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Subject: ERA24LA375, Fuel Control Unit and Fuel Pump Inspection

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The FCU and fuel pump were attached together. The fuel supply line from the fuel pump to the FCU showed that there was no lockwire between the FCU inlet fitting and the fuel line "B" nut. The fuel line was disconnected from the FCU end, and the fuel pump was separated from the FCU. The FCU drive shaft splines showed the presence of a brownish deposit similar to grease along with wear on the portion of the drive shaft engaging in the fuel pump spline. Reviewing the engine maintenance manual (EMM) 3032842 section 73-20-00 removal / installation paragraph, there is no recommendation to use grease while installing the FCU on the fuel pump. The drive shaft was rotating normally with the fingers. The mounting plate showed presence of particles in the bellows nut cavity. There were two colors of anti-tamper paint, white on top of red on the mounting plate retaining bolts and the bellows nut. The underneath red anti-tamper paint was undamaged. The external surface was relatively clean, however blackish deposits in the vicinity of the power lever and the shutdown valve were present. The condition lever was bent at the airframe connecting point and the condition lever minimum adjustment stop was bent as well. Brownish / reddish coloration was present on some portions of the condition lever. The condition lever was rotating on its full range without restriction. The power lever was also rotating normally. The reverse thrust yield shield showed a varnish like deposit. The P3 drain orifice was clean, and the special orifice looked clean. The fuel inlet filter was generally clean. A small section showed a brownish color. The lockwire on the deadband adjustment screw, the idle and the high idle adjustment roller were bigger compared to the other ones. The idle and high idle are permissible field adjustments,

not the deadband. The seals and antitamper paint were at the right location. There was a VSE service label present on the cover.

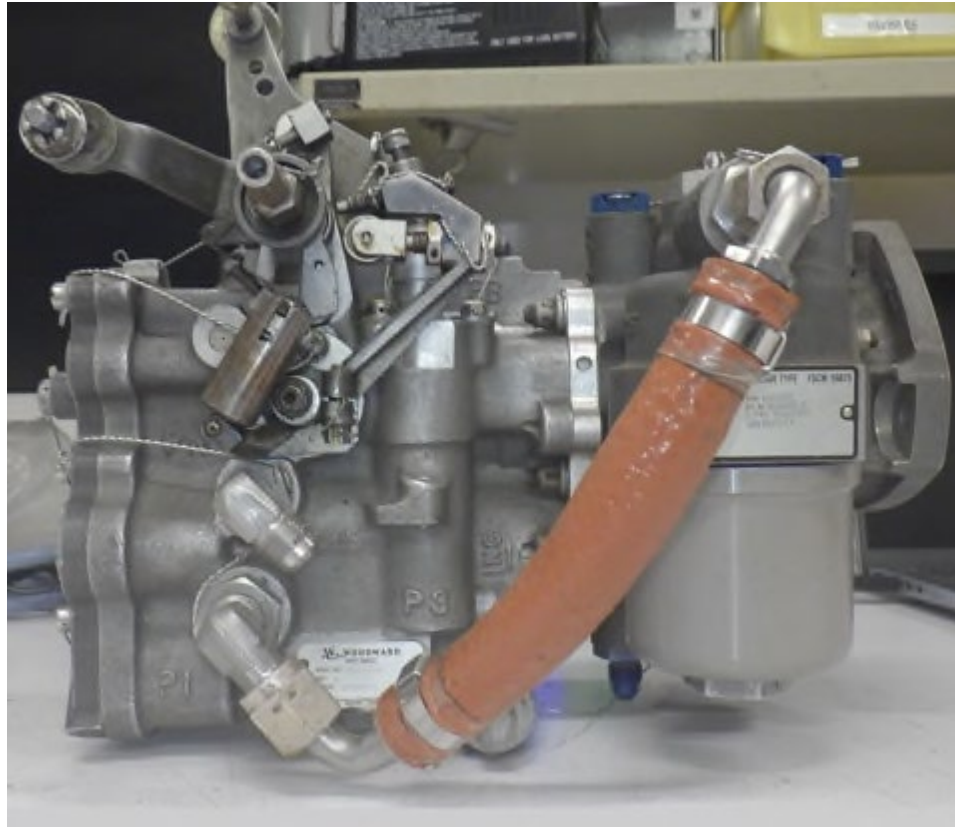


Figure 1: FCU and fuel pump, as-received, attached together. (Courtesy of P&WC)

Fuel Control Unit

The unit was installed on the test rig in preparation for the test as received in accordance with the Woodward CMM 73-20-07 Rev. 5. Prior testing the unit, the FCU setting were adjusted to get the fuel flow output at mid-range. The FCU was ran for roughly 5 minutes. Throughout this period the fuel flow output did not change. The following are the deviations to the CMM requirements observed as received.

