AIR ACCIDENTS INVESTIGATION INSTITUTE
Beranových 130 199 01 PRAGUE 99

Ref. No. CZ -12 - 514

# FINAL REPORT

## Investigation into the serious incident of aircraft type ATR 42-500, registration mark OK-JFJ, at LKPR aerodrome on October 31, 2012

Prague

May 2014

**Abbreviations used (engl./czech)**

| | |
|---|---|
| AGL | Above Ground Level / Nad úrovní země |
| AFM | Airplane Flight Manual / Letová příručka letadla |
| AOA | Angle of Attack / Úhel náběhu |
| AMSL | Above Mean Sea Level / Nad střední hladinou moře |
| ATC | Air Traffic Control / Služba řízení letového provozu |
| ATPL(A) | Airline Transport Pilot Licence / Průkaz dopravního pilota letounů |
| ATR | Aircraft manufacturer / Výrobce Avions de Transport Régional |
| BEA | Bureau d'Enquêtes et d'Analyses / Francouzský úřad pro vyšetřování |
| CAP | Crew Alerting Panel / Varovný panel |
| CAS | Calibrated Airspeed / Kalibrovaná rychlost |
| CG | Centre of Gravity / Vyvážení |
| CM1 | Crew Member 1 / Člen letové posádky 1 |
| CM2 | Crew Member 2 / Člen letové posádky 2 |
| CSAT | Czech Airlines Technics |
| CSA | Czech Airlines J.S.C./ České aerolinie, a.s. |
| ČHMÚ | Czech Hydrometeorological Institute / Český hydrometrologický ústav |
| Cu | Cumulus / Kumulus |
| DFDR | Digital Flight Data Recorder/ Digitální Zapisovač letových údajů |
| daN | Dekanewton (unit of force- kg m.s$^{-2}$) /Dekanewton (jednotka síly-kg m.s$^{-2}$) |
| EGPWS | Enhanced Ground Proximity Warning Systém / Rozšířený systém varování před srážkou se zemí |
| FCOM | Flight Crew Operating Manual / Provozní příručka letové posádky |
| FH | Flight Hour / Letová hodina |
| FI (A) | Flight Instructor / Letový instruktor |
| FIN | Functional Item Number / Funkční číslo položky |
| FIR | Flight Information Region / Letová informační oblast |
| FL | Flight Level / Letová hladina |
| ft | Feet (unit of length-0,3048 m) / Stopa (měrová jednotka-0,3048 m) |
| g | Gravitational acceleration (9,81 m.s$^{-2}$) / Tíhové zrychlení (9,81 m.s$^{-2}$) |
| h | Hour (unit of measurement of time) / Hodina (jednotka času) |
| IAS | Indicated airspeed / Indikovaná vzdušná rychlost |
| JIC | Job Instruction Card / Technologická karta |
| Kg | Kilogram (unit of mass) / Kilogram (jednotka hmotnosti) |
| km | Kilometre (unit of length) / Kilometr (jednotka délky) |
| kt | Knot (unit of speed-1,852 km h$^{-1}$) / Uzel (jednotka rychlosti-1,852 km h$^{-1}$) |
| LC | Line Check / Traťové přezkoušení |

| | |
|---|---|
| LKMT | Ostrava Mošnov airport / Veřejné mezinárodní letiště Ostrava Mošnov |
| LKPR | Praha Ruzyne airport / Veřejné mezinárodní letiště Praha/Ruzyně |
| m | Meter (unit of length) / Metr (jednotka délky) |
| MAC | Mean Aerodynamic Chord / Střední aerodynamická tětiva |
| METAR | Aviation routine weather report / Pravidelná letecká meteorologická zpráva |
| MFC | Multi Function Computer / Multifunkční počítač |
| min | Minute (unit of time) / Minuta (jednotka času) |
| N | Newton (derived unit of force / Newton (jednotka síly) |
| OAT | Outside Air Temperature / Teplota venkovního vzduchu |
| QAR | Quick Access Recorder / Provozní zapisovač letových dat |
| RA | Radio altitude / Výška z radiovýškoměru |
| s | Second (unit of time) / Sekunda (jednotka času) |
| SAT | Static Air Temperature / Statická teplota vzduchu |
| SC | Stratocumulus (druh oblačnosti) |
| SCT | Scattered / Polojasno |
| SEP (Land) | Single Engine Piston (Land) / Kvalifikace pro jednomotorový pístový letoun |
| SIM | Simulator / Pilotní cvičná kabina |
| TAS | True airspeed / Pravá vzdušná rychlost |
| TAT | Total Air Temperature / Celková teplota vnějšího vzduchu |
| TRI | Type Rating Instructor / Instruktor typové kvalifikace |
| TST (MPA) | Test Flights (Multi-pilot aeroplane) / Zkušební lety ( vícepilotní letoun) |
| UTC | Co-ordinated Universal Time / Světový koordinovaný čas |
| VMC | Visual Meteorological Conditions / Meteorologické podmínky pro let za viditelnosti |
| VRTG | Vertical Acceleration / Vertikální zrychlení |
| VSR | Reference Stall speed / Vztažná pádová rychlost |
| ÚCL | Civil Aviation Authority / Úřad pro civilní letectví |
| ÚZPLN | Air Accidents Investigation Institute / Ústav pro odborné zjišťování příčin leteckých nehod |
| °C | Temperature on the Celsius scale / Teplota ve stupních Celsia |

## A) Introduction

| | |
|---|---|
| Owner/Operator : | Czech Airlines J.S.C. |
| Manufacturer and aircraft model: | Avions de Transport Régional, ATR 42 – 500 |
| Registration mark: | OK-JFJ |
| Site: | LKPR, TRA70, FIR Prague |
| Date and time: | October 31, 2012, 10:40 UTC (all times are UTC) |

## B) Synopsis

On October 31, 2012, following maintenance operations, during a non-revenue test and handover flight of ATR 42-500 the functionality of the Stick Shaker/Stick Pusher system was being tested. During the test, the alert of exceeding value of angle of attack was not activated and the Stick Pusher System (Stall Protection System) did not activate. The stall took place with a significant left roll.

The operator and manufacturer have provided the information relevant to determination of the cause and investigation of the incident.

