COMANDO DA AERONÁUTICA

CENTRO DE INVESTIGAÇÃO E PREVENÇÃO DE ACIDENTES AERONÁUTICOS

FINAL REPORT
IG-136/CENIPA/2013

OCCURRENCE:	**SERIOUS INCIDENT**
AIRCRAFT:	**PP-PTU**
MODEL:	**ATR-72-212A**
DATE:	**26JUL2013**

NOTICE

According to the Law nº 7565, dated 19 December 1986, the Aeronautical Accident Investigation and Prevention System – SIPAER – is responsible for the planning, guidance, coordination and execution of the activities of investigation and prevention of aeronautical accidents.

The elaboration of this Final Report was conducted taking into account the contributing factors and hypotheses raised. The report is, therefore, a technical document which reflects the result obtained by SIPAER regarding the circumstances that contributed or may have contributed to triggering this occurrence.

The document does not focus on quantifying the degree of contribution of the different factors, including the individual, psychosocial or organizational variables that conditioned the human performance and interacted to create a scenario favorable to the accident.

The exclusive objective of this work is to recommend the study and the adoption of provisions of preventative nature, and the decision as to whether they should be applied belongs to the President, Director, Chief or the one corresponding to the highest level in the hierarchy of the organization to which they are being forwarded.

This Report does not resort to any proof production procedure for the determination of civil or criminal liability, and is in accordance with Appendix 2, Annex 13 to the 1944 Chicago Convention, which was incorporated in the Brazilian legal system by virtue of the Decree nº 21713, dated 27 August 1946.

Thus, it is worth highlighting the importance of protecting the persons who provide information regarding an aeronautical accident. The utilization of this report for punitive purposes maculates the principle of "non-self-incrimination" derived from the "right to remain silent" sheltered by the Federal Constitution.

Consequently, the use of this report for any purpose other than that of preventing future accidents, may induce to erroneous interpretations and conclusions.

N.B.: This English version of the report has been written and published by the CENIPA with the intention of making it easier to be read by English speaking people. Taking into account the nuances of a foreign language, no matter how accurate this translation may be, readers are advised that the original Portuguese version is the work of reference.

SYNOPSIS

This is the Final Report of the 26JUL2013 serious incident with the ATR-72-212A aircraft model, registration PP-PTU. The serious incident was classified as “[ICE] Icing and [LOC-I] Loss of Control in Flight”.

During the cruise flight, at Flight Level (FL) 160, while the aircraft was flying in icing condition, with the de-ice system deactivated and anti-icing activated, its performance was degraded, leading to a first reduction in the Indicated Airspeed (IAS).

Following a strong vibration, the crew reduced the power of both engines at 20 % TQ, causing the speed to decrease down to 10 Kt below the minimum speed in icing conditions. The Aircraft stall warning (stick shaker and stick pusher) activated, the pilot counteracted the pusher and the aircraft stalled.

Normal flight was re-established upon reaching FL110 and landing was performed without any noticeable event on the Deputado Luis Eduardo Magalhães International Airport (SBSV), Salvador - BA.

The aircraft was not damaged.

The four crewmembers and the 58 passengers left unharmed.

An Accredited Representative of the Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile (BEA) – France, (State where the aircraft was designed and manufactured) was designated for participation in the investigation.

An Accredited Representative of the Transportation Safety Board (TSB) - Canada, (State where the engine was designed and manufactured) was designated for participation in the investigation.

CONTENTS

GLOSSARY OF TECHNICAL TERMS AND ABBREVIATIONS

AC	Alternating Current
ACC-RF	Recife Air Control Center
ADC	Air Data Computer
AFM	Aircraft Flight Manual
AMM	Aircraft Maintenance Manual
ANAC	Brazil’s National Civil Aviation Agency
AOA	Angle of Attack
APM	Aircraft Performance Monitoring
APP-SV	Approach Control Salvador
ASAS	South Atlantic Subtropical Anticyclone
AT47	ATR Aircraft Type Rating (which included the ATR-72-212A model)
ATC	Air Traffic Control
ATIS	Automatic Terminal Information Service
BEA	*Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile*
CA	Airworthiness Certificate
CCAS	Centralized Crew Alert System
CENIPA	Aeronautical Accident Investigation and Prevention Center
CMA	Aeronautical Medical Certificate
CMV-RE	Recife Weather Surveillance Center
CSN	Cycles Since New
CVR	Cockpit Voice Recorder
DA	Airworthiness Directive
DFDR	Digital Flight Data Recorder
EASA	European Aviation Safety Agency
EWIS	Electrical Wiring Interconnect System
FCOM	Flight Crew Operating Manual
IAS	Indicated Airspeed
IEP	Ice Evidence Probe
IFR	Instrument Flight Rules
IFRA	Instrument Flight Rating – Aircraft
JIC	Job Instruction Card
LH	Left Hand
MEL	Minimum Equipment List
METAR	Aviation Routine Weather Report
MFC	Multifunction Computer
MSIS	Minimum Severe Icing Speed
MSN	Manufacturer Serial Number

NSCA	Aeronautics Command System Standard
PCM	Commercial Pilot License – Airplane
PLA	Airline Pilot License – Airplane
PLA	Power Lever Angle
PPR	Private Pilot – Airplane category
PUM	Pitch Uncoupling Mechanism
QAR	Quick Access Recorder
RBAC	Brazilian Civil Aviation Regulation
REDEMET	Aeronautics Command Meteorology Network
RH	Right Hand
SAT	Static Air Temperature
SBAR	ICAO Location Designator – Aracaju Aerodrome - SE
SBMO	ICAO Location Designator - Zumbi dos Palmares International Airport, Maceió - AL
SBSV	ICAO Location Designator - Deputado Luís Eduardo Magalhães International Airport, Salvador - BA
SIGWX	Significant Weather
SIPAER	Aeronautical Accident Investigation and Prevention System
SOP	Standard Operating Procedures
SPECI	Selected Special Aeronautical Weather Report
STAR	Standard Instrument Arrival
TAT	True Air Temperature or Total Air Temperature
TPR	Aircraft Registration Category of Regular Public Transport
TSB	Transportation Safety Board
TSN	Time Since New
UTC	Universal Time Coordinated

1. FACTUAL INFORMATION.

Aircraft	**Model:** ATR-72-212A **Registration:** PP-PTU **Manufacturer:** GIE Avions de Transport Régional	**Operator:** Trip Linhas Aéreas
Occurrence	**Date/time:** 26JUL2013 - 2200 UTC **Location:** En Route Flight **Lat.** 11°48'12"S **Long.** 038°09'09"W **Municipality – State:** Esplanada - BA	**Type(s):** [ICE] Icing [LOC-I] Loss of Control in Flight **Subtype(s):** NIL

1.1 History of the flight.

The aircraft took off from the Zumbi dos Palmares International Aerodrome (SBMO), Maceió - AL, to the Deputado Luís Eduardo Magalhães Aerodrome (SBSV), Salvador - BA, at 2110 (UTC), to carry personnel with 4 crewmembers and 58 passengers on board.

Around 2142 (UTC), on FL160, the aircraft entered a region that had the conditions of ice accretion. Although the aircraft anti-icing was activated, the air pneumatic de-icing was not activated by the flight crew. Then, there was a significant degradation of aircraft performance, leading to a reduction in the Indicated Airspeed (IAS).

The aircraft initial cruise speed was 202kt. The aircraft lost 10 kt prior to the activation of anti-icing. The crew heard a noise described as similar to that of a compressor stall, followed by a loud vibration.

The aircraft reached 180 kt when the power levers were reduced to 20% TQ, leading the IAS to reduce down to 148 kt, and the autopilot was disconnected. The crew did not identify the cause of the vibration.

Approximately 4 second after the autopilot was disconnected, the Angle of Attack (AOA) increased, resulting in the activation of the stall protection systems (stick shaker and stick pusher). The pilots counteracted the pusher, which resulted in the loss of aircraft control. During the loss of control, Pitch Uncouping Mechanism (PUM) triggered.

The crew declared emergency and, upon reaching the FL110, the control of the aircraft was restored. Landing was performed in a controlled way on SBSV.

The aircraft was not damaged.

The 4 crewmembers and 58 passengers left unharmed.

1.2 Injuries to persons.

Injuries	Crew	Passengers	Others
Fatal	-	-	-
Serious	-	-	-
Minor	-	-	-
None	4	58	-

1.3 Damage to the aircraft.

There was no damage to the aircraft.

1.4 Other damage.

None.

1.5 Personnel information.

1.5.1 Crew's flight experience.

Flight Hours		
	Captain	Copilot
Total	5,300:00	1,640:35
Total in the last 30 days	48:55	63:55
Total in the last 24 hours	06:55	06:55
In this type of aircraft	1,738:20	1,211:30
In this type in the last 30 days	48:55	63:55
In this type in the last 24 hours	06:55	06:55

N.B.: The data related to the flown hours were obtained through the aircraft operator's records.

1.5.2 Personnel training.

The captain graduated at the Air Force Academy (AFA), in Pirassununga – SP, in 1978 and got his License based on his military experience.

The copilot took the PPR course at the Votuporanga Aerodrome – SP, in 2000.

1.5.3 Category of licenses and validity of certificates.

The captain had the PLA License and had valid AT47 aircraft type Rating (which included the ATR-72-212A model) and IFRA Rating.

The copilot had the PCM License and had valid AT47 aircraft type Rating and IFRA Rating.

1.5.4 Qualification and flight experience.

The pilots were qualified and had experience in the type of flight.

1.5.5 Validity of medical certificate.

The pilots had valid CMAs.

