**Endelig rapport HCLJ510-000387**

Rapport over hændelsen med Diamond DA 40D OY-RBB ved Roskilde den 7. juni 2007.

Den lange sagsbehandlingstid skyldes det forhold, at Havarikommissionen i undersøgelsen har samarbejdet med andre europæiske lande, hvor lignende havarier/hændelser var indtruffet.

I Danmark afsluttede vi undersøgelsen og udsendte rapporten i februar 2009 til de involverede parter samt myndighederne i Danmark, Østrig og European Aviation Safety Agency (EASA).
Da Havarikommissionen havde anvendt materiale fra en ikke afsluttet undersøgelse i Holland, var det ikke muligt at offentliggøre rapporten.

Rapporten over det Hollandske havari er nu offentliggjort. Samarbejdet førte til, at The Dutch Safety Board og Havarikommissionen i Danmark blev enige om at udsende en enslydende rekommandation til EASA. Denne kan ses i rapporten.

Endelig rapport over hændelsen som indtraf med luftfartøjet Diamond DA 40D 1 nm vest for Københavns Lufthavn Roskilde den 7. juni 2007 er hermed offentliggjort.

**FINAL REPORT**

| | | | |
|---|---|---|---|
| HCLJ510-000387 | **Incident** | | |
| Aircraft type: | Diamond DA 40D | A/C Registration: | OY-RBB |
| Engine: | Thielert TAE 125-01 | Type of flight: | Test flight, VFR |
| Crew: | 1- no injuries | Passengers: | 1 - no injuries |
| Place: | 1 nm west of Copenhagen Airport, Roskilde (EKRK) | Date and time: | 07.06.2007 1330 UTC |

The Danish Accident Investigation Board (AIB) was notified about the incident from the Pilot on 7 June 2007 at 1340 hrs UTC.

**Synopsis**

At base leg to runway 11 at EKRK the aircraft lost engine power. The pilot was forced to land in a cornfield west of the airport. The aircraft was undamaged and the pilot uninjured.

Summary

The one second drop in the fuel rail pressure shown in the downloaded FADEC ECU data strongly suggested that the engine had suffered from an electrical interruption failure of the rail pressure valve or other related parts of the engine FADEC system. However, the investigation has not been able to recreate the electrical failure why evidence was not available to allow the cause of the incident to be determined with any degree of certainty.

The investigation found that the FADEC system, in case of an electrical interruption failure in the fuel rail pressure control closed loop system of the FADEC, was not fail safe. In most cases, the FADEC system would fail in the safe direction. However, when an electrical interruption occur in this system the rail pressure drops to a minimum of 130 BAR within one second causing the engine to lose power.

Safety Recommendations

As a result of its investigation of this incident, the Danish Accident Investigation Board makes the following recommendation to the European Aviation Safety Agency (EASA):

**DENM-2011-01**

**The Danish Accident Investigation Board recommends EASA:**

**To a review of the TAE-125-01 diesel engine design with the emphasis on the fail-safe design principle and how it's been applied to an individual engine component, as well as to the complete power plant system including its electronic failure modes.**

## 1. Factual information

### 1.1 History of the flight

The flight, during which the incident occurred, was a local test flight, VFR from Copenhagen Airport, Roskilde (EKRK).

The purpose of the test flight was to check the function of a new Engine Control Unit (ECU) that was installed in the aircraft.

The test flight was performed at 2000 ft without it leading to any technical remarks. The pilot moved the engine power control lever towards idle and initiated a descent back to EKRK. At left hand base leg to runway 11 the pilot advanced the engine power control lever to adjust the glide to the threshold of runway 11. There was no reaction from the engine when the pilot added full power. The engine did not respond to the pilot input but stayed at low power, he observed no warnings. At this point it was not possible to reach the runway. An emergency was declared by the pilot and he informed EKRK TWR that he was forced to land west of the airport. The landing was successful without any damage to the aircraft.

The incident occurred in daylight and under visual meteorological conditions (VMC).

### 1.2 Injuries to persons

| *Injuries* | *Crew* | *Passengers* | *Others* |
|---|---|---|---|
| Fatal | - | - | - |
| Serious | - | - | - |
| Minor/None | 1 | 1 | - |

### 1.3 Damage to aircraft

The aircraft was not damaged.

### 1.4 Other Damage

Some of the corn on the cornfield was damaged.

## 1.5 Personnel information

The pilot: Male, 40 years

Certificate: Airline Transport Pilot License (ATPL) issued 2 January 2006

Medical: Expire date 22 September, 2007

| Flying experience: | Last 24 hrs | Last 90 days | Total |
|---|---|---|---|
| All types | 3 | 112:10 | 6190 |
| DA 40 | 0:40 | 5:55 | 1600 |
| Landings | 1 | 21 | - |

## 1.6 Aircraft information

### 1.6.1 General

Manufacturer: Diamond Aircraft Industries GmbH.

Aircraft Type: Four seat low-wing monoplane composite construction aircraft.

Serial No.: D4.211.

Engine: Manufactured by Thielert Aircraft Engines GmbH.

Engine type: TAE 125-01, based on a current automobile engine, 1,7 liters (103 cu in), 135 hp, in-line four-cylinder, turbocharged, common rail direct injection diesel engine.

Engine control: Full Authority Digital Engine Control (FADEC). The system allows the pilot to control all engine parameters through a single power control lever. The Engine Control Unit (ECU) takes inputs from sensors, including the load selected by the pilot, adjusts for variables such as air temperature, engine temperature and Barometric pressure, in order to control fuel common rail pressure, fuel injection (quantity and timing), propeller pitch and boost.

Boost control, propeller control and fuel rail pressure control are closed loop systems, meaning they monitor the actual output of the system and correct it to the desired value. The control loops will continue to function as long as the primary input from the sensor and the actuator is functional.

The ECU has two independent channels, designated ECU A and ECU B. If one ECU channel fails, the system automatically switches to the other ECU channel, a “check engine” light illuminates and an entry into the system event log is made. A switch placed on the instrument panel allows the pilot manually to switch from ECU channel A to B if the automatic switch-over should fail.

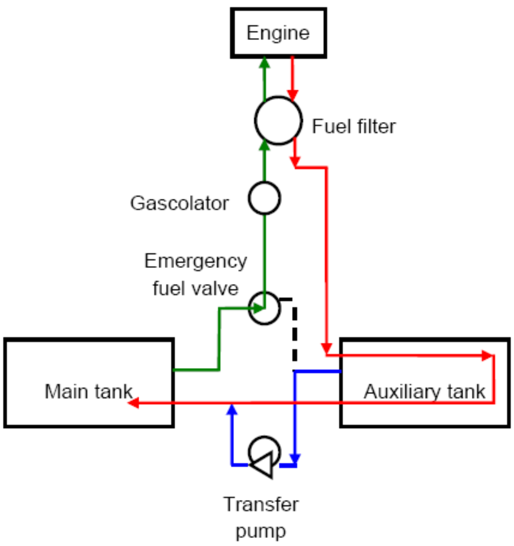
The FADEC system has methods of storing and logging data. Recorded FADEC ECU data from the event log and the on-board logger can be downloaded for post-flight analysis.

Fuel system: Each fuel tank has a capacity of 56,8 liters, of which 53 liters is useable.

Fuel type is Jet A1.

The fuel system is not equipped with a fuel booster pump.

The fuel passes from the tank by suction through a gear type low pressure fuel feed pump. The fuel pressure is increased to 3,5 BAR before continuing to a piston type high pressure fuel pump where fuel pressure is increased to a maximum of 1350 BAR, entering into the common rail and therefrom to the fuel injectors. The actual fuel pressure in the common rail is measured by a rail pressure sensor. The FADEC interprets the rail pressure, compares it to a target value, and adjust the rail pressure control valve to reach the correct pressure. Return fuel flows back to the main fuel tank.




Propeller system: Reduction gearbox, overload clutch, variable pitch propeller.

Maintenance: On 23 May 2007 the latest 100 hrs inspection was performed at aircraft total flying time 309:30 hrs.
The gearbox, clutch, clutch shaft, alternator, engine fuel feed pump and engine fuel high pressure pump was replaced.
The airworthiness certificate issued by the Danish Civil Aviation Authority was valid.

Flying time: At the time of the incident the aircraft and engine total flying time was 319:30 hrs.

1.6.2 Aircraft engine power loss history

On 6 March 2007 during warm up before flight the engine suffered a power loss.
The event log had registered a Pressure Rail Sensor failure. The troubleshooting that followed revealed no physical failures in the system. Afterwards the engine was running without remarks.

On 31 May 2007 the pilot flying the aircraft experienced some shudders from the engine. The engine shudders continued why the pilot decided to fly back to the airport. Just before touch down the annunciate panel and the instrument panel lights illuminated equivalent to activate the “acknowledge button”.
After landing during taxi the engine stopped without any warnings.

Water and moisture was found in the manifold pressure (Map) sensor line. The Map sensor is a part of the FADEC system. The ECU was replaced and one hour ground run performed without remarks, before the flight on 7 June 2007.

### 1.7 Meteorological information

The visibility was more than 10 km. Wind direction and speed was 130° / 8 kt. Temperature 22° C and there were no clouds.

### 1.8 Aids to navigation

Not relevant.

### 1.9 Communication

The Actual Air Traffic Control radio communication was not obtained.

### 1.10 Aerodrome information

Not relevant.

### 1.11 Flight recorders

None required none installed.

### 1.12 Aircraft and engine investigations

1.12.1 Aircraft examination

Prior to the recovery of the aircraft from the field the fuel quantity in the tanks was measured and the FADEC ECU data stored on the on-board logger downloaded.
The main tank (L/H wing) contained approximately 45 liters.
The auxiliary tank (R/H wing) contained approximately 52 liters.
No fuel leaks were observed in the area of the engine compartment.

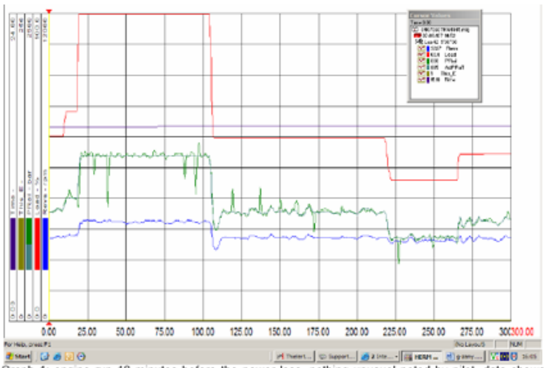
1.12.2 Aircraft fuelling history

A review of the fuelling records showed that, on 29 May 2007 the aircraft was filled to full (106 liters useable). The aircraft completed five flights before the incident flight on 7 June 2007, with a total block time of 4:30 hours. If an average fuel consumption of 19 liters per hour is assumed, for a cruise power setting of 75% engine load (as quoted in the DA 40D Airplane Flight Manual), the aircraft should have approximately 22 liters of fuel remaining in the tanks.
The aircraft was refuelled to full before the incident flight.

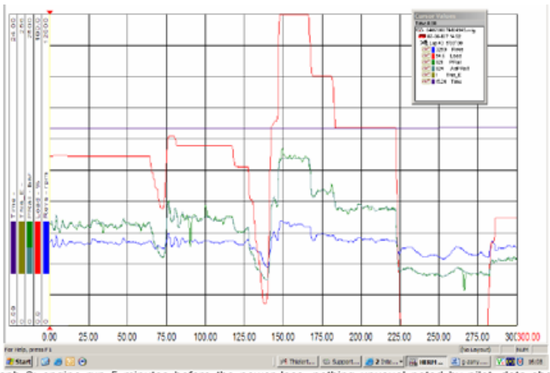
1.12.3 FADEC ECU data

The ECU data logger showed fluctuating fuel rail pressure on the former flight on 31 May 2007.

The ECU data logger graph 1 and 2 (below) shows that, the rail pressure was fluctuating during the incident flight on 7 June 2007. The event log remarks were “Low Prail” and High negative Prail delta”.

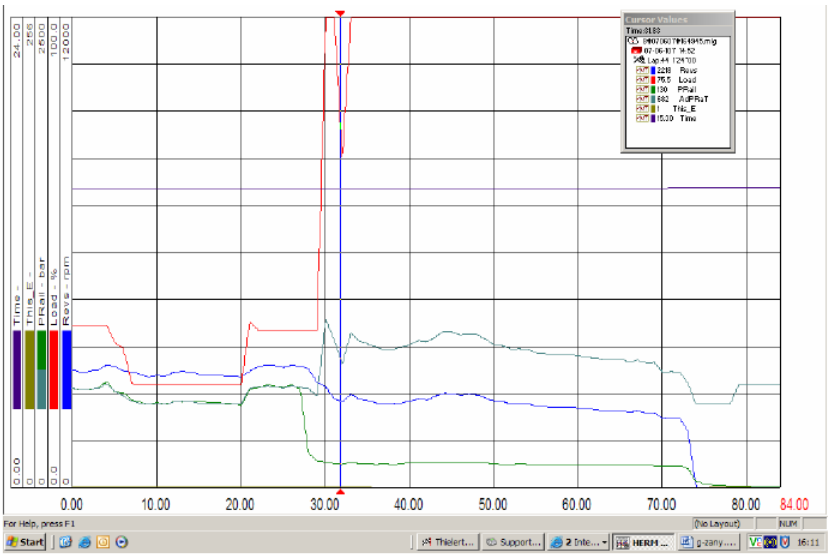


Graph 1: engine run 10 minutes before the power loss, nothing unusual noted by pilot, data shows fluctuations in the rail pressure



Graph 2: engine run 5 minutes before the power loss, nothing unusual noted by pilot, data shows fluctuations in the rail pressure

The ECU data logger graph 3 (below) shows that, the rail pressure dropped to a minimum of 130 BAR within one second, the engine stayed at low RPM and there was no engine reaction to power control lever movement.




Graph 3: Rail pressure drops to a minimum of 130 bars, causes the engine to quit

1.12.4 Engine and fuel system examination

The aircraft was brought to a Maintenance Centre hangar.

The airframe and engine fuel system were inspected and no leaks or loose connections were found.

Fuel filter was disassembled by a licensed mechanic. According to the mechanic the fuel filter bowl contained the same amount of fuel as when he replaced the filter at 100 hrs inspection. The exact amount of fuel in the filter bowl was not measured.

The pictures below show the quantity of fuel found in the filter bowl that was removed from another Diamond DA 40D aircraft. According to the licensed mechanic it was the same amount of fuel that was found in the filter bowl removed from OY-RBB.

The fuel filter bowl would normally contain 250 to 300 milliliters of fuel.

A representative from the engine manufacturer inspected visually the engine and the electrical wiring loom, and found no defects. The fuel filter was reinstalled in the aircraft. The fuel filter was bleeded by use of an external pump.

The engine was started and ground run performed without any remarks. The ECU data logger showed no rail pressure fluctuation during ground run after the fuel system was inspected, the fuel filter reinstalled and bleeding performed.

Afterwards a transparent hose was installed between the fuel filter and the low pressure fuel feed pump. The engine was started and air bubbles were induced into the fuel system. The engine ran rough but was able to bleed the air out of the system. This test was also performed on another DA 40D aircraft (OY-RBA) with the same result.

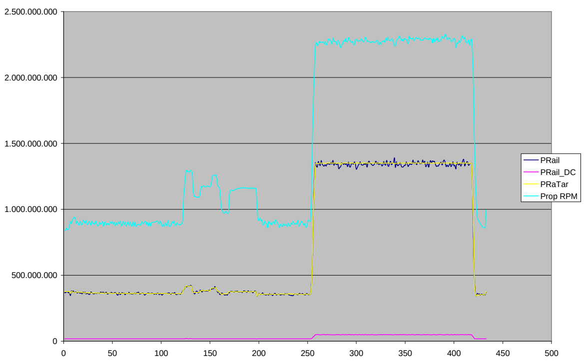
The Danish AIB is aware that, the low pressure fuel feed pump is unable to suck fuel from the tank if the pump is dry, but the test showed that it was able to handle a fuel/air mixture without stopping down the engine.

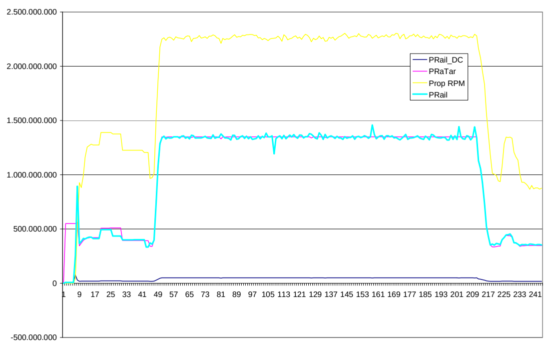
To exclude the engine fuel pumps as a root cause to the incident, full power test runs were performed to compare the engine fuel pump combination with a set of new pumps.

The full power test with the old fuel pump combination installed showed no abnormalities, see graph below left.

It was difficult to restart the engine after installation of the new fuel pump combination. It was necessary to bleed the fuel system several times to get the engine started.

The full power test with new pumps installed showed one drop in fuel rail pressure, see graph below right.



1.12.5 Leak tightness test of the fuel system

On 6 August 2007 the aircraft was tested for fuel leaks in order to see if there was a possibility for air to enter the fuel system through a leakage. It was shown that the fuel system was leak proof.

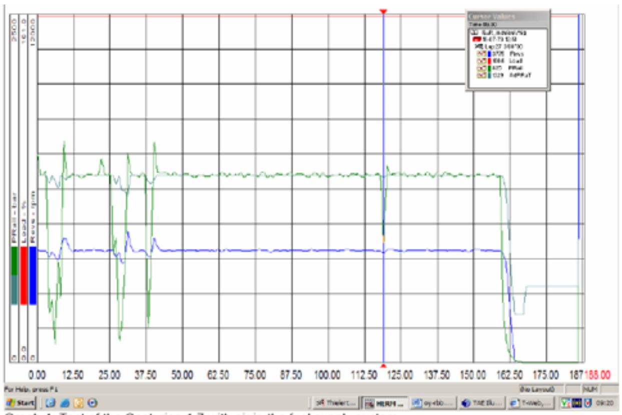
The complete report “Leak tightness test of the fuel system” is enclosed as Appendix No. 1

1.12.6 Information given by the engine manufacturer

On 29 June 2007 the engine manufacturer issued an Occurrence investigation report regarding the incident.

Among other information the report stated that:

*Earlier tests of the Centurion 1,7 engines* (TAE 125-01), *done with air in the fuel supply, show the similar rail pressure fluctuation than in this occurrence of the OY-RBB. This is visualized in graph 4* (below).



Graph 4: Test of the Centurion 1.7 with air in the fuel supply system

The engine manufacturer Occurrence investigation report gave the following conclusion:

“*During investigation the engine started immediately using the same components than installed in the affected aircraft with just venting the fuel system. The engine data of the occurrence show similar behaviour of engine test bench results performed with different fuel air mixtures. Based on these findings it is identified that the total loss of engine power is caused by fuel starvation at the engine fuel pumps. The air could be introduced into the fuel system through leakage or previous dry flown fuel tanks.”*

The complete report “Occurrence Investigation Report” is enclosed as Appendix No. 2.

The engine manufacturer tested all components of the engine fuel system together with the engine and no failures were found on the engine. All parts of the fuel system were tested on another engine and everything worked properly. Additionally, the engine electrical wiring loom was inspected in regard to broken wires. There were no findings.

### 1.12.7 Ground and flight tests

According to the Aircraft manufacturer the fuel system was tested during type approval of the DA 40D.

*"An almost empty fuel filter could be bleeded so far, that no air bubbles were visible in a transparent hose installed between the fuel filter and the low pressure fuel feed pump within 10 minutes. Once the engine is running and due to the high fuel flow (82 liters per hour at idle rpm) the fuel system begins to bleed itself automatically. At the beginning the engine could run a bit rough but after a few seconds it should run normally. One finding during this test was that, the engine tolerates a rather high quantity of air."*

#### 1.12.7.1 Ground and flight tests performed at Wiener Neustadt Airfield (LOAN), Austria

To show the behaviour of the engine when air was introduced through a leakage into the fuel system, ground and flight tests were performed October/November 2007 at LOAN.

The aircraft fuel system was modified in a way so that in a ground test either a continuous air flow or a certain amount of air at once could be introduced into the fuel system. With the available air flow measuring device a maximum air flow of 870 ml/min could be introduced into the fuel system. The engine kept running smoothly and the ECU data did not show any effect to the engine parameter. It also could be shown that the maximum amount of air introduced at once that does not force the engine to shut down was 110 ml.
In the flight test it could be shown that an amount of 250 ml air at once introduced into the fuel system leads to a power loss down to 3% for about two seconds. Due to wind milling the engine restarts and recovers after some seconds of power fluctuation.

The complete test report "Behaviour of the TAE 125 engine with air in the fuel system" is enclosed as Appendix No. 3.

#### 1.12.7.2 Additional ground tests performed at LOAN, Austria

Additional ground tests conducted by representatives from the aircraft and the engine manufacturers were performed in February 2008 and in April 2008 at LOAN.

The tests in February were conducted to show the behaviour of the engine with air introduced into the fuel system.
The tests in April were conducted to show the behaviour of the engine fuel rail pressure when the rail pressure valve suffers from electrical defects.

The following could be shown:

- An air flow of 2000 ml/min air that was introduced into the fuel system had no noticeable affect to the running engine. The fuel flow at 100% power was measured with 2550 ml/min in a former ground test.
- When a valve that was mounted to the inlet of the fuel filter bowl was opened and air was sucked in, the rail pressure in the ECU chart does not decrease abruptly.

- Switching the rail pressure valve into opened position by interrupting the electric circuit the rail pressure in the ECU chart fell to a value that was identical to the rail pressure that was maintained after the engine shut down of the OY-RBB incident flight.
- When air was injected into the fuel system the display of the rail pressure in the ECU chart depends on the sample rate of the recording.

The complete tests report “Supplement to Occurrence Report No. 01” is enclosed as Appendix No. 4.

1.12.7.3 Flight test performed at LOAN, Austria on 22 August 2008

The flight test was performed to show the behaviour of the engine in case of excessive slipping and in the moment of the depletion of the main fuel tank. In both cases air enters the fuel system through the fuel extraction point in the main fuel tank and will causes the engine to lose power.

Prior the test flight the main fuel tank was completely drained. Afterwards fuel in portions of 1/16 US gallons (0,24 liters) were filled into the main fuel tank. The first green fuel indication light lit up when 1 6/16 US gallons (5.2 liters) of fuel were filled into the main fuel tank. When 3 US gallons (11,36 liters) was filled into the main fuel tank the fifth green indication light lit. With this amount of fuel in the main fuel tank (L/H) and about 6 US gallons (22,71 liters) of fuel in the auxiliary fuel tank (R/H) the test flight was performed within the range of glide angle to the airfield.

The following four scenarios were tested during the flight.

1. Slipping
2. Depletion of the main fuel tank and operating the fuel transfer pump
3. Depletion of the main fuel tank and switching the fuel selector valve to the R/H fuel tank
4. Depletion of the main fuel tank and operating the fuel transfer pump – second test

1. Slipping.

The aircraft was flying with a power setting of 100% in 4000 ft. Slipping with full rudder to the right was performed. The fuel in the main fuel tank (L/H) flows in the direction of the wingtip. The engine can only use fuel that is left in the fuel trap of the main tank.

Test scenario time 2:03 minutes.

- 00:00 Slipping initiated
- 00:47 Power loss began (indicated on the Auxiliary Engine Display (AED))
- 01:54 Aircraft was levelled out
- 02:03 Engine restarts

2. Depletion of the main fuel tank and operating the fuel transfer pump.

The aircraft was flying with a power setting of 100% in 4000 ft until the engine started to lose power due to the lack of fuel.

Test scenario time 04:22 minutes.

- 00:00 Power loss began (indicated on the AED)
- 00:11 Power loss to 80%
- 00:34 Power loss to 60%

- 03:55 Engine quits
- 04:10 Fuel transfer pump was switched on and fuel was transferred from R/H tank to L/H tank
- 04:22 Engine restarts

3. Depletion of the main fuel tank and switching the fuel selector valve to the R/H fuel tank
The aircraft was flying with a power setting of 100% in 4500 ft until the engine started to lose power due to the lack of fuel.
Test scenario time 05:08 minutes.

- 00:00 Power loss began (indicated on the AED)
- 00:15 Power loss to 80%
- 00:27 Power loss to 60%
- 04:48 Engine quits
- 04:59 Fuel selector valve switched to the R/H fuel tank
- 05:08 Engine restarts

4. Depletion of the main fuel tank and operating the fuel transfer pump – second test
The aircraft was flying with a power setting of 100% in 4500 ft until the engine started to lose power due to the lack of fuel.
In order to find out if a wind milling engine due to lack of fuel would damage the High Pressure Fuel Pump, the crew continued descending down to 2000 ft.
Test scenario time 06:00 minutes.

- -06:00 Red fuel indication light came on
- 00:00 Power loss began (indicated on the AED)
- 00:14 Power loss to 80%
- 01:02 Power loss to 60 %
- 04:39 Engine quits
- 05:50 Fuel transfer pump switched on
- 06:00 Engine restarts

The flight test report concluded:
*"In all four cases the engine restarted by it self after levelling out the aircraft or by restoring the fuel supply. In all four cases the rail pressure does not drop abruptly, but decreases slowly. It does not make a difference for the restart behaviour whether the fuel supply is restored by switching on the fuel transfer pump or by switching the fuel selector valve to the R/H tank. The engine restarts after about 10 seconds by itself.*
*Therefore it could be shown that air in the fuel system due to slipping or depletion of the main tank does not cause the engine to fail permanently."*

The complete tests report "Supplement to Occurrence Report No. 02" is enclosed as Appendix No. 5.

### 1.13 Medical and pathological information

The pilot was properly certified.

## 1.14 Fire

There was no fire.

## 1.15 Survival aspects

The pilot left the aircraft without any difficulties.

## 1.16 Test and research

No test and research done.

## 1.17 Organisational and management information

No further information.

## 1.18 Additional information

### 1.18.1 Other Thielert TAE 125-01 engine related occurrences

The AIB received information about occurrences in United Kingdom, Germany, France and Finland in which the TAE 125-01 engine were involved.
The occurrences were all engine and/or engine system malfunction related and several of these failures were related to the FADEC system.

The numbers of Diamond DA 40D occurrences from 2004 until July 2007 known by the AIB were:
2004 – Seven. 2005 – Three. 2006 – Nine. 2007 – Six.

The total number of TAE 125-01 engine related occurrences in the UK (all types of aircrafts) from 2004 until July 2007 was 28 occurrences.

The above mentioned occurrences are not meant to be compared statistically with other types of engines. The list of occurrences just shows that TAE 125-01 engine FADEC related malfunctions were not uncommon.

### 1.18.2 Robin DR 400 forced to land as a result of an engine failure

The Danish AIB was informed by the Dutch Safety Board about a Thielert TAE 125-01 engine equipped Robin DR 400 registered as PH-SVU that was forced to land at a field in the Netherlands due to an engine failure.

The investigation conducted by the Dutch Safety Board found that the electrical wiring connected to the fuel rail pressure sensor was damaged by chafing. Sparks from the damaged area was visible when electrical power was connected to the electrical wiring.
According to the FADEC ECU data the electrical failure caused the rail pressure control valve to open. The fuel rail pressure dropped to approximately 130 BAR, which caused the engine to lose power.

The ECU data from the Robin DR 400 incident was examined and compared with the ECU data from the OY-RBB incident.

The ECU data from OY-RBB in comparison with the data from PH-SVU are shown on the graphs "FADEC ECU data graphs in comparison" enclosed as Appendix No. 6.

Parameters taken from the downloaded ECU data were identical:

| OY-RBB | PH-SVU |
|---|---|
| • Low Prail | • Low Prail |
| • High negative Prail delta | • High negative Prail delta |
| • Large input Throttle (Load) in one second interval | • Large input Throttle (Load) in one second interval |
| • Rail pressure target / Rail pressure sensor divergence | • Rail pressure target / Rail pressure sensor divergence |
| • Constant AdjDC value 40% (maximum value) | • Constant AdjDC value 40% (maximum value) |
| • Rail pressure drops to approximately 130 BAR | • Rail pressure drops to approximately 130 BAR |

The Dutch Safety Board published their report regarding PH-SVU in March 2011. The report is available on: www.onderzoeksraad.nl/docs/rapporten/2008078_PH-SVU_ENG.pdf

### 1.19 Useful or effective investigation techniques

None used in this investigation.