The AAII commission set up to look into the incident cause was made up of:

| | |
|---|---|
| Chairman of commission: | Ing. Lubomír Stříhavka |
| Member of commission: | Ing. Zdeněk Formánek<br>Ing. Josef PROCHÁZKA<br>Ladislav MUSIL,<br>Ing. Tomáš ROZSYPAL<br>Ing. Petr VOLDÁN |

The final report was issued by:

**Air Accident Investigation Institute**
Beranových 130
199 01 Praha 99
Czech Republic

on May 26, 2014

## C) The report includes the following main parts:

1) Factual information
2) Analysis
3) Conclusions
4) Safety recommendation
5) Appendix

# 1 Factual information

## 1.1 History of the Flight

### 1.1.1 General

Upon the new operator's request, CSA in cooperation with CSAT prepared a plan of maintenance and airworthiness provisions and operational measures between October 6, 2012 and October 31, 2012 as a part of the handover procedures. One of the requirements included the change of the top paint coating of the aircraft. The task of repainting was submitted to an external contractor to whose premises the aircraft was relocated. Further maintenance and airworthiness provisions and tests were carried out at the home base of CSA and CSAT. On October 31, 2012 the non-revenue test and handover flight was scheduled after the repainting. The purpose of the said flight was to check the aircraft and its systems as required by the Czech Airlines Maintenance Program except the power units in-flight shutdown and relighting. Besides others, the functionality test of the Stick Shaker/Stick Pusher System was part of the program, namely for different wing flaps (hereinafter the "flaps") configurations with activated as well as deactivated Stall Warning System and the limit of Stick Pusher activation under the indicated conditions of Icing Angle of Attack.

### 1.1.2 Incident Flight History Evaluation from QAR and DFDR data

Take-off procedure commenced at 9:44:45. CM1 began to rotate at 09:45:01 at IAS value of 108 kt. After two seconds the aircraft lifted off from the ground. In accordance with the TEST FLIGHTS APPENDIX 1 the CM1 forwarded the column and started the descent of the aircraft until the EGPWS activation ("DON'T SINK" warning). The landing gear was retracted at 09:45:50 at the altitude of 2,450 ft, RA 1,103 ft, the flaps were retracted at 09:46:56 at the flight level of 5,237 ft, RA 3,697 ft. The autopilot was engaged at 09:48:33 while climbing through 9,300 ft. Between 09:54 and 09:56 the crew desangaged and engaged autopilot several times. The autopilot remained in engaged then.

From 09:56:30, the recorded angles of attack 1 and 2 were showing constant values of 6.5 degrees and 5.8 degrees respectively. The recorded TAT at that moment was -25 °C, corresponding to a calculated SAT of -29.5 °C. The aircraft was at that moment climbing through 21,300 ft with the altitude target of FL 250. The FL 250 was reached at 10:10:00.

The crew started descent at 10:12:20 and deactivated the autopilot. The IAS value temporarily increased to 251 kt before the crew levelled the aircraft off at FL170 at 10:16:00 and the autopilot was engaged.

At 10:21:35 the crew disengaged the autopilot and started slight descent at IAS between 215 kt and 225 kt to FL160. In idle flight mode the crew was decelerating by approximately 1 kt. At 10:22:52 ICING AOA alert lighted up and remained on even at the moment of aircraft reducing speed under 123 kt (expected speed for Stall Warning in icing conditions). The speed reduction continued, ICING AOA alert was not reset. The aircraft reached the speed of 101 kt (expected speed for Stall Warning in normal conditions) and continued to reduce speed. At 10:24:02 when IAS value was 94 kt a stall occurred at the flight level of 15,820 ft, accompanied by the sudden change in g-load factor (g-break) which dropped down from 0.98 g to approx. 0.85 g in less than 0.5 second. The pitch angle was approx. 12 degrees. The stall was accompanied by a sudden left wing stall and consequent significant left roll. The ICING AOA alert was not on.

At 10:24:06 the left roll reached the value of 88.9 degrees, the pitch angle was decreasing and reached the value of 26.1 degrees down (nose-dive entry). At the stall, CM1 used the right ailerons (deflection at 9 degrees), followed by a nose up input (elevator from -11 degrees to -18 degrees). During the nose up manoeuvre the deflection of right ailerons was decreased. CM2 then applied a significant push down (using force greater than 10 daN) and used the deflection of right ailerons (the value of deflection was 13 degrees). The IAS speed measured during the stall was reduced down to the value of 89 kt. After 25 seconds from the commencement of the stall, the crew managed to level the roll and the pitch at 13,800 ft. At 10:25:15 the aircraft started to climb again.

At 10:26:41, while the aircraft was climbing through 15,700 ft, the crew began to reduce speed at faster rate than in the first instance. During the speed reduction the aircraft reached FL160. The ICING AOA alert was on and had not been reset before the stall.

At 10:27:06 another stall occurred at IAS 92 kt and g-load factor (g-break) 0.93 g. The aircraft started to roll to the left, and the crew at the same time applied the right ailerons and a nose down. The flaps were extended to 15 degrees position. The left roll reached the value of 33.8 degrees and the pitch was -9 degrees. Within 20 seconds after the stall the aircraft was stabilised at FL150.

The crew climbed again up to FL160 and reduced the speed again with the flaps extended at 15 degrees position and the ICING AOA alert on. The speed reduction commenced at 10:28:12. The pitch angle reached the value of 9.8 degrees at 10:28:34. The crew continued without any roll, CM1 reduced the level of the pitch to -2 degrees within five seconds through nose up input. The lowest value of IAS at 82 kt was recorded at 10:28:37. There was no stall.

Later, the crew carried out the same manoeuvre with retracted flaps and with the "ICING AOA" alert on. The lowest value of IAS at 94 kt was recorded at 10:37:12. The aircraft did not roll and no stall was recorded. The remainder of the flight was uneventful and the aircraft landed at 11:10:35.

### 1.1.3 The Pilot's Statement on the Course of the Test

According to the statement of the pilot, the flight was carried out at FIR Prague. The executive flight levels from FL100 to FL170 were restricted for the low speed evaluation test flights. The flight was carried out in daylight conditions.