1.6 Aircraft information.

The aircraft serial number 891, was manufactured by GIE Avions de Transport Régional, in 2009 and it was registered in the TPR category.

The aircraft had valid Airworthiness Certificate (CA).

The last inspection of the aircraft, the "800FH" type, was carried out on 05JUL2013 by the Trip Airlines maintenance organization, in Belo Horizonte – MG, having flown 169 hours and 50min after the inspection.

The last revision of the aircraft, the "1CFH" type, was carried out on 20DEC2012 by the Trip Airlines maintenance organization, in Belo Horizonte – MG, having flown 4,329 hours after the revision.

The aircraft maintenance records were updated.

The aircraft had Time Since New (TSN) of 9,362 hours and 10min and Cycles Since New (CSN) of 9,087 cycles.

Description of ice protection systems.

The aircraft had systems that allowed it to operate in a variety of environmental conditions and, in particular, in icing atmospheric conditions.

The ATR 72-212A had an Ice Evidence Probe (IEP), installed on the left side, outside the cockpit. The IEP is the primary means to detect ice accretion (Figure 1).

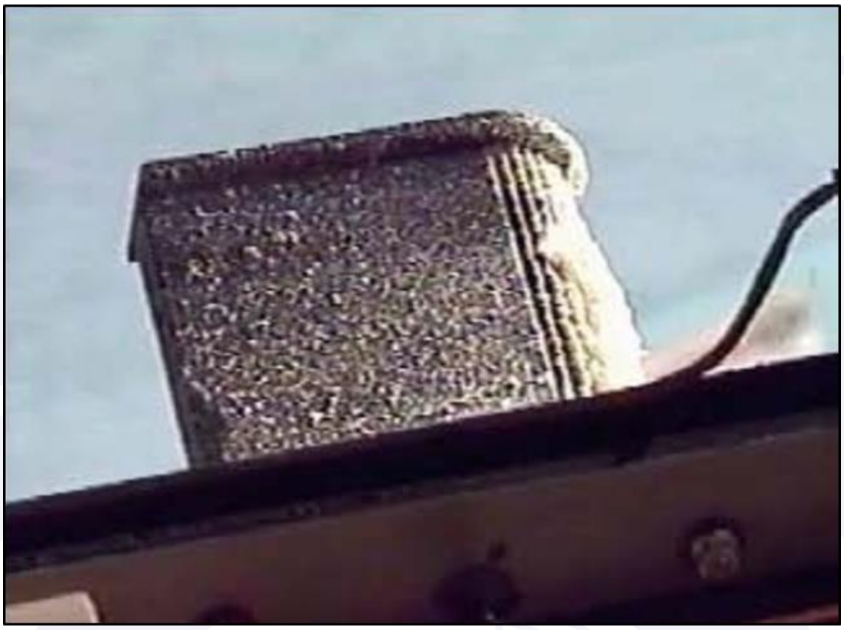

Figure 1 – View of the IEP, seen from the left piloting spot (Ice & Rain, ATR Training Center).

Additionally, an Electronic Ice Detector, connected to the CCAS, provided a warning signal “as soon as” and “during the period that” the ice accretion was identified by the detector.

The ATR-72-212A ice protection system was provided by:

a) electrical heating (anti-icing) supplied by ACW current which consist of:

- propeller blades;
- windshields;
- front of the side windows;
- probes; and
- horns of flight control surfaces.

For the electric heating of the ice protection system, the power was supplied by the ACW generators.

(b) a pneumatic de-icing system that operated in the following areas:

- wing leading edges;
- horizontal tailplane leading edge; and
- engine air intakes / gas path de-icer.

For the pneumatic ice protection system, the engines supplied bleed air through the LH and RH (Left and Right Hand) valves, regardless the position of the engine bleed valves.

The rain removal from the front windshield was achieved by windshield wipers.

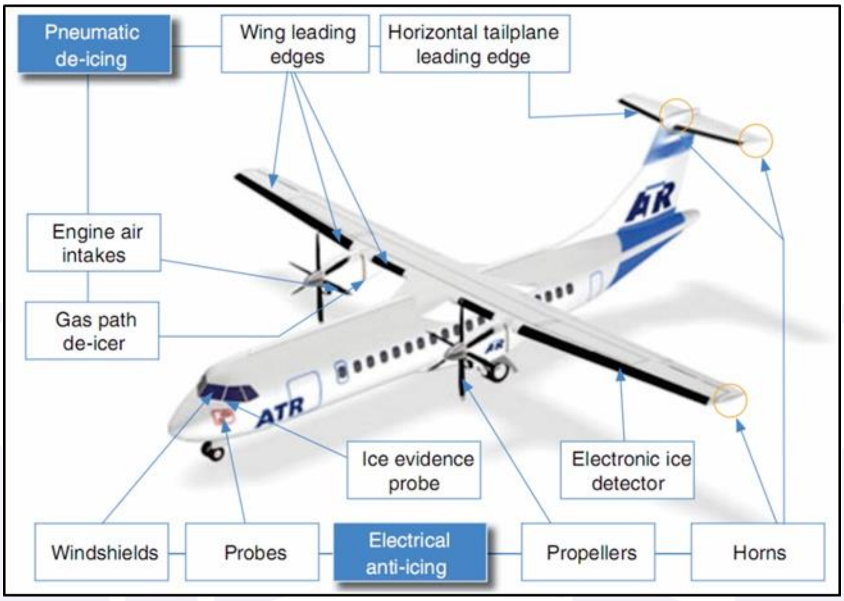

Figure 2 - ATR-72 Basic Ice Protection System.

The manufacturer has defined a philosophy based on three levels of ice protection (permanent anti-icing / heating level; pending weather conditions anti-icing level and de-icing level):

- (1) Permanent anti-icing/heating level (electrical heating of probes, and windshields) to be selected on during preliminary cockpit preparation as per SOP;
- (2) Ice protection level (anti-icing - electrical heating of the defogging side windows, horns of flight control surfaces and the inside of the leading edges of the propeller blades); and
- (3) De-icing level - pneumatic system of wing leading edges and horizontal stabilizers, engine air inlets and intake ducts.

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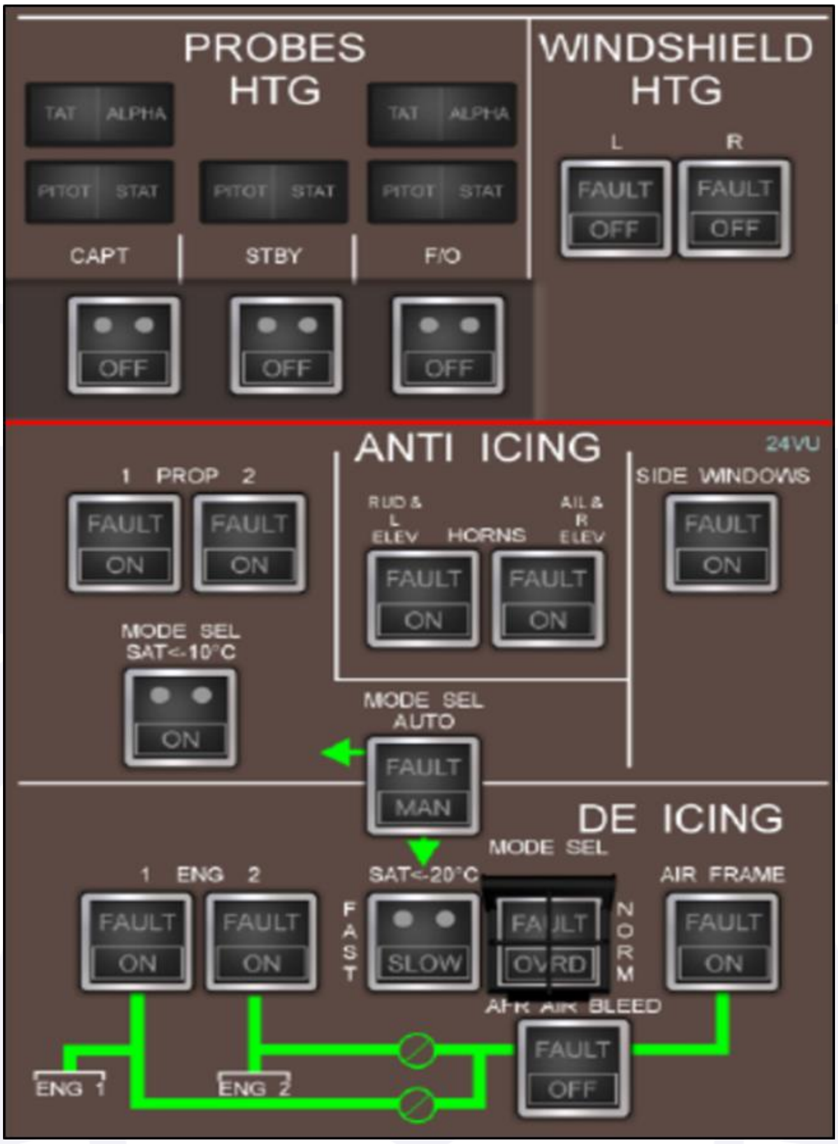

Figure 3 - Control panel of the anti-icing and de-icing systems of the ATR-72-212A aircraft, subdivided into the three levels of ice protection.

Additionally, the aircraft is equipped with an Aircraft Performance Monitoring Function (APM).

The APM function is monitoring the aircraft drag to alert the crew when performance degradation is identified in icing conditions or when icing conditions have been encountered during flight.

The APM system monitors aircraft in-flight performance in order to enhance flight crew awareness of the risk of severe icing conditions. It compares the aircraft theoretical drag with the drag calculated in flight. It monitors cruise speed and compares it with ICING BUG.