## 2. Analysis

The pilot, who held an ATPL, was properly licensed.

The last inspection of the aircraft was performed on 23 May 2007 and the aircraft held a valid airworthiness certificate.

The fuel tanks contained approximately 97 liters of fuel. Approximately 10 liters was used during the flight.

No fuel leaks or loose connections were found in the airframe or in the engine fuel system that could explain that air was introduced to the fuel system during flight. The fuel system was found leak proof.

The quantity of fuel found in the filter bowl was normal compared to a filter bowl removed from another DA 40D aircraft.

The fuelling history and the quantity of fuel in the fuel tanks excludes that fuel starvation, either due to dry flown tanks on the earlier flights or during the incident flight or due to an open fuel fitting, was the cause of the incident. Also the test results showed that air introduced into the fuel system had no noticeable affect to the running engine, and an open fuel fitting on the engine would cause the rail pressure to drop to 0 BAR despite the wind milling propeller. An open fuel fitting on the suction side of the filter bowl would cause the rail pressure to drop to a minimum of 130 BAR in about five to six seconds instead of one second registered on the ECU data from the incident.

Several flight tests showed that the engine was able to restart after depletion of the fuel tank causing the engine to stop. The wind milling propeller was able to bleed the fuel system sufficiently in about 10 seconds resulting the engine to restart it selves.

The ECU data shows that the engine lost power when the fuel rail pressure dropped to a minimum of 130 BAR within one second. Prior to the drop in fuel pressure the fuel rail pressure was fluctuating.
Similar fluctuations were found on the data downloaded from the former flight on 31 May 2007.
This situation is similar to the ECU data from the performed tests (Appendix No 4) where electrical interruptions were produced. According to the test results the interruption of the electrical circuit caused the rail pressure to drop to about 130 BAR (wind milling) and was followed by shudder of the engine. The intensity of the shudders was dependant on the duration of the electrical interruption. Very short interruption resulted in shudders which were hardly noticeable.
During the flight on 31 May 2007 the pilot felt shudders from the engine and after landing during taxi the engine stopped unintentional.
The situation is not similar to the ECU data from the tests where air flow was introduced into the fuel system. Therefore it must be assumed that fuel starvation due to air in the fuel system was not the cause of the incident.
After the incident the fuel filter was removed checked and reinstalled, the system was bleeded and the engine started without any problems. The engine ran without remarks and the ECU data showed no fluctuation of the fuel rail pressure. This and the test results (Appendices No 3, 4, 5 and 6) indicate that the incident probably was caused by an electrical interruption failure of the rail pressure valve or other related parts of the engine FADEC system.
However, the engine manufacturer tested the engine fuel components on another engine and found no failures, why the AIB is of the opinion that the mentioned FADEC electrical failure was intermittent, which could explain the other engine problems that had occurred on this aircraft.
Intermittent electrical and/or computer related failures are difficult to recreate, bad connections, moisture or foreign bodies are able to let the failures come and go.

During warm up before flight on 6 March 2007 the aircraft suffered an engine power loss. The event log registered a Pressure Rail Sensor failure. The troubleshooting that followed found no physical failures indicating, that an intermittent failure most likely had occurred.
On 31 May 2007 the engine failed during taxi without any warnings, before that the pilot felt shudders from the engine, which could be indication of intermittent electrical interruptions within the engine FADEC system.
The FADEC ECU data was compared with data downloaded from the interruption of the electrical circuit test, another aircraft that undoubtedly had suffered from an engine power loss due to an electrical interruption failure within the engine control system. The ECU data was identical to the data downloaded from OY-RBB, supporting the opinion that the incident was caused by an electrical interruption failure. It was shown that shutters from the engine appeared to engines that suffered from electrical interruptions.

An overview of engine related incidents in other countries showed that engine malfunctions related to the engine FADEC ECU system was not uncommon why the AIB is of the opinion that the FADEC system fitted to the TAE 125-01 engine are sensible and not fail safe.

The Danish AIB is of the opinion that it is proven that air in the fuel system could not be the cause of the incidents that occurred to OY-RBB on 6 March 2007, on 31 May 2007 and the engine power loss incident on 7 July 2007. No physical failures were found in the FADEC system or in the engine fuel system but, the investigation found that the downloaded FADEC ECU data strongly suggested that the engine had suffered from an electrical interruption failure within the FADEC system causing the fuel rail pressure valve to open and the engine to lose power.

The investigation found that the FADEC system, in case of an electrical interruption failure in the fuel rail pressure control closed loop system of the FADEC, was not fail safe. In most cases, the FADEC system would fail in the safe direction. However, when an electrical interruption occur in this system the rail pressure drops to a minimum of 130 BAR within one second causing the engine to lose power.

## 3. Conclusions

### 3.1 Findings

1. The pilot was properly licensed.
2. The aircraft held a valid airworthiness certificate.
3. The fuel tanks were almost full; 10 liters of fuel were used during the incident flight.
4. No fuel leaks were found and the fuel system was tested to be leak proof.
5. No physical failures were found in the FADEC system or in the engine fuel system.
6. It was shown that air introduced into the fuel system had no noticeable affect to the running engine.
7. It was proven that a wind milling propeller was able to bleed the fuel system in about 10 seconds resulting the stopped engine to restart it selves.
8. The ECU data from the tests where air was introduced into the fuel system was not identical to the ECU data from the incident flight.
9. It was proven that interruption of the electrical circuit caused the fuel rail pressure to drop to a minimum of 130 BAR within one second.
10. The ECU data from the incident flight, the interruption of the electrical circuit tests and data from the Dutch Safety Board investigation of the accident to Robin DR 400, PH-SVU, which undoubtedly had an electrical circuit interruption, was identical.
11. Engine shutters appeared to the engine when it suffered from electrical interruptions.
12. FADEC ECU data strongly suggested that the engine had suffered from an electrical interruption failure of the rail pressure valve or other related parts of the engine FADEC system.
13. The engine lost power when the fuel rail pressure valve opened and the rail pressure dropped to a minimum of 130 BAR within one second.
14. The fuel rail pressure control closed loop system of the FADEC was found not to be fail safe. An electrical interruption failure, in the fuel rail pressure control closed loop system of the FADEC, will cause the fuel rail pressure to drop within one second and the engine to lose power.

### 3.2 Factors

1. The engine lost power when the fuel rail pressure valve opened and the rail pressure dropped to a minimum of 130 BAR within one second.

### 3.3 Summary

The one second drop in the fuel rail pressure shown in the downloaded FADEC ECU data strongly suggested that the engine had suffered from an electrical interruption failure of the rail pressure valve or other related parts of the engine FADEC system. However, the investigation has not been able to recreate the electrical failure why evidence was not available to allow the cause of the incident to be determined with any degree of certainty.

The investigation found that the FADEC system, in case of an electrical interruption failure in the fuel rail pressure control closed loop system of the FADEC, was not fail safe. In most cases, the FADEC system would fail in the safe direction. However, when an electrical interruption occur in this system the rail pressure drops to a minimum of 130 BAR within one second causing the engine to lose power.

## 4. Safety recommendations

As a result of its investigation of this incident, the Danish Accident Investigation Board makes the following recommendation to the European Aviation Safety Agency (EASA):

**DENM-2011-01**

**The Danish Accident Investigation Board recommends EASA:**

**To a review of the TAE-125-01 diesel engine design with the emphasis on the fail-safe design principle and how it's been applied to an individual engine component, as well as to the complete power plant system including its electronic failure modes.**

## 5. Appendices

Appendix No 1: Leak tightness test of the fuel system.

Appendix No 2: Occurrence Investigation Report (Engine manufacturer).

Appendix No 3: Behaviour of the TAE 125 engine with air in the fuel system.

Appendix No 4: Supplement to Occurrence Report No. 01.

Appendix No 5: Supplement to Occurrence Report No. 02.

Appendix No 6: FADEC ECU data graphs in comparison.

# Appendix No 1:

# Leak tightness test of the fuel system

**The appendix consists of 4 pages.**

# Leak Tightness Test of the Fuel System

Date/place: 6-Aug-2007, Wiener Neustadt
Performed by Johannes Huemer
Aircraft: DA 40 D, OY - RBB, S/N D4.211, at 319:30 hrs

## Purpose of test

The fuel system of the DA 40 D, OY-RBB was tested for leaks in order to see if there is a possibility for air to enter the fuel system through a leakage and to cause the engine to starve of fuel.

**Picture 1** sealed finger filter of the main tank

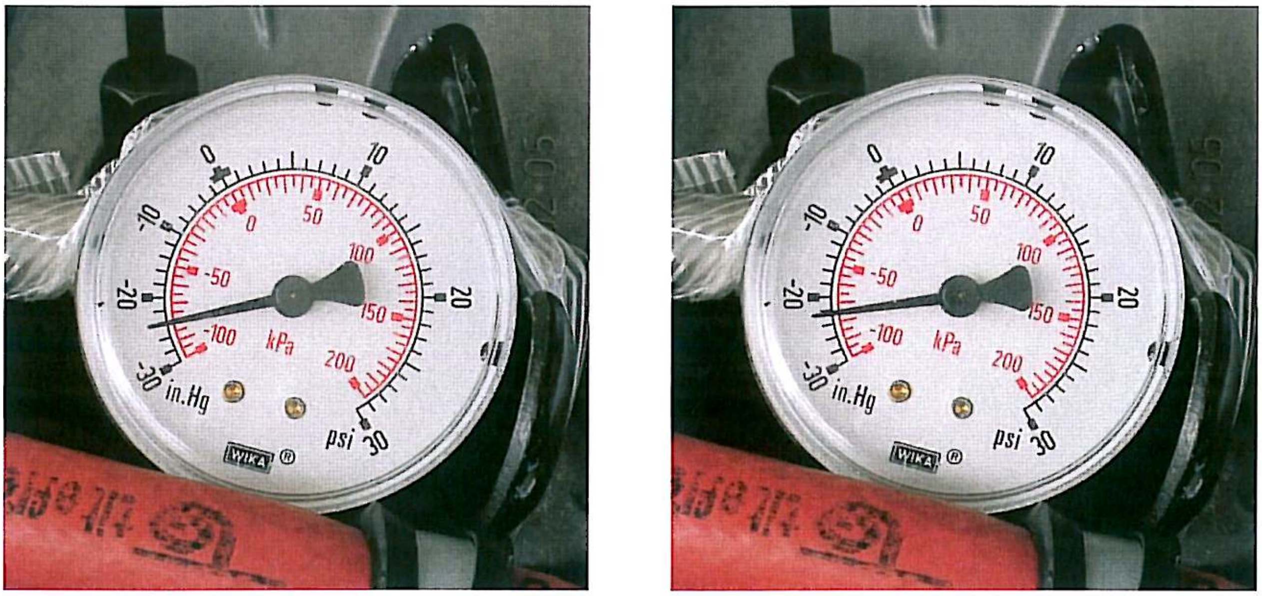
**Picture 2** connection to the low pressure pump

**Test procedure**

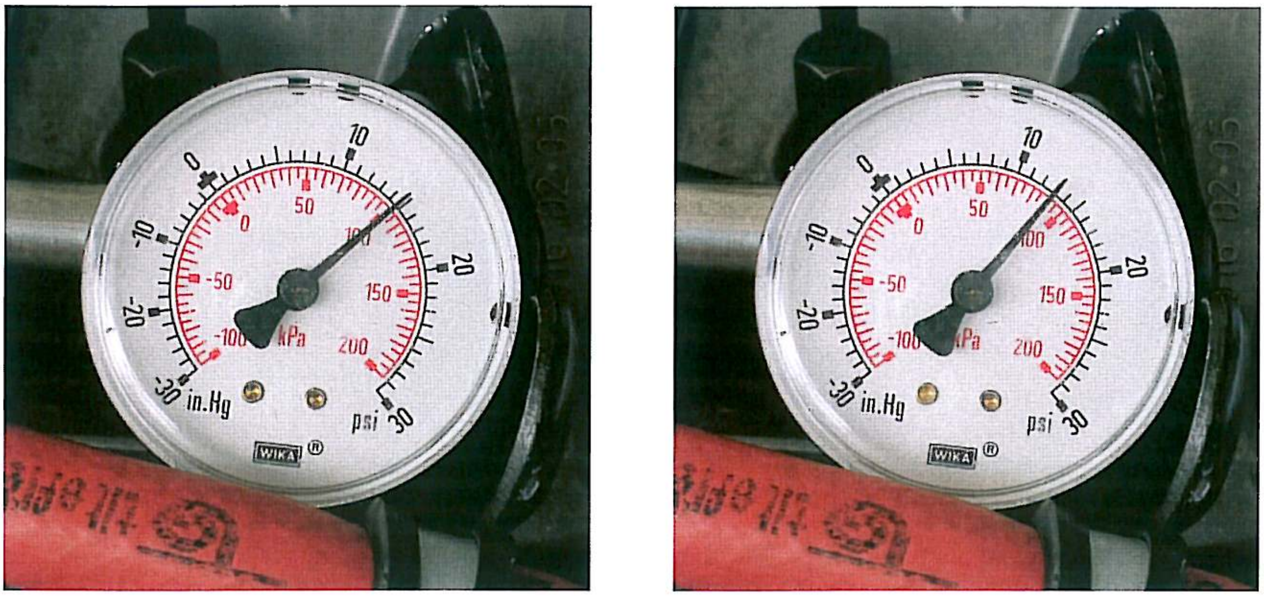
The finger filter was taken out of the main tank and connected to the fuel system connector of the fuselage, see **Picture 1.** The finger filter was covered with a plastic tube with its end sealed.

**Picture 2** shows the connection to the low pressure pump. A shut off valve was connected to the fuel hose which also had a connection to a pressure gauge. A low pressure of -0,8 bar has been applied. The shut off valve was closed and the increase of the pressure has been observed (**Picture 3**). Two hours after the beginning of the test the pressure increased about 50 mbar.

The test was made without the vibrations of the engine. When low pressure is applied to a system, loose and leaky parts can be leak tight because the over pressure of the surrounding atmosphere presses them together. These leakages can be identified by applying positive pressure, because loose parts are pushed away from each other. Therefore a second test of the fuel system with a positive pressure of 1 bar was conducted (**Picture 4**). 5,5 hours after the beginning of the test the pressure decreased about 0,1 bar.




**Picture 3** low pressure gauge at the beginning of the test (left) and 2 hours later (right).




**Picture 4** overpressure gauge at the beginning of the test (left) and 5,5 hours later (right).

**Results**

In two tests it has been shown that the fuel system of the OY - RBB is leak-proof.

The pressure loss of 20 - 25 mbar in the first hour is a result of the test setup itself. The used connections and shut off valve are defined to be liquid proof. Such connections and valves are never 100 % air proof. Thus it is obvious that due to the introduction of 11 additional connectors and an own shut off valve a negligible amount of air enters the system. This effect is the higher the low pressure is. Taking into account that the test simulates the minimum allowable pressure (200 mbar absolute) and that during engine operation the low pressure in the fuel line is only 200 mbar relative it can be said, that it is impossible for a countable amount of air to enter the fuel system.

Thus it is proven that the fuel system of the DA 40 D, call sign OY-RBB, is leak-proof. Under consideration of proper maintenance (tight fittings and filter as reported by the accident investigation board) it can be excluded that air in the fuel system is the reason for the total loss of power.

DAI recommends investigating the engine control system including sensors, harness, FADEC hardware and software.

# Appendix No 2:

# Occurrence Investigation Report (Engine manufacturer).

**The appendix consists of 7 pages.**

# Report

# OY-RBB
# Loss of power event

# June 7th, 2007

# Status: closed

| Prepared by: | Checked by: | Approved: |
|---|---|---|
| | | |

# Index:

# 1 Introduction

A Diamond DA40 TDI had a complete loss of power event during flight. The aircraft landed in a field without any damage. The pilot did not suffer any injuries.

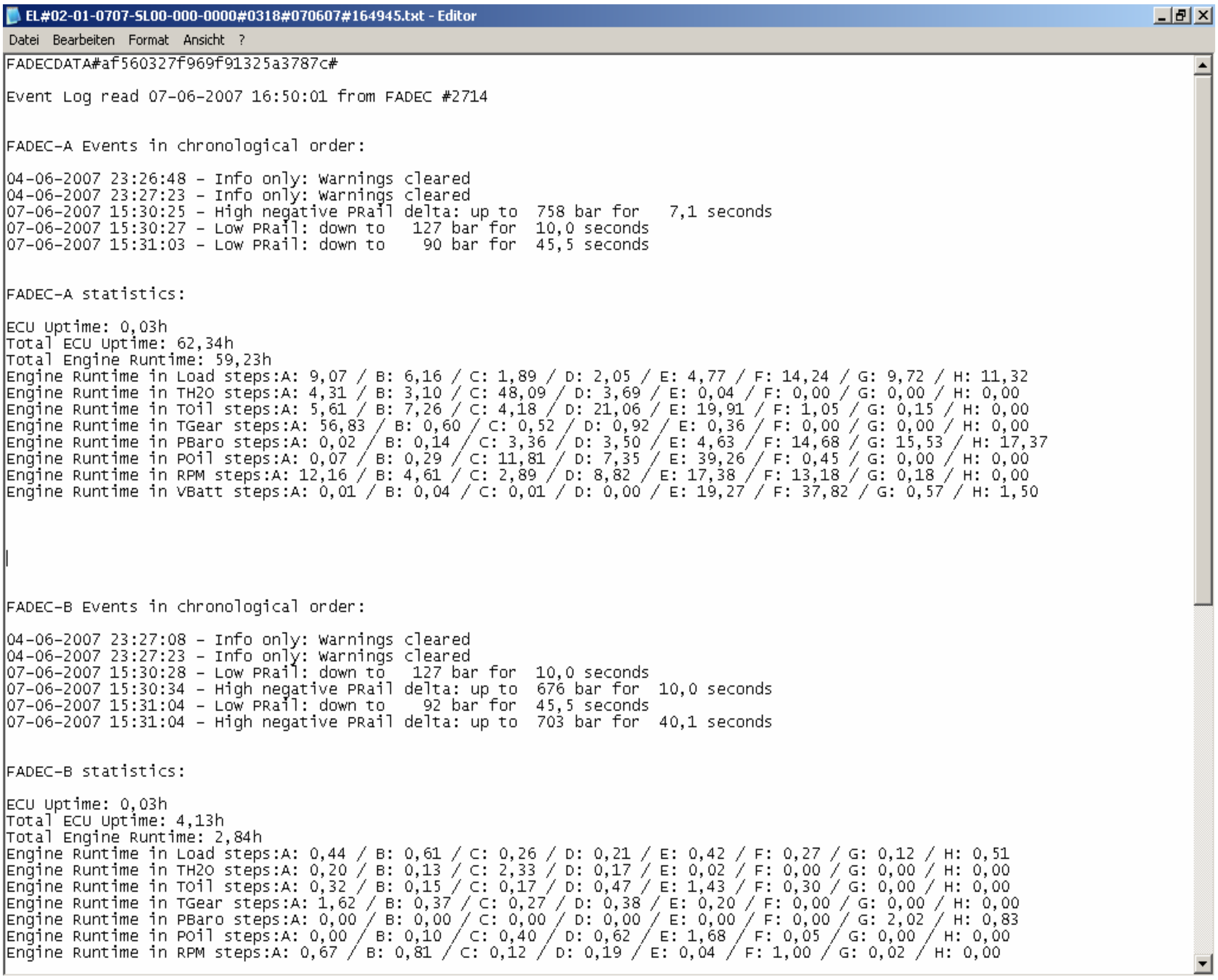
# 2 Facts

## 2.1 Initial inspection

### 2.1.1 FADEC Data

**Event log:**

There were some remarks in the eventlog of the engine FADEC from June 7th. These were "Low Prail" and "High Negative Prail delta" which caused the engine warnings. See attachment 1 for details.



EL#02-01-0707-SL00-000-0000#0318#070607#164945.txt - Editor

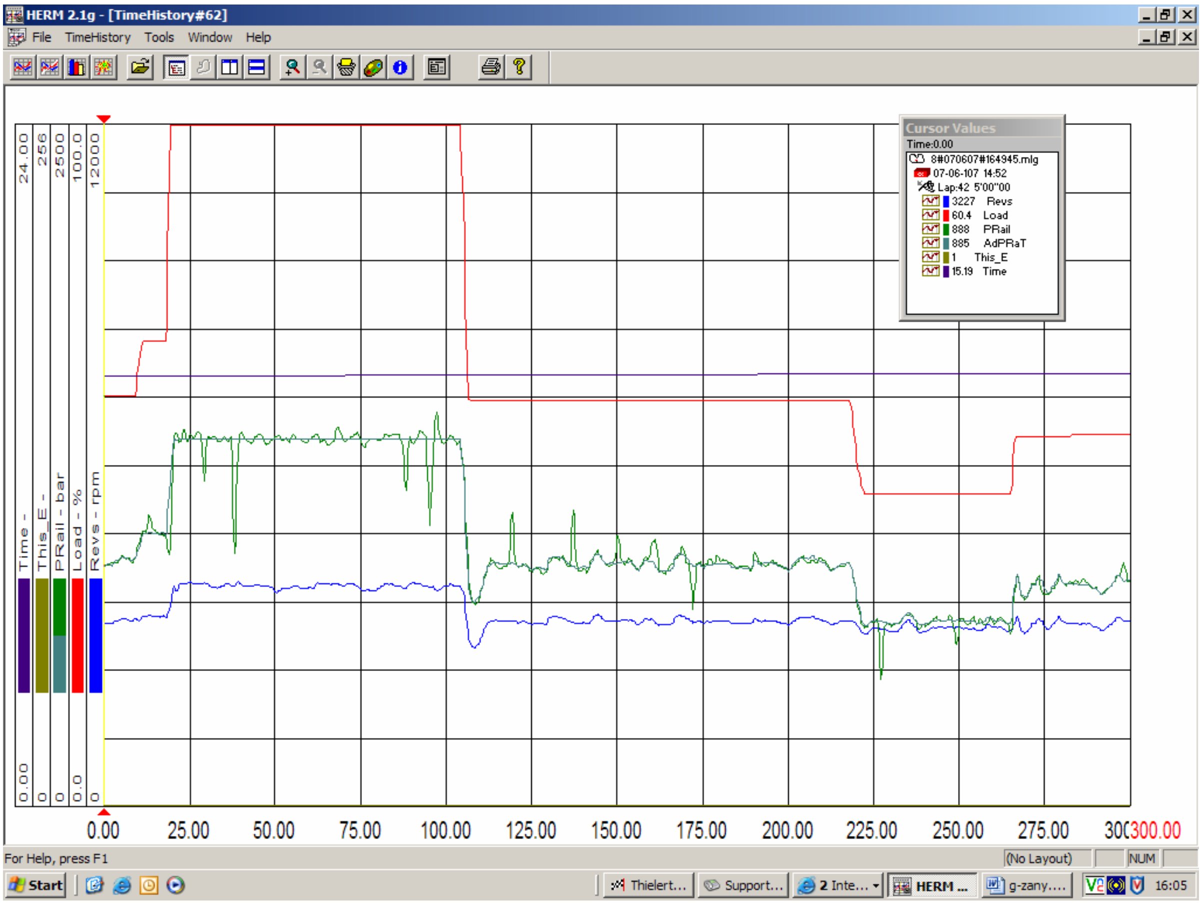
Datei Bearbeiten Format Ansicht ?

```
FADECDATA#af560327f969f91325a3787c#

Event Log read 07-06-2007 16:50:01 from FADEC #2714


FADEC-A Events in chronological order:

04-06-2007 23:26:48 - Info only: Warnings cleared
04-06-2007 23:27:23 - Info only: Warnings cleared
07-06-2007 15:30:25 - High negative PRail delta: up to  758 bar for   7,1 seconds
07-06-2007 15:30:27 - Low PRail: down to   127 bar for  10,0 seconds
07-06-2007 15:31:03 - Low PRail: down to    90 bar for  45,5 seconds


FADEC-A statistics:

ECU Uptime: 0,03h
Total ECU Uptime: 62,34h
Total Engine Runtime: 59,23h
Engine Runtime in Load steps:A: 9,07 / B: 6,16 / C: 1,89 / D: 2,05 / E: 4,77 / F: 14,24 / G: 9,72 / H: 11,32
Engine Runtime in TH2O steps:A: 4,31 / B: 3,10 / C: 48,09 / D: 3,69 / E: 0,04 / F: 0,00 / G: 0,00 / H: 0,00
Engine Runtime in TOil steps:A: 5,61 / B: 7,26 / C: 4,18 / D: 21,06 / E: 19,91 / F: 1,05 / G: 0,15 / H: 0,00
Engine Runtime in TGear steps:A: 56,83 / B: 0,60 / C: 0,52 / D: 0,92 / E: 0,36 / F: 0,00 / G: 0,00 / H: 0,00
Engine Runtime in PBaro steps:A: 0,02 / B: 0,14 / C: 3,36 / D: 3,50 / E: 4,63 / F: 14,68 / G: 15,53 / H: 17,37
Engine Runtime in POil steps:A: 0,07 / B: 0,29 / C: 11,81 / D: 7,35 / E: 39,26 / F: 0,45 / G: 0,00 / H: 0,00
Engine Runtime in RPM steps:A: 12,16 / B: 4,61 / C: 2,89 / D: 8,82 / E: 17,38 / F: 13,18 / G: 0,18 / H: 0,00
Engine Runtime in VBatt steps:A: 0,01 / B: 0,04 / C: 0,01 / D: 0,00 / E: 19,27 / F: 37,82 / G: 0,57 / H: 1,50



FADEC-B Events in chronological order:

04-06-2007 23:27:08 - Info only: Warnings cleared
04-06-2007 23:27:23 - Info only: Warnings cleared
07-06-2007 15:30:28 - Low PRail: down to   127 bar for  10,0 seconds
07-06-2007 15:30:34 - High negative PRail delta: up to  676 bar for  10,0 seconds
07-06-2007 15:31:04 - Low PRail: down to    92 bar for  45,5 seconds
07-06-2007 15:31:04 - High negative PRail delta: up to  703 bar for  40,1 seconds


FADEC-B statistics:

ECU Uptime: 0,03h
Total ECU Uptime: 4,13h
Total Engine Runtime: 2,84h
Engine Runtime in Load steps:A: 0,44 / B: 0,61 / C: 0,26 / D: 0,21 / E: 0,42 / F: 0,27 / G: 0,12 / H: 0,51
Engine Runtime in TH2O steps:A: 0,20 / B: 0,13 / C: 2,33 / D: 0,17 / E: 0,02 / F: 0,00 / G: 0,00 / H: 0,00
Engine Runtime in TOil steps:A: 0,32 / B: 0,15 / C: 0,17 / D: 0,47 / E: 1,43 / F: 0,30 / G: 0,00 / H: 0,00
Engine Runtime in TGear steps:A: 1,62 / B: 0,37 / C: 0,27 / D: 0,38 / E: 0,20 / F: 0,00 / G: 0,00 / H: 0,00
Engine Runtime in PBaro steps:A: 0,00 / B: 0,00 / C: 0,00 / D: 0,00 / E: 0,00 / F: 0,00 / G: 2,02 / H: 0,83
Engine Runtime in POil steps:A: 0,00 / B: 0,10 / C: 0,40 / D: 0,62 / E: 1,68 / F: 0,05 / G: 0,00 / H: 0,00
Engine Runtime in RPM steps:A: 0,67 / B: 0,81 / C: 0,12 / D: 0,19 / E: 0,04 / F: 1,00 / G: 0,02 / H: 0,00
```

