Ministry of Economic Affairs and Communications
Safety Investigation Bureau

ECCAIRS EE051/180310/SCF-PP, LOC-I

ACCIDENT INVESTIGATION
FINAL REPORT

AN-26B, SP-FDO
Tallinn, Estonia
18. March 2010

Tallinn, 2012

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ABBREVIATIONS

V_r	Rotation speed
CVR	Cockpit Voice Recorded
FDR	Flight Data Recorder
V_1	Critical engine failure recognition speed
FM	Flight Manual
WOW	Weight On Wheels, “Air-Ground” switch
PF	Pilot flying
MC	Medical certificate
MTOW	Maximum Take Off Weight
TR	Type rating
ATIS	Automatic Terminal Information Service
EASA	European Aviation Safety Agency
UTC	Universal Time Coordinated (local time UTC+3)
APU	Auxiliary Power Unit
CAA	Civil Aviation Authority
AFM	Aircraft Flight Manual
OM	Operations Manual

SYNOPSIS

On March 18 2010 at 07:18 An-26B type aircraft wearing Polish registration marks SP-FDO took off from Helsinki for scheduled cargo flight to Tallinn. During approach to EETN RWY 26, approximately 7 nautical miles from the RWY threshold, the crew noticed smoke smell in the cockpit and vibration on the LH engine. Crew decided to shoot down the LH engine and continued approach. During final phase of the approach the aircraft deviated from its intended flight path to the left, had difficulties maintaining the glide slope and flight parameters. When crossing the airport boundaries the aircraft was not configured for landing and made low pass over the RWY 26. In the West end of the RWY the aircraft turned left and started slow climb. The flight continued on a low altitude over the highway E263, aircraft lost altitude, hit the bushes in the vicinity of the Lake Ülemiste and made a crash-landing on the lake ice. After skidding 200 m on the ice the aircraft come to rest, all 5 crewmembers and 1 passenger escaped the aircraft. One crewmember sustained minor injuries during crash-landing. The aircraft sustained minor damage to the fuselage and substantial damage to the landing gear. During the evacuation from the lake the aircraft fuselage and wing sustained major damage and the hull was written off.

The fuel from the aircraft tanks caused minor environmental damage.

The accident was investigated by Estonian Safety Investigation Bureau in accordance with ICAO Annex 13 and EU regulation 996/2010. Polish State Commission of Aircraft Accident Investigation participated in the investigation as State of Registry through appointed accredited representative. The sole purpose of the investigation was to determine the causes of the accident and make safety recommendations to avoid similar occurrences in future. The investigation report is not to be used for apportioning any blame or liability.

The investigation determined the cause of the accident as:

1. The failure of the left engine lubrication oil system, leading to the failure of the rear compressor bearing and inflight engine failure.
2. The failure of the crew to maintain the approach path and adhere to single engine landing procedures.

1. FACTUAL INFORMATION

1.1. History of the flight

Exin Co was operating An-26B for regular cargo flight between Tallinn and Helsinki. The crew performed last maintenance check in Tallinn on previous day and made uneventful flight to Helsinki on 17th March afternoon. Next morning the aircraft took off from Helsinki for regular flight EXN3589 to Tallinn at 09:46 local time. The takeoff weight was 23,954 kg, 46 kg below the MTOW. Four crewmembers, company mechanic and one cargo attendant were on board.
During takeoff crew used RU 19-300 APU for additional thrust as prescribed in AFM. The RU 19-300 was shot down after takeoff.
The flight was uneventful until 08:14:50, 9.5 nm from the runway 26. When power levers were retarded to flight idle crew noticed engine vibration and smelled a smoke in the cockpit. The engine chip detector indicator in the cockpit was lit. After short discussion about which engine should be shot down the flight engineer shot down the left engine and the captain tried to start the RU19A-300 (APU) to gain more thrust.