If drag and speed degradation exceeds threshold values, alerts are triggered. APM alerts are:

- CRUISE SPEED LOW

  Indicates a limited degradation in drag (in the order of 10%) combined with a speed at least 10 kt below the expected cruise speed. This alert is available in cruise phase only.

- DEGRADED PERFORMANCE

  Indicates a significant degradation in drag (in the order of 22 to 28%, depending of the IAS). In cruise, it is combined with a speed at least 15 kt to 20 kt below the expected cruise speed.

  During the climbing, cruising or descent, if an abnormal drag increase induced a decrease in speed, this alert was given in combination with a single chime.

- INCREASE SPEED

  Indicates that the conditions for DEGRADED PERF are met and that the speed is lower than ICING BUG +10 kt.

  During the cruise flight, up or down, if the drag was abnormally high and the IAS was lower than MSIS (equivalent to Red Bug + 10 kt), this message would flash in association with a single chime and a MASTER CAUTION alarm.

  Depending on the circumstances, the INCREASE SPEED signal could be triggered at the same time as the degraded performance.

<u>APM and MFC maintenance records in the technical logbook.</u>

16JUL2013:

> "APM inop on the ground - Accepts reset in flight.
>
> Performed operational test according to JIC 30-84-00 OPT 10000. APM operating normally."

21JUL2013:

> "APM FAULT.
>
> Reset the system, tested according to JIC 30-84-00 OPT 10000."

26JUL2013:

> "Pack valve 2 inoperative in flight. Only works on the ground.
>
> Performed INV of the MFC #1 and #2 according to item 02 and 03 of this TGB 123276 for T/S
>
> MFCs have been reversed for T/S malfunction search according to AMM JIC -3148-81 RAI 10,000 agreement (P/N OFF: LA4E 20606 HM 0100 - S/N OFF: 4E 200 3560 - P/N ON: LA4E 20606 HM 0100 - S/N ON: 4E 200 4281) / POS #1
>
> MFCs were reversed for T/S malfunction search according to AMM JIC -3148-81 RAI 10,000 agreement (S/N OFF: LA4E 20606 HM 0100 - S/N OFF: 4E 200 4281 - P/N ON: LA4E 20606 HM 0100 - S/N ON: 4E 200 3560) / POS #2"

<u>Red BUG</u>

The left and right speedometers had speed reference bugs that could be adjusted manually (Figure 4).

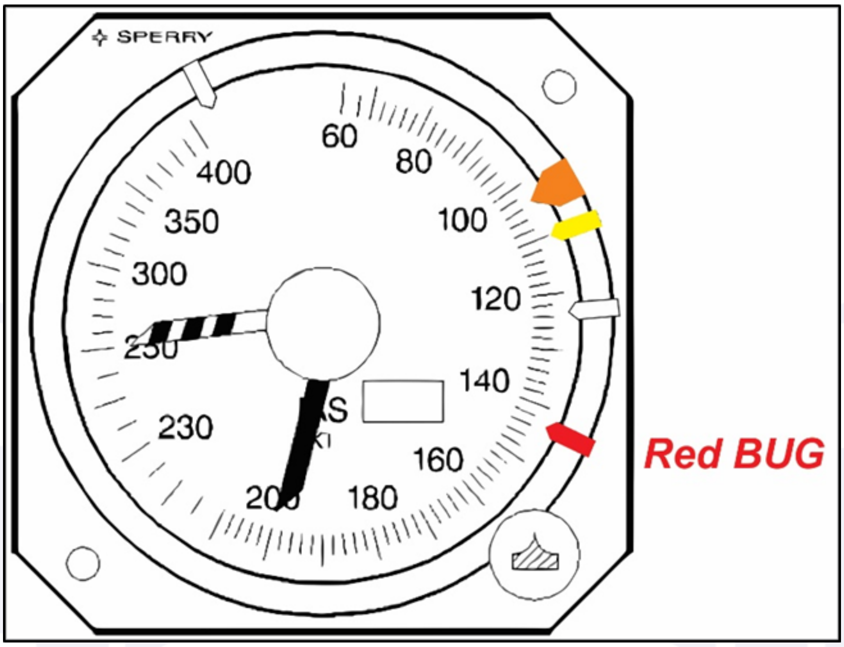

Figure 4 - ATR-72-212A speedometer illustration.

The red bug indicates the minimum flight speed under icing conditions (with flaps retracted and low bank angle) and should be adjusted for each flight according to the weight of the aircraft.

During the initial field investigation, it was observed that only the instrument on the right post had the Red Bug installed and it was set at 160 kt. It was also found that there was no record of the absence of Red Bug in the aircraft technical logbook.

Pitch Uncoupling Mechanism (PUM)

The ATR-72-212A aircraft elevator consisted of two control surfaces (left and right) located at the top of the tail structure. Pilots operated it by pushing or pulling the control column in the cockpit, which resulted in varying the pitch of the aircraft. During normal operation, the left and right surfaces of the elevator moved in the same direction and amplitude.

The ATR-72-212A had a mechanism called the Pitch Uncoupling Mechanism (PUM), located between the right and left surfaces of the elevator, at the tail of the aircraft. In the case of the elevator become stuck, the decoupling could be triggered, so that the surfaces operated independently of each other.

The captain's and copilot's linkage were connected by a pitch uncoupling mechanism located in the horizontal stabilizer. The pitch uncoupling mechanism was installed between the last elevator control bellcranks. A symmetrically forked cam was attached to the left bellcrank shaft. A roller mechanism attached to the right bellcrank shaft was held engaged on the cam by means of a leaf spring. If rotation of either shaft was opposed by the other shaft outside defined limits the roller was forced out of the cam groove, momentarily compressing the spring and the two shafts uncouple. This closes a micro switch, causing illumination of master WARNING light and activation of repetitive chime.

In case of jamming, pitch control will be recovered by applying on both control columns a differential force (520 N) disengaging the pitch coupling system. The non-affected channel enables the aircraft to be operated safely. System recoupling had to be performed on ground. Reconditioning of the mechanism can only be performed on the ground by means of a remote control from a control pushbutton switch installed on the maintenance panel in the flight compartment to an electrical actuator installed close to the pitch uncoupling mechanism (Figure 5).

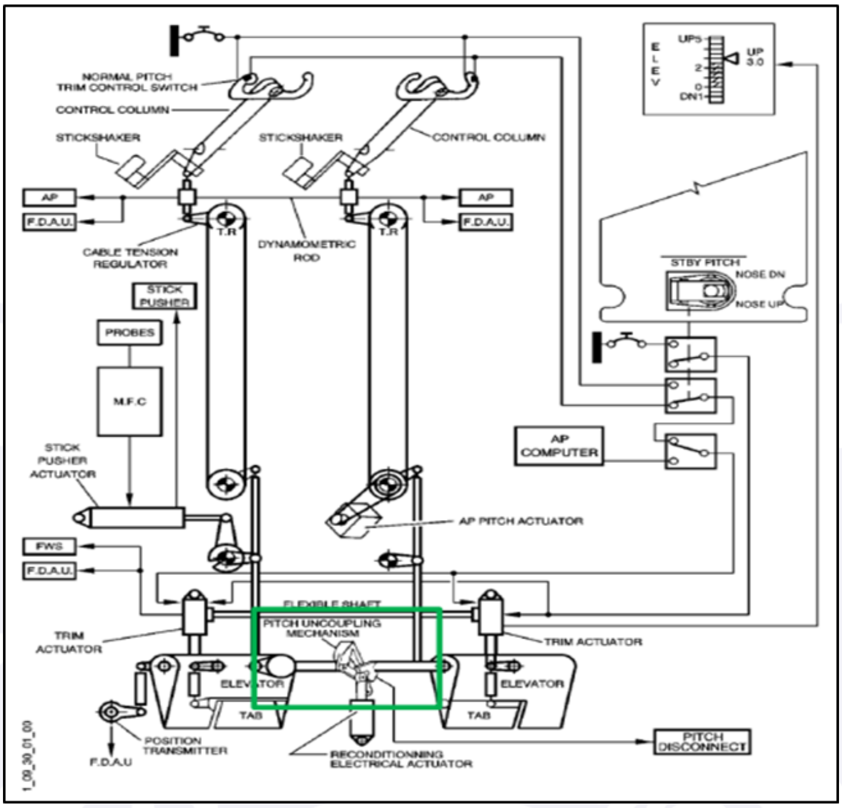

Figure 5 - ATR-72-212A aircraft elevator and PUM control system (Contribution Report, ref BEA pp-u130726, 08AUG2014).

During flight, in the absence of elevator control locking, the PUM could be activated in the following situations:

- simultaneous actuation on the controls, with both pilots applying great effort (about 500 N each) in the opposite direction; or
- single abrupt activation of one crewmember (applying about 500 N opposite to the moment of the elevator surface), in particular in case of opposite elevator jamming.

The levels of effort required to activate PUM, whether double acting or single acting, could be reduced in situations involving successive acting.

Activating the stick pusher could also alter the force required to activate the PUM since that system generated efforts at the elevator control column. However, in a standard flight configuration, the stick pusher activation alone would not generate the PUM activation.

When the PUM was triggered, a PITCH DISCONNECT indicator light would illuminate on the CCAS, the MASTER WARNING light would cycle, and the Continuous Repetitive Chime sound warning were activated.