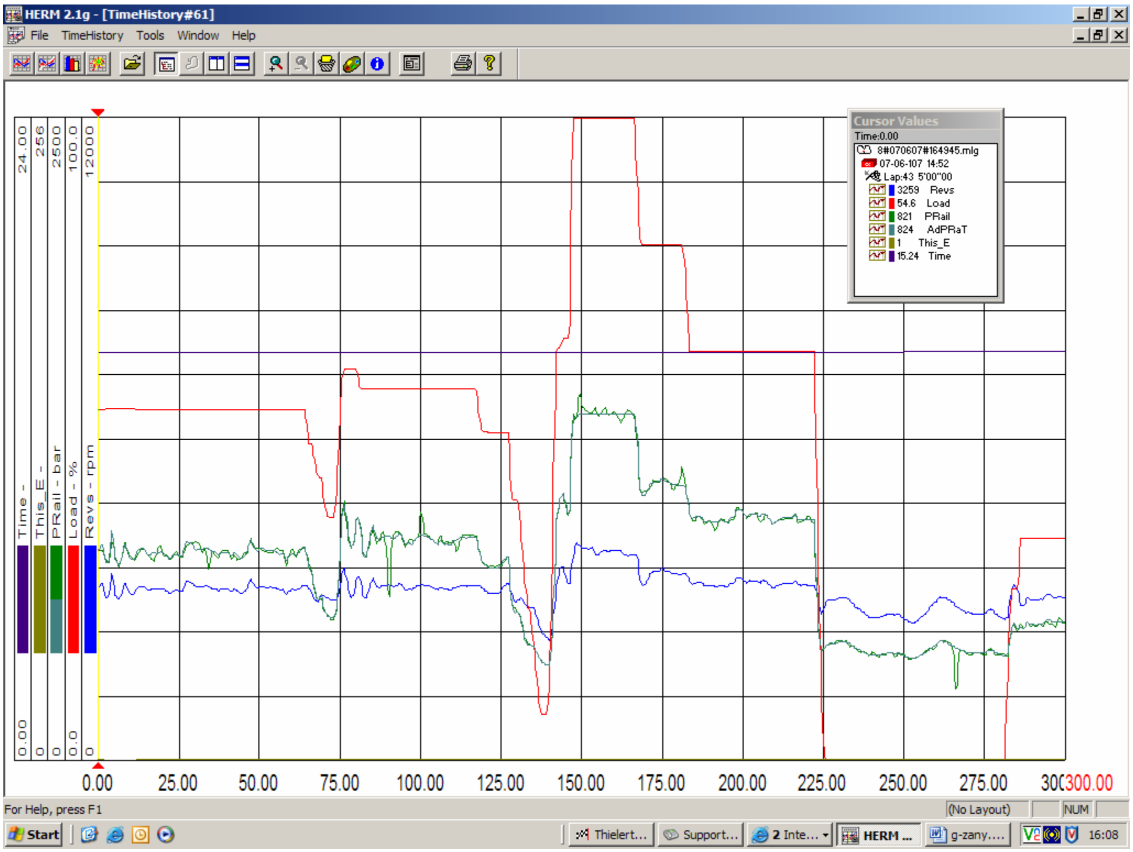
Fig 1: eventlog entries, read out after the incident

**Data Logger*.***

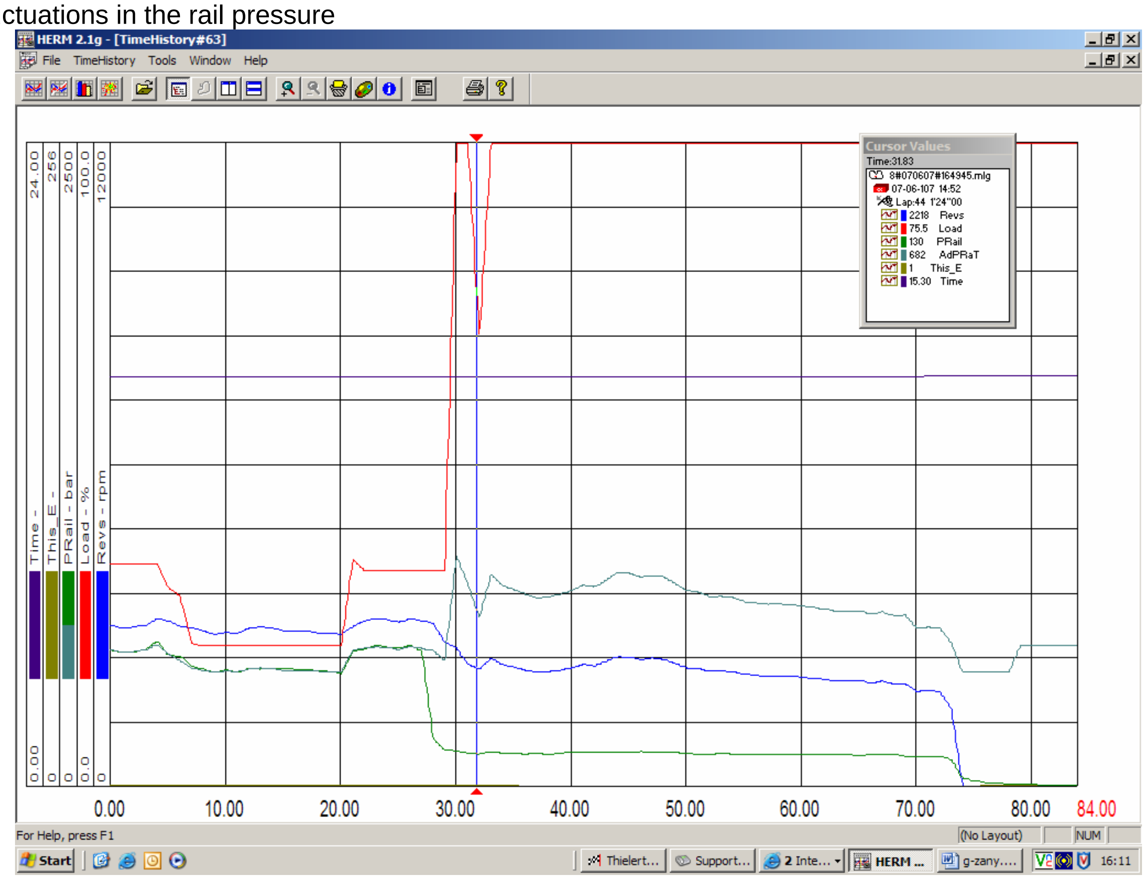
The engine was started at approximately 14:59 local time, on June the 7th. Purpose of the flight was a system check after exchange of the FADEC. The engine was running properly at that time, no warnings were triggered; nothing unusual was noted by the pilot. At 15:07 the pilot began with the take-off run. Few minutes after take-off the pilot did several engine operation tests with load settings between idle and maximum power. Until the power loss, nothing unusual was noted by the pilot. However, the data of the on-board logger shows heavy fluctuations of the rail pressure. This is visualized in graphs 1 and 2. At approx 15:30 the rail pressure dropped to a minimum of 130 bar. This is visualized in graph 3. Due to this the engine lost its power completely and the pilot was forced to land on a field with no damage to the aircraft.




Graph 1: engine run 10 minutes before the power loss, nothing unusual noted by pilot, data shows fluctuations in the rail pressure




Graph 2: engine run 5 minutes before the power loss, nothing unusual noted by pilot, data shows fluctuations in the rail pressure




Graph 3: Rail pressure drops to a minimum of 130 bars, causes the engine to quit

# 3 Analysis

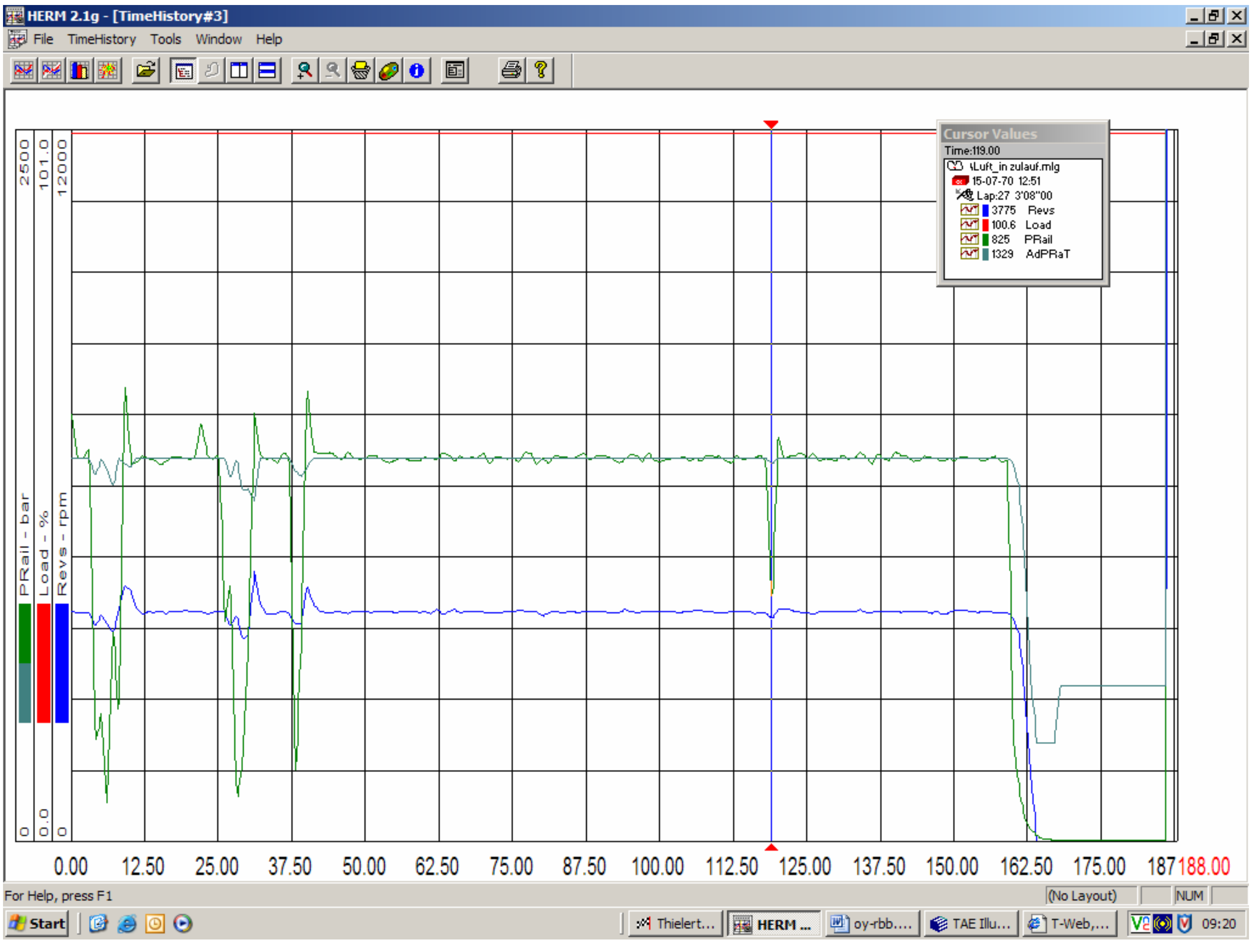
## 3.1 Analysis of the FADEC data

The FADEC data are showing several peaks and drops in the rail pressure. This behavior is not caused by an electric failure. In case of an electric failure at the rail pressure control, there would be different entries in the eventlog. Therefore it is not likely that this failure is caused by an electric failure either of the sensor or actuator or loom. The power supply for the FADEC was present at all time. The battery voltage was also stable during the whole event.

This behavior is also not caused by any mechanical failure of any components of the engine. In case of a mechanical failure of the engine components of the fuel system the rail pressure would not show these very short time peaks and drops, the logger data would rather show an difference between the rail pressure and its designated target value, which would trigger a FADEC warning in a quite earlier stage of the flight. Therefore it is not likely that this failure is caused by a mechanical failure of engine components

In conclusion the failure has to be found in the fuel supply to the engine.

Earlier tests of the Centurion 1.7 engines, done with air in the fuel supply, show the similar rail pressure fluctuations than in this occurrence of the OY-RBB. This is visualized in graph 4.

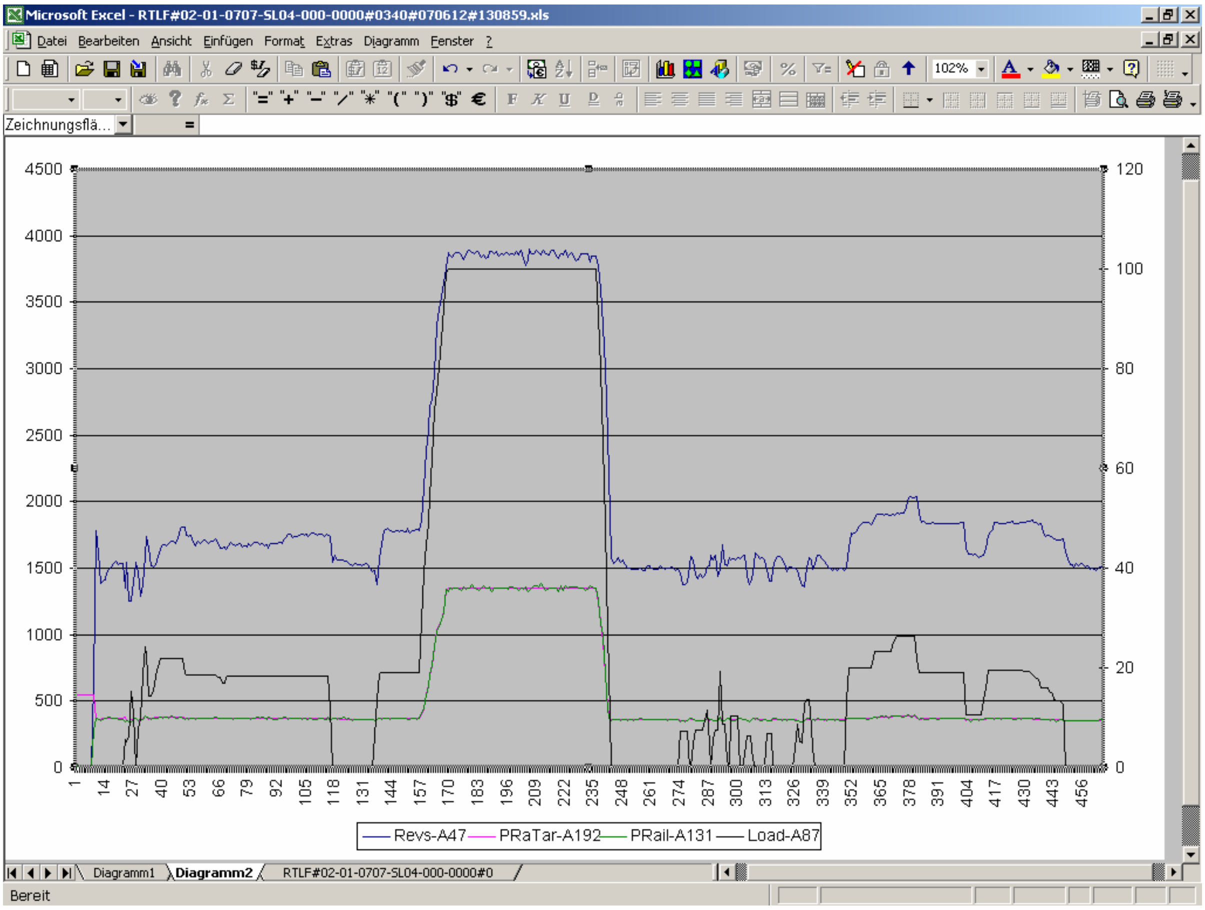



Graph 4: Test of the Centurion 1.7 with air in the fuel supply system

## 3.2 Analysis of the aircraft

After the incident the aircraft was recovered and brought to the nearest service centre. Investigation of the aircraft showed approx 14 gal of fuel in the aux. tank and 12 gal in the main tank. An investigation of the fuel filter bowl was also done by the Service Center. This was done without the presence of a representative of Thielert Aircraft Engines, so the exact amount of fuel in the filter bowl is unknown also potential leakage could not be identified.

The investigation of the aircraft by a representative of Thielert Aircraft Engines showed no mechanical defects, nor any electrical failures. The fuel filter was placed back in the aircraft and the system was thoroughly bleeded with the use of an external pump. The engine started immediately after that and ran without any further problems. This is visualized in graph 5.



Graph 5: engine ground run after bleeding the fuel system

Previous test bench tests showed that the air in the fuel filter is not bleeding automatically at a DA40 installation.

# 4 Conclusion

During investigation the engine started immediately using the same components than installed in the affected aircraft with just venting the fuel system. The engine data of the occurrence show similar behavior of engine test bench results performed with different fuel air mixtures. Based on these findings it is identified that the total loss of engine power is caused by fuel starvation at the engine fuel pump. The air could be introduced into the fuel system through leakage or previous dry flown fuel tanks.

TAE recommend investigating the aircraft fuel supply system regarding leakages and interviewing pilots of previous flights.

# Appendix No 3:

# Behaviour of the TAE 125 engine with air in the fuel system.

**The appendix consists of 14 pages.**

# Behaviour of the TAE 125 engine with air in the fuel system

### Purpose of test

The tests have been conducted to show the behaviour of the engine when air is introduced through a leakage into the fuel system. To simulate a leakage the fuel system of the DA 40 D has been modified in a way so that air can be introduced by two means. First it was of interest how the engine responds to a continuous introduction of air into the fuel system. This test should simulate a leakage somewhere between the main tank and the fuel filter. A second test allows the introduction of a certain amount of air at once into the fuel system. This test was conducted in order to simulate the response of the engine in case of sucking an air cushion which possibly has been formed in the fuel filter housing.

All tests have been performed on a TAE 125-02 engine. As the high pressure section of the TAE 125-01 engine is equal to the high pressure section of the TAE 125-02 engine the test result is applicable for the entire TAE 125 engine series.

## Ground Test - Introduction of Continuous Air Flow

Date/place: 31-Oct-2007, Wiener Neustadt
Performed by: Johannes Huemer, Herbert Kogelbauer
Aircraft S/N: D4.321
Engine S/N: 02-02-01854

### Test Equipment

Fuel flow measuring device:

Biotech flowmeter - Ovalradzähler Serie VZS-007-ALU, 5 L/min

Display ARS 260-EC-01-Serie

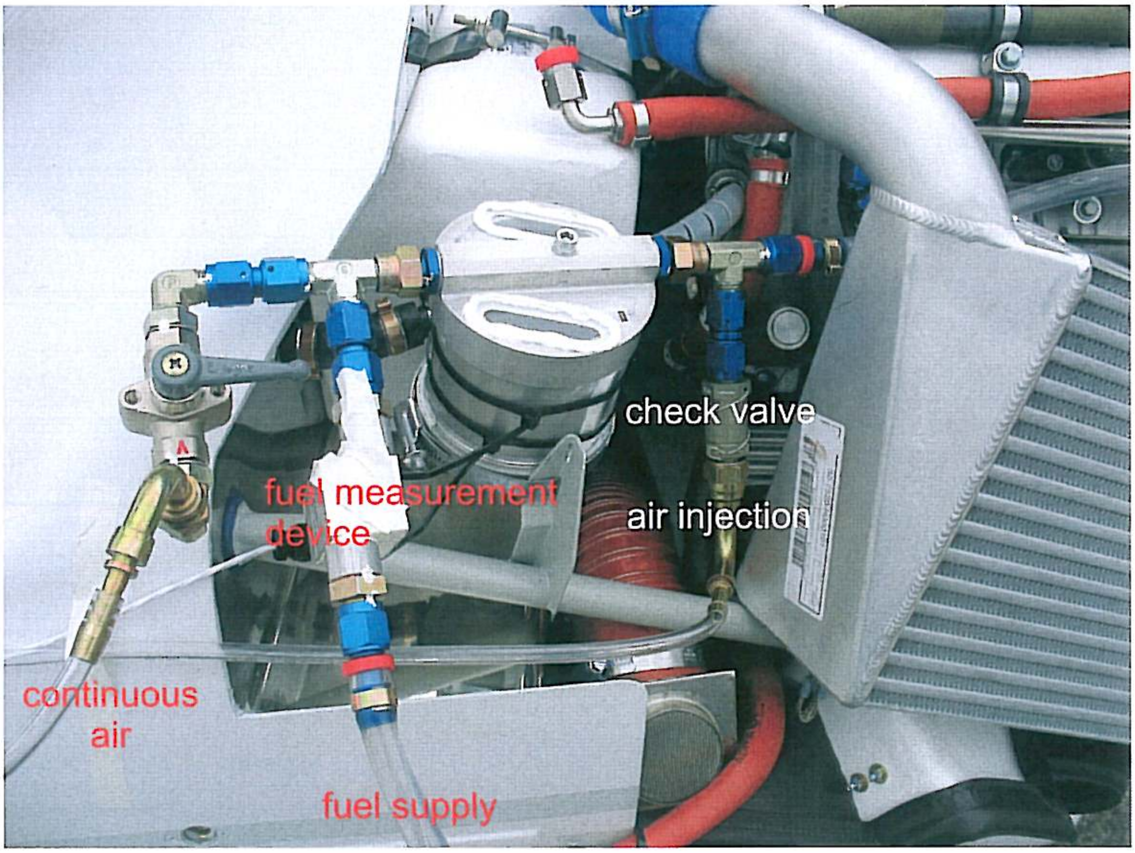
Air flow measuring device:

Analyt-MTC – Rotameter , Schwebekörperströmungsmesser – Messrohr 150 mm, max. 814 ml/min

**Test Arrangement**

Due to the high flow resistance of the rotameter it has been connected to compressed air. With a regulating valve on the rotameter the air flow can be adjusted from 0 to ~870 ml/min. The air that passes throug the rotameter is led to a shut off valve which has been positioned at a T-fitting at the inlet of the fuel filter housing, as shown in **Picture 1**.

The fuel flows through a transparent tube from the bulkhead to the fuel measuring device. Before the fuel and the air enter the fuel filter housing they are brought together over a T-fitting which has been mounted to the inlet of the fuel filter housing. The fuel filter housing has been equipped with two windows on the superficies surface and on the top. The outlet of the fuel filter housing has been connected with the feed pump.



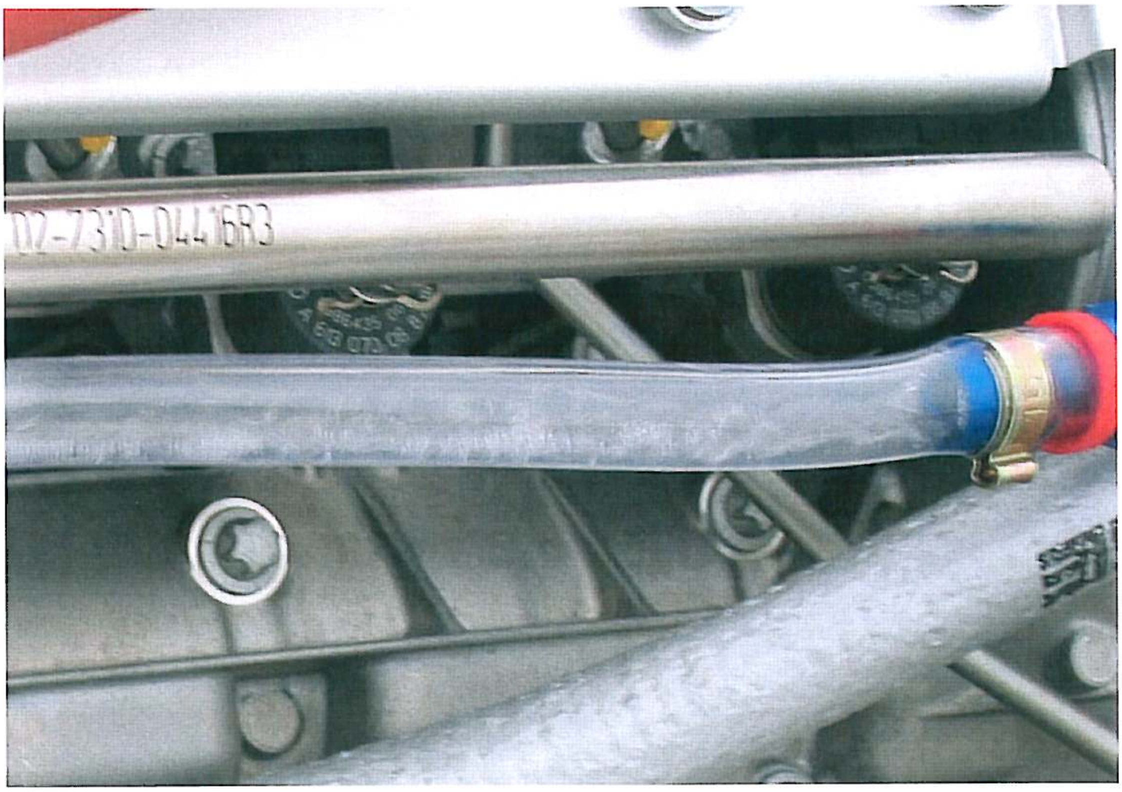

**Picture 1** Test Arrangement

**Results**

The test run has been recorded. A real time log file is available.

After a warm up it has been shown at various power settings that the transparent tube between the bulkhead and the fuel measuring device was free of air bubbles. With the air shut off valve in closed position also no air bubbles could be seen in the transparent tube between the fuel filter housing and the feed pump.

During the test the air quantity has been increased continuously up to the last mark of the measuring scale (814 ml/min). When opening the regulating valve totally the levitation ball of the rotameter could be lifted a little bit higher up to the end of the rotameter tube. Interpolating the additional measuring range it can be assumed that the maximum airflow was about 870 ml/min. **Picture 2** shows that the air forms a thick air tube in the center of the transparent tube.

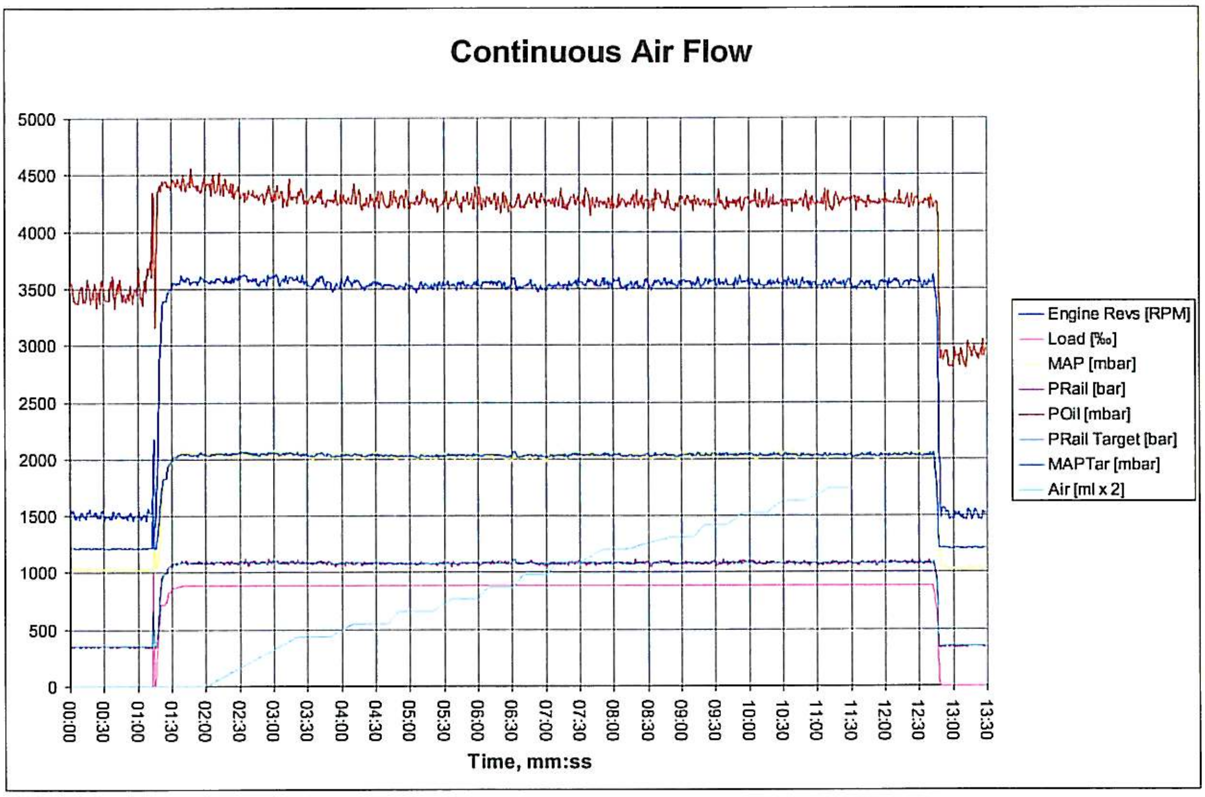



**Picture 2** Air contamination in the fuel at 80% power setting and 2,55 l/min fuel flow

**Picture 3** shows a diagram with the most relevant parameters of a test run performed at 80% power setting. It can be seen that no fluctuations or other conspicuities occurred.