The low idle test point (T.P.) was 164 RPM above the CMM maximum limit. With the RPM adjusted to the nominal setting, the fuel flow output was 13 pounds per hour (PPH) above the CMM set point. This is a permissible field adjustment. The high idle T.P. was 407 RPM above the CMM maximum limit. With the RPM adjusted to the nominal setting, the fuel flow output was 69 PPH above the CMM set point. This is a permissible field adjustment. During this test, it was observed that the minimum stop bolt head was

bent. The shutdown lever T.P. showed that in the open settings, the fuel flow output was 9 PPH below the CMM minimum limit. It was noticed that the shutdown valve cap was fretting against a lockwire when pressed down in the shutdown position. No remarkable wear was present on the cap and lockwire. The maximum reverse T.P. was 213 RPM below the CMM minimum limit. With the RPM adjusted to the nominal setting, the fuel flow output was 42 PPH below the CMM set point. This is a permissible field adjustment. The maximum forward T.P. was 18 RPM below the CMM minimum limit. With the RPM adjusted to the nominal setting, the fuel flow output was 51 PPH below the CMM set point. The dead band adjustment was 14.5 degrees above the CMM maximum limit. The CDP (P3) schedule testing showed that the lower portion of the schedule was below the CMM minimum requirements. T.P. 6.1 was 21 PPH below the CMM minimum limit. T.P. 6.2 was 23 PPH below the CMM minimum limit. T.P. 6.3 was 14 PPH below the CMM minimum limit. T.P. 6.4 and 6.5 were within the CMM limits, however on the low side of the tolerance band. The CDP (P3)-Py schedule T.P. 7.1 was 2 PPH below the CMM minimum limit. The T.P. 7.2 was 17 PPH below the CMM minimum limit. The start and acceleration schedule showed that most of the fuel flow output was below the CMM minimum limit for P3 values below 100 psia which was as the CDP (P3) schedule testing. T.P. 9.2 with the power lever (P/L) set to high idle and the condition lever (C/L) set to maximum, the fuel flow output was 6 PPH below the CMM minimum limit. With the P/L set to maximum and the C/L to idle, the fuel flow output was 2PPH below the CMM minimum limit. T.P. 9.3, with the P/L set to high idle and the C/L set to maximum, the fuel flow output was 12 PPH below the CMM minimum limit. With the P/L set to idle and the C/L set to idle, the fuel flow output was 2 PPH below the CMM minimum limit. With the P/L set to maximum and the C/L set to idle, the fuel flow output was 7 PPH below the CMM minimum limit. T.P. 9.4, with the P/L set to high idle and the C/L set to maximum, the fuel flow output was 20 PPH below the CMM minimum limit. With the P/L set to idle and the C/L set to idle, the fuel flow output was 6 PPH below the CMM minimum limit. With the P/L set to maximum and the C/L set to idle, the fuel flow output was 13 PPH below the CMM minimum limit. T.P. 9.5, with the P/L set to high idle and the C/L set to maximum, the fuel flow output was 17 PPH below the CMM minimum limit. With the P/L set to idle and the C/L set to idle, the fuel flow output was 12 PPH below the CMM minimum limit. With the P/L set to maximum and the C/L set to idle, the fuel flow output was 14 PPH below the CMM minimum limit. T.P. 9.6, with the P/L set to high idle and the C/L set to maximum, the fuel flow output was 14 PPH below the CMM minimum limit. With the P/L set to idle and the C/L set to idle, the fuel flow output was 13 PPH below the CMM minimum limit. With the P/L set to maximum and the C/L set to idle, the fuel flow output was 14 PPH below the CMM minimum limit. T.P. 9.7, with the P/L set to maximum and the C/L set to idle, the fuel flow output was 18 PPH below the CMM minimum limit. T.P. 9.8, with the P/L set to maximum and the C/L set to idle, the fuel flow output was 20 PPH below the CMM minimum limit. T.P. 9.9, with the P/L set to maximum and the C/L set to idle, the fuel flow output was 20