SP-FDO track on approach to EETN

During the approach the air traffic controller noticed the aircraft deviation from the approach path to the left and notified the crew. According to the FDR and CVR data the crew was unable to maintain a proper approach path both in lateral and vertical dimensions. The attempts to start RU19A-300 engine failed.
Visual contact with the RWY was established 0.5 nm from the threshold. The aircraft crossed the airport boundary being not configured for landing and with IAS 295-300 km/h. The flaps were extended for 10˚ over the threshold; the landing gear was lowered after passing the RWY threshold and retracted again.

The aircraft made a high speed low path over the runway on ca 10-15 feet altitude with the landing gear traveling down and up again. Flaps were extended over runway, and then retracted again seconds before impact. At the end of the RWY the full power on right engine was selected, aircraft climbed 15-20 feet and started turning left. Crew started retracting flaps and lowered landing gear. Aircraft crossed the highway at the end of the RWY on altitude ca 30 feet, then descended again, collided with the treetops at the lake shore and made crash-landing on the snow- and ice-covered lake waterline. Due to the thick ice the aircraft remained on the ice and glided 151 m on the ice with heading 238˚ before coming to full stop.
After the impact the flight engineer shoot down the RH engine and power and released all engine fire extinguishers. All persons onboard escaped immediately through the main door.
No emergency was declares and despite suggestions from FO go-around was not commanded.

1.2. Injuries to persons

One crewmember sustained minor injuries.

1.3. Damage to aircraft

The aircraft landed on the snow-covered ice with its landing gear partly lowered and not locked. During the impact both left and right main gear and nose and gear bay doors were damaged and broken. From impact with the trees the leading edges of the wing and stabilizer sustained serious damages. One propeller blade on the RH engine was bent. The cockpit was filled with snow and ice coming in through nose gear bay and damaged cockpit floor.
The fuselage sustained skin damage from the impact and sliding on the ice.
Initially the ice under the aircraft fuselage sustained the weight of the aircraft, but in ca 30 minutes it started to break and the aircraft started to sink. To avoid sinking trough the ice the aircraft was supported by wooden beams under the wing and through the cockpit side windows.
Ülemiste Lake is the drinking water source for Tallinn and to avoid fuel spill and water contamination the evacuation of the aircraft was of high priority. During evacuation the aircrafts wing and the fuselage sustained severe damages.

1.4. Other damage

No other persons were injured. The fuel and oil leakage to the Ülemiste Lake was limited and controlled.
The contamination control and wreckage evacuation proved to be costly and demanding joint effort of water utility company, Rescue Department and other authorities.

1.5. Personnel information

Crew experience

	Total hours		On type		IFR	
Name, position	Total	Last 90 days	Total	Last 90 days	Total	Last 90 days
/---/ Captain	4695:00	83:40	2295:00	83:40	2295:00	83:40
/---/ First Officer	990:00	51:30	495:00	51:30	495:00	51:30
/---/ Navigator	9071:00	32:50	9071:00	32:50	4414:00	32:50
/---/ Engineer /---/, mechanic	5575:00	74:00	5575:00	74:00	2460:00	74:00

Licenses, ratings and medical certificate validity

Captain	ATPL(A)-PL, TR An-26, MC valid Class 1
First Officer	CPL(A)-PL, TR An-26, MC valid Class 1
Navigator	Flight Navigator License, TR An-26, MC valid Class 2
Flight Engineer	FEL-PL, TR An-26, MC valid Class 2

Crew training records were examined by investigation. Captain and FO had received the last CRM training in May 2009.
No simulator training was given to crewmembers. Engine failure and similar training was made with simulations in actual flight.