Within these 13 minutes the air flow has been increased from 0 to about 870 ml/min in steps of about 56 ml/min. The fuel flow was 2,55 l/min.

The engine did not show any response to the introduction of air. The engine kept on running smoothly. No rough running or shuddering occurred. No ECU A or B warning came up. There are no entries of a low p-Rail warning in the event log.

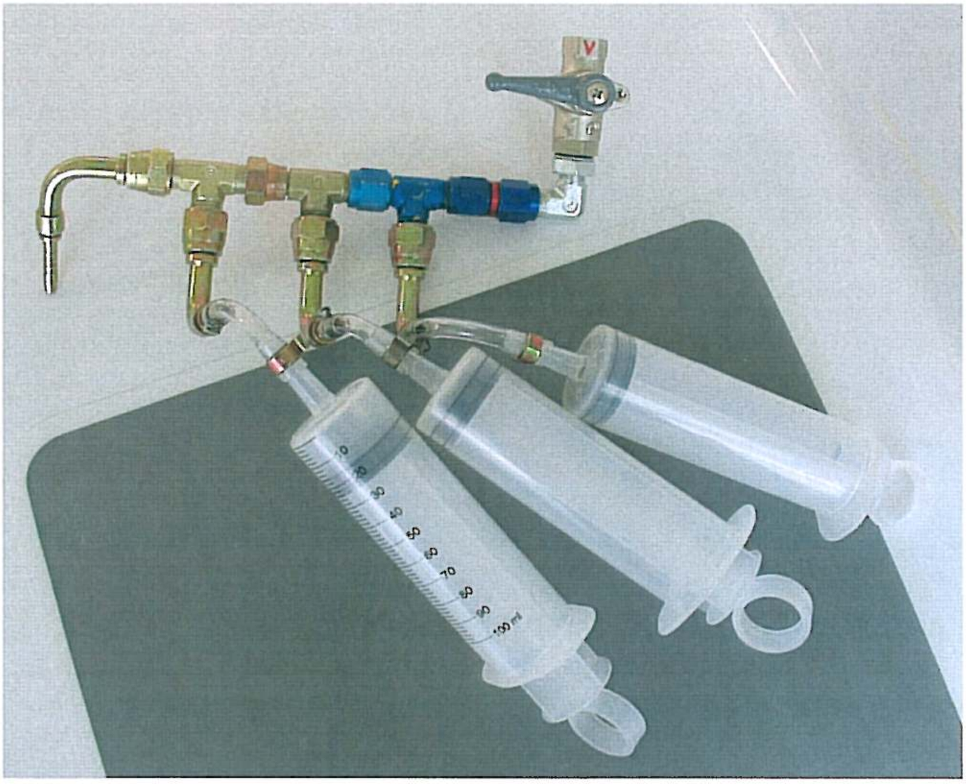



**Picture 3** Continuous introduction of air starting with 0 l/min at 01:30 up to about 870 ml/min at 11:30

## Ground Test - Introduction of Air at once

Date/place: 31-Oct-2007, Wiener Neustadt
Performed by: Johannes Huemer, Herbert Kogelbauer
Aircraft S/N: D4.321
Engine S/N: 02-02-01854

### Test Equipment



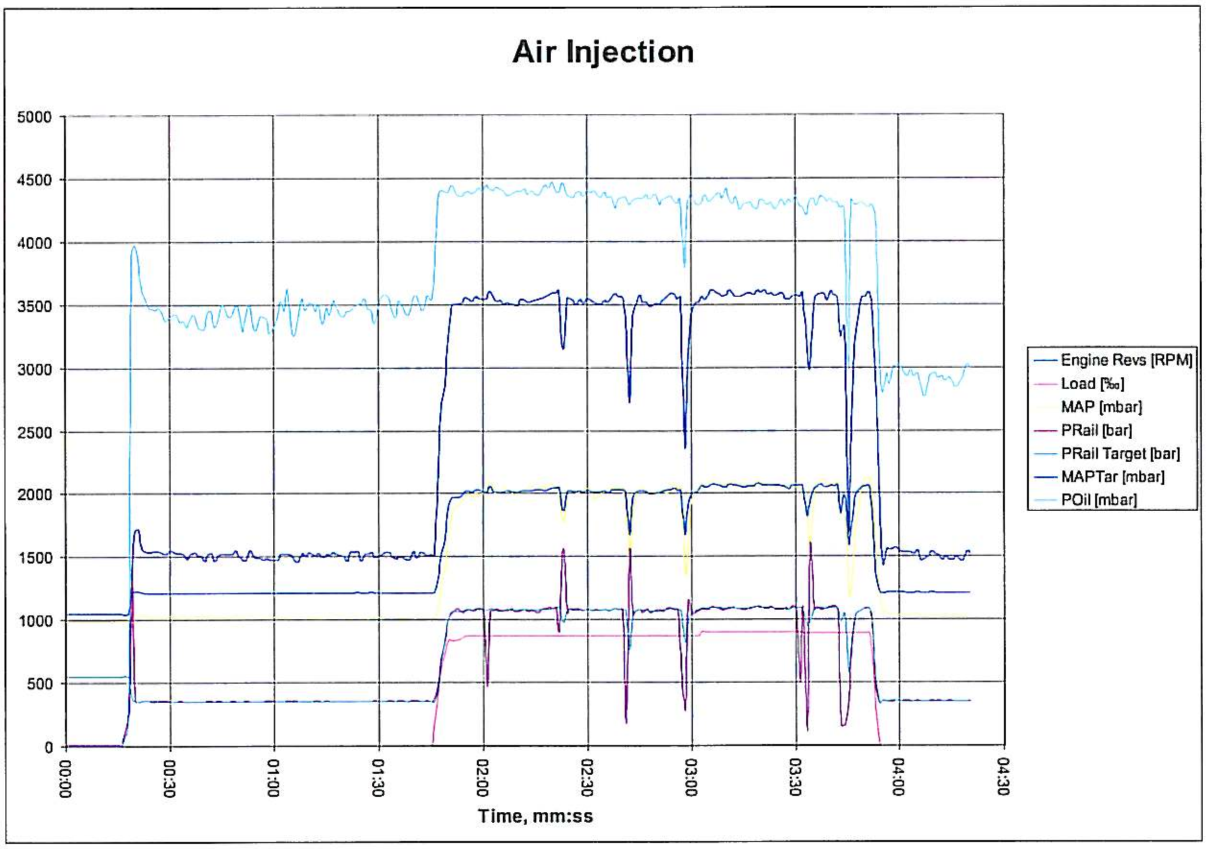
**Picture 4** Air injectors 3 x 100 ml

### Test Arrangement

In order to simulate the behaviour of the engine when sucking a possible air cushion 3 injectors have been combined in a parallel way so that an amount of 300 ml air can be injected at once (**Picture 4**). These three injectors have been connected to a check valve with an opening pressure of 0,6 bar. This guaranties that air enters the fuel hose only by compressing the injectors. Air cannot be sucked due to the negative pressure of the fuel system. The check valve was mounted to a T-fitting which was positioned at the outlet of the fuel filter housing.

## Results

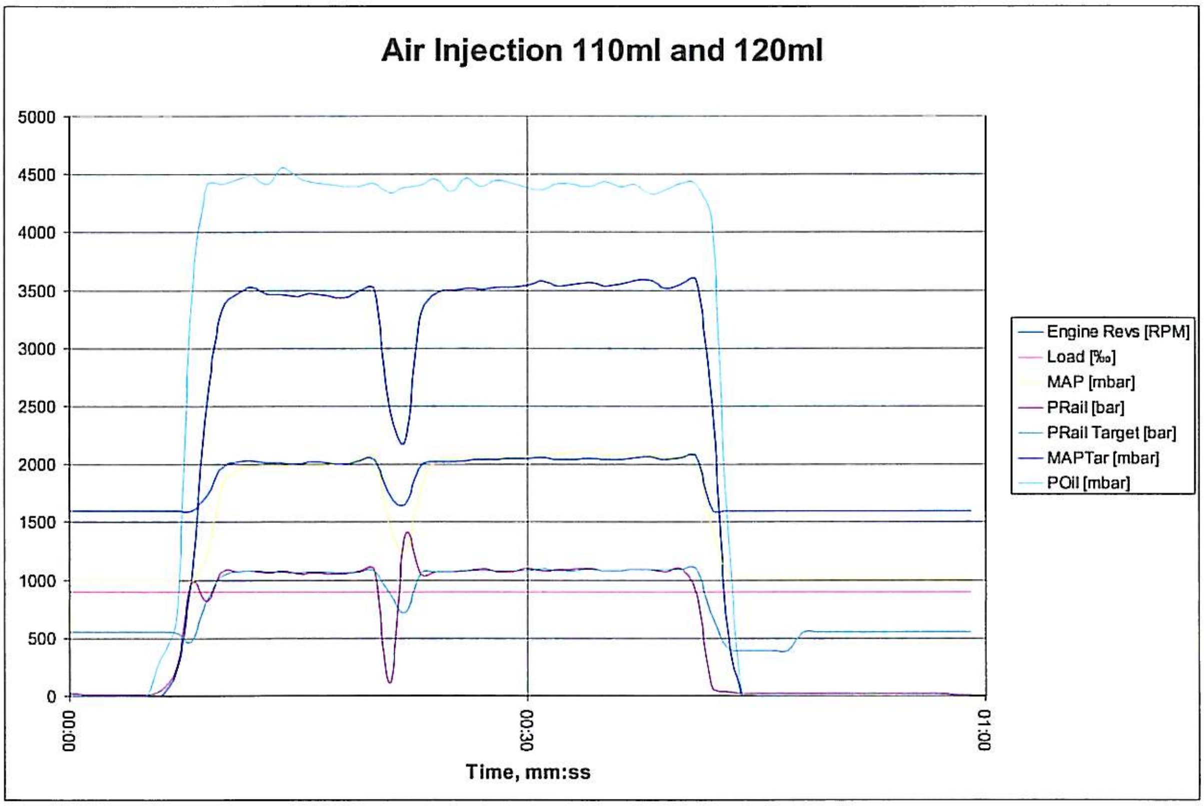
The test run has been recorded. A real time log file is available.




**Picture 5** Injection of 50ml at 02:00, 70ml at 02:23, 100ml at 02:40 and 03:00

The first test run which is shown in **Picture 5** was performed with a single injector of 100 ml. It was started with an injection of 50 ml at 02:00 without a decrease of the RPM. But it can be seen that the rail pressure dropped. This was followed by an injection of 70ml at 02:23 with a slight decrease of the RPM and a slight drop of the rail pressure. Two injections of 90 ml each at 02:40 and 03:00 caused the RPM and the rail pressure to drop significantly. But the engine was able to recover every time. A remarkable detail is that in the majority of cases the drop of the rail pressure is followed by a compensating positive peak.

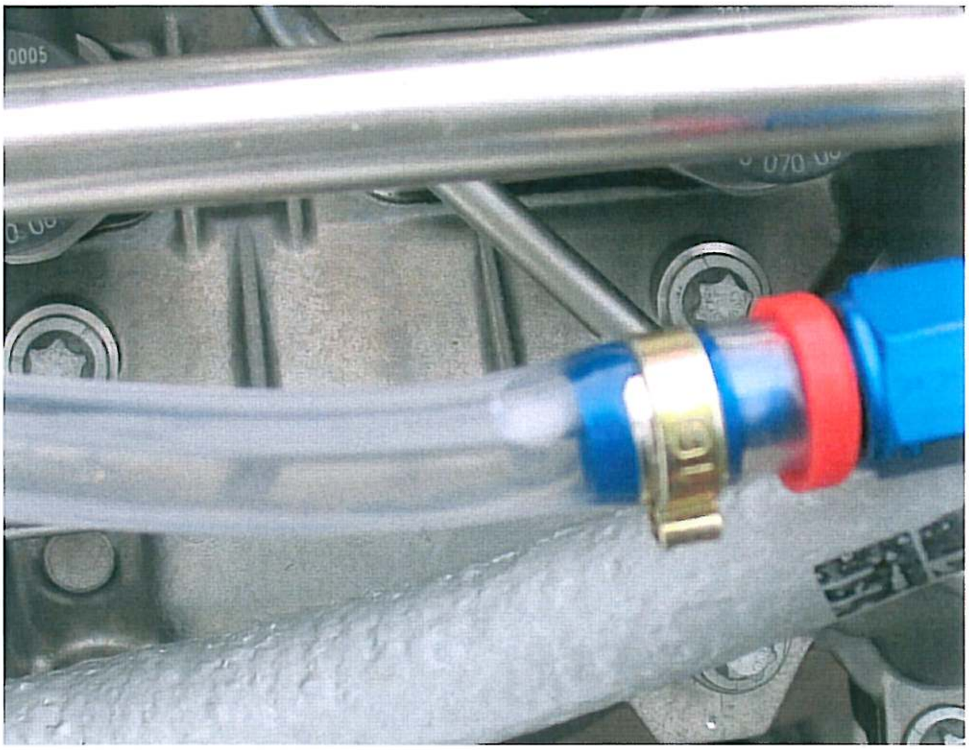
For a second test the arrangement of injectors in **Picture 4** was used. The amount of air has been increased up to 110ml air, with which the engine can cope barely. An injection of 120 ml air forces the engine to shut down. This is shown in **Picture 6**.




**Picture 6** The engine is able to recover after an injection of 110 ml air. An injection of 120ml air forces the engine to shut down.

Again the negative peak of the rail pressure is followed by a positive peak. **Picture 7** shows the end of a long air bubble of 120 ml. Behind the air bubble the transparent tube was completely filled with fuel again.

These tests have been conducted on the 31-~~Nov~~ Oct-2007. There are no entries of a p-Rail warning in the event log on this day on page 9 and 10.



**Picture 7** The end of a long air bubble of 120ml

## Flight Test - Introduction of Air at once

Date/place: afternoon of 5-Nov-2007, Wiener Neustadt
Crew: Fritz Lehner, Ingmar Mayerbuch Ingmar, Johannes Huemer
Aircraft S/N: D4.321
Engine S/N: 02-02-01854

### Purpose of test

The ground test has shown that the engine is able to recover after an injection of 110 ml air. When injecting more than 110 ml air in a ground run the angular momentum of the propeller is not high enough to prevent the shut down of the engine. During normal operation in flight the propeller drives the engine due to wind milling even in the event of fuel starvation. It was assumed that this matter supports the engine when recovering after sucking a certain amount of air. In order to show this behaviour a flight test was conducted.

**Test Arrangement**

The tube that connects the 3 injectors with the fuel system was routed out of the cowling through the right side window into the cockpit. A second test pilot sitting on the rear seat recorded this test on a camcorder.

**Result**

It has been shown that injecting the full volume of the injectors, which is 250ml, cannot force the engine to shut down permanently. The power decreases down to 2 - 3 % for about 2 seconds. After this short period the engine recovers, followed by a fluctuation of power and revolution. The engine needs 5 to 10 seconds to establish again constant power and revolutions. Again there is no entry in the event log.

**Event Log**

FADEC-A Events in chronological order:

14.09.2007 12:00:05 - Info only: Warnings cleared
14.09.2007 12:00:21 - Info only: Warnings cleared
14.09.2007 12:00:24 - Info only: Warnings cleared
10.10.2007 05:17:19 - Load Sensor failed for 10,0 seconds
10.10.2007 06:44:34 - Load Sensor failed for 10,0 seconds
17.10.2007 07:36:30 - Load Sensor failed for 10,0 seconds
17.10.2007 07:36:30 - Info only: Left low fuel for 10,0 seconds
17.10.2007 10:46:37 - Load Sensor failed for 9,7 seconds
22.10.2007 15:20:16 - Info only: Left low fuel for 10,0 seconds
22.10.2007 15:23:58 - Info only: Left low fuel for 10,0 seconds
23.10.2007 07:23:15 - Info only: Warnings cleared
02.11.2007 12:39:27 - Info only: Left low fuel for 10,0 seconds
02.11.2007 12:39:54 - Info only: Left low fuel for 10,0 seconds
02.11.2007 12:40:36 - Info only: Left low fuel for 10,0 seconds
02.11.2007 12:40:50 - Info only: Left low fuel for 10,0 seconds
02.11.2007 12:47:48 - Info only: Left low fuel for 10,0 seconds
02.11.2007 12:48:01 - Info only: Left low fuel for 10,0 seconds
02.11.2007 12:48:47 - Info only: Left low fuel for 55,2 seconds
05.11.2007 08:44:45 - Info only: Left low fuel for 10,0 seconds
05.11.2007 08:45:06 - Info only: Left low fuel for 30,7 seconds
05.11.2007 08:45:17 - Info only: Left low fuel for 10,0 seconds
05.11.2007 08:45:55 - Info only: Left low fuel for 47,6 seconds
05.11.2007 08:46:14 - Info only: Left low fuel for 10,0 seconds
05.11.2007 08:50:46 - Info only: Left low fuel for 282,7 seconds
05.11.2007 09:06:35 - Info only: Left low fuel for 10,0 seconds

FADEC-B Events in chronological order:

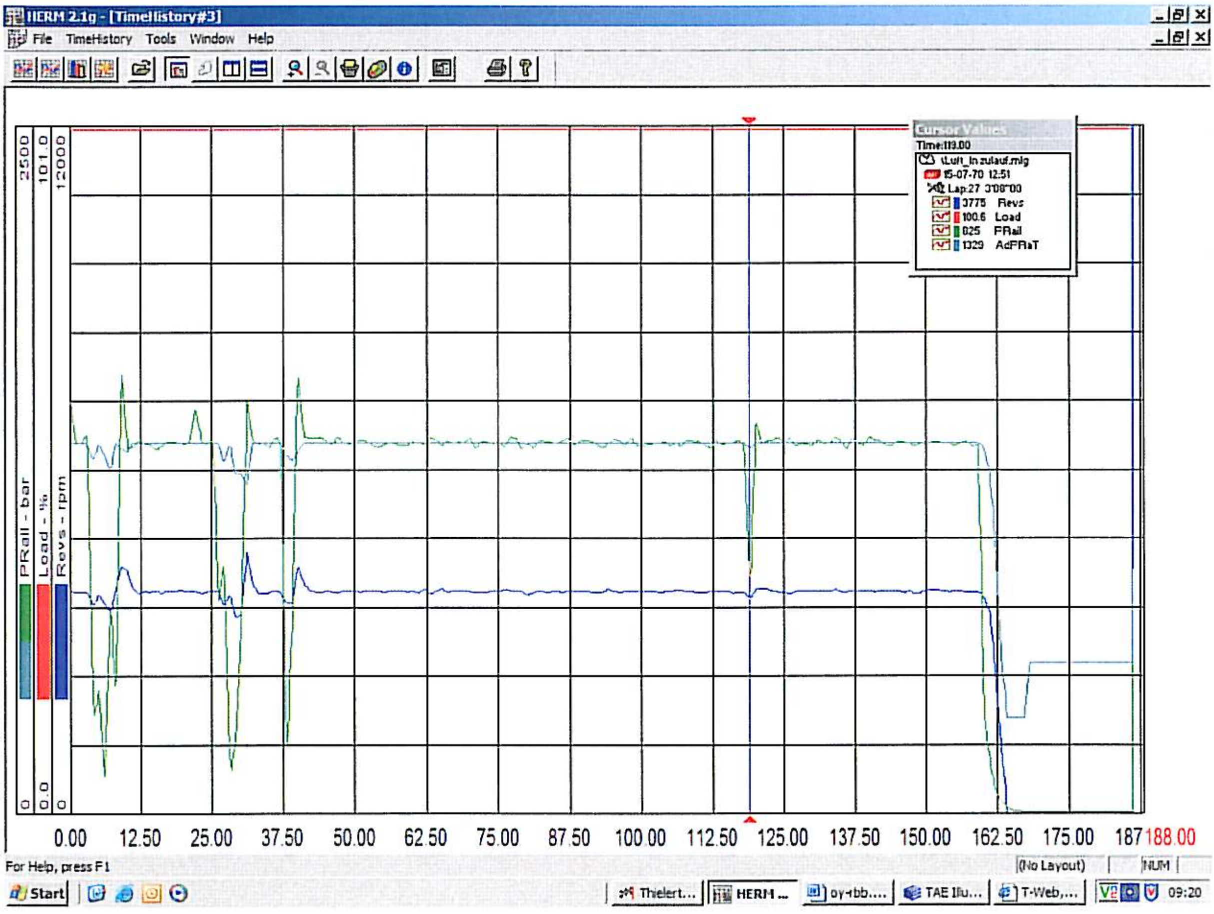
14.09.2007 12:00:08 - Info only: Warnings cleared
14.09.2007 12:00:18 - Info only: Warnings cleared
14.09.2007 12:00:24 - Info only: Warnings cleared
10.10.2007 05:17:21 - Load Sensor failed for 10,0 seconds
10.10.2007 06:44:36 - Load Sensor failed for 10,0 seconds
17.10.2007 07:36:33 - Load Sensor failed for 10,0 seconds
17.10.2007 07:36:33 - Info only: Left low fuel for 10,0 seconds
22.10.2007 15:20:19 - Info only: Left low fuel for 10,0 seconds
22.10.2007 15:24:01 - Info only: Left low fuel for 10,0 seconds
23.10.2007 07:23:19 - Info only: Warnings cleared
02.11.2007 12:39:32 - Info only: Left low fuel for 10,0 seconds
02.11.2007 12:39:58 - Info only: Left low fuel for 10,0 seconds
02.11.2007 12:40:40 - Info only: Left low fuel for 10,0 seconds
02.11.2007 12:40:54 - Info only: Left low fuel for 10,0 seconds
02.11.2007 12:47:53 - Info only: Left low fuel for 10,0 seconds
02.11.2007 12:48:06 - Info only: Left low fuel for 10,0 seconds
02.11.2007 12:48:52 - Info only: Left low fuel for 55,3 seconds
05.11.2007 08:44:50 - Info only: Left low fuel for 10,0 seconds
05.11.2007 08:45:11 - Info only: Left low fuel for 30,6 seconds
05.11.2007 08:45:22 - Info only: Left low fuel for 10,0 seconds
05.11.2007 08:46:00 - Info only: Left low fuel for 42,1 seconds
05.11.2007 08:46:20 - Info only: Left low fuel for 10,0 seconds
05.11.2007 08:50:51 - Info only: Left low fuel for 281,6 seconds
05.11.2007 09:06:40 - Info only: Left low fuel for 10,0 seconds

The ECU was read out on 6-Nov-2007 in the morning, after the flight test. The flight test was performed in the afternoon of 5-Nov-2007. The ground test was performed on 31-Oct-2007. In the above event log there is no entry concerning a low rail pressure or a problem with the fuel supply during the tests. The seven entries concerning the "info only: left low fuel" came up during the flight preparation in the morning and do not have anything to do with the conducted tests.

**Comparison of the results of this test with the ECU data of the engine failure of the DA40 D, OY-RBB and a TAE test with air in the fuel system**

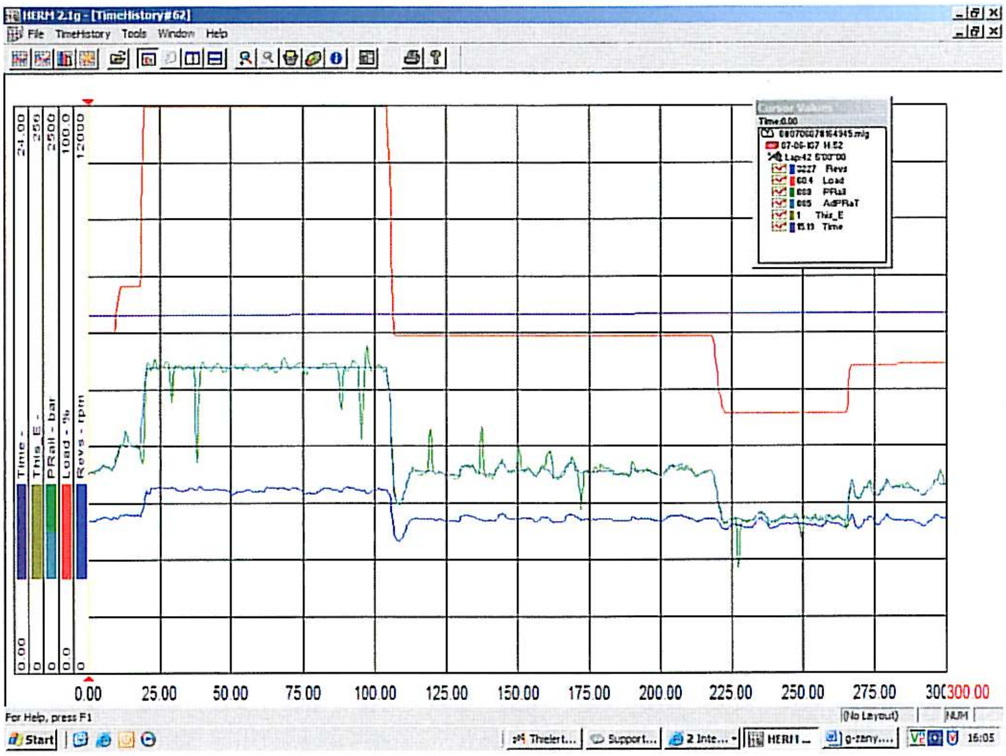
The **Pictures 5 and 6** (air injection during ground run) show very clearly that the drop of the rail pressure is followed by a sudden increase of the rail pressure above the actual level.

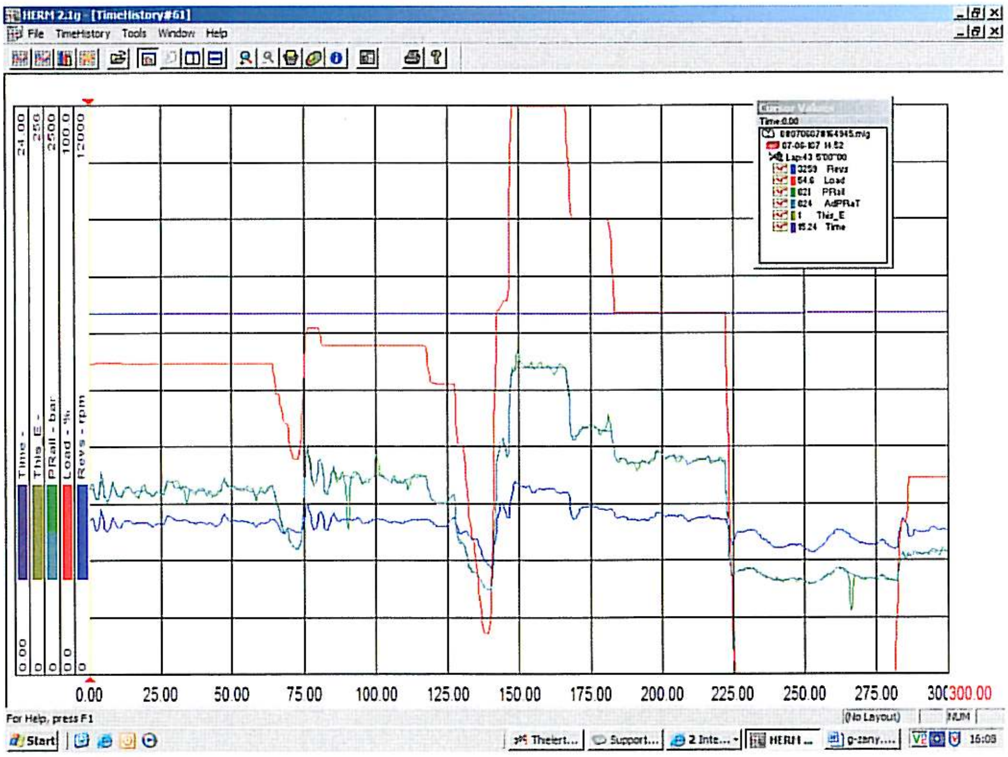
The same characteristics of the rail pressure can be found in **Picture 8**, the chart of a TAE bench test with air in the fuel system. Again negative peaks are followed by positive peaks.