The pilot flying (CM1) was piloting within the scope of Test Flight Qualification Course of the operator. CM2 was the Pilot-in-Command. There were six other crew members on board.

The first test of the system commenced in clean configuration with Icing AOA alert activated at approximate FL160. According to the documentation, the Stick Shaker activation should take place under given conditions at the speed of approx. 123 kt IAS. This eventuality, however, did not materialise and the crew continued to lose speed and to maintain the level direct flight in order to ascertain the threshold of Stall Warning System activation. At the speed value of approx. 92 kt IAS stall occurred without any previous significant aerodynamic manifestations (buffeting etc.). The Stick Shaker/Stick Pusher System was not activated. The stall was accompanied by a sudden left wing stall and consequent significant left roll. From the pilot's perspective this meant an initial phase of stall-spin. Both pilots responded to this fact by applying the steps of avoiding the stall-spin.

After the flight had been stabilised, two more Stall Protection System tests were attempted with the maximum possible change of centre-of-gravity position. During one of the said attempts, the other crew members were asked to move into the rear part of the cabin, during the next one into the front part. In neither case the tested system was activated and the pilots therefore found the said system as inactive and inoperative. During the descent towards the approach, the Stick Shaker/Stick Pusher Fault alert went on and after about ten seconds off again.

## 1.2 Injuries to persons

| Injuries | Crew | Passengers | Others (inhabitants, etc) |
|---|---|---|---|
| Fatal | 0 | 0 | 0 |
| Serious | 0 | 0 | 0 |
| Light/no injury | 0/8 | 0/0 | 0/0 |

During the entire flight no person on board was injured or harmed.

## 1.3 Damage to Aircraft

No damage to the aircraft was caused during the incident flight. Both MFCs, both AOA sensors, and FIN 29GB relay were replaced as a precautionary measure after the performed flight.

## 1.4 Other damage

NIL

## 1.5 Personnel information

### 1.5.1 Pilot flying (CM1)

| | |
|---|---|
| Men, age: | 37 y |
| Pilot license: | ATPL (A) issued 8. 2. 2011 |
| | TRI (ATR 42/72) valid to 28. 2. 2014 |
| Medical: | Valid to 1. 2. 2014, 1 class. |
| Total on all types : | 5469 h 06 min |
| Total as the PIC: | 2533 h 56 min |
| Total on type: | 2533 h 56 min |
| In last 30 day: | 29 h 10 min |

CM1 has been the rest 13 hours before flight, duty of services has 6 hours 52 min. Last examination LC passed on January 27, 2012 and SIM July 19, 2012.

### 1.5.2 PIC (CM2)

| | |
|---|---|
| Men, age: | 37 y |
| Pilot license: | ATPL (A) issued 28. 2. 2012 |
| | FI (A) valid to 31. 7. 2014 |
| | TRI (ATR 42/72) valid to 31. 3. 2013 |
| | TST (MPA) valid |
| | other – SEP (Land) valid to 30. 6. 2013 |

| | |
|---|---|
| Medical: | Valid to 21. 11. 2013, 1 class. |
| Total on all types : | 3996 h 34 min |
| Total as the PIC: | 2389 h 51 min |
| Total on type: | 3981 h 27 min |
| In last 30 day: | 40 h 34 min |

PIC has been the rest 13 hours before flight, duty of services has 6 hours 52 min. Last examination LC passed on January 26, 2012 and SIM August 27, 2012.

1.5.3. Other Crew Members

The crew further comprised of three CSAT engineers, one CSA representative, and two representatives of the operator to be.

## 1.6 Aircraft information

1.6.1 General Specifications of the Aircraft

The ATR 42 is a twin-turboprop, short-haul regional airliner built in France and Italy by ATR (Aerei da Trasporto Regionale or Avions de transport régional).

| | |
|---|---|
| Type: | ATR 42-500 |
| Registration mark: | OK-JFJ |
| Manufacturer: | Avions de Transport Régional |
| Year of manufacture: | 2004 |
| Serial number (s/n): | 623 |
| Airworthiness certificate: | valid |
| Total flight time: | 17,891 FH |
| Insurance policy: | valid |

1.6.2 Powerplant

| | |
|---|---|
| Engine no.1 – type/serial number: | PW 127E, s/n EB0202 |
| Manufacturer: | Pratt & Whitney Co., Canada |
| Total flight time: | 13.676 FH |
| Propeller/serial number: | Hamilton Standard 568F-1, s/n FR20050352 |
| Total flight time: | 7,758 FH |

| | |
|---|---|
| Engine no.2 – type/serial number: | PW 127E, s/n EB0189 |
| Manufacturer: | Pratt & Whitney Co., Canada |
| Total flight time: | 14,677 FH |
| Propeller/serial number: | Hamilton Standard 568F-1, s/n FR20040751 |
| Total flight time: | 16,051 FH |

### 1.6.3 Aircraft Operation

A brief summary of service and maintenance tasks performed on the aircraft prior to and after the serious incident.

October 6, 2012 The last commercial flight with CSA - no Stall Warning fault/alert reported.

6 - 21 October 2012 Checks carried out during the procedures of handover to another operator: 1YE, 2YE, 8YE, A, 2A, 3A, 4A, 4000 FH, before the commencement of the tasks the interior and exterior cleaning had been performed on the aircraft.

October 21, 2012 Non-revenue flight LKPR-LKMT - overflight to the external contractor for repainting - (no Stall Warning fault/alert reported).

October 28, 2012 Line Check and Weekly Check performed at LKMT (workorders 125582 and 1254718).

October 28, 2012 Non-revenue flight LKMT-LKPR - return of the repainted aircraft to the base (no Stall Warning fault/alert reported).

October 29, 2012 Tasks performed on the aircraft following the repainting (workorder 1252908).

October 30, 2012 Line Check performed at LKPR (workorder 1255902).

October 31, 2012 External Inspection (workorder 1256264).

October 31, 2012 Handover flight performed during which the incident occurred.

The crew stated the Stall Warning fault.

November 1, 2012 Stall Warning check pursuant to JIC 273600-FUT-10010 - no failure reported. Replacement of both MFCs, both AOA sensors, and FIN 29GB relay had been carried out as a precautionary measure before the flight.