PPH below the CMM minimum limit. T.P. 9.10, with the P/L set to maximum and the C/L set to idle, the fuel flow output was 13 PPH below the CMM minimum limit. T.P. 9.11, with the P/L set to maximum and the C/L set to idle, the fuel flow output was 12 PPH below the CMM minimum limit. T.P. 9.12, with the P/L set to maximum and the C/L set to idle, the fuel flow output was 7 PPH below the CMM minimum limit. The maximum flow test T.P. 10.1 was 23 PPH above the CMM maximum limit.

Following the test as received, the deadband was adjusted to the CMM maximum limit. The low idle, high idle, maximum reverse and maximum forward T.P. were re-checked and found within the CMM limit.



Figure 2: FCU installed on the test stand. (Courtesy of P&WC)

To understand why the P3 schedule and the start and acceleration schedule were showing fuel flow lower than the CMM minimum limit for P3 pressures below 100 psia, the FCU was partially disassembled. The mounting plate was removed giving access to the bellows. The bellows showed signs of external surface contamination of a brownish color and whiteish deposit.

The bellows housing cavity also showed presence of brownish and whiteish contaminants. The bellows was removed from the mounting plate to measure the length. There was no dimension "L" recorded on the bellows end plate. As per the Woodward Service bulletin 83212-73-023 released in 2014, as per paragraph 3 C (1), bellows assembly manufactured prior to December 1999 and bellows assembly manufactured prior to January 1993 are not marked with an "L" dimension. Due to the

age of these unmarked parts in addition to the lack of a length reference, these bellows assemblies shall be replaced. For reference, the bellows was measured to 1.0121

The cover was removed showing that the clocking between the 3D cam and the power lever was suitable. The ball head components were unremarkable. The tack shaft fuel filter was removed and found clean. The 3D cam profile was normal. The discharged flow adjustment set screw was removed by screwing it inward instead of outward of the housing. The set screw driving end was damaged therefore the tool was slipping. A vise grip plier was used to rotate the adjustment screw, damaging its threads. The fuel valve was removed. The plunger was moving freely in the sleeve in all directions. The fuel valve disassembly showed that the components were in good condition and the filter screen was clean. The compressor discharge pressure (CDP) rod guide hat could be removed from the rod indicating that the glue securing the hat on the rod lost its integrity. A service bulletin was released to introduce a new CDP rod guide with a brazed hat.



Figure 3: Bellows with contamination. (Courtesy of P&WC)



Figure 4: Bellows contamination. (Courtesy of P&WC)



Figure 5: Bellows housing cavity contamination. (Courtesy of P&WC)

Fuel Pump

The external surface showed granular deposits on different areas like sand. The input shaft was missing. On the input shaft side, there were remains of white grease on the inner diameter of the carbon seal. This is normal, the white grease is used during the input shaft installation. The drain hole on the input shaft side was dry. The fuel bowl hexagon section was slightly damaged. The filter bowl was removed exposing a wet fuel filter. The fuel filter showed several black dots. The filter bowl cavity and the housing cavity were clean. The inlet screen was removed and found generally clean. The inlet screen housing cavity was clean. The gears teeth were visible from the inlet port and looked in good condition. The drive gear splines on the FCU side were covered with a brownish deposit. The fuel line going to the FCU was properly secured on the outlet fitting. There was some deposit on the mating face with the FCU mainly around the four studs. The bypass port O-ring was present and in good condition. The drain hole on the FCU side was also dry. The inlet and drain port were clean.

The fuel pump was satisfactorily tested in accordance with the Argo Tech CMM 73-10-12 Rev.2. Based on the test results, it was collectively agreed that the fuel pump disassembly was not necessary.

Conclusions

Testing did not replicate the reported engine issue. However, disassembly of the FCU revealed a corroded bellows. The FCU manufacturer investigation revealed a leaking bellows because of a silver deficiency at the interface of the solder joint, which is consistent with oxidation due to corrosion.

During the event, this condition would have allowed the bellows to expand, subsequently moving the FCU fuel valve to the minimum fuel flow output as observed in the engine data recorded at the time of the event, preventing further power modulation.