**Picture 8** TAE engine test with air in the fuel, taken from TAE Occurrence Investigation Report OY-RBB

The rail pressure peaks in the graphs given in **Picture 9** show different characteristics. These are the graphs of the OY-RBB ECU read out shortly before the engine failure. The negative peaks are not followed by positive peaks. There are also single positive peaks.




**Picture 9** ECU charts of the OY-RBB shortly before the engine failure, taken from TAE Occurrence Investigation Report OY-RBB

From this comparison it can be concluded that air in the fuel system is not the root cause of the rail pressure fluctuations. Thus air in the fuel system cannot be the reason of the engine shut down of the OY-RBB in June 2007.

**Fuel Level in the Fuel Filter Housing after removing the Fuel Filter**

An investigation of the fuel level in the fuel filter housing has shown that after opening the filter housing and removing the filter the considerations below meet the situation in the field.

A completely filled fuel filter housing incl. filter without any aircushion contains about 310 ml fuel. A vented fuel filter housing incl. filter contains about 270 ml fuel. That is a difference of about 40 ml fuel. This means that there is always an air cushion of about 40 ml. The used volume of the fuel filter is about 200 ml.

The inner diameter of the fuel filter housing is 8 cm. Therefore the fuel contained in 1cm height of the fuel filter housing is about 50 ml.

If the fuel filter is removed the fuel level drops about 4 cm. Taking into account that there is an aircushion of 40 ml then the fuel level should be about 5 cm below the edge of the fuel filter housing.

**Picture 10** shows this situation. These are fuel filter housings of two DA 40 D´ s which were maintenanced at DAI-M at the time when the ground and flight tests have been conducted. Both show a normal fuel filter level, as it is calculated above.

**Picture 10** Fuel filter housings after removing the fuel filter

# Appendix No 4:

# Supplement to Occurrence Report No. 01.

**The appendix consists of 19 pages.**

| AIRPLANE | |
|---|---|
| Type: | DA 40 D |
| Serial No.: | D4.211 |
| Call Sign: | OY-RBB |
| Operator: | Copenhagen A & M |
| TSN: | 319:30 |
| **ENGINE 1** | |
| Type: | TAE 125-01 |
| Serial No.: | n. k. |
| TSN / TSO: | 319:30 |
| **ENGINE 2** | |
| Type: | n. a. |
| Serial No.: | n. a. |
| TSN / TSO: | n. a. |
| **PROPELLER 1** | |
| Type: | MTV-6-A/187-129 |
| Serial No.: | n. k. |
| TSN / TSO: | n. k. |
| **PROPELLER 2** | |
| Type: | n. a. |
| Serial No.: | n. a. |
| TSN / TSO: | n. a. |
| **EQUIPMENT** | |
| Type: | n. a. |
| Serial No.: | n. a. |
| Type: | n. a. |
| Serial No.: | n. a. |

~~**Note:** Contents of this document are preliminary information, which may change during further investigation.~~

R. Kremnitzer

Occurrence: The aircraft's engine lost power and the pilot was forced to land in a cornfield.

Date: 7-Jun-2007

Location: Roskilde, Denmark

- Draft Report from the Danish AIB, 8-Aug-2007:

The Danish Accident Investigation Board investigated this incident. The report states that the AIB was unable to find with certainty what the cause of the power loss was. However, it was stated that air in the fuel leading to fuel starvation was the suspected cause. On the other hand the AIB can not exclude that other parts of the engine fuel system regulating the fuel rail pressure could have caused the pressure fluctuation and/or the fuel rail pressure drop.

- Pressure loss test, conducted by Johannes Huemer, 6-Aug-2007:

The report of this test was forwarded to the authorities on the 14-Sep-2007 (AIB Denmark) and 21-Sep-2007 (ACG).
The fuel system of the OY-RBB was tested for leaks in order to see if there is a possibility for air to enter the fuel system through a leakage and to cause the engine to starve of fuel. The fuel system was sealed and both positive and negative air pressure was applied. No leaks were found.
Because the aircraft's wings had been dismantled before the aircraft was transported to DAI-A it is not possible to test the connection of the fuel line between the fuselage and the left wing in its original condition. Although it can be concluded that a leak in this area would have led fuel to leak out, which was not found.
Regarding the connections at the fuel filter bowl, it is stated in the draft report of the AIB that the airframe and engine fuel system were inspected and no leaks or loose connections were found.

R. Kremnitzer
15. JULI 2009
STAMP / DATE / SIGN
Chief, Office of Airworthiness

- Ground and flight test - air in fuel system, conducted by Johannes Huemer, 31-Okt-2007:

The report of this test was forwarded to the authorities on the 19-Dec-2007.
The fuel system was modified in a way so that in a ground test either a continuous air flow or a certain amount of air at once can be introduced into the fuel system. With the available air flow measuring device a maximum air flow of 870 ml/min could be introduced into the fuel system. The engine kept running smoothly and the ECU data did not show any affect to the engine parameter. It also could be shown that the maximum amount of air introduced at once that does not force the engine to shut down is 110 ml.
In a flight test it could be shown that an amount of 250 ml air that is introduced at once into the fuel system leads to a power loss down to 3% for about 2 seconds. Due to wind milling the engine restarts and recovers after some seconds of power fluctuation.

- Ground test, conducted by Eric Bollen (TAE) and Johannes Huemer (DAI), 15-Feb-2008 in Wiener Neustadt

Aircraft: DA40D
OY-RBB
S/N D4.211

Equipment: air flow regulator GFC 17, Analyt MTC

The following could be shown:

- An airflow of 2000 ml/min air that is introduced into the fuel system had no noticeable affect to the running engine. The fuel flow at 100% power was measured with 2550 ml/min in a former ground test.
- When a valve that is mounted to the inlet of the fuel filter bowl is opened and air is sucked in, the rail pressure in the ECU chart does not decrease abruptly.
- Switching the rail pressure valve into opened position by interrupting the electric circuit the rail pressure in the ECU chart falls to a value that is identical to the rail pressure that was maintained after the engine shut down of the OY-RBB in Denmark on the 7-Jun-2007.
- When air is injected into the fuel system the display of the rail pressure in the ECU chart depends on the sample rate of the recording.

The results of this ground test and comparisons with similar incidents are summarized on the pages 3 - 12.

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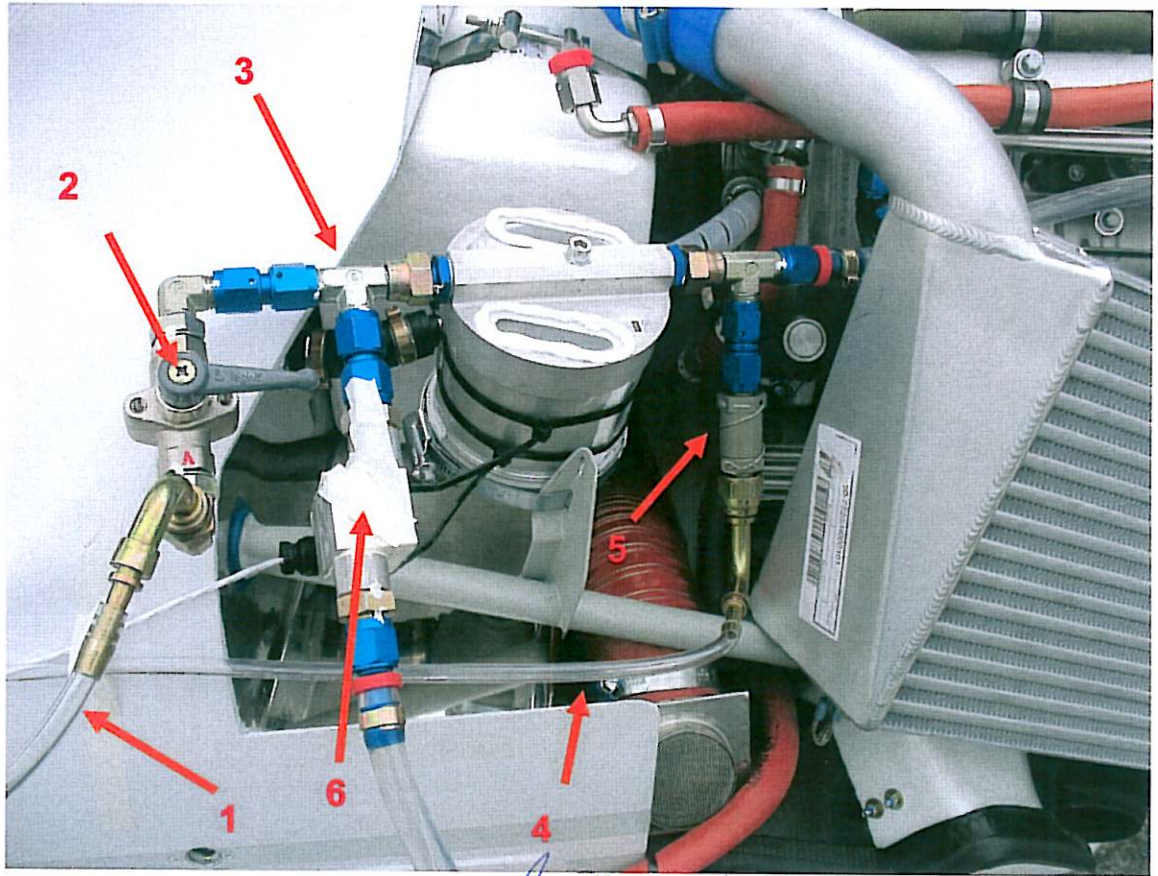
This picture shows the test arrangement. Through the tube (1) a continuous air flow can be introduced which is provided by an air flow regulator that is connected to pressurized air.

For one test the tube (1) was taken off and the shut off valve (2) was opened to simulate a loose fuel inlet fitting (3).

The tube (4) was used to introduce a certain amount of air at once into the fuel system. Part (5) is a check valve. Part (6) is a fuel flow measurement device which was not used during this test.



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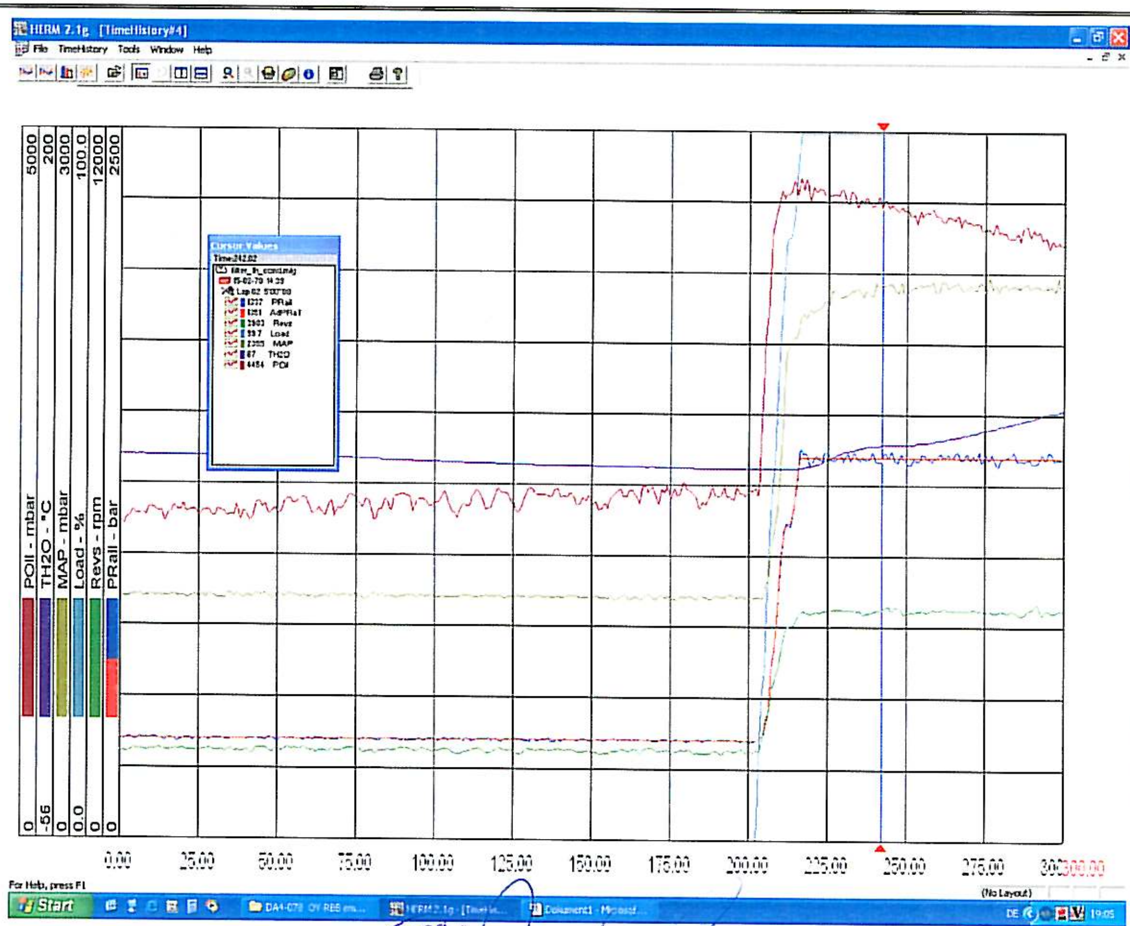
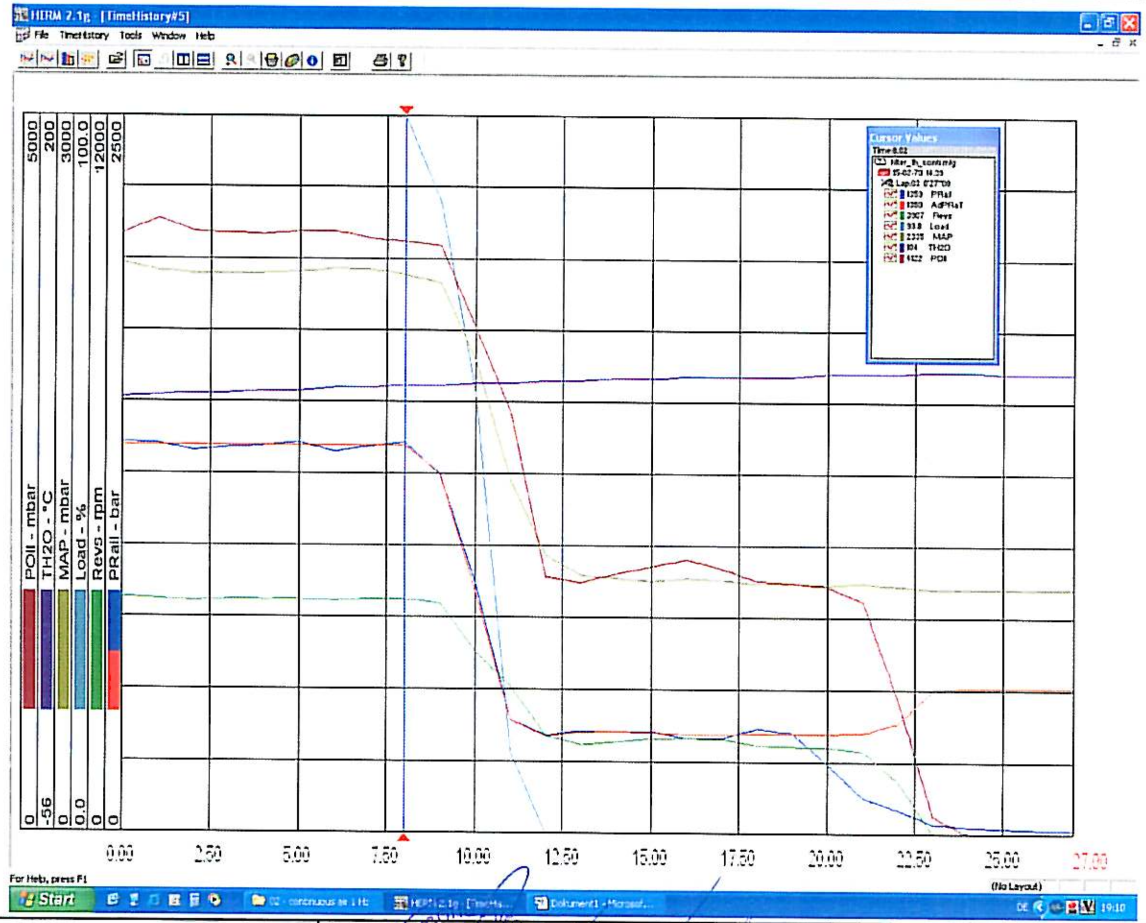
This chart shows a continuous introduction of air during a ground test. The airflow was started with 600 ml/min at about second 250 and was raised continuously. The coolant temperature rose quickly due to the lack of cooling air during the ground test. This chart is continued on the next page.

(02 - continuous air 1 Hz / luft-v-filter-1h-conti - lap 2)



Due to overheat the power had to be reduced after 60 sec. By then the air flow has been raised continuously up to about 2000 ml/min. The air did not show any noticeable influence on the engine. The rail pressure was recorded with a sample rate of 1Hz.

(02 - continuous air 1 Hz / luft-v-filter-1h-conti - lap 3)



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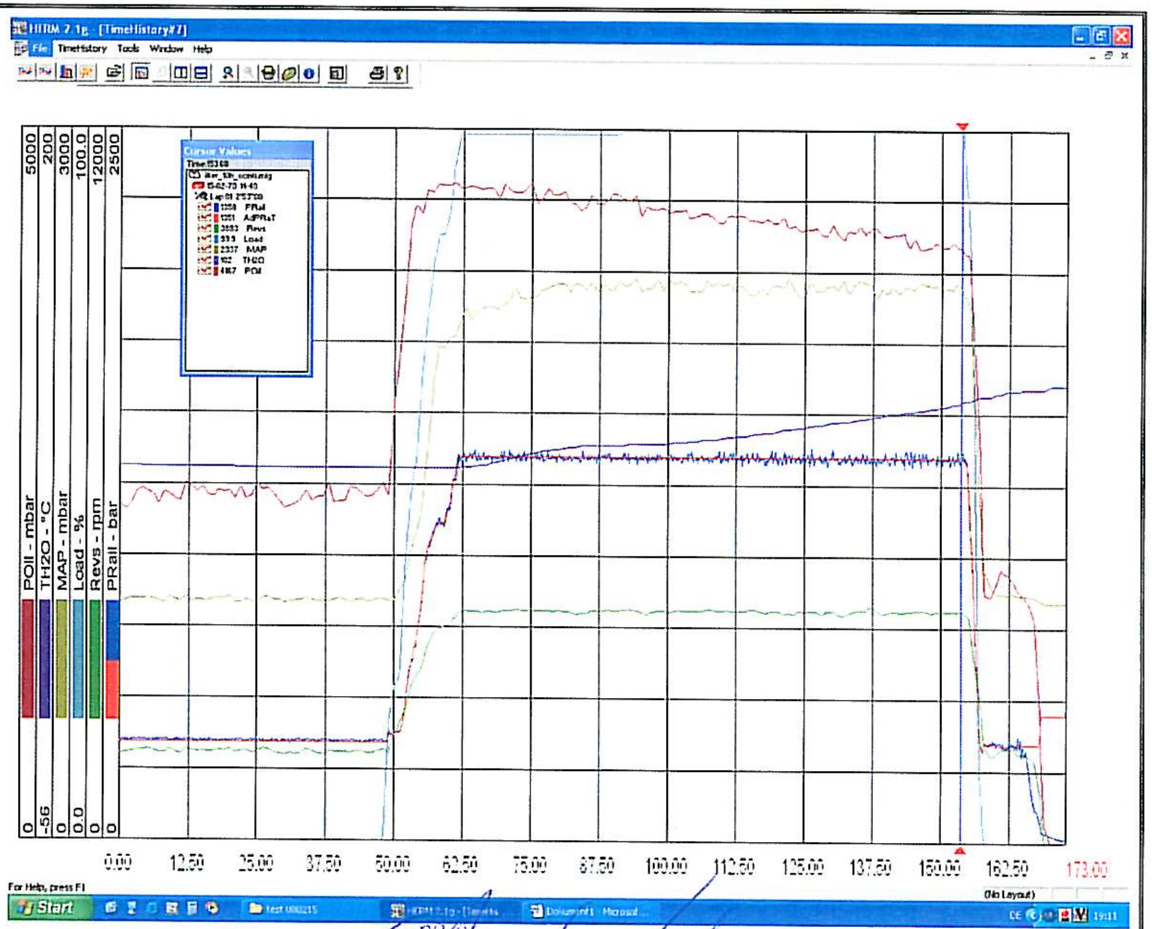
This ground test was repeated with a recording sample rate of 10 Hz. The airflow was started at about second 75 again with 600 ml/min air and was raised continuously up to 2000 ml/min air at about second 150 when the power had to be reduced due to high temperature. The engine did not show any influence.

(03 - continuous air 10 Hz / luft-v-filter-10h-conti - lap 1)



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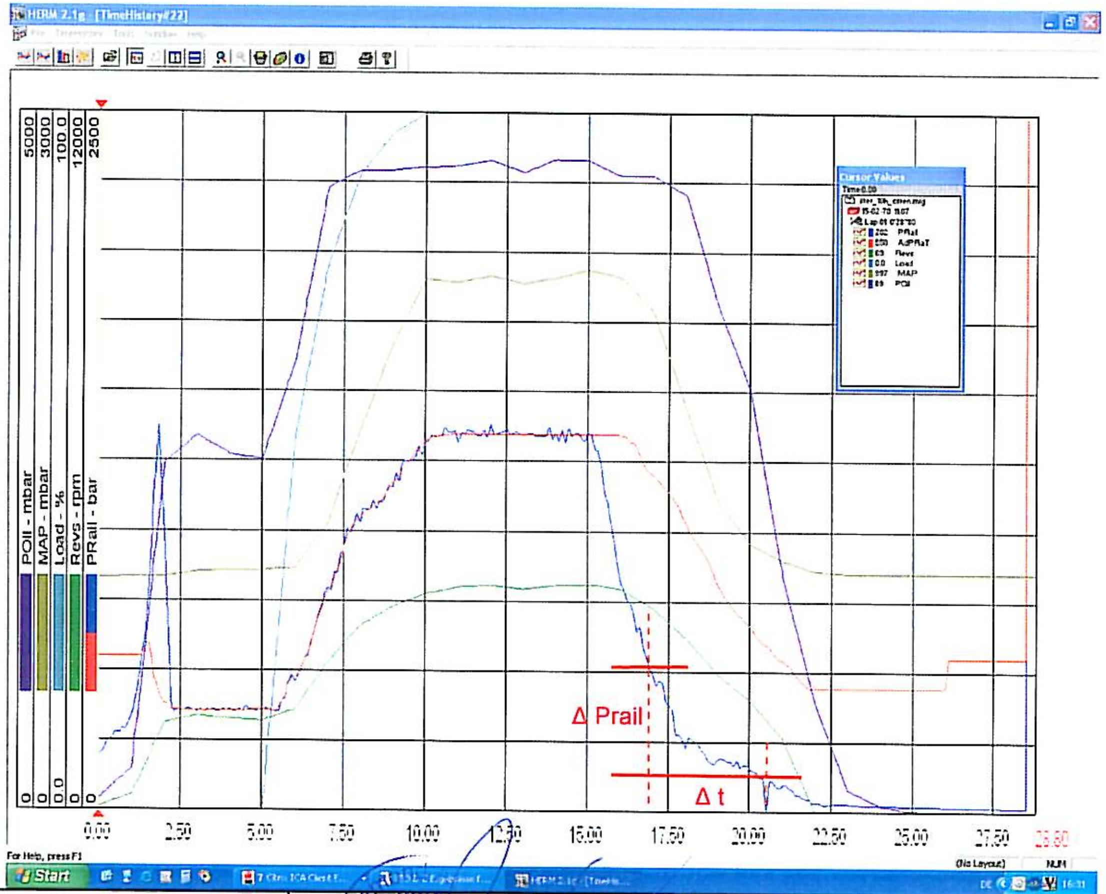
For the next ground test the tube (1) on the picture on page 3 was taken off. At full power the shut off valve (2) was opened to simulate the behaviour of the engine when the fuel fitting on the inlet side of the fuel filter bowl gets loose and falls off.

To compare the behaviour of the drop of the rail pressure of this situation with the engine failure of the OY-RBB, the same range of rail pressure drop (ΔPrail) that occurs at the moment of the engine shut down of the OY-RBB (next page) is marked in the ECU chart of this page.

The valve was opened at second 15. The ECU chart shows that the rail pressure reaches ~ 520 bar at second 16.50 and continues decreasing within 3,5 seconds down to 140 bar at second ~ 20.50.

The rail pressure was recorded with a sample rate of 10 Hz.

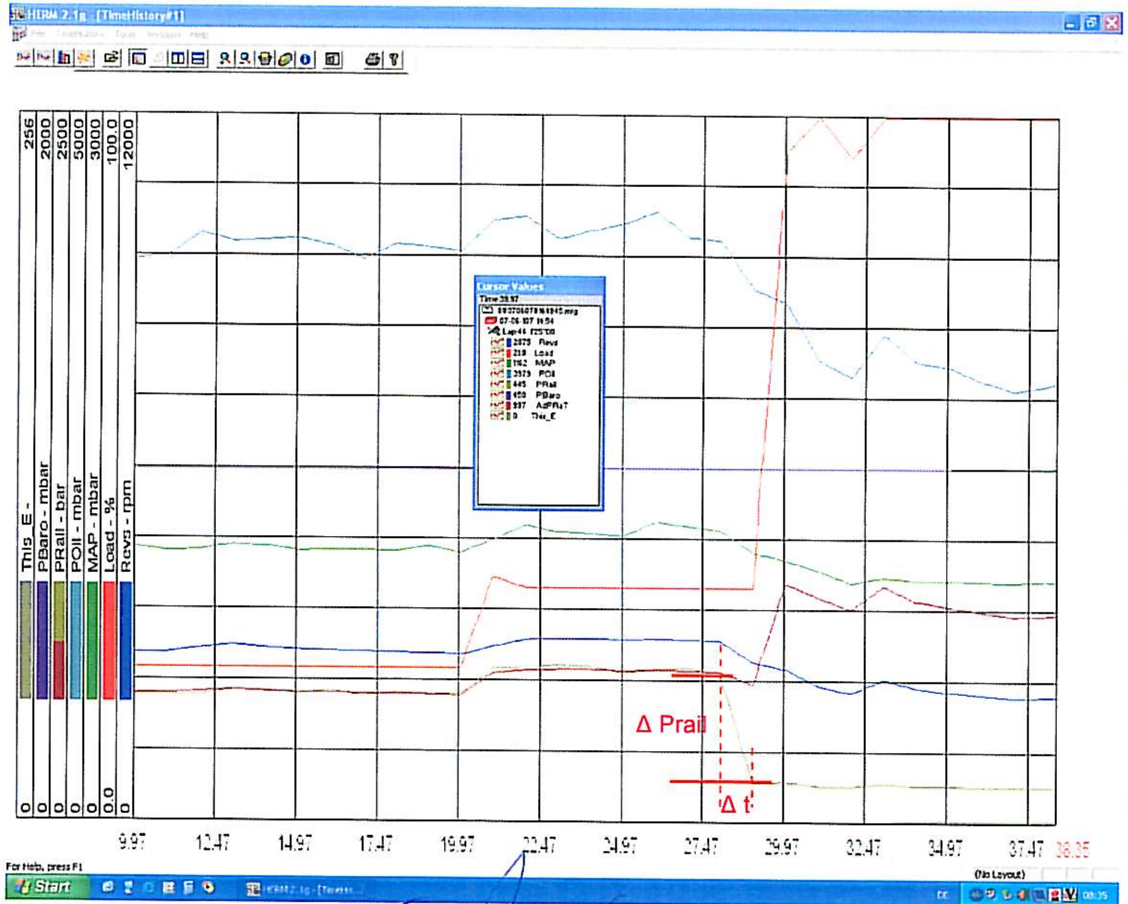
(01 - shut off valve opened - 10 Hz / luft-v-filter-10h-offen - lap 1)



When the engine failed on the OY-RBB on the 7-Jun-2007 the rail pressure fell from 520 bar to 140 bar within one second. A rail pressure of 140 bar was maintained due to wind milling.