1.6. Aircraft information

1.6.1. General

Manufacturer:	AVIANT Kyiv Aviation Plant
Model:	An-26B
MTOW	24 000 kg
Serial number:	105-03
Year of manufacture	1980
Flight hours:	25,941
Last maintenance:	A2 18.03.2010
Airworthiness Review Certificate	valid
Engine:	АИ24 ВТ
S/N:	Н47522032 ВТП
Date of manufacture:	21.05.1975
Last overhaul:	17.01.2005

	Since new	Since overhaul
Hours	12,320	1,979
Cycles	7,707	1,675

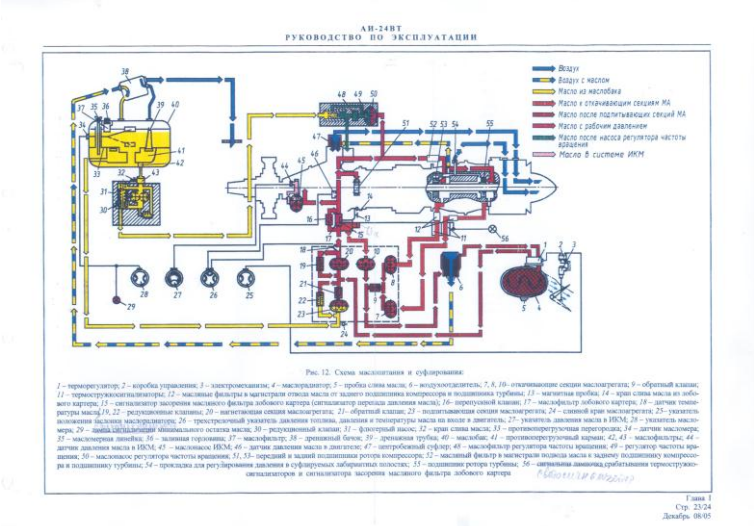
The An-26B is a transport airplane designed to carry cargoes (either stacked on standard pallets or without pallets) and wheeled vehicles along short and medium range routes. The airplane is equipped with two main propulsion turboprop engines with the propellers and one auxiliary turbojet engine. The main engines are accommodated in nacelles on the wing center section.
EASA has issued Restricted Type Certificate EASA.IM.A.351 to *State-Owned Company ANTONOV Aviation Scientific Technical Complex* for An-26 and An-26B. The aircraft was equipped by modern avionics to comply with the certification criteria.

1.6.2. Usage of APU (RU19A-300)

The aircraft An-26 B has two turboprop engines АИ24 ВТ. The specific characteristic of this aircraft type is the use of RU19A-300 – a combined APU and jet engine. It provides the aircraft additional thrust up to 800 kg to improve take off characteristics and improve safety in case of engine failure. RU19A-300 is mounted on wing behind the right main engine. With RU19A-300 operating the critical engine is left engine, with inoperative RU19A-300 the critical engine is right engine.
For take-offs the RU19A-300 must be generally started, but can be switched off after take-off. With MTOW (24,000 kg), in ISA conditions, with one engine inoperative and the other providing take-off power and with RU19A-300 inoperative the aircraft should be capable of climbing with vertical speed 0.75 m/s (148 fpm) on sea level in clean configuration (climb gradient 1.35% at 200 km/h). The AFM does not provide climb rate values with one engine inoperative, no usage of RU19A-300 and flaps and/or landing gear extended.

The RU19A-300 it electrically started from the captains left side panel, its power is managed by a single lever next to main power levers. RU19A-300 has speed and altitude limitations for starting it inflight: V≤350 km/h and H≤6500 m.
The “Start RU19A-300 inflight” check-list consists of 15 items, including resetting electrical power sources and requires coordinated actions of two crewmembers.

1.6.3. Engine АИ24 ВТ oil system and vent system (breather)
Engines single main shaft is supported by three bearings - two radial roller bearings and one radial-axial ball bearing (rear compressor bearing). The bearing oil system features beside the oil supply and scavenge systems vent tubes which allow the oil vapors and air-oil mixture to escape from bearing casings and help to maintain required bearing temperatures. The vent ducts from turbine radial bearing and turbine bearing labyrinth cavities lead separately to the jet nozzle in the rear part of the engine. The pressure in the vents is regulated by selecting washers with different diameter orifices to the breather tubing connection and is individual for every engine.
The vent ducts are made of aluminum alloy pipes and interconnected with hosepipes.
The oil is drained from rear compressor bearing casing and turbine bearing casing through two separate magnetic chip detectors (TSS).