November 2, 2012 Test flight repeated before the handover - the system was functioning in compliance with the technical specifications requirements, no Stall Warning fault/alert reported.

November 7, 2012 The handover of the aircraft to the new operator.

November 11, 2012 The overflight of the aircraft with a new registration to the new client (the aircraft reg.OK-JFJ is no longer operated by the ČSA).

### 1.6.4 Stall Protection System

The ATR 42-500 is equipped with the Stall Protection System that includes the audio warning, Stick Shaker, and Stick Pusher. The system is activated by multifunctional computer (MFC), when the average value of the both angles of attack detected by the AOC sensors exceeds the limit values as defined in FCOM 01.02.10.

The FCOM tables provide the reference AOA and not local AOA (See Annex - ATR Technical Directorate Technical Note). Stick Shaker/Stick Pusher System activation is based on the local AOA value. With the flaps at 0 degrees and low engine power the local AOA limit for the Stick Shaker activation is 18.5 degrees and for the Stick Pusher activation 22 degrees. In icing conditions (cruise) the thresholds are 10.4 degrees and 13.5 degrees respectively.

The Stick Pusher limit value is reduced as a function of the rate of change of the angle of attack. If the rate of change of the local angle of attack is higher than 4.87 degrees per second, the limit value of the local AOA is reduced by 3 degrees.

*Note: If the difference between the two local angles of attack exceeds 4 degrees, the Stick Shaker/Pusher is temporarily restrained. When such a difference is confirmed during five seconds, Stick Shaker/Pusher fault detection illuminates on the CAP board and the system becomes inactive.*

## 1.6.5 Weight and Balance

According to the data provided by the operator, the aircraft took off at a weight of 14,292 kg (with a centre of gravity at 22.2 % MAC) and was intended to land at a weight of 13,792 kg (with a centre of gravity at 21.7 % MAC). It can be estimated from the amount of consumed fuel that at the time of the first stall (approximately 40 minutes after take-off), the weight of the airplane was approximately 13,912 kg, with a CG close to 22 % MAC.

At this weight, the AFM published reference stall speed (VSR) with flaps at 0 degrees and retracted landing gear is approximately 96 kt CAS. Therefore the stall warning activation maximum airspeed is the VSR value multiplied by 1.05 or VSR + 5 kt, which is 101 kt.

## 1.6.6 Low Speed Flights

To test the airplanes at the end of the manufacturing process, ATR uses a test flight manual describing a series of tests that are performed by flight test crews.

<table>
<tr><td rowspan="7">STALL<br>CLEAN<br>CONFIGURATION</td><td colspan="5">- PWR MGT MCT<br>- At 160 KT PLA to FI••<br>**CALL ON PA Cabin System Specialist before next Manoeuvre**<br><br>- Record trim at 1.3 Vs1g<br><br>- LH HORN ON then OFF<br>- Decelerate to SW icing<br>- Depress ICING AOA P/b<br>- Decelerate to stall at a rate of 1 kt/sec approx.</td><td colspan="4">Fu : /<br>TQ ≈ 0<br>Trims: IAS :<br>Pitch : 1,6UP ± 0,6<br>Roll<br>Yaw: (0,5 L to 1,0 R)<br>ICING AOA illuminated<br><br>ICING AOA extinguished</td></tr>
<tr><td rowspan="2">WEIGHT</td><td rowspan="2">TRIM</td><td colspan="2">SW</td><td rowspan="2">SP</td><td rowspan="2"></td><td rowspan="2">SW<br>icing</td><td rowspan="2">SW</td><td rowspan="2">SP</td></tr>
<tr><td>ICING</td><td>NORMAL</td></tr>
<tr><td>13,5</td><td>124</td><td>121</td><td>100</td><td>95</td><td>IAS</td><td></td><td></td><td></td></tr>
<tr><td>14</td><td>126</td><td>123</td><td>101</td><td>96</td><td colspan="4" rowspan="3">TQ(SP) = ≥ 5%</td></tr>
<tr><td>14,5</td><td>128</td><td>125</td><td>103</td><td>98</td></tr>
<tr><td>15</td><td>130</td><td>127</td><td>105</td><td>100</td></tr>
</table>

The table of values recorded at low speed test flights

The procedure is aimed at verification of Stall Warning, Stick Shaker, and Stick Pusher functions in relevant regimes. The crew assumes the device activation at relevant airspeed values. If the device is not activated, the low speed test flight is terminated.

The first one to perform is the test with "ICING AOA" (lower limit values of AOA) on in clean configuration as there is a sufficient stall margin ensured. To activate the Warning System at lower limit values the button "ICING AOA" is reset and the warning is switched off. Upon further speed reduction a repeated warning is initiated at limit values of AOA in normal conditions (with no icing).

Fig. 1 AOA senzor

1.6.7 Stall Recovery

The AFM for ATR 42-500 includes in the part "Emergency procedures" in Chapter 4.5 the procedure "Recovery after stall or abnormal roll control" depicted below:

**4 . 05 . 06 - RECOVERY AFTER STALL OR ABNORMAL ROLL CONTROL**

| | |
|---|---|
| CONTROL WHEEL | PUSH FIRMLY |
| ■ **If flaps $0^0$ configuration** | |
| FLAPS | 15° |
| PWR MGT | MCT |
| CL 1 + 2 | 100% OVRD |
| PL 1 + 2 | NOTCH |
| ATC | NOTIFY |
| ■ **If flaps are extended** | |
| PWR MGT | MCT |
| CL 1 + 2 | 100% OVRD |
| PL 1 + 2 | NOTCH |
| ATC | NOTIFY |

NOTE: This procedure is applicable regardless the LDG GEAR position is (DOWN or UP).

*Note: the most important step in the procedure is the extension of the flaps to 15 degrees position (unless already extended) and forwarding the column.*

1.6.8 Aircraft Repainting

The overflight of the aircraft to the paint shop in Ostarva (LKMT) as carried out on October 21, 2012. According to the requirements of CSAT the old paint was removed and the aircraft was repainted with white paint in compliance with the technical documentation of the client in accordance with the specifications for painting ATR42/72 (Repainting of CSA/HCA Aircraft Technical Conditions for ATR 42/72). The new registration mark, national flag, and the flag of EU were not applied. The control surfaces were repainted and re-balanced no sooner than at the home base according to workorder No. 1252908. The return overflight was carried out on October 28, 2012.