The time period Δt of the drop of the rail pressure at the moment of the engine shut down of the OY-RBB is much shorter than the Δt that results from an open fuel filter inlet fitting.

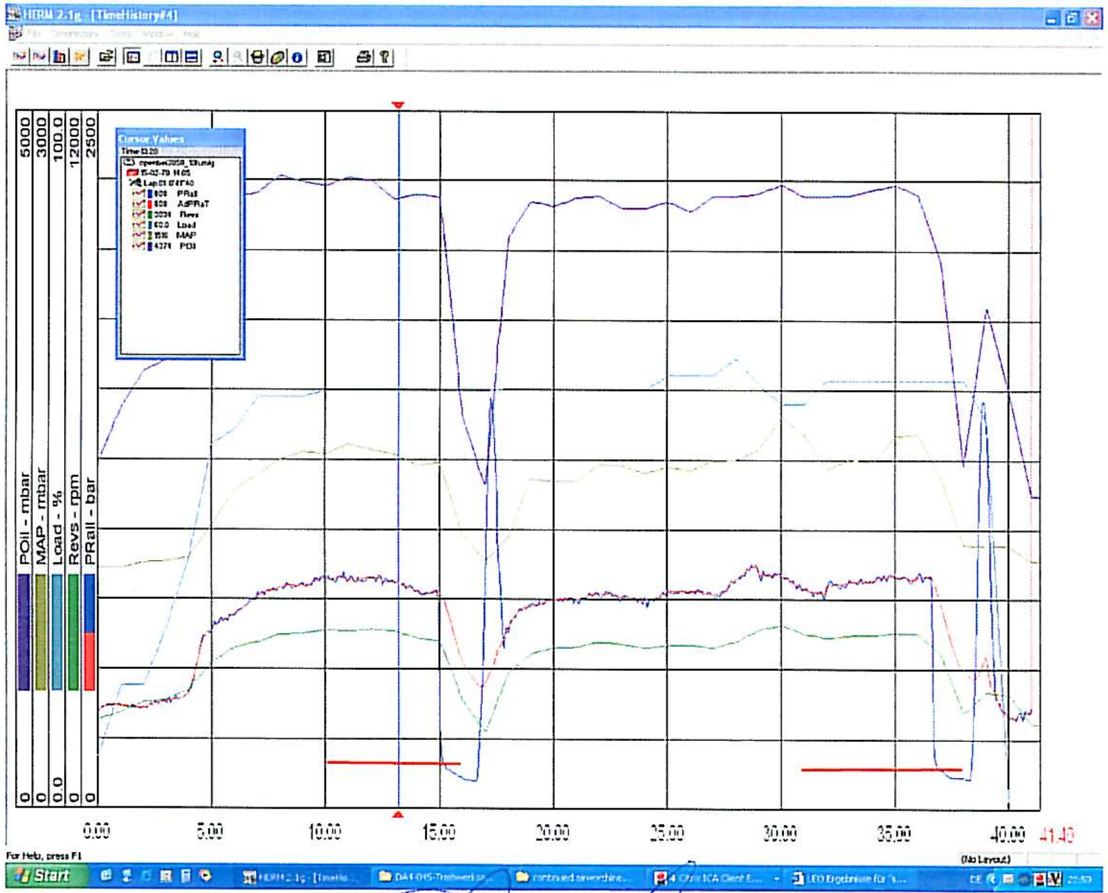
The rail pressure was recorded with a sample rate of 1 Hz.



The ECU chart of this ground test shows what happens when the rail pressure valve is opened at about 3000 rpm. This situation is quite similar to the one as it was shortly before the engine shut down of the OY-RBB. The electric circuit of the rail pressure valve was interrupted at seconds 15.00 and 36.50 and the rail pressure fell abruptly down to about 140 bar as it already could be seen in the incident of the OY-RBB in Denmark.

In this case the rail pressure continues decreasing proportionally to the RPM. Shortly prior to the engine shut down the rail pressure valve was connected again.

In case of wind milling the 140 bar would have been maintained. The recording sample rate was 10Hz.




(11 - railvalve opened at 3050rpm - 10 Hz / railv_openbei3050_10h - Lap 1)

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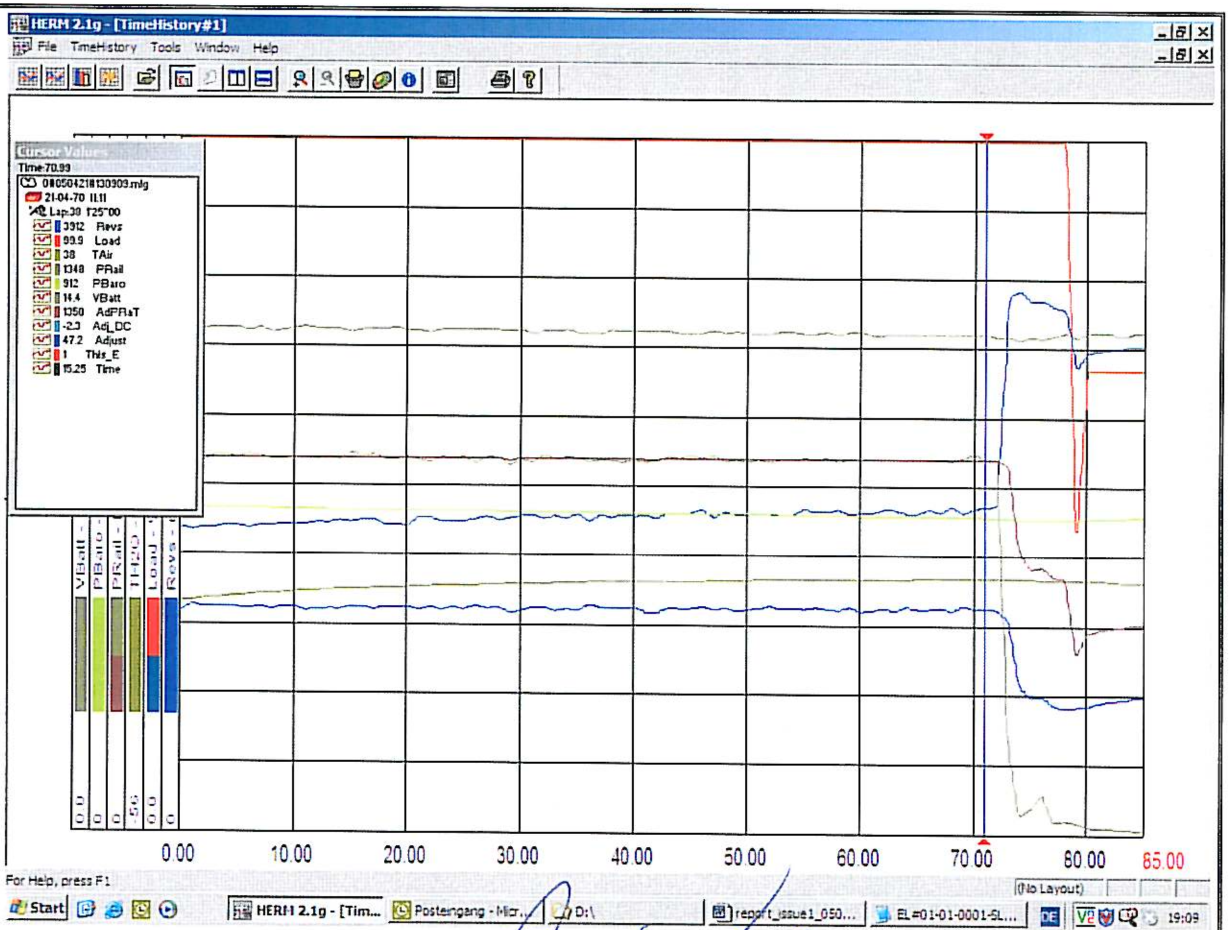
The ECU chart (sample rate 1 Hz) of this page shows the drop of the rail pressure of the OE-KWL which was caused by a loose fuel fitting on the engine. Although the propeller continued wind milling the rail pressure drops to zero without maintaining the 140 bar because of the feed pump sucking air and not being able to be supplied with fuel anymore. Therefore the rail pressure of about 140 bar could not be maintained.

Comparing the drop of the rail pressure of this ECU chart with the ECU chart on page 7 it can be seen that due to an open fuel fitting on the engine the rail pressure drops more abruptly. The fuel filter works as a damper. In case of an open fuel filter inlet fitting the remaining fuel in the filter bowl mixes with air. Because the engine can cope with a high percentage of air in the fuel the decrease of the rail pressure in case of an open fuel filter inlet fitting occurs slower than it decreases in case of an open fuel fitting on the engine.




| | | | STAMP / DATE / SIGN<br>B. Kremnitzer<br>Chief, Office of Airworthiness | page 10 / 19 |
|---|---|---|---|---|

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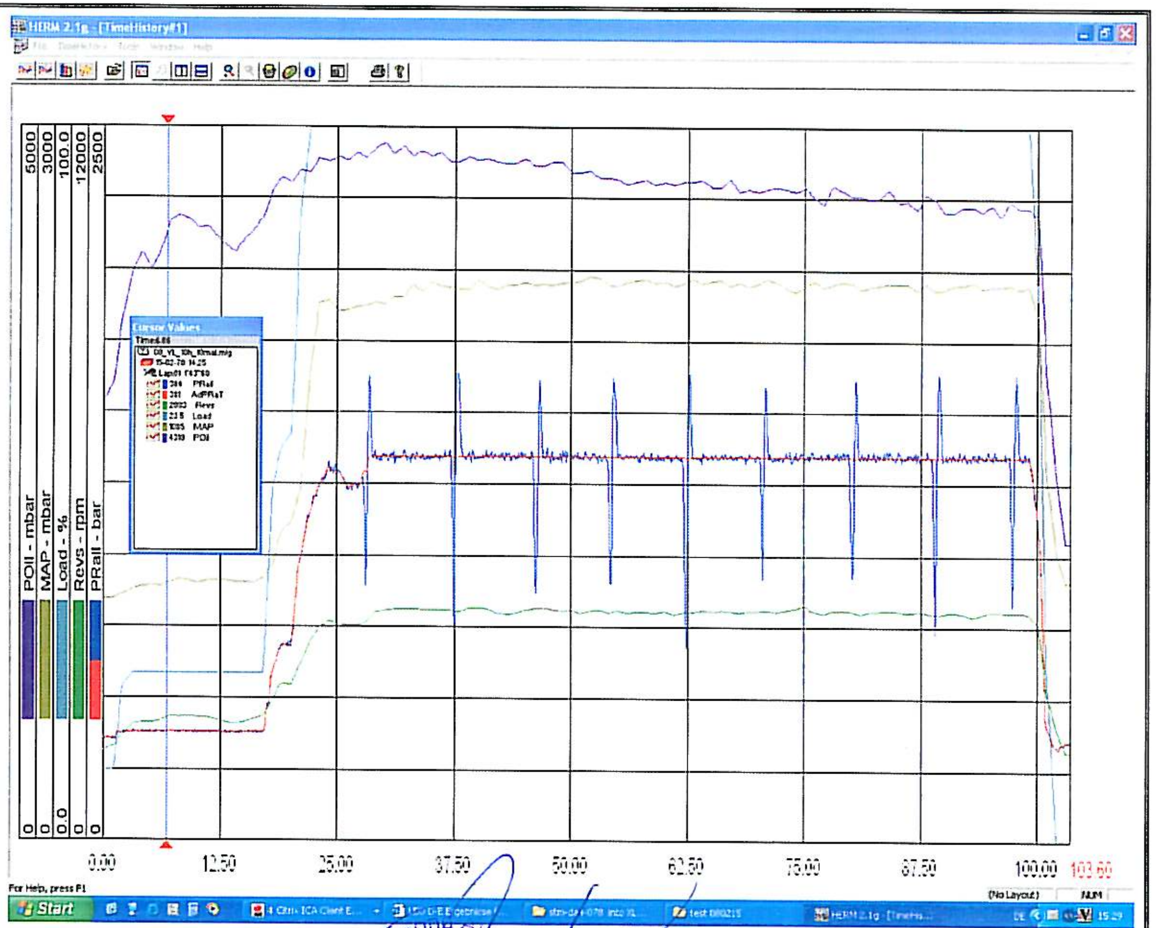
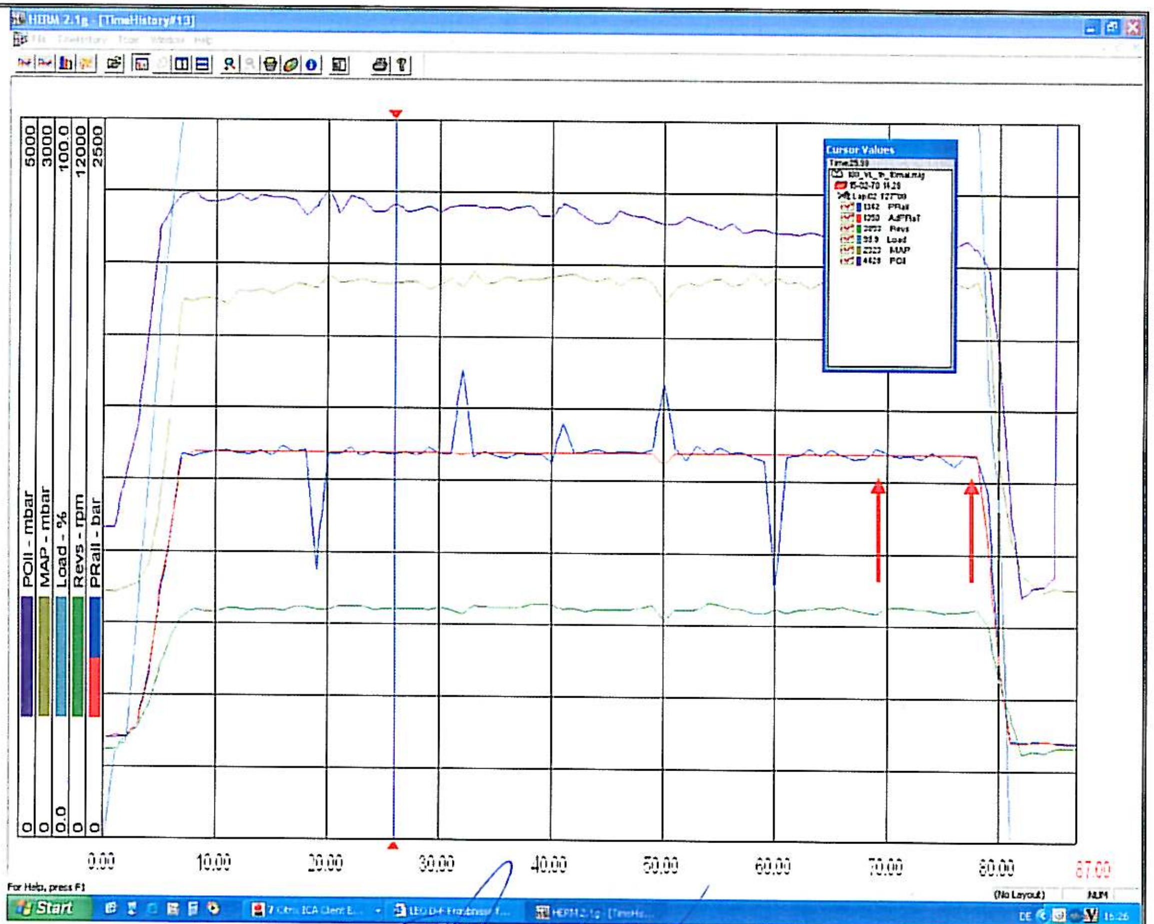
This ECU chart shows several air injections of 50 ml at once during a ground test. The rail pressure was recorded with a sample rate of 10 Hz. The air bubble causes a decrease in the rail pressure. The FADEC tries to balance the drop of the rail pressure which results in a positive peak. For each of the nine injections the charts look equal.

(05 - 9 injections of 50 ml air - 10 Hz / luft-z-FuM100-VL-10h-10mal - Lap 1)



The same injections of air look differently when the recording sample rate of the rail pressure is changed to 1 Hz. In this case either the drop in the rail pressure is recorded or the balancing positive peak is recorded. Sometimes the recording points miss the negative and following positive peak at all, as it is marked by the two red arrows.

(04 - 7 injections of 50 ml air - 1 Hz / luft-z-FuM100-VL-1h-10mal-Lap 1)

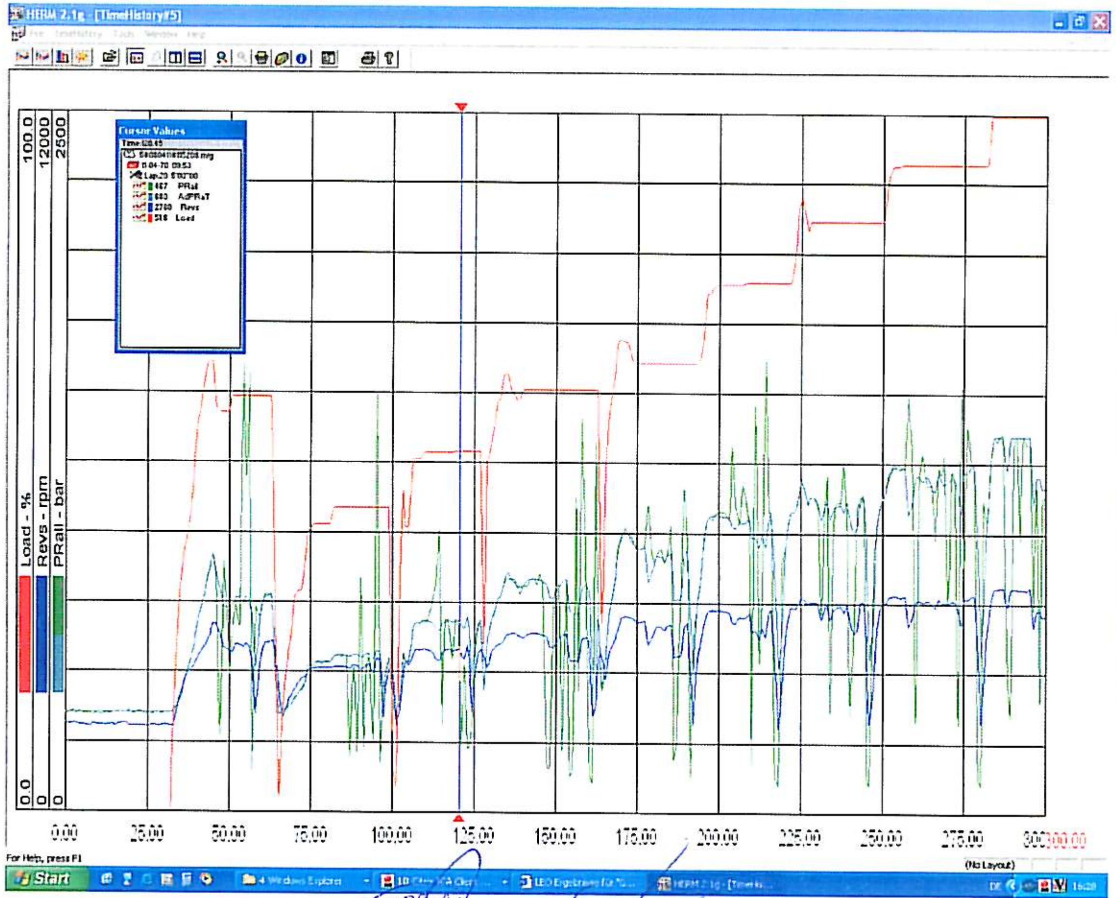


- Ground test, conducted by Johannes Huemer (DAI) and Christian Pieler (DAI-M) , 11-Apr-2008 in Wiener Neustadt

  Aircraft: DA40D - OY-RBB - S/N D4.211

This ground test was performed to show the behaviour of the rail pressure when the rail pressure valve suffers an electrical defect. For that purpose an additional cable with a switch was added between the loom and the rail pressure valve. The results of this ground test and comparisons with similar incidents are summarized on the pages 13 - 16.

This picture shows the behaviour of the rail pressure at different power settings. After having adjusted a certain power setting the electrical circuit of the rail pressure valve was interrupted every 2 - 3 seconds for a few tenth of a second. Each peak or rather each combination of a positive and a negative peak represents an interruption of the electrical circuit.



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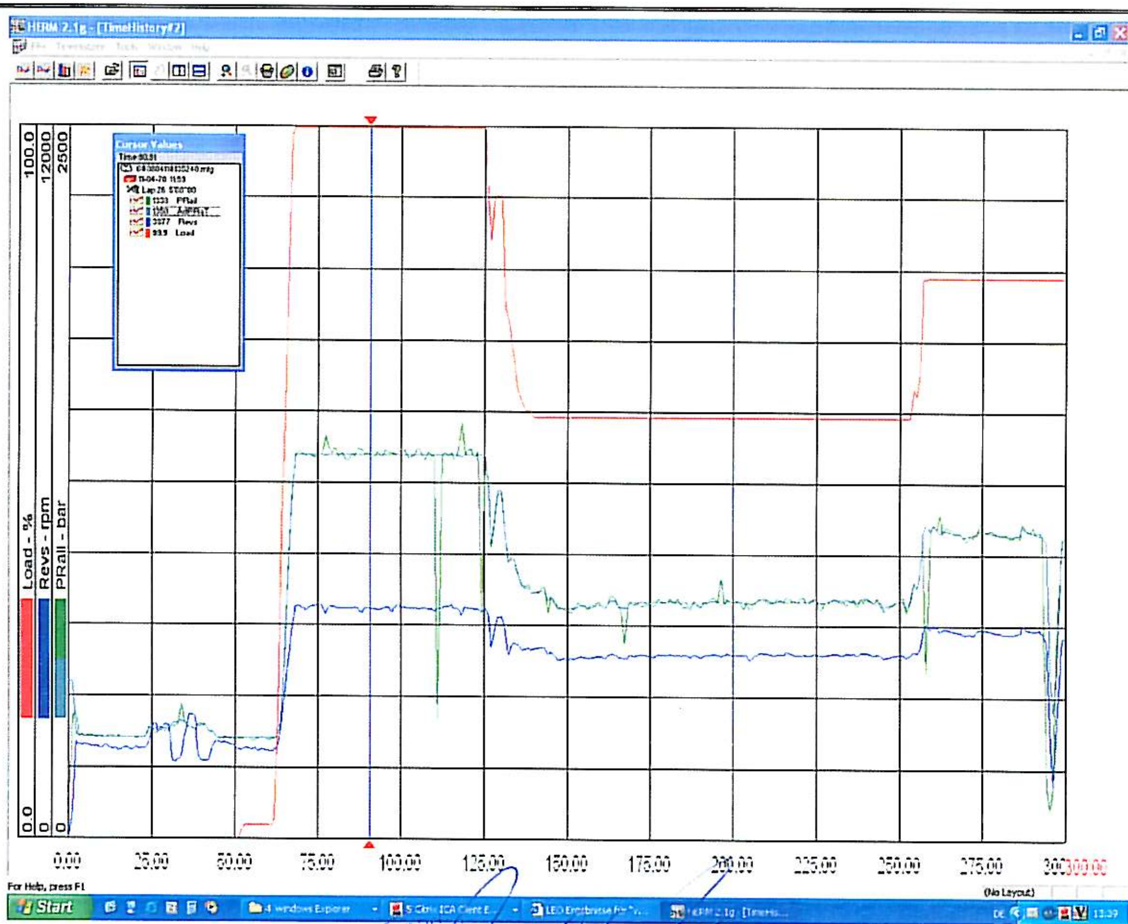
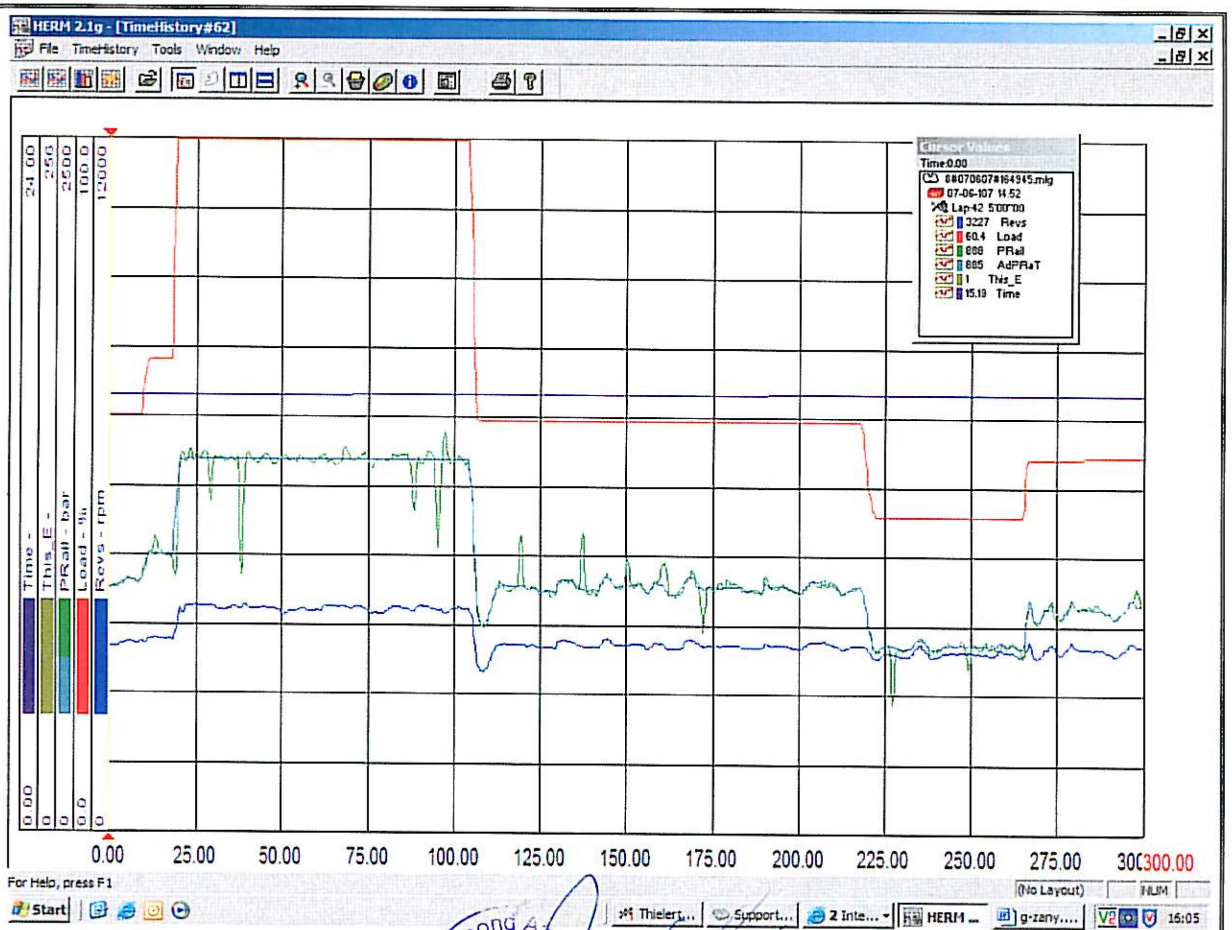
This ground test was repeated choosing a power setting that was similar to the one which is shown on the next page, which is about 10 minutes prior to the engine shut down of the OY-RBB. The additionally installed cable was used to produce electrical interruptions approximately every 10 seconds. It could be noticed the each interruption of the electrical circuit was followed by a shudder of the engine. The intensity of the shudders was dependent on the duration of the electrical interruption. Very short interruptions resulted in shudders which were hardly noticeable. The ECU chart shows negative and positive peak in the rail pressure.

As it was described above it is not possible to record each electrical interruption due to the low recording sample rate of 1 Hz.



This chart shows Lap 42 of the ECU data of the OY-RBB, about 10 minutes prior to the engine shut down on 7-June-2008.