1.7 Meteorological information.

With regard to the weather conditions, prior to takeoff, the crew had the following METAR of the places of origin, destination and alternative:

SBMO 261900Z 10006KT 8000 FEW010 SCT017 BKN080 25/23 Q1018=

SBMO 262000Z 10004KT 9999 SCT016 BKN070 25/23 Q1018=

SBSV 261900Z 09011KT 5000 HZ SCT010 BKN015 FEW020TCU BKN070 25/21 Q1019=

SBSV 262000Z 11009KT 6000 SCT010 BKN015 FEW020TCU BKN070 24/21 Q1019=

SPECI SBSV 262022Z 15011KT 3000 RA BKN010 BKN015 FEW020TCU BKN070 24/21 Q1019=

SBSV 262100Z 13012KT 4000 -RA BKN010 SCT015 FEW020TCU BKN070 23/21 Q1019 RERA=

SBAR 261900Z 09005KT 9999 SCT015 BKN100 24/21 Q1018=

SBAR 262000Z 08005KT 9999 SCT015 BKN100 24/21 Q1018=

In the two hours prior to takeoff, the departure Aerodrome (SBMO) operated under visual conditions, with the base of the layer constituting a ceiling between 8,000ft and 7,000ft and a temperature of 25°C.

In the same period, the destination Aerodrome (SBSV) operated under visual conditions, however, with visibility restriction of 5,000m at 1900 (UTC) due to dry mist (HZ) and 6,000m at 2000 (UTC). The base of the layer was a ceiling at 1,500ft, there were few cumulus clouds with a large vertical extension based on 2,000ft (FEW020TCU) and temperature ranging from 25°C to 24°C.

At 2022 (UTC), a SPECI was issued for SBSV, reporting visibility reduction to 3,000m, due to rain (RA) and the base of the layer constituting ceiling at 1,000ft. At that time, the Aerodrome was operating under IFR.

The alternative Aerodrome (SBAR - Aracaju, SE) remained operating under visual conditions, with visibility above 10km, based on the layer constituting a ceiling at 10,000ft and a temperature of 24ºC.

There was also a SIGWX, Significant Weather, available from 1731 (UTC), valid from 27JUL2013 to 0600 (UTC) as shown in Figure 6:

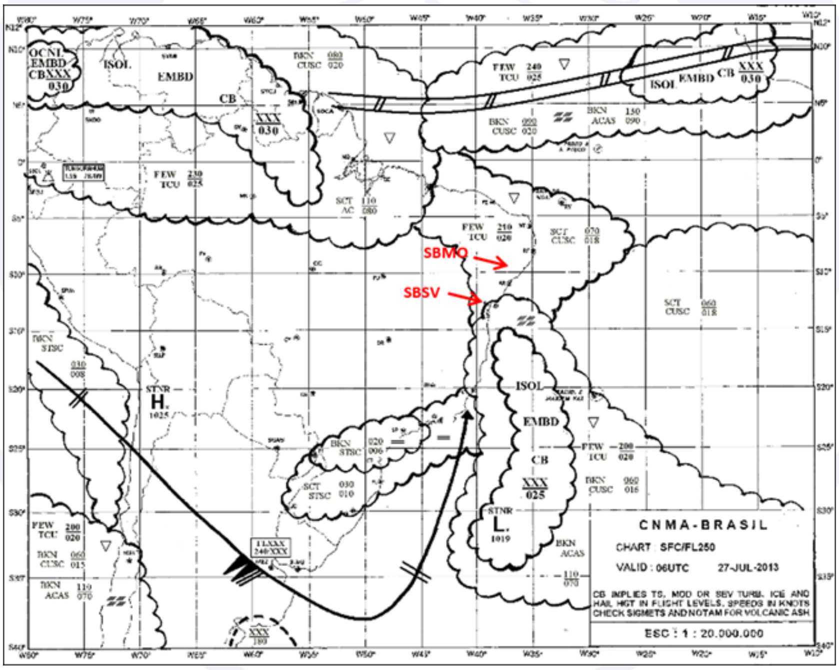

Figure 6 - SIGWX chart from ground level to FL250, updated at 17h31min (UTC), valid on 27JUL2013 at 06h00min (UTC).

The SIGWX chart pointed to the presence of few large vertical cumulus clouds at 2,000ft and top on the FL210, as well as the scattered cumulus clouds and stratocumulus at 1,800ft and top on the FL070, in the intended route region of the aircraft.

Information available in the last two hours prior to the loss of control of the aircraft did not show ice formation conditions on the route and planned flight level.

At 2200 (UTC), at the moment of the loss of control of the aircraft, a GOES 12 satellite image, available from the REDEMET, was generated, which highlighted the weather conditions from South America (Figure 7).

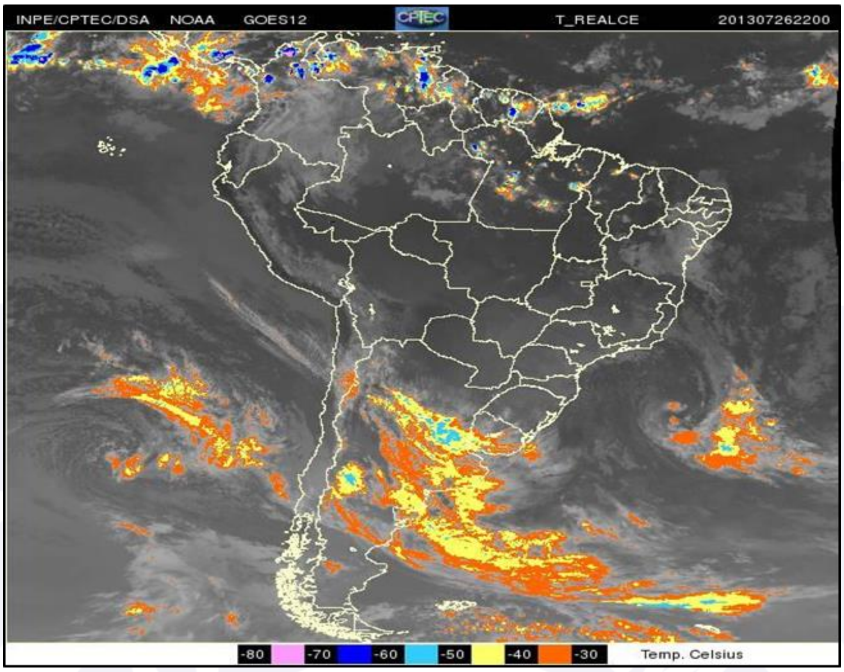

Figure 7 - Image of 2200 (UTC) generated by the GOES 12 satellite.

At the request of the Investigation Team, the Recife Meteorological Surveillance Center (CMV-RE) issued an opinion on the weather conditions prevailing on the Maceió-Salvador route on 26JUL2013 from 2000 to 2400 (UTC), between FL100 and FL180 levels.

The opinion identified that on 26JUL2013 there was strong anticyclonic circulation, generated by the ASAS, positioned East of 030° W and North of 20° S, carrying considerable moisture from the ocean to the continent through the winds from the East and Southeast, making the weather quite unstable at low levels under significant rainfall conditions.

The sky was cloudy to overcast, with clouds formed by raindrops and ice crystals, altastratus (AS) and castellated Cumulus (TCU) with reasonable vertical development on the Maceió-Salvador route, mainly between Aracaju and Salvador.

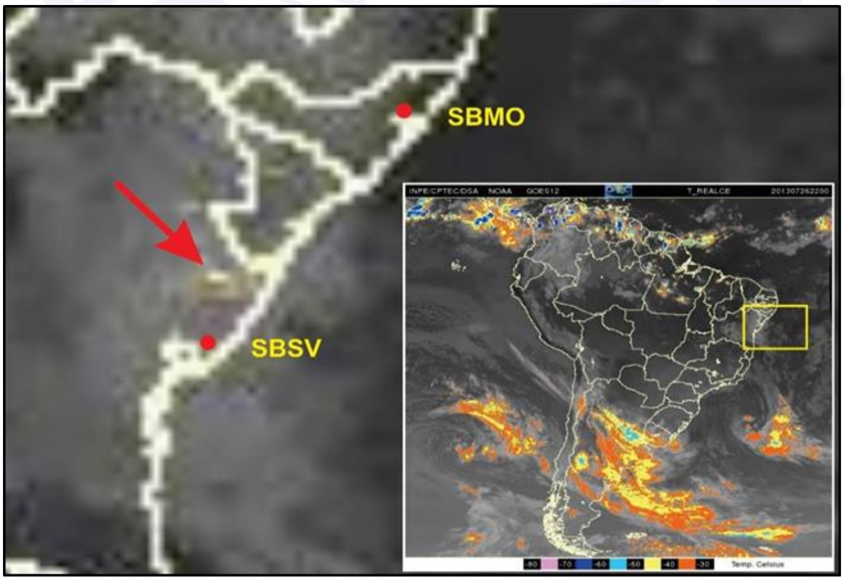

Figure 8 - Highlight of the region analyzed by CMV-RE. The arrow indicates the position where the loss of control of the aircraft occurred.

The aircraft flew on FL160, between the Isotherms from 0° C to -10° C, where it is possible to form ice (light, moderate or strong).

According to the survey of the real-time conditions, the diagnosis of the parameters and the meteorological phenomena in question, it was found that the weather conditions were not favorable to the air operations on the screen route between flight levels FL100 and FL210.

There were indicators that pointed to the possibility of mild-moderate turbulence and ice formation among the isotherms already mentioned. As a result, ice may have occurred at position indicated by the arrow.

1.8 Aids to navigation.

Nil.

1.9 Communications.

According to the recordings, the crew maintained full radio contact with the air traffic control and there was no technical abnormality of communication equipment throughout the flight.

The PP-PTU communications with the air traffic control, at terminals and the en-route were made clearly, with nothing significant to report.

1.10 Aerodrome information.

The occurrence took place outside of the Aerodrome.

