

Test ECU 210415 at ULpower – 5 July 2023 - N468MM - NTSB ref WPR23LA184

The ECU arrived in May, 2023 at the offices of ULpower in Ieper, Belgium. The unpacking, read-out and a test run of the ECU was done in presence of an investigator of the AAIU(Be) at the facilities of UL Power, on Wednesday 5 July 2023.

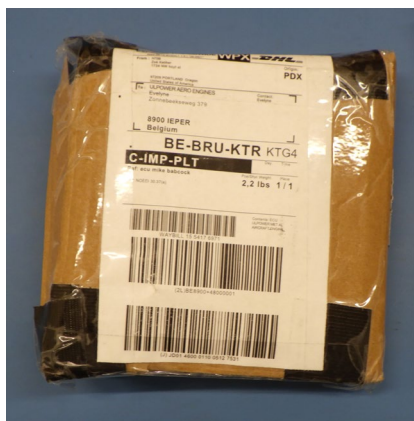


Figure 1, Package arrived at ULpower



Figure 2, ECU 210415 unpacked

The ECU was identified as serial number 210415 and first visually checked for damage.

It was then connected to the computer and powered. It was specifically requested to UL Power to first download the raw data (in .txt or .csv format) before connecting the device to the engine data analysis application LogWorks. But this didn't seem possible because the system immediately converts the datafile to a .diff format when it is downloaded.

According to UL Power, the internal log memory of the ECU has a storage capacity of 20 min but only the last 20 sessions recorded can be downloaded. So there can be for example 40 sessions of 30 seconds, but only the last 20 sessions are downloaded.

A new session will start and stop when the engine RPM rises and falls below 600 RPM. The ECU turns off when the supply voltage drops below 5,3V. A poor grounding could also affect the supply voltage. The sample rate of the logger is 2 seconds.

The total recorded time of the last 20 sessions was approximately 90 sec. Each session lasted 3 to 6 seconds. The most recent recorded session is session 1.

From the data we observe that:

- No major changes were measured during the 20 sessions.
- An evolution in air pressure and supply voltage was measured over all 20 sessions.
- The engine RPM was varying around 600 RPM.
- The throttle valve was in open position in all 20 sessions.
- The ignition switch was in off-position in all 20 sessions.

Based on this data, no conclusions could be made about the engine condition during the accident flight.

All 20 sessions were plotted in a graph. A print screen of each session is the appendix of this report.

After downloading, the ECU was connected to an electronic test bench and a test program was run. Because during the test the memory is overwritten, this test should be done after downloading. In the test all functions, in- and output signals were checked. An oscilloscope was then connected to check again the output signals of the ECU. During the entire test program, no anomalies were found, and the ECU was working properly.

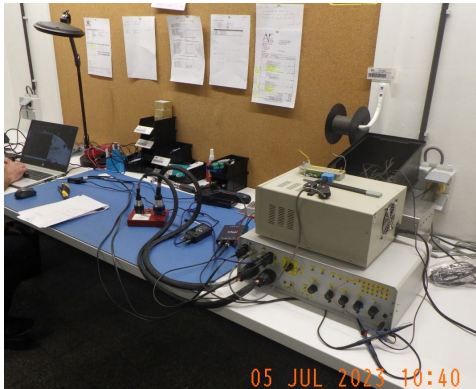


Figure3, ECU test run set up at ULpower facilities

The ECU remains available at ULpower.

After the functional tests we performed, the last 20 small sessions in the internal memory were overwritten by 4 larger sessions. As the ECU's recording capacity is up to 20 minutes, and at all time the last 20 sessions in the memory can be downloaded, UL Power was therefore able to recover an additional 13 minutes of engine data from the ECU's internal memory. This data was provided to the AAIU(Be) on 7 July 23 and can be found in appendix in '210415 ECU mike babcock after ECU test .diff, session 5'.