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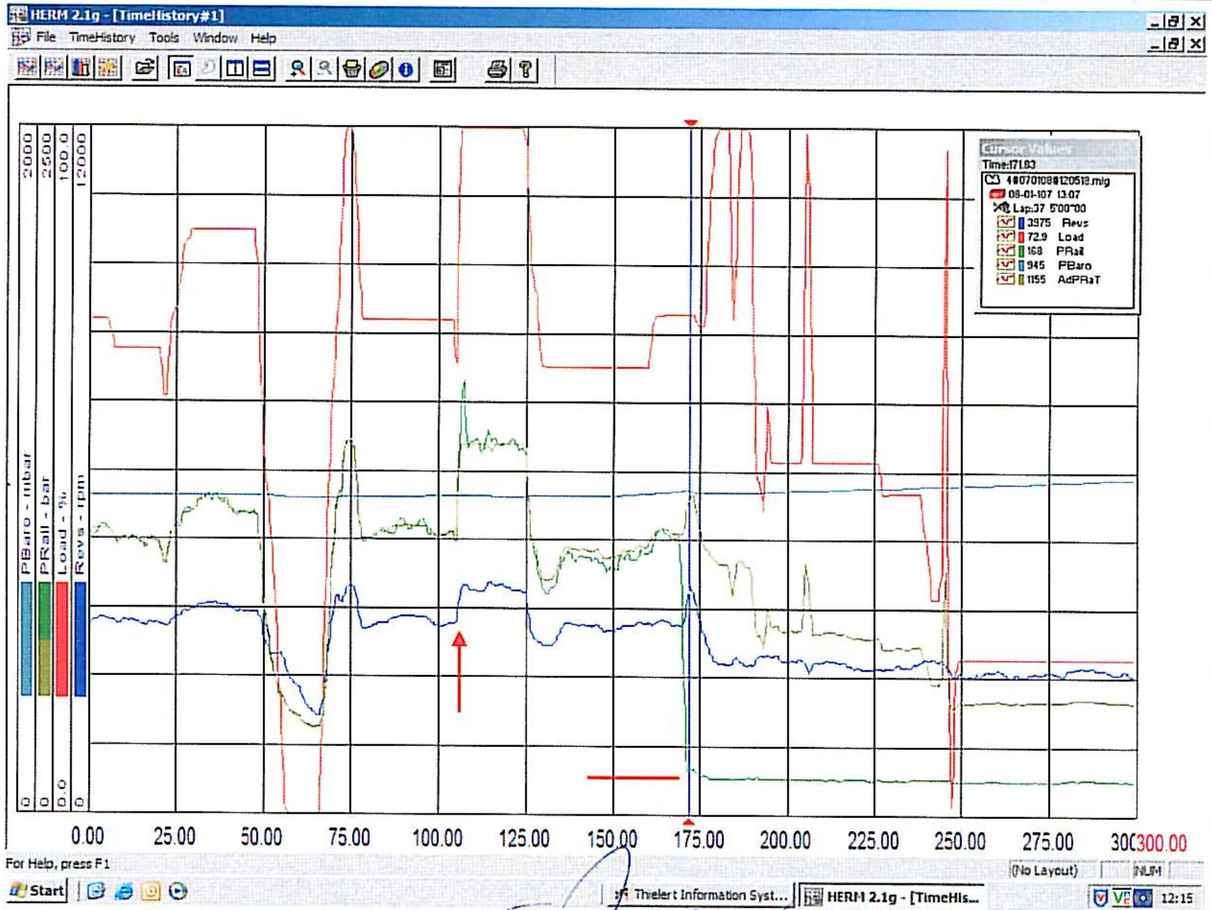
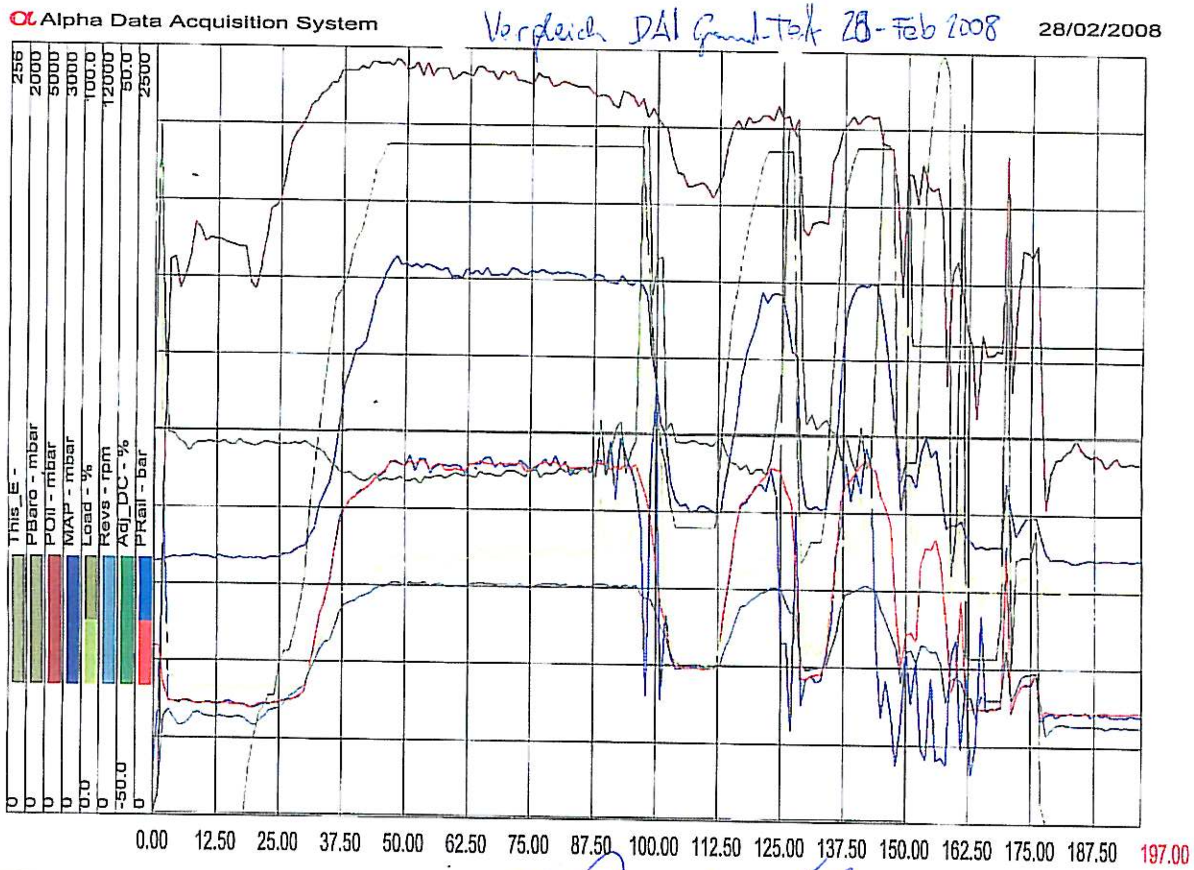
The chart which is shown on this page shows the engine shut down of the G-ZANY. The pilot of the G-ZANY reported two engine shudders shortly before the engine shut down. When the engine failed the rail pressure dropped to about 140 bar and was maintained due to wind milling.

The red arrow shows a fluctuation of the rail pressure which might be one of the reported engine shudders.



The ECU chart on this page was recorded during a separate ground run conducted on the 28-Feb-2008 and was added to this report for comparison reasons. It shows the behaviour of the engine when the fuel fitting at the fuel filter outlet fitting is opened very slowly. Air is sucked by the feed pump and the rail pressure starts fluctuating. Secondary it can be seen that when reducing the load (at second 112 and 187) the engine parameters return to standard conditions. With higher load the rail pressure starts fluctuating again.



Conclusions:

- On pages 4 - 6 it is described that the introduction of a continuous air flow of 2000 ml/min does not influence the engine. In a pressure loss test, conducted on 6-Aug-2008, it was shown, that the fuel system of the OY-RBB was leak proof. The fuel line connection between the main tank and the fuselage was opened after the incident. It is assumed that a leakage in this area which allows air to enter the fuel system so that the engine shuts down, which means with a rate of more than 2000 ml/min would have been noticed on ground due to a fuel leakage. According to the investigation report of the Danish AAIB no loose fuel fittings were found. Therefore it can be assumed that a leakage in the fuel system was not the cause of the rail pressure fluctuations or the engine shut down of the OY-RBB.

- The ECU chart on page 17 shows the consequences of a slightly opened fuel fitting on the engine which is a wildly fluctuating rail pressure. This behaviour could not be observed in the ECU charts of the G-ZANY and the OY-RBB. Therefore it can be assumed that a slightly opened fuel fitting was not the cause of the two occurrences.

- After the engine failures of the G-ZANY (page 16) and OY-RBB (page 8) the rail pressure dropped to about 140 bar which was maintained due to wind milling. Open fuel fittings cause the rail pressure to drop to zero as it is shown on page 7 and page 10. Therefore it can be assumed that fuel starvation either due to dry flown tanks or due to an open fuel fitting is not the cause of these incidents.

- The display of single positive or single negative rail pressure peaks is the result of the low recording frequency of 1 Hz. Recordings with a rate of 10 Hz (page 11) show that each drop of the rail pressure which is caused by an injection of air is followed by a positive peak which is the consequence of the attempt of the FADEC to balance the rail pressure.
  After the recording sample rate had been changed back to 1 Hz, the same injections of air displayed only the positive peak or the negative peak or even no peak (page 12). Therefore it can be assumed that each single peak represents a drop of the rail pressure which is overshot by a positive peak.

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- During a ground test, which is described on page 13 and page 14, the electrical circuit of the rail pressure valve was interrupted for a short moment. The fluctuations of the rail pressure show the same characteristics as the rail pressure fluctuations caused by an injection of a certain amount of air. Therefore it can be assumed that a short drop of the rail pressure which was not controlled by the FADEC, independently of its cause, results in an overshooting of the rail pressure.

- The ECU chart on page 9 shows that an interruption of the electrical circuit of the rail pressure valve causes the rail pressure to drop to about 140 bar. In a wind milling situation the 140 bar would be maintained as it occurred after the engine failures of the G-ZANY and the OY-RBB. Therefore it can be assumed that both incidents might have been caused by an electrical failure of the rail pressure valve.

- The pilots of the G-ZANY reported that prior to the engine failure the engine shuddered two times. During the ground tests the engine shuddered after each interruption of the electrical circuit of the rail pressure valve. The ECU charts on page 14 and page 15 show that the rail pressure peaks caused by the interruption of the electrical circuit look very similar to the rail pressure peaks that occurred prior to the engine shut down of the OY- RBB. Therefore it can be assumed that the rail pressure fluctuations in both incidents, the G-ZANY and the OY-RBB, might have been caused by a related electrical defect that also caused the final engine shut down.

| | | | | |
|---|---|---|---|---|
| | | | Diamond Office of Airworthiness EASA.21J.052 DOA-05 R. Kremnitzer 1 5. JULI 2009 STAMP / DATE / SIGN Chief, Office of Airworthiness |  |

# Appendix No 5:

# Supplement to Occurrence Report No. 02.

**The appendix consists of 13 pages.**

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| AIRPLANE | |
|---|---|
| Type: | DA 40 D |
| Serial No.: | D4.211 |
| Call Sign: | OY-RBB |
| Operator: | Copenhagen A & M |
| TSN: | 319:30 |
| **ENGINE 1** | |
| Type: | TAE 125-01 |
| Serial No.: | n. k. |
| TSN / TSO: | 319:30 |
| **ENGINE 2** | |
| Type: | n. a. |
| Serial No.: | n. a. |
| TSN / TSO: | n. a. |
| **PROPELLER 1** | |
| Type: | MTV-6-A/187-129 |
| Serial No.: | n. k. |
| TSN / TSO: | n. k. |
| **PROPELLER 2** | |
| Type: | n. a. |
| Serial No.: | n. a. |
| TSN / TSO: | n. a. |
| **EQUIPMENT** | |
| Type: | n. a. |
| Serial No.: | n. a. |
| Type: | n. a. |
| Serial No.: | n. a. |

Occurrence: The aircraft's engine lost power and the pilot was forced to land in a cornfield.

Date & location of occurrenc: 7-Jun-2007 / Roskilde, Denmark

## Flight test report

Pilot: Fritz Lehner
2nd crew: Johannes Huemer
Aircraft: DA40D
S/N: D4.211
Call Sign: OY-RBB
Date: 22-Aug-2008
Time: 17:14 - 18:12
Fuel: 3 gal LH, 6 gal RH
Location: LOAN

Subject & Reason:

The flight test was conducted to show the behaviour of the engine in case of excessive slipping and in the moment of the depletion of the main tank. In both cases air enters the fuel system through the fuel extraction point in the main tank and causes the engine to lose power. Air in the fuel system was suspected to be the reason of the engine shut down of the OY-RBB.

Preparation:

Prior to the flight the main tank was completely drained. Then fuel in portions of 1/16 US gallons was added to the tank. The first green fuel indication lit up when 1 and 6/16 US gallons of fuel were filled into the main tank. After 3 US gallons of fuel the 5$^{th}$ green fuel indication light was lit. With this amount of fuel in the LH tank and about 6 US gallons in the RH tank the flight test was conducted.

All tests were conducted within the range of glide angle to the airfield.

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Conducted Tests

1) Slipping
2) Depletion of the main tank & operating the fuel transfer pump
3) Depletion of the main tank & switching the fuel selector valve to the RH tank
4) Depletion of the main tank & operating the fuel transfer pump - second test

1) Slipping:

The aircraft was flying with a power setting of 100% in 4000 ft. Slipping with full rudder to the right was performed. The fuel in the main tank flows in the direction of the wingtip. The engine can only use the fuel that is left in the fuel trap of the main tank.

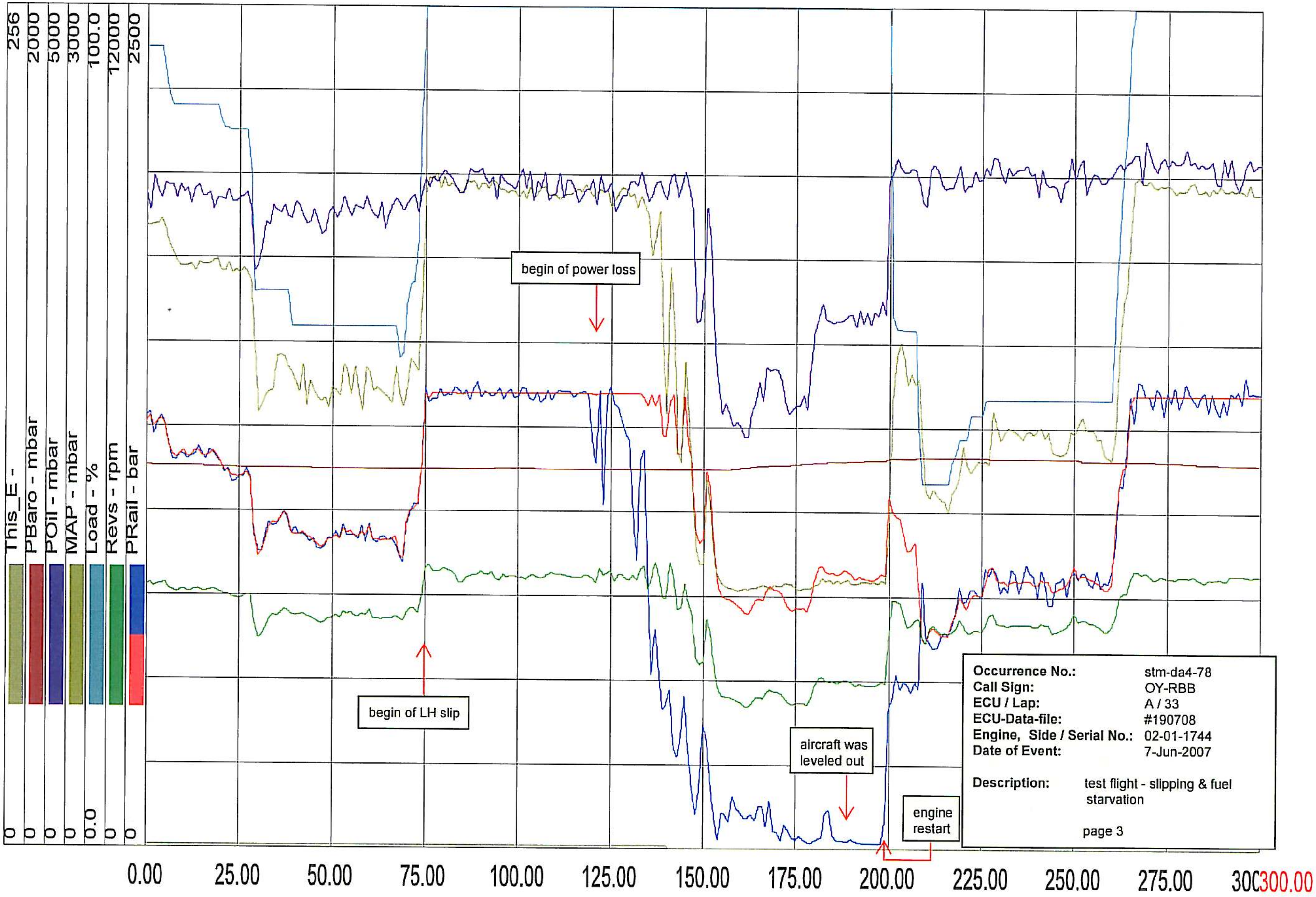
| | |
|---|---|
| 00:00 | slipping initiated |
| 00:47 | begin of power loss (indicated on the AED - Auxiliary Engine Display) |
| 01:54 | aircraft was levelled out |
| 02:03 | engine restarts |

47 seconds after slipping was initiated the load indication started to drop. The airspeed was reduced to about 75 kts. While decreasing the load indication was fluctuating in a range of 20%. After the load indication remained permanently below 5% the aircraft was levelled out 67 seconds after the begin of power loss.
9 seconds later the engine restarted by itself.

The following page shows the corresponding ECU chart.

Alpha Data Acquisition System

22/08/2008



2) Depletion of the main tank & operating the fuel transfer pump

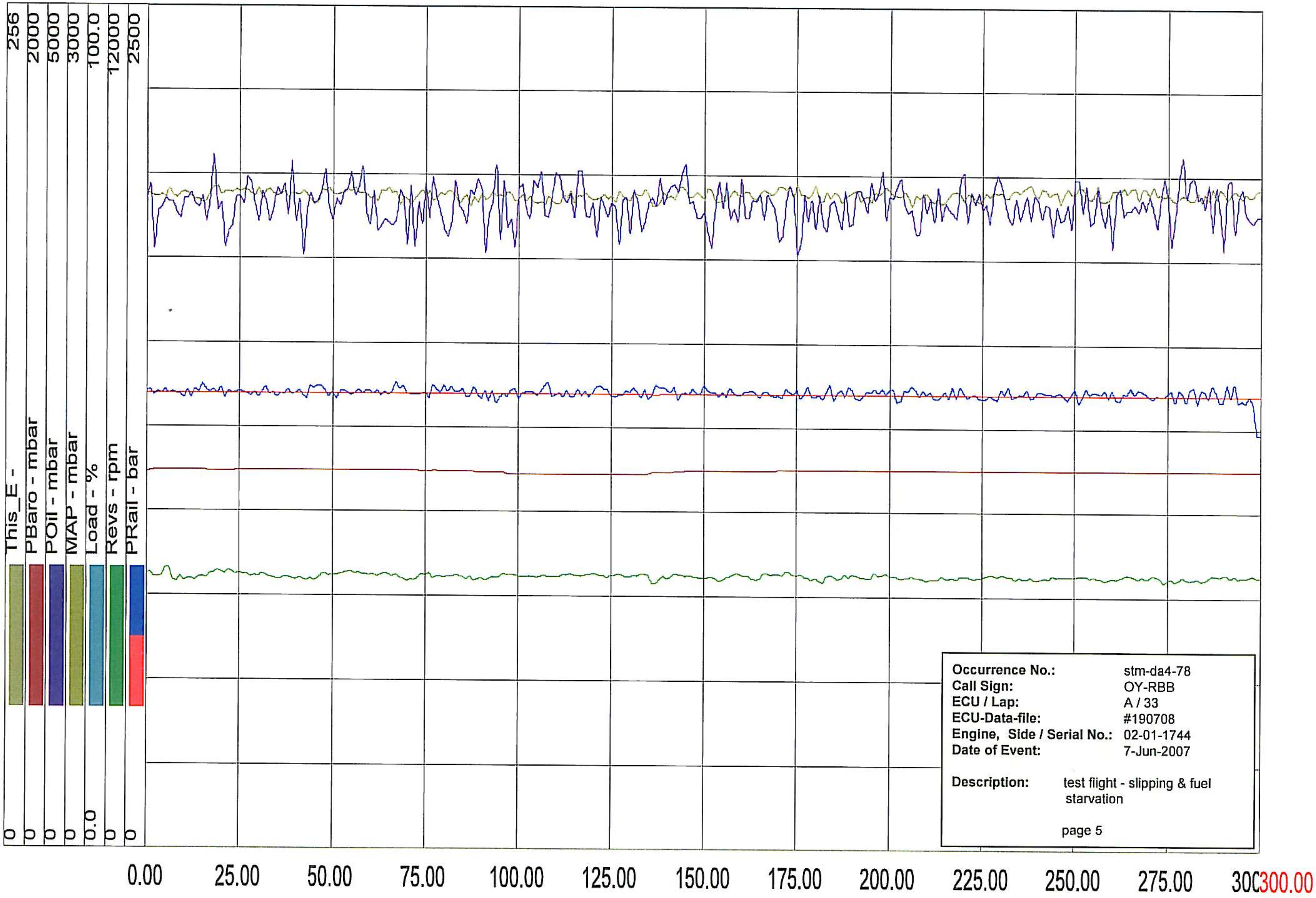
| | |
|---|---|
| 00:00 | begin of power loss (indicated on the AED) |
| 00:11 | power loss to 80% |
| 00:34 | power loss to 60% |
| 03:55 | engine quits (permanently below 5% load) |
| 04:10 | fuel transfer pump switched on |
| 04:22 | engine restarts |

The aircraft was flying in 4000ft with a power setting of 100% until the engine started to lose power due to the lack of fuel. The load indication was fluctuating within a range of about 20%.
11 seconds after the engine started to lose power the fluctuating load indication decreased to about 80%, 23 seconds later down to about 60%. The airspeed was reduced to 75 kts.
As the engine keeps wind milling it is difficult to say when the engine quit. Therefore the engine was considered to have quit when the load indication remained permanently below 5%. This happened 3:55 minutes after the engine started to lose power.
15 seconds later the fuel transfer pump was switched on in 2500ft. The engine restarted by itself 12 seconds later.

The following pages shows the corresponding ECU chart.

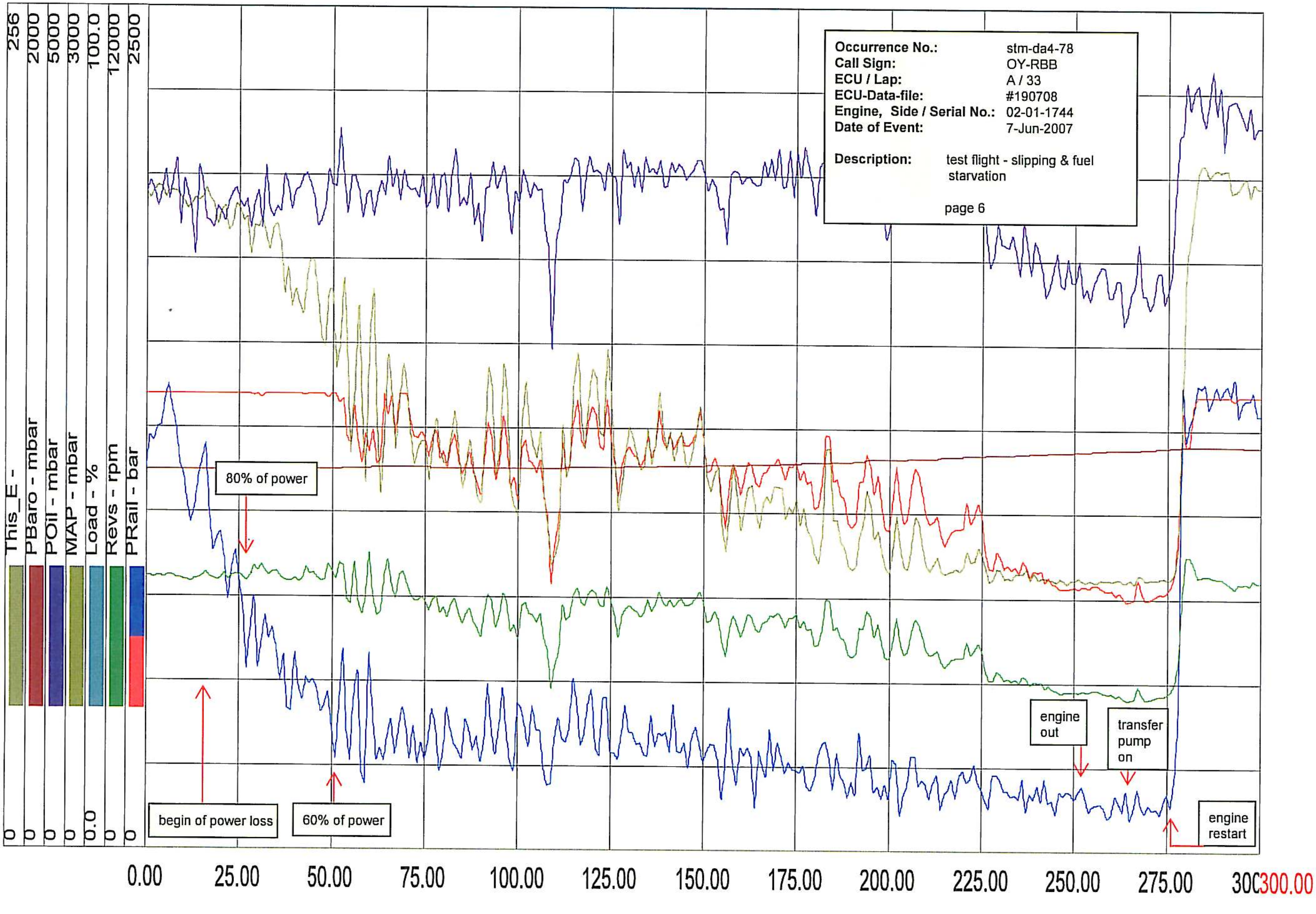
Alpha Data Acquisition System

22/08/2008



Alpha Data Acquisition System

22/08/2008

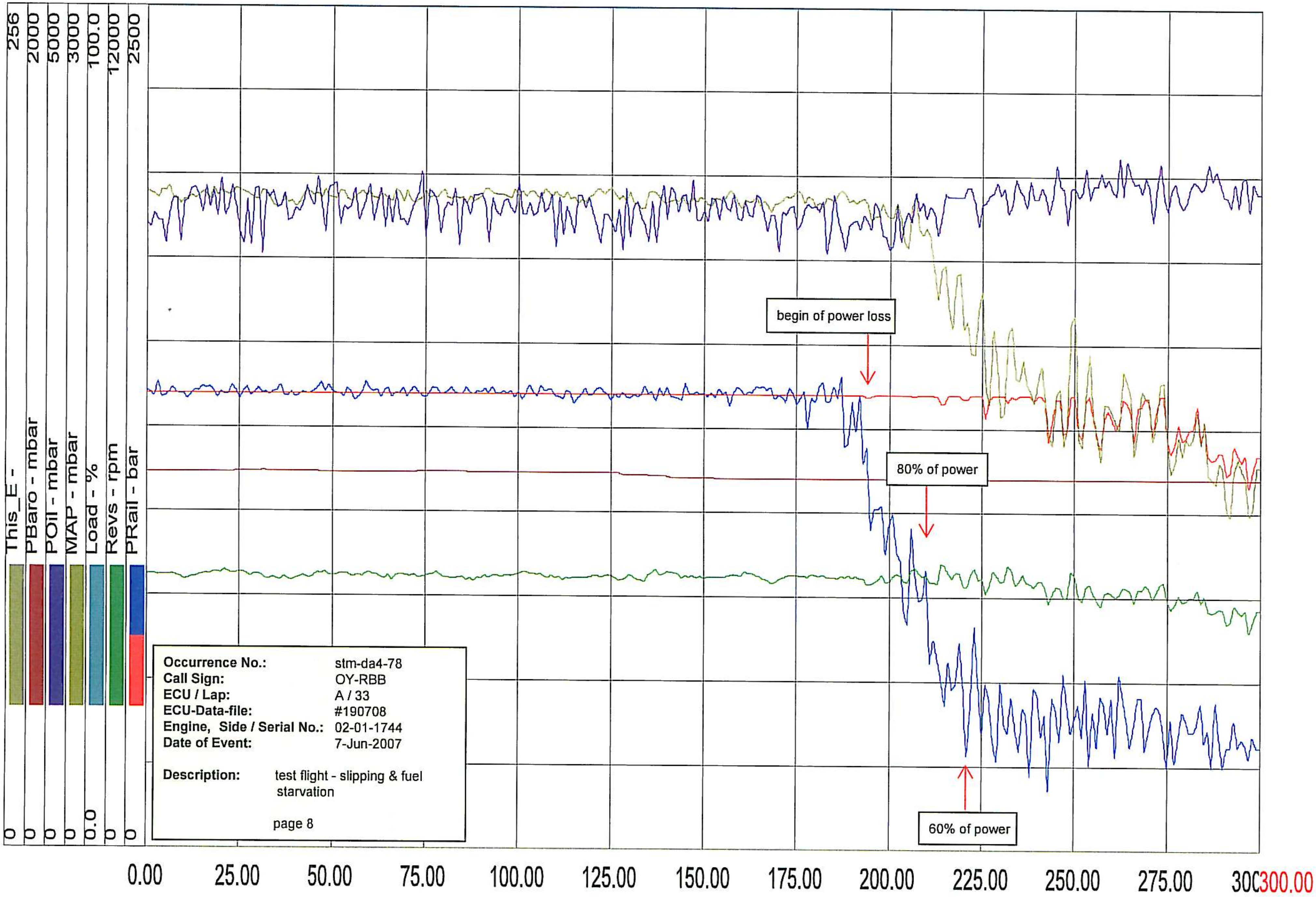


3) Depletion of the main tank & switching the fuel selector valve to the RH tank

| | |
|---|---|
| 00:00 | begin of power loss (indicated on the AED) |
| 00:15 | power loss to 80% |
| 00:27 | power loss to 60% |
| 04:48 | engine quits (permanently below 5% load) |
| 04:59 | fuel selector valve switched to the RH tank |
| 05:08 | engine restarts |

The aircraft was flying in 4500ft with a power setting of 100% until the engine started to lose power due to the lack of fuel. The load indication was fluctuating within a range of about 20%.
15 seconds after the engine started to lose power the fluctuating load indication decreased to about 80%, 12 seconds later down to about 60%. The airspeed was reduced to 75 kts.
4:48 minutes after the engine started to lose power the load indication remained permanently below 5 % and was considered to have quit. 11 seconds later the fuel selector valve was switched to the RH tank in 2600ft. The engine restarted by itself 9 seconds later.