1.11 Flight recorders.

The aircraft was equipped with a DFDR and a CVR that had memory with a recording capacity of more than two hours.

The recording was performed at the Flight Recorder Laboratory of the CENIPA, in Brasília - DF.

According to the CVR audio, all flight preparation, taxi and takeoff occurred without abnormalities.

During the climb, there was a message of PACK FAULT. After the crew shut down PACK 2, the message disappeared.

On the en-route flight, flying on FL160, the crew was directed by the ACC-RF to perform STAR, BONF and to report when it was ready for the descent.

When preparing for the arrival, the crew verified that they would enter a region with heavier cloud formations and that some detour would be necessary. At this point, the crew's dialogue revealed some doubts about the use of the weather radar and the captain suggested to the copilot that the manual be consulted.

The captain turned on the 'fasten seat belts' lights and instructed the flight attendants to remain seated, due to the possibility of turbulence.

The ACC-RF directed the aircraft with nationality and registration marks PP-OCT to proceed ahead with the ADOLF position, awaiting coordination with the Salvador Approach Control (APP-SV) to proceed with the head BONF position.

At 21h43min43s (UTC), the captain asked the copilot to perform the Entering Icing Conditions Checklist procedure and the latter collated:

Entering Icing Conditions

Anti-ice, Propeller, Horns, Side Windows on

Propeller, Horns,

Mode Select ALT

Minimum Maneuver Speed... Speed Bug set and observer

It will be 171.

Following these procedures, the crew made left-hand offsets in coordination with the ACC-RF and returned to the ADOLF head.

At 21h49min25s (UTC), the captain requested that the "fasten seat belts" lights to be turned off.

At 21h51min24s (UTC), the captain commented to the copilot about the observed loss of performance on the aircraft from flying in icy conditions. The copilot agreed, saying that "the anti-icing system also contributes to the loss of power".

Moments later, the captain left the cabin, leaving the controls with the copilot. In the meantime, there was a request from the ACC-RF to maintain the ADOLF head arrival profile.

At 21h53min48s (UTC), the copilot turned on the "fasten seat belts" lights and requested a left turn for the ACC-RF. At that moment there was a sound indicating that the aircraft was flying in a rainy area.

At 21h54min47s (UTC), the captain returned to the cabin, resumed commands and coordinated detours with the ACC-RF.

The copilot complained about the weather radar indications, being guided by the captain to adjust the range and angle of the antenna.

According to the aircraft manufacturer data, on the FL160 (ISA +10) the IAS should correspond to 210 kt, the approximate Torque (TQ) of 72.5% and the Fuel Flow of 357kg/h. Except for the lower IAS indication, denoting the degradation of aircraft performance, these parameters were as expected.

At 22h00min (UTC), the IAS value reached 180 kt, with the autopilot engaged and the power lever in the notch position. This IAS was 30 kt below the expected speed. At this time, the crew was trying to copy the information from the ATIS.

At 22h00min08s (UTC), there was a vibrating noise in the cabin, which progressively increased in intensity.

At 22h00min10s (UTC), power was reduced from 72% to 20% TQ.

At 22h00min23s (UTC), the fasten seat belts rang was activated and the flight chief instructed passengers to remain seated and with their belts fastened.

From then on, cabin actions and communications were disturbed amid a succession of alarms and stick shaker triggering, in the following sequence (UTC time):

- 22h00min28s - there was a triple alarm. The copilot requested a descent;
- 22h00min30s - stick shaker (duration 4 seconds);
- 22h00min33s - the copilot declared MAYDAY MAYDAY MAYDAY to APP-SV;
- 22h00min35s - stick shaker (duration 2 seconds);
- 22h00min39s - stick shaker (duration 34 seconds);
- 22h01min14s - stick shaker (duration 2 seconds); and
- 22h01min16s - triple alarm.

Amid the stick shaker and alarm triggers, the captain asked the copilot to shut down the engine. The copilot asked if he should cut both engines, but got no answer.

At 22h01min21s (UTC), both condition levers were set in the feather position. It was possible to hear the change of speed of the propellers.

At 22h01min24s (UTC), the condition lever 1 was set back into auto position and the power lever 2 was moved to 50°.

At 22h01min27s (UTC), propeller 2 reached feather position and propeller 1 was back regulated at 82% Np.

At 22h01min36s (UTC), the power lever 2 was retarded to FI position.

At 22h01min39s, the condition lever 2 left feather position.

At 22h01min43s (UTC), the condition lever 2 was back in feather position.

Finally, at 22h01min57s (UTC), the condition lever 2 was set back in the auto position.

At 22h02min06s (UTC), propeller 2 was back regulated at 82% Np.

At 22h01min24s (UTC), the copilot asked if he could start one of the engines and the captain answered affirmatively.

According to data obtained from the DFDR reading, it was possible to verify that the aircraft flew on the FL160 when it had a rapid speed variation followed by a loss of 5,000ft altitude.

Total Air Temperature (TAT) corresponded to +3.8ºC and the engines were running at a steady regime of 64% (TQ - engine 1) and 69% (TQ - engine 2) until power lever reduction as observed in Power Lever Angle (PLA), Power Lever Angle parameters.

Between 22h00min42s and 22h01min03s (UTC), engines regulation at low thrust (Power Lever on FI), high AOA and low speed, led to ± 2% of variation around the NP target value of 82%.

At about 22h01min30s (UTC), the vibration ceased and the crew took back the control and management of the flight. They identified that both engines were still running and that the PITCH DISCONNECT light was on in the CCAS.

The APP-SV directed the aircraft to SBSV, and the crew opted to maintain the speed around 170 kt (IAS) until approaching for landing.

According to DFDR readings, there was no evidence of malfunction or engine failure in flight.

At the time vibration began, the PACK VALVE 2 was OFF.

With respect to the electrical anti-icing system, the anti-icing propellers were ON, probes right and left anti-icing - ON, horns and elevators de-ice - ON.

Regarding the pneumatic de-icing system, both the ice boots and the airframe de-ice remained OFF throughout the flight.

The engine torque values remained as expected, indicating no compressor stall during the event.

1.12 Wreckage and impact information.

Nil.

1.13 Medical and pathological information.

1.13.1 Medical aspects.

The crewmembers underwent new CMA revalidation tests after aeronautical occurrence.

No evidence was found that problems of physiological nature could have affected the flight crew performance.

1.13.2 Ergonomic information.

Nil.

1.13.3 Psychological aspects.

Nil.

1.14 Fire.

There was no fire.

1.15 Survival aspects.

Nil.

1.16 Tests and research.

During the evaluation of the aircraft DFDR data, it was found that at the end of the pre-flight stage of the occurrence, the APM changed its status from ON to OFF, remaining in this condition throughout the flight.

The APM was in the OFF status at the end of the previous flight, on the ground. When the APM was OFF, calculations were performed normally, but alerts were inhibited.

Also, it was possible to verify that the APM was adjusted from 15T to 21T (21 Tons, corresponding to the aircraft weight) before the takeoff (Figure 9).

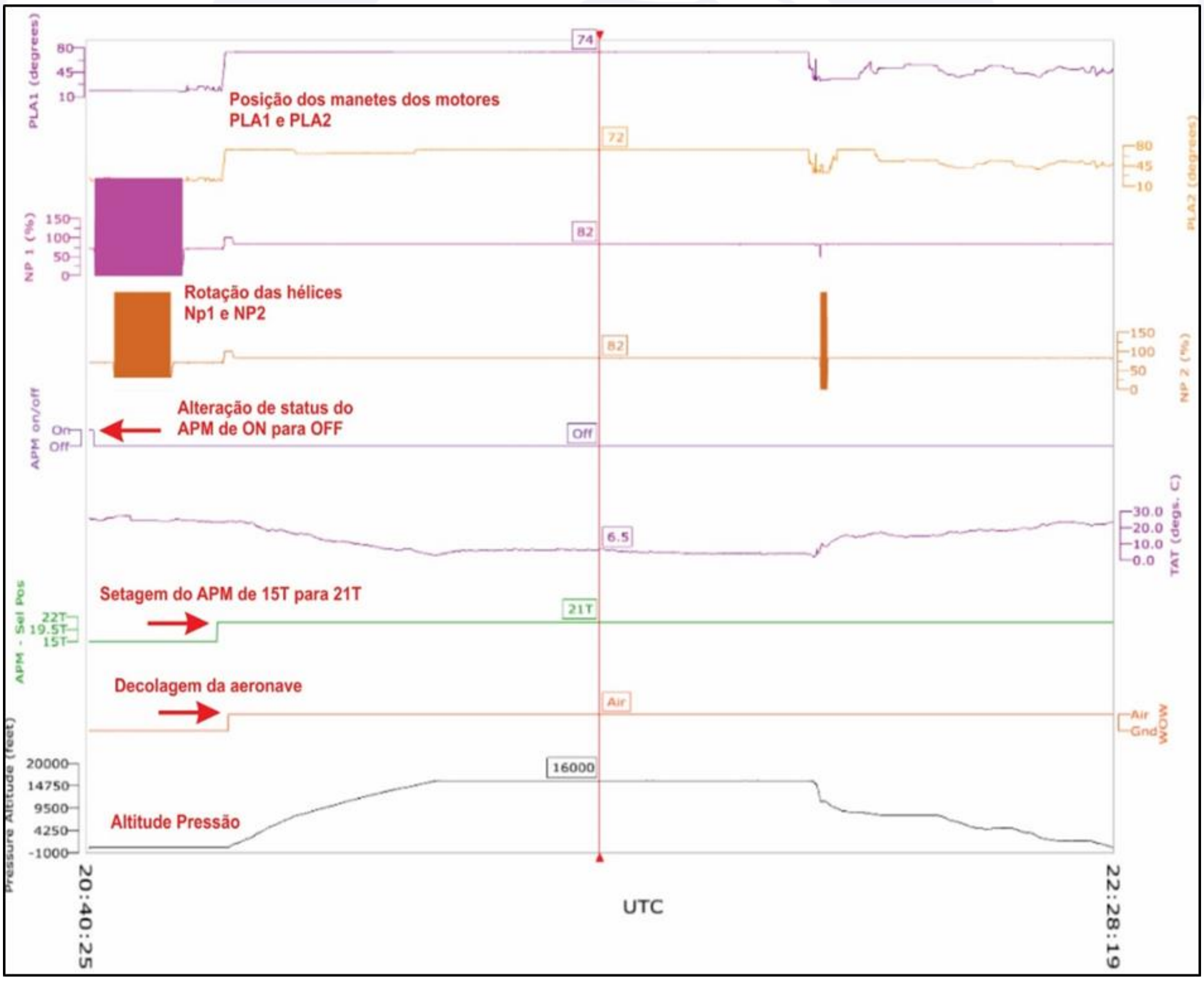

Figure 9 - DFDR data of the PP-PTU aircraft.

