to cause high cycle fatigue failures.

Signature on file

Douglas A. Hall
Sr. Principal Engineer
Fuel System Structures