The following pages show the corresponding ECU chart.




| | |
|---|---|
| **Occurrence No.:** | stm-da4-78 |
| **Call Sign:** | OY-RBB |
| **ECU / Lap:** | A / 33 |
| **ECU-Data-file:** | #190708 |
| **Engine, Side / Serial No.:** | 02-01-1744 |
| **Date of Event:** | 7-Jun-2007 |

**Description:** test flight - slipping & fuel starvation

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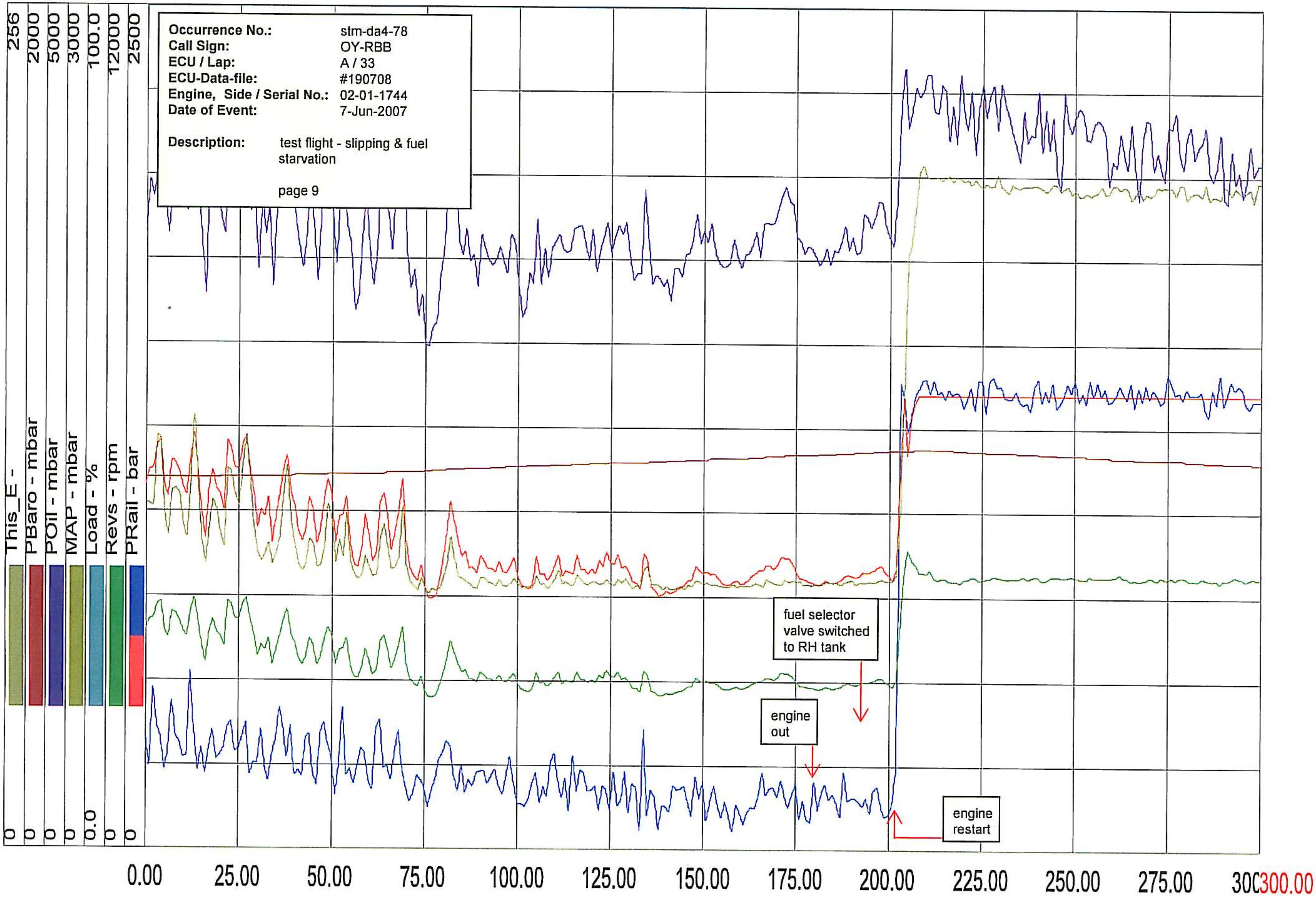
α Alpha Data Acquisition System 22/08/2008



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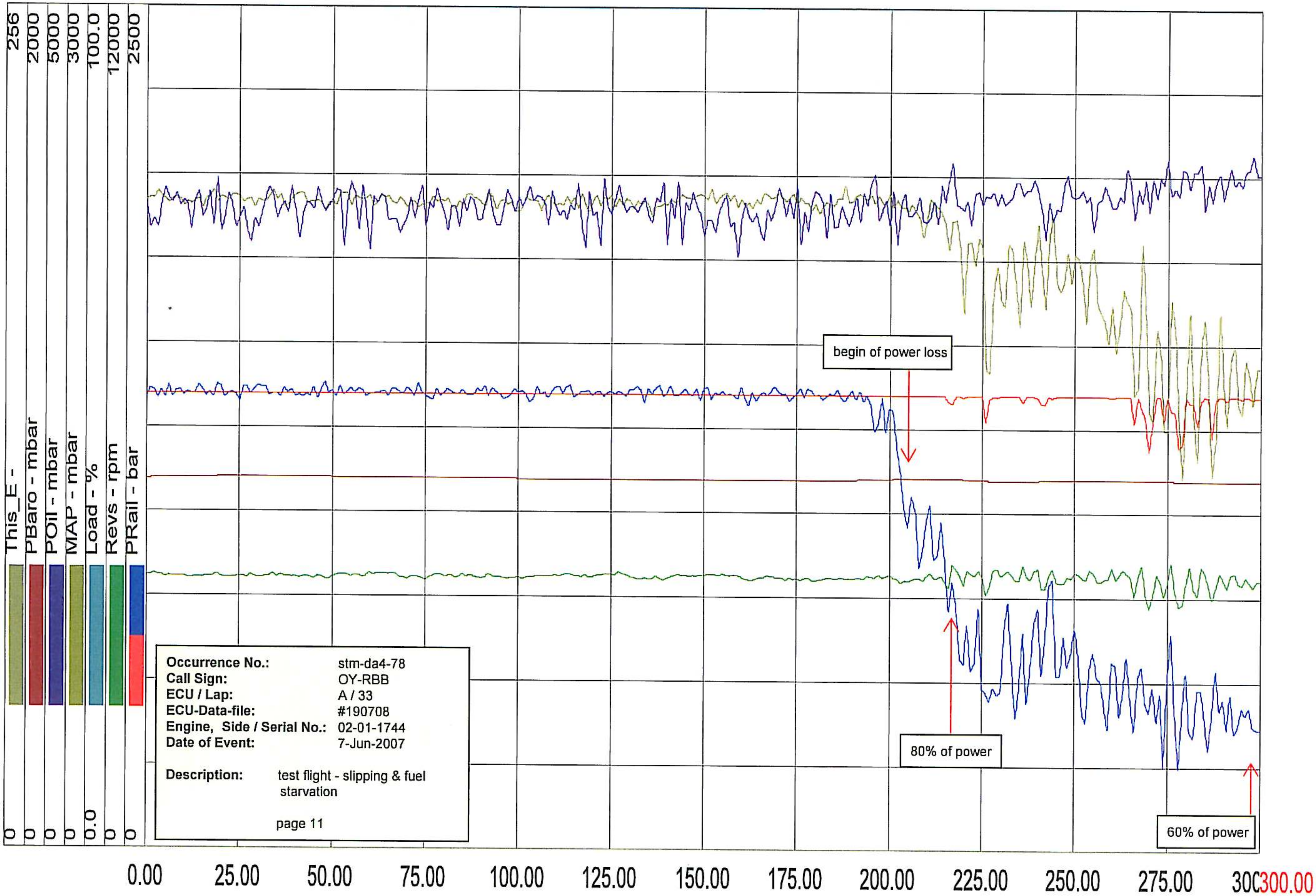
4) Depletion of the main tank & operating the fuel transfer pump - second test

| | |
|---|---|
| -6:00 | red fuel indication light lights up |
| 0:00 | begin of power loss (indicated on the AED) |
| 0:14 | power loss to 80% |
| 1:02 | power loss to 60% |
| 4:39 | engine quits (permanently below 5% load) |
| 5:50 | fuel transfer pump switched on |
| 6:00 | engine restarts |

The aircraft was flying in 4500 ft with a power setting of 100%. After the red light of the fuel indication had lit up it needed about 6 minutes until the engine started to lose power due to the lack of fuel. The load indication was fluctuating within a range of about 20%.
14 seconds after the engine started to lose power the fluctuating load indication decreased to about 80%, 48 seconds later down to about 60%. The airspeed was reduced to 75 kts.
4:39 minutes after the engine started to lose power the load indication remained permanently below 5 % and was considered to have quit. In order to find out if a wind milling engine due to lack of fuel damages the High Pressure Pump so that a restart is not possible anymore the crew continued descending down to 2000 ft. 1:16 minutes after the engine was considered to have quit the fuel transfer pump was switched on. The engine restarted by itself 10 seconds later.

The following pages show the corresponding ECU chart.

STAMP / DATE / SIGN
Chief, Office of Airworthiness




| | |
|---|---|
| **Occurrence No.:** | stm-da4-78 |
| **Call Sign:** | OY-RBB |
| **ECU / Lap:** | A / 33 |
| **ECU-Data-file:** | #190708 |
| **Engine, Side / Serial No.:** | 02-01-1744 |
| **Date of Event:** | 7-Jun-2007 |

**Description:** test flight - slipping & fuel starvation

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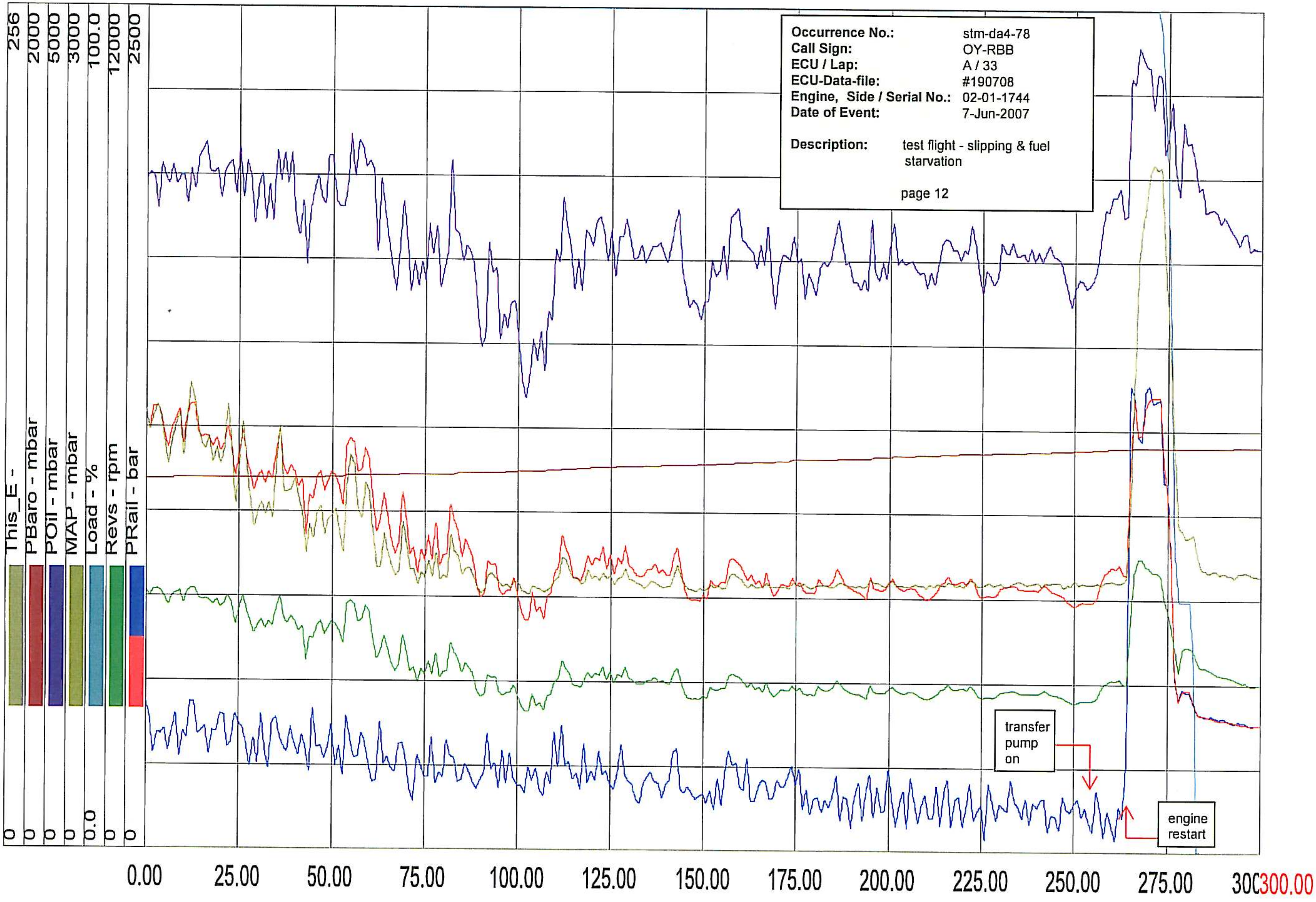
Alpha Data Acquisition System

22/08/2008



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Conclusion

In all four cases the engine restarted by itself after levelling out the aircraft or by restoring the fuel supply. In all four cases the Rail Pressure does not drop abruptly, but decreases slowly. It does not make a difference for the restart behaviour whether the fuel supply is restored by switching on the fuel transfer pump or by switching the fuel selector valve to the RH tank. The engine restarts after about 10 seconds by itself.

Therefore it could be shown that air in the fuel system due to slipping or depletion of the main tank does not cause the engine to fail permanently.

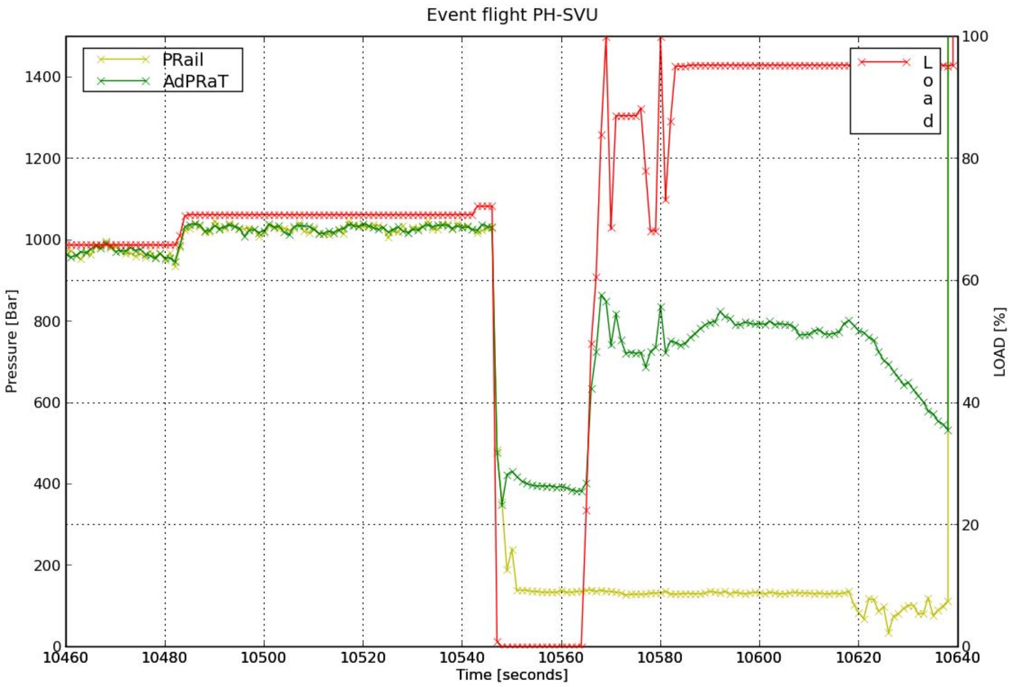
STAMP / DATE / SIGN
Chief, Office of Airworthiness

# Appendix No 6:

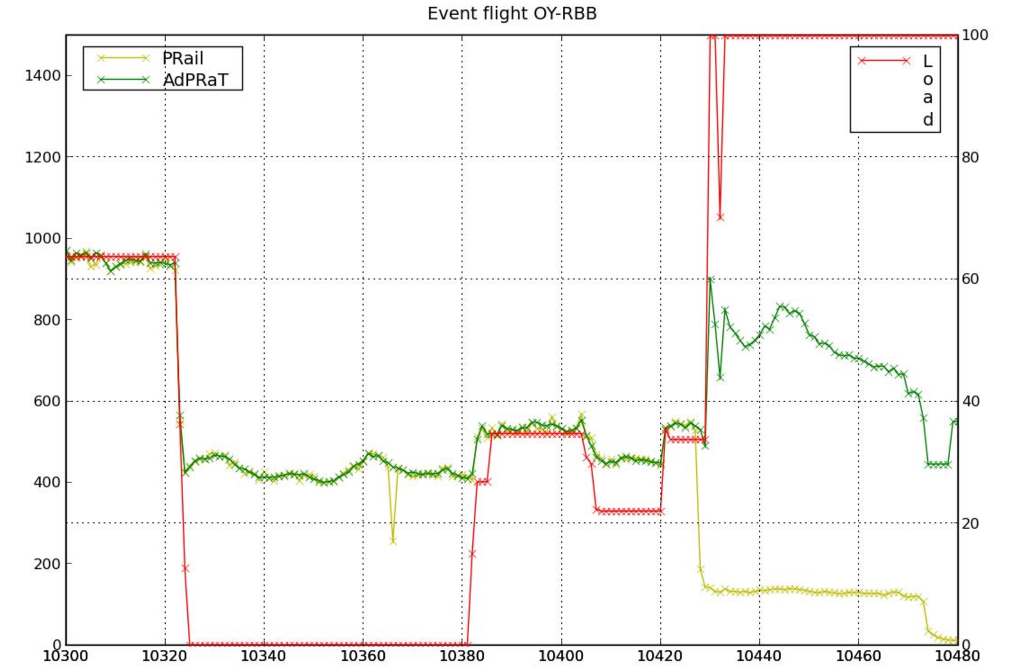
# FADEC ECU data graphs in comparison.

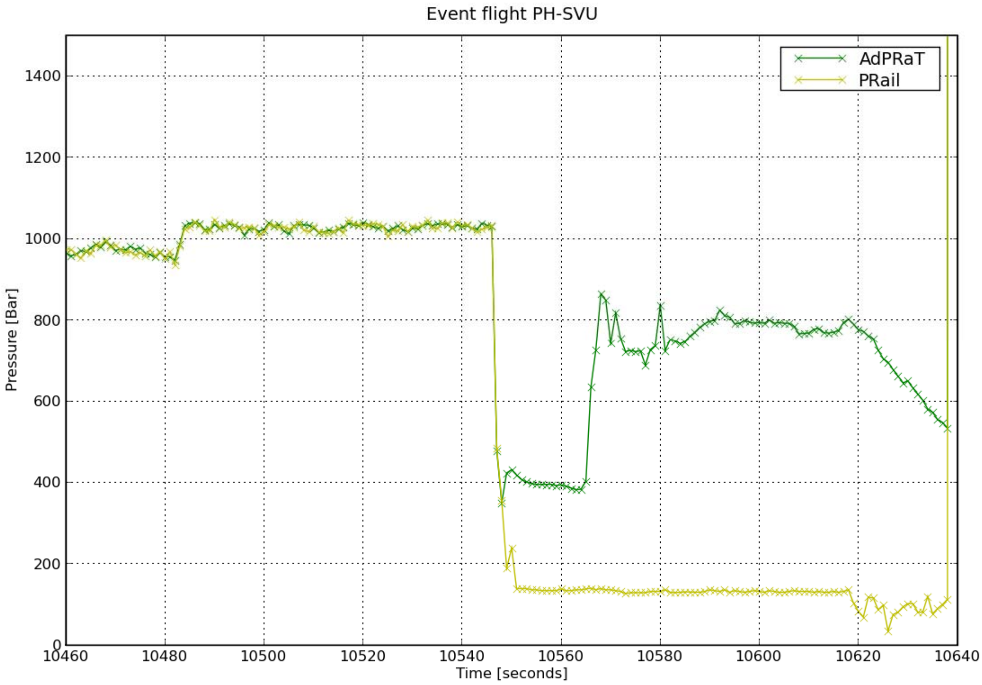
**The appendix consists of 3 pages.**

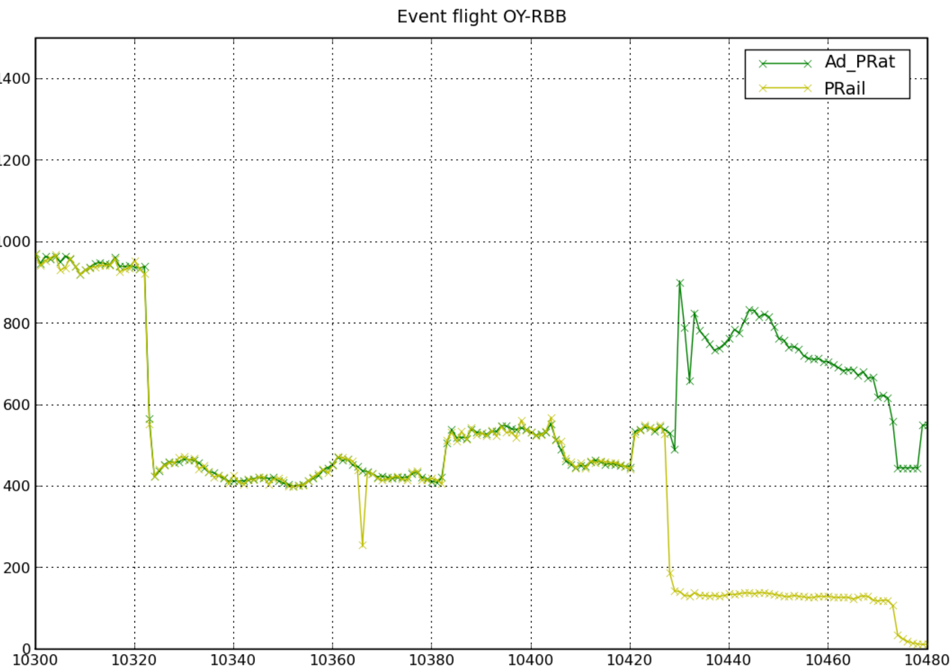
Event: Engine rundown during training flight.
Dutch registration PH-SVU
Aircraft Robin DR 400




Event: Engine rundown during test flight.
Danish registration OY-RBB
Aircraft Diamond DA 40D




Event flight PH-SVU
AdPRaT
PRail
Pressure [Bar]
Time [seconds]
0
200
400
600
800
1000
1200
1400
10460
10480
10500
10520
10540
10560
10580
10600
10620
10640


Event flight OY-RBB
Ad_PRat
PRail
0
200
400
600
800
1000
1200
1400
10300
10320
10340
10360
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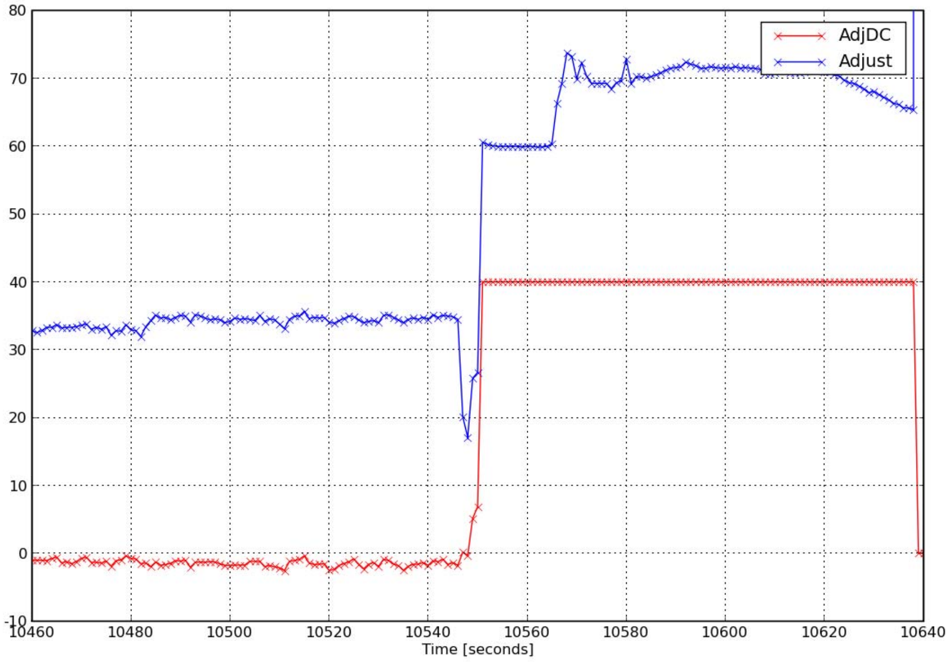
10400
10420
10440
10460
10480

Event flight PH-SVU




Event flight OY-RBB