Figure 10 - ATR-72-212A APM Control Panel set to 21T under three conditions: Normal (ON), Fault (FAULT), and OFF indications (respectively).

In the search for information that could identify a possible operating and/or fault condition that would result in the APM inoperativeness, it was sought to survey the operating conditions of Trip Airlines fleet in the 45 days prior to the serious incident.

On several aircraft flights of the airline fleet, invalid APM settings were detected, due to crews not selecting takeoff weight at the start of the flight. Takeoff weight should be selected on the APM panel prior to takeoff by rotating the selector button. If the indicated value already corresponded to the takeoff weight, the button should be moved out of adjustment and back to the selected weight.

If the crew did not select any weight, the APM would calculate the weight during takeoff, but the value would be less accurate.

From 2,659 flights analyzed, in 328 the APM showed OFF status (12.3% of flights), in part or throughout the flight (Figure 11).

AERONAVE	QUANTIDADE DE VOOS COM APM OFF
PP-PTT	131
PP-PTU	71
PP-PTR	62
PP-PTO	59
PP-PTP	2
PP-PTL	1
PP-PTM	1
PP-PTN	1
PP-PTQ	0
PP-PTY	0
PP-PTZ	0
PR-TKA	0

Figure 11 - In-flight status records of the APMs of Trip Airlines fleet in the 45-day period prior to the occurrence.

Six of the captains who operated the PP-PTT and PP-PTR registration aircraft on flights that showed APM OFF in the Quick Access Recorder (QAR) data were consulted and stated that the equipment was “set up” according to checklist, that they remained ON and there was no indication that they were OFF or FAULT.

Analyzing the QAR data, it was found that of the seventeen flights prior to the serious incident, in eight flights, the APM had an OFF status. Six consecutive flights were performed with the APM in the OFF status. There were six APM transitions from ON to OFF on the ground, five of them occurred at the end of the flight and one at the beginning. Each of these transitions had the same sequence of events:

- landing gear down and extended flaps;

- APM Fault, due to Air Data Computer (ADC) discrepancy signal, Flight Data Computer;

- MASTER CAUTION alarm;

- cancellation of MASTER CAUTION; and

- APM selected in OFF.

The APM compared altitude, IAS, and TAT information provided by both ADC.

When the aircraft was on the ground, these parameters were more sensitive to external conditions and the APM could detect a discrepancy, leading to an APM fault.

The aircraft manufacturer has updated the MFC to prevent this spurious fault of the APM on the ground. The new MFC Part Number (PN): ED35 E109-0105 has been introduced on the aircraft production and an equipment upgrade has been proposed since early 2011.

According to the manufacturer, an APM test should be performed every day during preliminary cockpit preparation (according to Flight Crew Operating Manual (FCOM) - 2.03.06). In this case, the test would not be successful if the APM was off.

The APM push button failure (208TU push button) has been identified as the single failure, capable of disabling the APM without any indication. Daily testing, however, would detect such failure. If the OFF light had failed, such a failure could, however, be evidenced during the lamp test provided in the Cockpit Preliminary Preparation Checklist.

1.17 Organizational and management information.

Nil.

1.18 Operational information.

The flight plan presented by the airline on the SBMO-SBSV leg provided the take-off at 2010 (UTC) and the IF1 route under FL180 on the G677 to the vertical Aracaju - SE, heading to the fixed BONF, where it would take off. STAR to SBSV. The estimated route time was one hour and thirteen minutes with declared flight autonomy of two hours and fifty-three minutes (Figure 12).

```
(FPL-TIB5591-IS
-AT72/M-SDFGHIR/S
-SBMO2010
-N0257F180 DEND1A DENDO G677 ARU BONF
-SBSV0113 SBAR
-PBN/B2D2O2 DOF/130726 REG/PPPTU PER/B
-E/0253 P/TBN S/J
 A/WHITE AND BLUE
```

Figure 12 - Flight plan of the aircraft.

The aircraft Load sheet, Load Manifest, indicated 59 passengers on board and the estimated takeoff weight was of 20,948kg. At the time of boarding, however, the absence of one of the passengers was confirmed. Weight and balance data were within the aircraft center of gravity limits (Figure 13).

```
L O A D S H E E T          CHECKED     APPROVED
ALL WEIGHTS IN KILOGRAMS                                  1

FROM/TO FLIGHT  FLTDATE          A/C REG VERSION     CREW     DATE  TIME
MCZ SSA 5591    26JUL13          PP-PTU  68YB        2/2     26JUL13 1726
                        WEIGHT          DISTRIBUTION
LOAD IN COMPARTMENTS        539 1/328 2/211
PASSENGER/CABIN BAG        4385 47/11/1/0 TTL 59 CAB 0
                                Y 59 SOC 0
                                BLKD 0
***************************************************************
TOTAL TRAFFIC LOAD          4924
DRY OPERATING WEIGHT       13774
ZERO FUEL WEIGHT ACTUAL    18698 MAX 20500    ADJ
TAKE OFF FUEL               2250
TAKE OFF WEIGHT   ACTUAL   20948 MAX 22500 L  ADJ
TRIP FUEL                    820
LANDING WEIGHT    ACTUAL   20128 MAX 22350    ADJ
TAXI OUT FUEL                 50
                                      LAST MINUTE CHANGES
BALANCE AND SEATING CONDITIONS DEST SPEC  CL/CPT + -  WEIGHT
DOI       -14.8
 MACZFW     27.8
 MACTOW     28.8
 MACLAW     28.5
CABIN AREA
A      25            C      34
UNDERLOAD BEFORE LMC    1552              LMC TOTAL  + -
FLAP15 STAB TO        0.8 NOSE UP
```

Figure 13 - Load sheet of the occurrence flight.

The aircraft technical logbook provided information that the Pack Valve 2 was inoperative in flight. Thus, according to the aircraft Minimum Equipment List (MEL), the flight would be restricted to FL170. Thus, the crew proceeded as scheduled, but maintaining the FL160.

The following sequence of events has been described based on voice data extracted from the CVR, DFDR data and analysis by the BEA through Contribution Report, ref BEA pp-u130726, of 08AUG2014.

During the climb, PACK 2 FAULT was indicated.

At 21h33min (UTC), the aircraft flew leveled on the FL160 with Autopilot, coupled, 202 kt IAS and 6.3ºC TAT. The torque developed in the engines corresponded to 67% on the left engine and 73.5% on the right engine. Propeller speed was stable at 82%, high-pressure spool rotation speed was stable with 96% NH (Figure 14).

Figure 14 - Flight parameters of the PP-PTU aircraft at 21h33min34s (UTC).

At 21h37min (UTC), some en-route formations were identified and the pilots commented about the need to make detours.

At this point, it was observed that there were doubts among the pilots about the operation of the aircraft weather radar, demanding the need to consult the equipment manual.

At 21h41min (UTC), the ACC-RF directed the aircraft to turn right with the head of the fixed ADOLF.

After performing the turn, the crew identified that they were entering an area with ice formation, identified by the IEP and, at 21h44min13s (UTC), they performed the Entering Icing Conditions procedure. The procedures were stated by the copilot when it was reported “BUG 171 kt”. The BUG referred to the minimum operating speed under icing conditions on the ATR-72-212A aircraft.

According to the airline SOP, when entering ice-making conditions, the procedures provided by the aircraft manufacturer should be performed, as shown in Figure 15.

ENTERING ICING CONDITIONS

ANTI-ICING (PROP - HORNS - SIDE WINDOWS)....................................ON
MODE SEL..AUTO
MINIMUM MANEUVER/OPERATING ICING SPEEDS .... BUGGED AND OBSERVED
ICE ACCRETION ....MONITOR

AT FIRST VISUAL INDICATION OF ICE ACCRETION AND AS LONG AS ICING CONDITIONS EXIST

ANTI-ICING (PROP - HORNS - SIDE WINDOWS)...................CONFIRM ON
MODE SEL...CONFIRM AUTO
ENG DE-ICING ....ON
AIRFRAME DE-ICING ....ON
MINIMUM MANEUVER/OPERATING ICING SPEEDS .... BUGGED AND OBSERVED
BE ALERT TO SEVERE ICING DETECTION
In case of severe icing, refer to 1.09

■ **If significant vibrations occur**
BOTH CL .... 100 OVRD for not less than 5 minutes

LEAVING ICING CONDITIONS

DE-ICING AND ANTI-ICING MAY BE SWITCHED OFF

WHEN THE AIRCRAFT IS VISUALLY VERIFIED CLEAR OF ICE

ICING AOA CAPTION MAY BE CANCELLED AND NORMAL SPEEDS MAY BE USED

Figure 15 - Predicted Procedures for Entering Icing Conditions and Ice Accretion, according to the airline SOP.