АИ24 ВТ oil system (schematic)

1.7. Meteorological information

The accident happened during daytime. The weather in Tallinn Airport was:

Visibility:	6000 m
Clouds:	Overcast 400 ft
Wind:	220° 4 knots (2 m/s)
Temp/dew point:	-4/-5°C

1.8. Aids to navigation

The crew performed ILS approach to RWT 26. ILS frequency for this RWY was 109.3 MHz. The crew selected 109.3 MHz on NAV radio and had reliable ILS glideslope indication.

1.9. Communications

The communication during the event was held on Tallinn Approach frequency 127.9 MHz. The quality of the communication channel was good. The aircrafts crew language skills in English were average.

1.10. Aerodrome information

Tallinn Airport (ICAO: EETN) is located South of Tallinn. Its asphalt-concrete runway 08/26 has usable length 2820 m (threshold) and width 45 m. The runway elevation is 130 feet.

1.11. Flight recorders

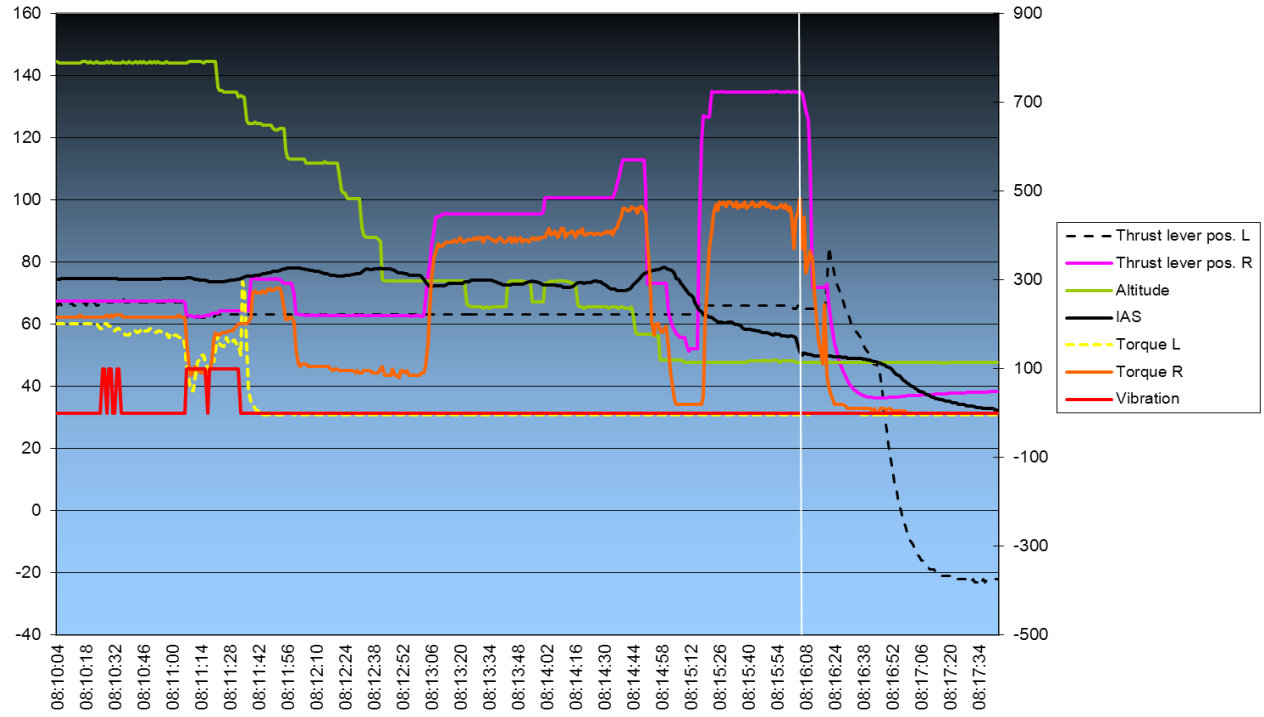
Aircraft was fitted with FDR and CVR. Both recorders were recovered; readout was performed at the ATM Aviation recorders lab in Warsaw. Additional voice recordings were received from Estonian Air Navigation Services; surveillance video recordings capturing the occurrence were received from Tallinn Airport.
The quality of the recordings was good.
FDR recorded the following sequence of events:

Note: The installed recording system does not record RU19A-300 operations. From landing gear operations only gear travel down is recorded. Flap position is not recorded.

Time	Description	Remarks
08:10:26	First intermittent engine vibration recorded	
08:11:07	Trust levers retarded, continuous vibration indication starts	
08:11:34	Left engine shut down, vibration indication ceases	
08:11:35	Right engine thrust lever advanced	
08:11:56	Right engine thrust lever retarded to flight idle	
08:13:05	Right engine thrust lever advanced to high power	
08:14:45	Right engine thrust lever fully retarded, aircraft on runway altitude, IAS 300 km/h	

08:15:14	Right engine thrust lever advanced to full power, landing gear travel down	
08:15:59	Landing gear travel down. Sudden loss of IAS from 174 to 137 km/h.	Contact with treetops
08:16:05	Right engine thrust lever retarded fully back	Crash landing on lake ice

Selected FDR parameters plot:



FDR selected parameters plot

CVR recordings are of good quality and provide information about chaotic decision making process in the cockpit. CVR transcripts are not part of this report.

1.12. Wreckage and impact information

Initially wreckage remained on the ice surface with damaged landing gear, moderate damage of fuselage, wing and empennage. One hour later the aircraft started to sink trough the ice and was supported with wooden beams under the wing and trough the cockpit side windows. To avoid serious environmental damage the evacuation of the wreckage was undertaken by rescue personnel. During the evacuation though the lake ice the airframe sustained substantial damages.

1.13. Medical and pathological information

All crewmembers tested negative for alcohol and psychotropic substances.

1.14. Fire

There was no post-impact fire.

1.15. Survival aspects

Not relevant.

1.16. Tests and research

Left engine teardown was performed in Tallinn by ESIB and engine manufacturer representatives with following findings:

1. The main axial bearing (rear compressor bearing) was severely damaged. The inner forward race was fractured, broken and severely warn. The bearings cage was fractured. Balls were deformed and indicated signs of non-rolling movement of the bearing.

Rear compressor bearing

2. The oil scavenge duct for axial bearing was completely obstructed by coke and metal debris.

Obstructed oil scavenge duct

3. The thermo-magnetic chip detector was completely obstructed with metal particles and coke.
4. Due to the bearing balls and race abrasion the compressor shaft assembly had travelled forward for ca 7-9 mm and made contact with static parts of the engine compressor.

5. The breather duct for labyrinth cavities was broken and the part was missing on the outside of the engine and the surrounding area covered with oil and coke.

Failed breather duct

6. The liner (washer) for regulating the pressure in labyrinth cavities was heat damaged and the original diameter of the orifice to rear compressor bearing was impossible to determine.

Breather duct regulating liner

7. The turbine rotor blades had several mechanical damages.
8. The engine burner was heat-damaged and with several cracks.

Fuel and oil were analyzed with no significant findings.

1.17. Organizational and management information

The operators Post Accident Audit was performed by Polish State Commission of Aircraft Accident Investigation. Auditors expressed their opinion mainly about crew training and manuals and pointed out numerous deficiencies [*full text*].
The company was previously regularly audited by Polish CAA. The CAA audit reports do not reflect deficiencies pointed out by State Commission of Aircraft Accident Investigation audit.