In the above mentioned technical specifications, there is an emphasis on the complete and thorough covering of all parts not to be painted, including the AOA sensor blades in order to avoid damage to the system.

1.6.9 Statement of the Manufacturer

Both AOA sensors p/n C16363AAA (s/n 788 and s/n 2246) were dismounted from the aircraft and handed over to the manufacturer and repair organisation Thales Avionics S.A. in a standard manner. Thales Avionics S.A. was required to put forward a deliverance regarding the found conditions of the sensors and issued the "Teardown report". The report states that the sensors were completely disassembled and no defect in sensor sealing was observed during dismantling. Corrosion was discovered inside the ball bearing of the sensor vane axis. Occurrence of corrosion is attributable to the detected presence of water inside the AOA sensors. Corrosion caused an increase in the force necessary for rotation of sensors' vanes. The measured force value was 0.12 N instead of the permitted value of 0.03 N. The measured value of ohmic resistance of the sensor de-icing heating system was beyond the limit values.

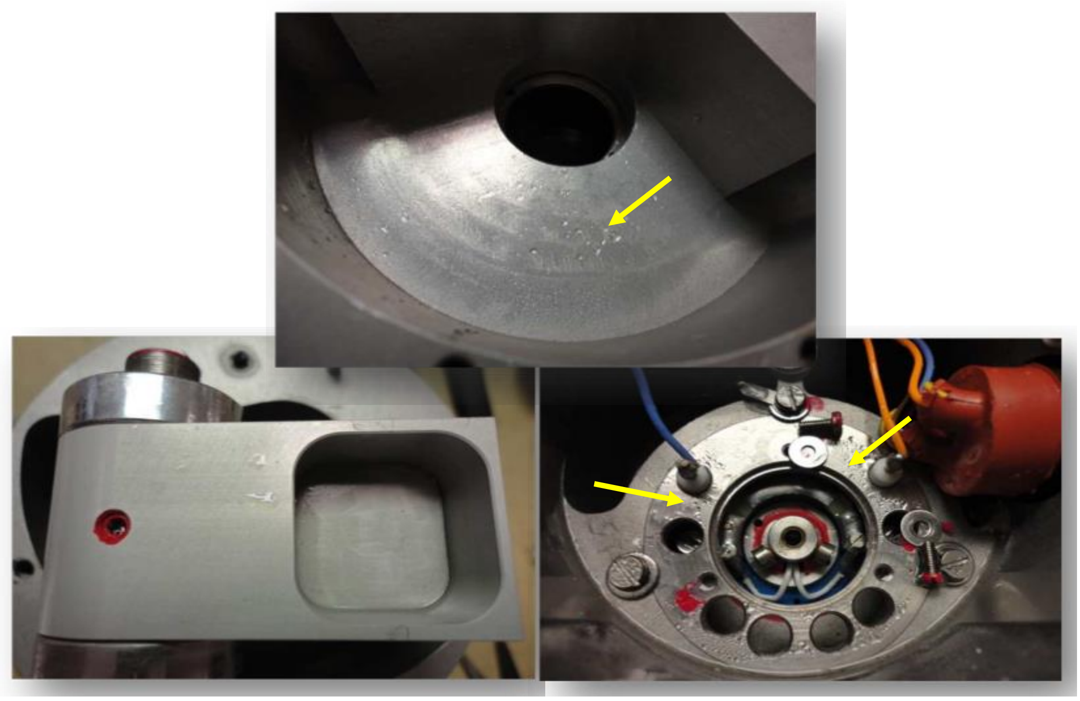


Fig. 2 Photograph of disassembled AOA sensors with water visible in both sensor bodies

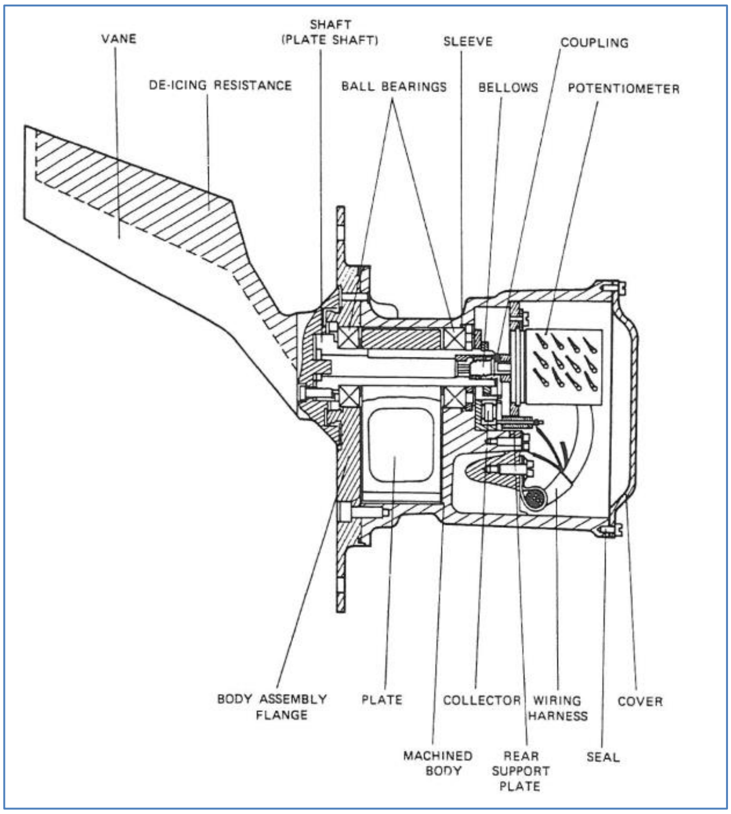



Fig. 3 Section through the AOA sensor

The aircraft manufacturer was notified of the arisen issue by means of the airworthiness report. The manufacturer has analysed the DFDR data over three flights preceding the event of which two assessed flights (October 6 and October 21, 2012) were carried out before aircraft repainting. The manufacturer has found out that during the first flight after repainting of the aircraft (October 28, 2012) both AOA sensors were blocked likewise in the case of AOA sensors blockage during the event test flight (October 31, 2012). The manufacturer in its report, the Technical Directorate Technical Note, Identification: DT/F-522/13, has stated that the AOA sensors were contaminated with water particles sprayed during cleaning of the aircraft before or after repainting.