The procedures prevised the activation of the anti-icing systems of the propellers, horns, and side windows. The mode selector (MODE SEL) should be checked at AUTO, the BUG set, and ice accretion conditions monitored.

Upon finding ice accretion ENG DE-ICING and AIRFRAME, DE-ICING (engine and wings and stabilizers deicing) systems should be triggered and, in case of significant vibration, the propeller speed throttle should be set to maximum (100% NP).

SEVERE ICING

MINIMUM ICING SPEED............................INCREASE RED BUG by 10 kt
PWR MGT...MCT
CL / PL ....100% / MCT
AP (if engaged).......FIRMLY HOLD CONTROL WHEEL and DISENGAGE
SEVERE ICING CONDITIONS..ESCAPE
ATC...NOTIFY

- **If an unusual roll response or uncommanded roll control movement is observed :**

  Push firmly on the control wheel
  FLAPS.. 15

- **If the flaps are extended, do not retract them until the airframe is clear of ice.**

- **If the aircraft is not clear of ice :**

  GPWS ....FLAP/GPWS OVRD
  STEEP SLOPE APPROACH (≥4.5°)........................ PROHIBITED
  APP/LDG CONF ....MAINTAIN FLAPS 15
  with "REDUCED FLAPS APP/LDG icing speeds" + 5 kt
  Multiply landing distance FLAPS 30 by 2.12.

DETECTION

Visual cue identifying severe icing is characterized by ice covering all or a substantial part of the unheated portion of either side window

and / or

Unexpected decrease in speed or rate of climb

and / or

The following secondary indications :

. Water splashing and streaming on the windshield
. Unusually extensive ice accreted on the airframe in areas not normally observed to collect ice
. Accumulation of ice on the lower surface of the wing aft of the protected areas
. Accumulation of ice on propeller spinner farther aft than normally observed

The following weather conditions may be conducive to severe in-flight icing :

. Visible rain at temperatures close to 0°C ambient air temperature (SAT)
. Droplets that splash or splatter on impact at temperatures close to 0°C ambient air temperature (SAT)

Figure 16 - Procedures for Severe Icing, according to the airline SOP.

In the case of severe icing conditions, procedures provided that Red Bug + 10 kt speed, 100% maximum continuous NP power would be maintained, hold stick firmly, uncouple autopilot, exit icing condition and notify the Air Traffic Control (ATC).

If the aircraft exhibited abnormal rolling behavior, the stick should be pushed firmly, lowering the flaps to 15°. The extended flaps should not be retracted until the fuselage is free of ice on its surface.

Regarding the ice detection, the manual stated that visual identification of severe ice was characterized by ice covering every unheated portion of any side window, a substantial part of it, and/or an unexpected decrease in speed or rate of climb.

Other secondary indications referred to:

- water splashing and dripping on the windshield;
- ice widely accumulated in areas of the structure where they were not normally observed;
- ice accumulation on the front of the lower wing surface in protected areas; and

- ice accumulation on the propeller spinner, further ahead than normally observed.

The following weather conditions could be conducive to severe ice formation:

- visible rain at temperatures around 0° C Static Air Temperature (SAT), Static Outdoor Air Temperature; and
- drops that spread or splash on impact at temperatures near 0° C SAT.

At 21h48min (UTC), the captain commented to the copilot about the aircraft poor performance when entering the ice formation area. Afterwards, the crew requested left turns to avoid weather formations. At that time, IAS was around 185 kt (25 kt below expected speed), performance degraded and Level 3 (de-icing) turned off.

At 21h54min (UTC), the CVR recorded a sound similar to the flight of the aircraft in a rainy region.

The ACC-RF transferred the communication to APP-SV, directing the aircraft to request the head of the fixed BONF to that APP.

At 21h59min59s (UTC), the indicated TAT was 2.6°C. The CVR recorded a loud vibrating noise from the aircraft and IAS had dropped to 184 kt.

Both engine throttle levers have been reduced to 50º PLA (20% TQ). With reduced power and ALT engaged autopilot, the aircraft pitch angle increased and IAS rapidly reduced to 158 kt (minimum ice-operating speed was 161 kt). According to the Captain, he disengaged the autopilot. At the same time, the torque of the engines reached 21% (Figure 17).

Figure 17 - Flight parameters of the PP-PTU aircraft at 21h59min59s (UTC).

The stick pusher activated. Since the captain countered the stick pusher, the AOA increased (local AOA LH 10.3º and 24 RH 10.6º) and both stick shakers were activated.

Following, the aircraft had a sharp wing turn (43º), although the stick was commanded to the right. The vertical speed indicated a drop of 1,350ft/min. (Figure 18).

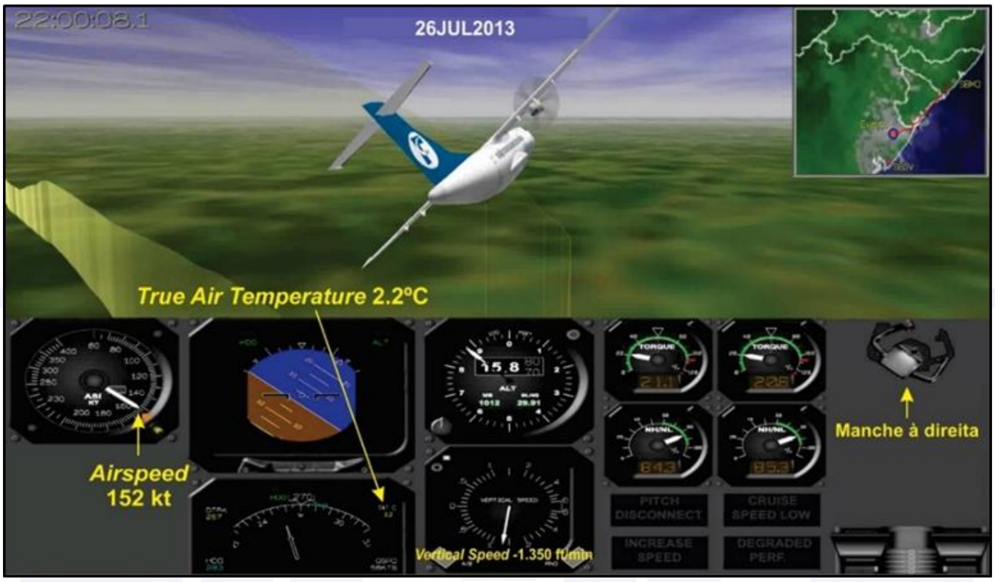

Figure 18 - Flight parameters of the PP-PTU aircraft at 22h00min08s (UTC).

The stick pusher was triggered for two seconds (local AOA LH: 16.3º and RH 15.9º). The aircraft pitch angle decreased (nose down attitude). Simultaneously to pusher activation, a nose up effort was recorded on captain side.

The speed momentarily stabilized at 151 kt, the aircraft reversed the bank to the right and the descent rate increased to 3,600 ft/min.

AOA went below the threshold, hence the stick pusher and stick shaker deactivated for a second. The stick was still being steered while the pitch angle reached 6°.

The stick pusher and stick shaker engaged a second time for two seconds (AOA LH location: 21.7º and RH 23.7º). The aircraft pitch angle then dropped to -8º. Simultaneously to pusher activation, a nose up effort is recorded on captain side.

AOA went below the threshold, hence the stick pusher and stick shaker deactivated for a second. The pitching angle increased again and reached 1°. The stick pusher and stick shaker engaged for the third time (AOA LH location: 12.6º and RH 14.6º).

The pitch angle remained at 1° and reached a roll angle of 24° to the right (Figure 19). Nose down input from the captain's side was recorded 10 second after the continuous activation of the 3rd stick pusher.

Figure 19 - Flight parameters of the PP-PTU aircraft at 22h00min19s (UTC).

Right bank angle decreased and aircraft started a new bank on the left.

Continuous nose up efforts were recorded on captain side and counteracted the action of the stick pusher. As a result, elevators moved several times between nose up (stick pusher not activated) and nose down (stick pusher activated) positions and pitch angle varied between -6° (nose down) and +5° (nose up).

Descent rate increased toward -5,000 ft/min and AOA increased durably above 20°. Then, stick pusher activated during 35 seconds (nose down order). When captain side nose up efforts reached -580 N (nose up order), PITCH DISCONNECT occurred.

The position of the right surface of the elevator reached the maximum value for "pitch down" and remained stable. The position of the left surface of the elevator remained in a neutral position. The pitch angle reached 21° and the aircraft began to roll to the left. At that time, the aircraft was flying on FL150 (AOA peaked at 52º).

At 22h00min24s (UTC), the "fasten seat belts" light came on and the flight attendants instructed passengers to remain seated with seat belts fasten. Afterwards, they sat in the nearest available seats.

Following, the pitching angle reached 17º and the speedometer indicated 0 kt (Figure 20).

Figure 20 - Flight parameters of the PP-PTU aircraft at 22h00min24s (UTC).

The pitching angle decreased significantly to -16º. At the same time, a maximum left rolling value of 58º has been reached.

The pitching angle was still decreasing as the rolling angle shifted from left to right.

When the aircraft was almost leveled (approximately -4º pitch angle, and roll angle around 1º left), there was a further reduction from +37° of the right roll and the pitch angle increased from -24º (nose down). Descent rate was more than 8,000 ft/min up based on the recorded parameters.