2. ANALYSIS

2.1. General

The chain of events started with engine failure and subsequent shut down ca 7 nm from runway and ended with the crash landing on the lake ice. In general single engine inflight shutdown on multiengine aircraft should not pose major problem with catastrophic impact on flight safety. Single engine failure is part of the normal flight crew training and aircraft should be prepared for this technically and operationally. Both aspects will be analyzed in following section.

2.2. Technical aspects

2.2.1. Engine failure

According to the engine examination data the engine failure was caused by failure of the compressor rear axial bearing. Broken breather duct and heat damaged pressure regulating washer caused improper ventilation of the bearing case and accumulation of the hot oil vapors to the bearing case. This led to temperature rise and coke formation in the bearing. Coke obstructed the scavenge oil channel and the oiling and cooling conditions of the bearing deteriorated even more. At some point the normal rolling was replaced by frictional movement of the bearing, which led to complete failure of the bearing.
The broken breather duct is made of aluminum with the wall thickness of 0.8 mm. The cause and the time of the fracturing could not be determined, but the coke on fracture surfaces and around the broken pipe ending indicate, that it happened prior the engine failure and with high probability days to weeks prior the accident flight. The brake point of the duct was close to the section wall on the engine and difficult to spot during maintenance.

2.2.2. Power availability and usage of RU 19-300 (APU)

After receiving vibration warning on the instrument panel, MHD warning and smelling smoke in the cockpit crew decided to shut down the LH engine. The post-accident engine examination revealed severe bearing damage and progressing engine damage, which, if continued to operate, would bring to the very serious and possibly uncontained engine failure. The consequences of such failure may pose serious risk to the aircraft. The decision to shut down the engine was in accordance with AFM.
The crew turned off the RU19A-300 after climb phase of the flight. The AFM recommends doing so in order to save fuel. The AFM does not require usage of APU during other phases of a flight. The single engine climb gradient of 1.35% provided by the aircraft manufacturer will significantly affected by changes in aircraft configuration and it can be presumed, that in landing configuration with landing gear and flaps extended and/or with deteriorated engine performance the aircraft is not capable to maintain positive climb rate. The additional use of engine energy to start

APU and manipulate the landing gear and flaps will also have negative effect on aircrafts performance. Opening the APU air intake cowl will increase the aerodynamic drag.
After shut down of the left engine the aircraft had enough engine power and energy to safely reach the runway and land using proper piloting technique and following the procedures prescribed for single engine operations. The aircraft was controllable and navigation equipment fully operational.
The attempts to start RU19A-300 failed for undetermined reason. The RU19A-300 had no known problems prior the flight and was used in this particular flight during take-off phase. The APU engine usually was able to produce required power in less than a minute from start. The inflight start procedure consists in 15 check-list items and requires several actions performed by at least two crewmembers. No check-list was read and there is no evidence on the recorder that necessary procedures were adhered to.
The speed and altitude were in limits necessary for normal start of the RU19A-300 (V ≤ 300 km/h and H ≤ 6500 m), the IAS at the time of the starting attempts was ca 300 km/h.

2.3. Crew coordination and training aspects

Based to the CVR and FDR recordings crew did not follow the AFM and checklists for single engine operations and the RU19A-300 inflight start. The crew action was poorly uncoordinated and not focused on safe approach and landing.
The situation was deteriorated by adverse meteorological conditions with low cloud base.
When attempts to start RU19A-300 engine failed the captain and the crew were in difficult position, because they could not be sure that due to the engine power limitations aircraft is capable to go around. Without airfield in sight and with no visual references, the crew had difficulties to follow the flight path. This caused the desire to conserve speed and energy and not to extend flaps and lower landing gear before runway is in sight and reachable. As the result of that the aircraft appeared over the runway with excessive speed and not configured for landing, leaving to the crew two choices – force aircraft to land with excessive speed with serious risk and high probability of not being able to stop the landing roll inside the perimeters of the runway or, alternatively, try to go around with engine power most likely not sufficient to sustain positive climb rate. The captain applied full power over the runway and tried to climb, but, based on inadequate flight performance of the aircraft, crash-landed the aircraft on lake ice as only realistic option to survive.
Crew communication during the event was sometimes chaotic and emotional, with no clear command and resource management.