## 1.7. Meteorological situation

### 1.7.1 Synoptic Situation

Description of the meteorological situation was made out from a report by the Czech Hydro-meteorological Office gave the following assessment of the weather conditions at the accident site:

| | |
|---|---|
| Ground wind: | 140°- 190°/ 6 - 10 kt |
| Altitude wind: | 2000 ft AGL 150°/05 kt, +8°C, 5000 ft AMSL |
| | 150°/12kt,0°C,10000 ft AGL 230°/16 kt, - 4°C |
| Meteorological visibility: | > 10 km |
| Weather: | Sky clear, without rainfall, |
| Cloudiness: | SCT Cu, SC 2500- 3500/6000 - 7000 ft AGL, |
| Freezing level: | 1500 ft AMSL |
| Icing: | NIL |

### 1.7.2 METAR

<u>METAR on LKPR 0930-1130 UTC</u>

LKPR 310930Z 16007KT 9999 FEW036 08/03 Q1007 NOSIG RMK REG QNH 1002

LKPR 311000Z 14009KT 9999 FEW036 08/03 Q1007 NOSIG RMK REG QNH 1002

LKPR 311030Z 14006KT 9999 FEW036 08/03 Q1006 NOSIG RMK REG QNH 1002

LKPR 311100Z 15007KT 9999 FEW025 09/03 Q1006 NOSIG RMK REG QNH 1002

LKPR 311130Z 16007KT 9999 FEW030 10/03 Q1006 NOSIG RMK REG QNH 1002

### 1.7.3 The Current Weather in Pilot's Statement

*"The test flight was carried out in 'above the standard' VMC conditions throughout the whole time. Neither meteorological nor any other anomalies occurred."*

## 1.8 Aids to navigation

NIL

## 1.9 Communications

The entire flight was conducted in FIR Prague and the crew was in contact with the respective ATC service units.

## 1.10 Aerodrome Information

The take-off and landing took place at LKPR.

## 1.11 Flight Recorders and Other Means of Recording

The compilation of data files concerning the event originating from the DFDR (type 2100-4043-00) and QAR flight recorders was obtained in order to determine the causes of the incident (type 214-021-0000101). The provided recorded data were legible and complete.

## 1.12 Description of incident site

NIL

## 1.13 Medical and pathological Information

NIL

## 1.14 Fire

NIL

## 1.15 Survival aspects

NIL

## 1.16 Tests and Research

Within the scope of the airworthiness report, the operator addressed the aircraft manufacturer who sent a deliverance "ATR Technical Directorate Technical Note, Identification: DT/F-522/13" on possible causes of the critical situation occurrence. The said deliverance was submitted to the AAII commission.

## 1.17 Organisational and Management Information

The operator held a valid Air Operator Certificate (AOC) No. CZ - 1.
The maintenance company held a valid licence to perform maintenance, repair and modification tasks on civil aircrafts and aircrafts owned by CSA.

The painting works performed on the aircraft were carried out by an authorised external company, pursuant to the approved CSAT technology standards.

## 1.18 Additional information

NIL

## 1.19 Useful or Effective Investigation Techniques

The serious incident has been investigated according to L 13 National Regulation (Investigation into Air Accidents and Incidents of the Czech Republic) and in accordance with the Regulation EU No 996/2010.

In the course of investigation, the conclusions of the report "ATR Technical Directorate Technical Note" issued by the manufacturer were employed and further the compliance with the stipulated technology procedures in aircraft paint restoration was verified at the external foreign painting company residing at the aerodrome in Ostrava. The procedures of protection of important systems were discussed with the managers of the company with emphasis on the procedures of AOA sensors protection and possible consequences for the given aircraft type operation.

# 2 Analysis

## 2.1 General

The commission based its assessment of the serious incident causes on flight data from the flight concerned, on the aircraft pilot's statement, and on documented data from the aircraft technical documentation.

## 2.2 Operational Aspects

### 2.2.1 Flight Crew Qualifications and Experience

- CM1 - flying pilot conducted the flight as part of training pursuant to Test Flight Qualification Course,
- CM2 - pilot-in-command was in the position of the training instructor,
- They both held valid licences of flight crew members with corresponding qualifications.

### 2.2.2 Aircraft Condition

The maintenance and operation of the aircraft and its engines were carried out in compliance with the aircraft manufacturer’s requirements.

Occurrence of water inside the AOA sensor may be attributed to the technological procedure used in removing the original coating of the aircraft. Given the demanding nature of the repainting technology it was impossible to clearly determine at which process stage water penetrated the sensor; whether it was because of insufficient protection of the critical place or due to water penetrating the protected place. During normal operation of the aircraft, the water will not penetrate the AOA sensor. The experience from the past shows that this may happen when aircrafts are pressure water cleansed without the AOA sensor protected. Penetration of water into the sensor body may have caused the blocking of internal movable parts of the AOA sensor in the environment with the temperature below 0°C when the water inside the sensor body freezes. During the overflight to the paint shop and the overflight from the paint shop the crew was not alerted to any sensor fault.

### 2.2.3 AOA Sensor in the Event Flight

The recorded data show that both AOA sensors provided constant values from the middle of the climb phase until the middle of the descent phase. The fact that they were providing correct measurements during take-off, initial climb, final descent and landing indicates that the most likely cause of malfunction was a temporary blockage of the sensors. Since they both show a similar behaviour almost at the same time, it is very likely that the cause for such blockage must be sought during that flight stage when the temperature of the environment falls below 0°C.

Both sensors became blocked while the aircraft was climbing through 22,000 ft. The measured TAT was then about -25°C, corresponding to an OAT of about –29.5°C. At that moment, the TAT values had been below 0°C for approximately 10 minutes. The sensors started moving again while the aircraft was descending through 8,000 ft (left AOA sensor) and through 6,500 ft (right AOA sensor). The positive TAT values had been measured one to two minutes prior to that.