UL power made the following observations in session 5 (13min42sec):

- The battery voltage is within operating limits.
- Both ignition coils 1 & 2 were activated when the engine was running. (ECU_f_4 = 3.0 V and means that the two ignition systems were on).
- The oil pressure is within operating limits.
- The manifold air temperature is max. +/-40 °C and within operating limits.
- The ECU (ambient) temperature is 40°C and within operating limits.
- The oil temperature is +/-85°C and is within operating limits. In the last minute of the session a rise in temperature is noticed (probably because the engine failed on that moment)
- At certain moments (from min 8:00 to 8:15 and 11:20 to 12:55), the engine RPM at 'Wide Open Throttle' (WOT) is 2350 RPM. This is lower than the optimal RPM at WOT of 2700 RPM. It is even below the minimum static RPM at WOT and minimum WOT straight & Level of 2400 RPM. The operating limits are described in the operating manual in appendix of the report. The low RPM values provide an additional load stress on the engine internal components.

- The pressure in the turbocharger during session 5 was at a maximum of 1250hPa. This should normally be 1350hPa.

The lower pressure in the turbocharger indicates that the boost pressure is not controlled by the ECU/boost controller. It is possible that the power supply of the boost controller has been interrupted. If the power supply to the boost controller is missing, the pressure in the turbocharger will be 250hPa higher than ambient pressure. In this case the engine will run leaner than in normal operation circumstances.

- The fuel pressure is only 2.55 to 2.83 bar and is on the low side. At WOT this should normally be 3.2 bar.

REV (RPM)	THR (Volt)			FUELP (bar)
	4.00	4.50	5.00	
2200	2.20			
2300	2.53	2.60		
2400	2.50	2.55		
2500		2.63		
2600		2.83		
2700		2.70		
2800				
2900				
3000				

- At the end of session 5 (at 13:40), the parameter ECU_f_5 becomes 2.0V. This parameter indicates that the 'Hall' sensors (which measure the engine RPM) have been checked for consistency. The error means that there was a discrepancy between the 'Sync' sensor and 'Position' sensor at that time. The same error was also found in the previous 20 sessions and could indicate that this error code was generated after the engine's crankshaft failed and caused a discrepancy between the Hall sensor parameters. The Hall sensors are located at the front and rear of the engine.

UL power made the following analysis after observing the engine data:

- It appears that the oil pressure was within limits but the pressure in the turbocharger was below operating limits. This may indicate a turbocharger installation error and should therefore be checked. Although such values do not directly lead to a crankshaft failure.
- If the pressure is lower in the turbocharger, the engine will run a little bit leaner. Therefore, the pressure always needs to be checked during the pre-flight check of the engine (ref. operating manual of UL Power).

Apparently, a pressure line from the boost controller to the wastegate was found loose.

- Apparently, the engine was subjected to relatively heavy loads at WOT. Although this does not directly lead to a crankshaft failure.
- The fuel pressure is lower than normal, which could cause detonation. However, no signs of detonation were found on the pistons and cylinder heads provided to UL Power by the customer.
- According to the NTSB intermediate report (ref WPR23LA184), metal particles were found during the last oil change. If some particles have entered the bearings of the turbocharger, this can lead to malfunctioning of the turbocharger. No particles or damage was found after inspection of the turbocharger.
- The cylinder heads show that the temperature has been high, and this is also confirmed by the customer.

According to UL Power, only two possible scenarios could explain the 20 small log sessions of 3-6 seconds.

- Very small power supply interruptions. It is therefore recommended to check the entire electrical system for continuity and grounding.
- The engine was turned off by using the ignition switches, while the ECU still was powered on. If the engine RPM then drops below 600 RPM and the ECU is logging a pointer, there is a chance that an erroneous pointer could be assigned and the data at that position in the logger becomes unreadable.

Conclusion:

1. The engine probably failed at 13:40 in session 5.
2. No obvious cause was found for the engine failure.
However,
 - The turbocharger was not operating within limits.
 - An erroneous installation of the turbocharger is possible.
 - At certain moments the engine RPM was below limits.
 - A discontinuity or a poor grounding of the electrical system is possible.
 - The fuel pressure was low; however, no signs of detonation were found.
 - The CHT temperatures were higher than normal.
3. The test run on 5 July 2023 showed that the ECU 210415 is still functioning properly