2.4. Supervision aspects

During the Post-Accident Audit in the operator company investigators examined the audit reports made by Polish CAA. Investigation found, that on several occasions the

deficiencies of the company practices, training and documentation remained unnoticed by CAA auditors. The adequate and timely undertaken corrective actions by CAA and company, e.g. simulator training, could mitigate the risk of accident in case of engine failure.

3. CONCLUSIONS

3.1. Findings

3.1.1. The crewmembers held all necessary licenses and ratings allowing them to perform the flight.
3.1.2. The aircraft mechanic did not hold necessary licenses to perform the maintenance tasks.
3.1.3. The left engine had preexisting lubrication system malfunction, consisting in the failure of the breather duct, for undetermined causes and time.
3.1.4. The left engine axial bearing was damaged due to failure in lubrication system, leading to the engine failure inflight.
3.1.5. The crew tired, but was unable to start RU19-300.
3.1.6. The crew had received no simulator training in such element as high speed rejected take off, engine failure between V_1 and V_2, EGPWS/TCAS activation, wind shear etc. The operator does not provide substitution training on any training device of turboprop aircrafts similar to An-26, which could develop skills required for airline pilots.
3.1.7. The audits performed in operator company by Polish CAA did not reveal inadequate training given to the crewmembers.

3.2. Causes and contributing factors to the accident

Causes of the accident:
1. The failure of the left engine lubrication oil system, leading to the failure of the rear compressor bearing and inflight engine failure.
2. The failure of the crew to maintain the approach path and adhere to single engine landing procedures.

Factors contributing to the accident:
1. Improper and insufficient crew training, *inter alia* complete absence of simulator training
2. The lack of effective coordination between crewmembers
3. The failure of the crew to start RU19A-300 (APU)
4. Adverse weather conditions
5. Inadequate company supervision by Polish CAA, consisting in not noticing the lack of flight crew training and companies generally pour safety culture.
6. Inadequate company maintenance practices, leaving preexisting breather duct failure unnoticed.

3.3. Measures taken during the investigation

During the investigation the operator implemented precautionary safety measures to avoid similar accidents happening in future [*full text in Polish*]:

1. Flight Operation Post holder and Chief of Pilots functions were separated;
2. Personal changes were made at the position of Flight Operation Post holder and Director of Training-Chief of Pilots;
3. The changes into crew training system was introduced related to increase of CRM training and non-normal situations;
4. The An-26 flight simulator training was implemented into flight crew training;
5. Critical analysis were performed regarding the following documents: SOP, QRH, Part D of Operational Instruction as well as The Safety and Accidents Preventative Program;
6. The Part A of the Operational Instruction was analyzed and changes were implemented;
7. The recruiting of pilots policy of the Exin company was changed;
8. The process of recurrent training of maintenance personnel was changed particularly involved the maintenance of critical areas of plane;
9. Under supervision of CAA the verification of practical skills of 100% crew of the Exin Company was performed.

4. SAFETY RECOMMENDATIONS

To the Exin Co:

1. To establish and implement internal training procedures for An-26B crewmembers to ensure adequate skills and preparedness for single engine operations. Such training should include simulator training and take into account the aircraft performance with one engine and RU-19A-300 inoperative.
2. To ensure proper licensing and training for personnel, involved in maintenance of the An-26B fleet.

To CAA Poland:

1. To review internal procedures with the aim to increase quality and effectiveness of the safety oversight.