*Note: this case of AOA sensors blockage is very similar to the event involving the A320 in November 2008 when, during a test flight, following repainting, the aircraft crashed near Perpignan (France). The BEA (French investigation authority) and Airbus, the aircraft manufacturer, conducted a follow-up test flight with the Airbus crew aimed at monitoring the functionality of the AOA sensors. This test showed that there was a delay (one to two minutes) between the sensor internal temperature and the TAT. The sensor became blocked 10 to 15 minutes after the TAT fell below 0°C and unblocked approximately five minutes after the TAT increased above 0°C. The examination of the sensor after the flight has confirmed that even a small amount of water in the sensor can block the mechanism by icing when the temperature falls below 0°C.*

### 2.2.4 Stall Protection System

The individual Stall Protection System components (Stall Warning, Stick Shaker, Stick Pusher) are activated upon achieving the minimum value (see 1.6.4), i.e. the mean value of both angle of attack readings. In the case of blockage of both AOA sensors at values below the minimum limit values, neither Stall Protection System component is activated (that was the event of the OK – JFJ aircraft).

In the case of blockage of only one of the two AOA sensors, the Stall Protection System may be activated, but at an AOA higher than the nominal value specified in the table. The amount of AOA increase needed for the device activation depends on the blocked AOA value. For instance, in flaps 0 deg., idle flight mode, the threshold value for the Stick Shaker activation is 18.5 degrees. If the blocked sensor value is 17 degrees, the other sensor must indicate (2 x 18.5) - 17 = 20 degrees for the Stick Shaker to activate. If the blocked value is 2 degrees and more below the activating threshold, the other AOA should indicate value by 4 degrees higher than the blocked AOA to activate the Stall Protection System. However, it would not happen as, in such case, the Stall Protection System is inoperative (see the note under 1.6.4).

### 2.2.5 Stall Analysis

Two stalls occurred during the test flight. For each of them, the aerodynamic lift coefficient was determined from the recorded data during the deceleration and compared with adequate reference data (flaps 0 degrees, gear up, flight idle) for the aircraft weight of 14,000 kg. It is necessary to emphasise that, because the angle of attack sensors were blocked during the event, the parameters had to be deduced from other recorded data. The aircraft trajectory was calculated based on the values of TAS and vertical speed.

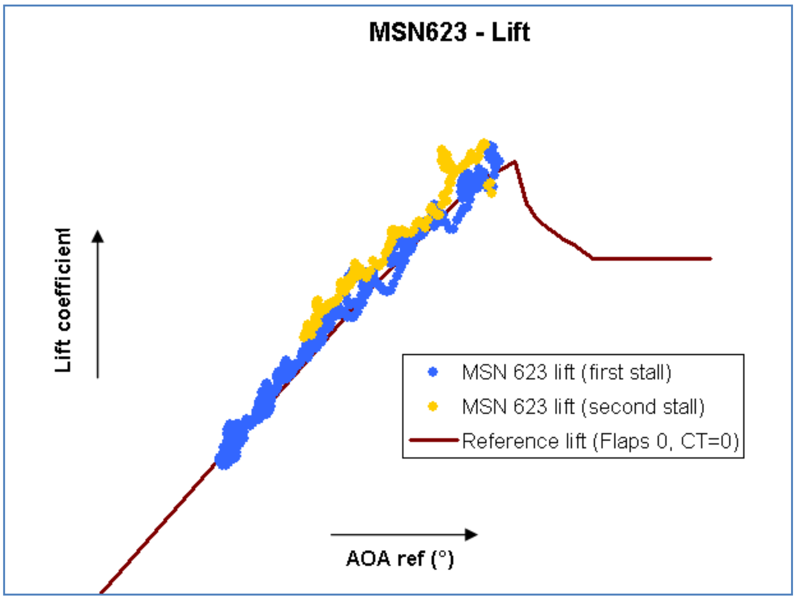



Fig. 4 Diagram AOA ref (°) / Lift coefficient

The comparison between the aerodynamic lift coefficients from the recorded data corresponded with the reference data for an icing-free aircraft in clean configuration regardless of the inaccuracy in determination of the angle of attack or the lift calculation.

The first stall occurred at a maximum angle of attack value of 16 degrees, at an IAS of 94 kt and an altitude of 15,800 ft. When the stall occurred, the aircraft was turning left slightly with a roll angle of about -2 degrees and a rate of heading change of about 0.3 degrees per second, and descending at a rate of about -750 ft $min^{-1}$. The IAS was decreasing at approximately -1 kt $s^{-1}$. The stall was even more intensified by the roll dynamics that increased from 10 degrees per second to as far as 30 degrees per second.

The crew was recovering the stall by applying a nose down input and recovering the roll by the opposite ailerons deflection. The ATR manufacturer has developed a special procedure dealing with stalls, titled "Recovery after stall or abnormal roll control“ (see 1.6.7.). The crew failed to consistently apply the manufacturer’s recommended procedure to stall recovery.

The analysis of data files and records has shown that the crew responded within one second by applying approximately 2/3 of the maximum deflection of right ailerons and left rudder deflection at 8 degrees. In the first second, the pitch was slightly released (elevator from -14 degrees to -12 degrees), then there was a short and strong pitch up input (elevator deflection -18.6 degrees) before releasing the elevator that moved to about 3.5 degrees in one second. At that time the left roll angle was approximately -74 degrees and the mean angle of attack was reaching more than 29 degrees. The pitch down input allowed the AOA to decrease; combined with the right ailerons deflection it allowed the roll recovery of the aircraft, and the longitudinal control was restored at 13,800 ft. During the manoeuvre, the pitch angle reached the maximum -26 degrees (pitch down) and the left roll angle equalled -89 degrees.

The second stall occurred at IAS 91 kt and FL160. The aircraft was approximately at the wings level. The maximum left roll of 35 degrees was reached in 2.5 seconds. The pitch decreased to about -9 degrees down in five seconds.

During the second stall the crew responded by applying a significant nose down input (elevator from -17 degrees to +3 degrees within two seconds) and full right ailerons deflection in about one second. This allowed reducing the angle of attack, to increase the airspeed and to arrest the roll motion. The crew then let the aircraft climb back to FL160.

In the case of the second stall, the applied manufacturer’s recommended procedures included extension of flaps to 15 degrees, fast right deflection of ailerons and pitch down.

## 2.3 Analysis of the Crew Procedure during the Stall Protection System Testing

The test flight of the ATR aircraft was conducted in compliance with the CZECH AIRLINES MAINTENANCE PROGRAM SECTION III – TEST FLIGHTS, detailing the procedure and sequence of flight tests. During the test flight the crew used the ATR 42-500-E3/4 form from APPENDIX 1. The form describes the procedures for individual tests. The crew fills the required flight data and parameters into the form. During the low speed evaluation tests the crew did not record the IAS values due to the system inoperability. The operator's procedures (MAINTENANCE PROGRAM SECTION III TEST FLIGHTS, APPENDIX 1) did not specify any data for any test on the speed when individual parts of the Stall Protections System are activated for the respective weight and configuration pursuant to the aircraft manufacturer's documentation. The procedures also did not stipulate the minimum speed for the respective weight and configuration under which the aircraft speed shall not drop in the case of inoperability of the Stall Protection System or its part, i.e. the speed at which the test is to be terminated was not specified.

During the low speed test flight the crew was intentionally reducing speed until the stall speed in spite of the Stick Shaker/Stick Pusher not being activated at the expected speed with an effort to identify the system activation threshold. According to the ATR manufacturer's opinion dated February 8, 2013 the crew's activity was incorrect.

*Note: Verification of the physical threshold of aircraft stall is carried out by the trained test flight pilots of the manufacturer during certification test flights. During test flights the test pilots of individual operators should not travel at a speed lower than the Stick Shaker activation speed. Such speed limit must be determined before each test flight for the respective aircraft weight and configuration.*

# 3 Conclusions

**Findings:**

- The pilots held valid pilot licences, qualifications for the flight at issue and valid medical certificates,
- The aircraft had a valid Airworthiness Review Certificate and a valid Maintenance Statement/Release,
- The meteorological conditions were not limiting the performance of the flight,
- The change in altitude and correlated changing temperature, namely when falling below zero, had a critical impact on the functionality of the AOA sensors contaminated by water,
- During removal of the old coating, the aircraft coating was probably pressure water cleansed without a sufficient protection of the AOA sensors,
- During the test flight two consequent stalls of the aircraft took place due to the incorrect activity of the crew when reviewing the functionality of the Stall Protection System,
- The Stall Warning, Stick Shaker/Stick Pusher system was not activated because the AOA sensors were blocked during the climb probably due to the freezing of internal movable sensor components,
- The pilots' procedure applied to the termination of a low speed test flight in the case of failure of the Stall Protection System or its part was not specified in the valid documentation of CSA for performance of test flights,
- Upon occurrence of an emergency, the crew stabilised the flight by adjusting the controls as follows: during the first stall the altitude loss necessary for stall recovery equalled 2,000 ft and during the second stall it equalled 1,000 ft, while the manufacturer's recommended procedure for stall recovery was not observed by the crew.

**Causes**

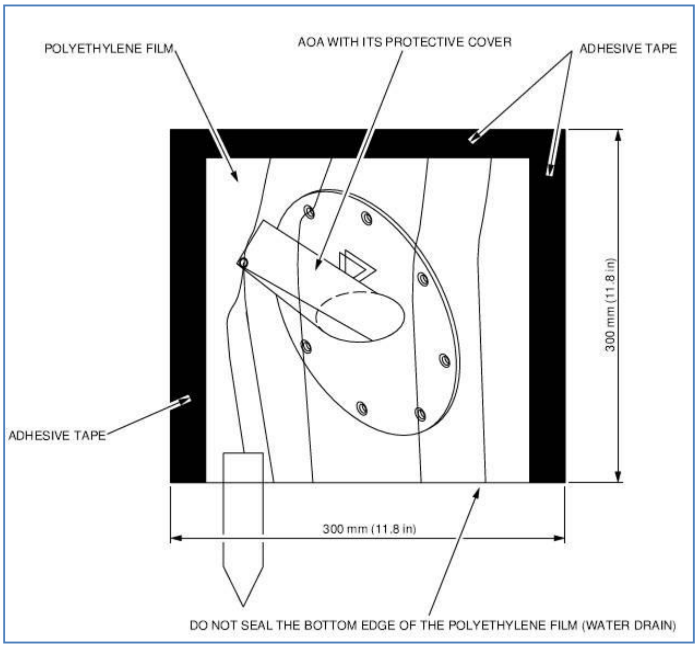
The aircraft stalled during a low speed test flight when the crew was intentionally reducing speed until the stall speed in spite of the Stick Shaker/Stick Pusher (caused by the freezing of the AOA sensors) not being activated. The blocked AOA sensors caused the consequent inoperability of the Stall Protection System (Stall Warning, Stick Shaker/Stick Pusher). It is very likely that water penetrated the AOA sensors during pressure water cleansing of the aircraft coating without sufficient protection of the AOA sensors in the external contractor's paint shop, which resulted in icing blockage of internal movable components of the AOA sensors in the environment with temperatures below zero.

## 4 Safety Recommendations

During investigation the AAII made the following recommendations:

a) CSAT and CSA as the aircraft operator promptly to adopted the following measure:

- they incorporated in the Repainting Technical Conditions Manual the duty to cover the AOA sensors prior to commencement of pressure water cleansing in compliance with the figure below.




b) the operator completed the test flight documentation for the respective aircraft weight and configuration with:
   - the speed when the Stick Shaker is activated with AOA/ON
   - the speed when the Stick Shaker is activated with AOA/OFF
   - the speed when the Stick Pusher is activated

c) the operator completed the test flight documentation with the procedure to be applied in the case of failure of the Stall Warning System.

On May 2011 the EASA issued the Safety Information Bulletin No. 2011-07 dealing with non-revenue test flights and subsequently on 30 July 2012 it issued the Notice of Proposed Amendment No. NPA 2012. The operators and maintenance organisations in charge of organising and conducting such flights are recommended to familiarise themselves with the text of the aforementioned documents.

## 5. Appendix

EASA SIB (Safety Information Bulletin) No. 2011-07 issued on May 5, 2011 available website http://ad.easa.europa.eu/ad/2011-07 .