AOA went below the threshold, hence the stick pusher and stick shaker deactivated for a second. The copilot requested an immediate descent from APP-SV and was allowed to descend to 2,000ft. In collating the information, the copilot declared a distress condition (MAYDAY).

The CVR recorded the sound of a triple alarm followed by intermittent stick shaker triggering. The stick pusher and stick shaker remained active for 34 seconds (Figure 21).

Figure 21 - Flight parameters of the PP-PTU aircraft at 22h00min29s (UTC).

The APP-SV authorized SBSV direct head and, from that moment, communication became very disturbed between the crewmembers, between the crewmembers and the APP-SV, and with other aircraft flying in the region.

At 22h00min40s (UTC), the aircraft crossed the FL110, with a 1,000ft/min descent rate, 181 kt IAS and the TAT increased to 10°C (Figure 22).

Figure 22 - Flight parameters of the PP-PTU aircraft at 22h00min40s (UTC).

The captain asked the copilot to cut the engine and he asked whether to cut both engines. Getting no response, the copilot selected both engines to FI and informed the captain that he had cut both engines. 44 seconds later, propeller n°2 was feathered.

The pitching angle decreased and reached -10º. The stick pusher and stick shaker triggered for the fourth time.

According to the pilots' reports, on 07JAN2013, one of the airline's aircraft (ATR-72-212A, PR-TKA registration) had a strong vibration on one of the propellers, which induced them to handle the vibration of the PP-PTU aircraft similar to PR-TKA, reducing engine power.

Finally, AOA went below the threshold, hence the stick pusher and stick shaker deactivated for a second. The aircraft stabilized and the pitching angle increased to 6º. The altitude was stabilized at around 11,000ft.

According to the DFDR data, the propeller 1 beta angle was reduced, but rapidly restored to initial value. This indicates a momentary selection of the copilot close to the feather position before being set again inside the auto position. The copilot remained in auto (82% NP) for the rest of the event.

The copilot asked if he could “start the engine,” being guided by the captain to start engine # 1.

The engine 2 remained feathered during 35 seconds. Then power lever 1 was moved gradually up to the notch (75°) while power lever 2 remained on Flight Idle. The speed increased to values above 180 kt. During this period, the asymmetrical engine thrust was through the rudder.

Then power lever 2 was moved forward and finally both power levers were set symmetrically. The flight stabilized under normal conditions on FL080, with TAT above 10ºC.

After discussing on pitch disconnect triggering conditions and engine conditions, the crew found that both engines were running normally and decided to proceed to SBSV landing at reduced speed.

The APP-SV was briefed by the captain on the normalization of flight conditions. He then reported to the passengers that they had had a vibration condition on one of the aircraft propellers and reported that they were proceeding for landing on Salvador - BA.

The landing on SBSV was performed without major problems.

Throughout the flight, no alerts were triggered by the APM.

1.19 Additional information.

Airworthiness Directive (DA) Nº 2009-0170

In 2009, a DA was issued by the EASA for ATR-42 and ATR-72 series aircraft.

This guideline was incorporated at the factory into ATR-72-212A aircraft with Manufacturer's Serial Number (MSN), Manufacturer Serial Number 699, 722, 724, and MSN 726 onwards, thus encompassing the PP- PTU.

This guideline required the installation of an APM with MFC function.

The directive was intended to minimize the dangers associated with inadvertently encountering severe ice conditions (which would be beyond the requirements for EASA Part 25-certified aircraft) by providing the flight crew with objective indications and timely warnings, when severe ice conditions were encountered.

The accumulated experience in the ATR-42/72 worldwide passenger and incident aircraft fleet has revealed that long exposure to severe ice conditions out of the certification envelope could result in unsafe conditions that would lead to rapid performance degradation, a sudden loss of lift on the aerodynamic and control surfaces, and the subsequent loss of control of the aircraft.

The directive stated that prolonged exposure to such conditions was due to crews' lack of knowledge of these extreme environmental conditions, leading to their late detection and/or incorrect application of manual procedures, requiring the crew to actively monitor the ice conditions found to avoid them as soon as they were recognized as serious.

Thus, to improve situational awareness of flight crews in icy conditions, the ATR developed an APM that was compatible with the ATR aircraft with MFC installed.

It was recognized that while the aircraft ice protection system was compatible with the certification envelope for flight under known ice conditions, the possible unsafe condition arising from prolonged exposure to a severe ice environment would be announced by the warnings provided by the APM.

As the APM alerts indicated only significant aerodynamic restrictions, the Aircraft Flight Manual (AFM) emergency procedures prevised severe ice conditions remained valid and enforceable. In these, the use of the APM could not result in any non-compliance with the procedures regarding previous visual indications for detecting severe ice formation conditions, because the APM function was solely intended to provide objective indications that would improve situational awareness.

Brazilian Civil Aviation Regulation No. 25

RBAC No. 25, which dealt with the airworthiness requirements for airplanes of the transport category, contained in Subpart F - Equipment the following requirements[1]:

> General
>
> § 25.1301 Function and installation.
>
> (a) Each item of installed equipment must:
>
> (1) Be of a kind and design appropriate to its intended function;
>
> (2) Be labeled as to its identification, function, or operating limitations, or any applicable combination of these factors;
>
> (3) Be installed according to limitations specified for that equipment; and
>
> (4) Function properly when installed.
>
> (b) EWIS must meet the requirements of subpart H of this part.

The § 25.1419 Ice protection of RBAC 25, under (e), brought the following requirements:

> (e) One of the following methods of icing detection and activation of the airframe ice protection system must be provided:
>
> (1) A primary ice detection system that automatically activates or alerts the flight crew to activate the airframe ice protection system;
>
> (2) A definition of visual cues for recognition of the first sign of ice accretion on a specified surface combined with an advisory ice detection system that alerts the flight crew to activate the airframe ice protection system; or
>
> (3) Identification of conditions conducive to airframe icing as defined by an appropriate static or total air temperature and visible moisture for use by the flight crew to activate the airframe ice protection.

Upset Prevention and Recovery Training (UPRT)

Between 2001 and 2011, air accidents resulting from Loss of Control in Flight (LOC-I) were the leading cause of fatalities in commercial aviation.

As a result, several initiatives were developed with the objective of reducing the number of LOC-I. Committees and working groups were formed to study aviation industry trends, advances in simulation technology, training requirements, equipment designs, and human performance.

In 2012, the ICAO and the FAA brought many of these groups together to participate in the discussions of the newly created Loss of Control Avoidance and Recovery Training (LOCART) Committee.

The studies developed by the LOCART demonstrated that some practices established in aviation were not only ineffective, but also contributed to inadequate responses in some flight situations.

[1] Brazilian Civil Aviation Regulation No. 25 was originally written in English.

For example, in certain cases, the techniques applied in stall training were based on the pilot's ability to achieve recovery with minimal loss of altitude. This resulted in practices that emphasized rapid application of power with minimal reduction in angle of attack (AOA) to minimize altitude loss rather than valuing the importance of reducing AOA to effectively restore the ability of the wings to generate lift.

Actions have been taken by both regulators and flight schools to correct these procedures with new training standards, emphasizing that effective recovery requires, above all, immediate reduction in the angle of attack. Crewmembers should also be aware that this AOA reduction, whenever the aircraft is in a low-energy state for high-altitude operations, may even require a substantial loss of altitude to ensure effective recovery.

Analysis of the LOC-I accident data indicated that the contributing factors to this type of occurrence can be categorized as being induced by aircraft systems, environmental factors, pilots, or any combination of these three factors. Of the three, pilot-induced accidents represented the most frequently identified contributing factor, mainly resulting from the application of incorrect procedures, including inadequate flight control information; crewmember disorientation; poor aircraft energy management; distraction of one or more crewmembers; and inadequate training.

The LOCART initiative resulted in the following recommendations for implementing improvements to existing training practices, which later became part of a comprehensive program of UPRT:

a) provide comprehensive academic training that covers the wide spectrum of issues related to abnormal attitudes in the early stages of commercial pilot learning, during type rating training, as well as throughout the pilot's professional career at regular training intervals ;

b) provide specific UPRT training in real flight while obtaining a commercial pilot license (on light aircraft capable of performing recommended maneuvers while maintaining acceptable margins of safety);

c) provide UPRT training on flight simulation training devices;

d) provide training scenarios involving conditions that may result in abnormal attitudes as part of type rating and recurrent training exercises in simulators specific to the aircraft type;

e) implement standards that require the UPRT to be delivered by suitably qualified and competent instructors; and

f) implement standards that require UPRT training in simulators to be conducted on suitably qualified devices (using the highest level of fidelity available).

1.20 Useful or effective investigation techniques.

Nil.

2. ANALYSIS.

It was a passenger’s flight.

There was an Airworthiness Directive (DA - No. 2009-0170) which determined the installation of a Multi-Function Computer (MFC), with Aircraft Performance Monitoring (APM) function, which had been incorporated into the aircraft by the manufacturer.

The application of this directive was intended to minimize the dangers associated with inadvertently encountering ice conditions by providing flight crews with warnings when severe ice conditions were encountered.

Regarding maintenance services, there were releases in the technical logbook of the aircraft with APM failure reports on 16 and 21JUL2013. In both cases, actions were taken in accordance with JIC 30-84-00 OPT 10000 and the problem was considered solved. On the day of the occurrence, the aircraft technical logbook reported PACK # 2 failure in flight.

The unavailability of PACK # 2 restricted the operation of the aircraft to the FL170, but did not make it unavailable for flight. Thus, according to the maintenance records, the aircraft had restrictions on its operation, however, it did not prevent the flight under the conditions performed.

The pilots were qualified and had the experience and training required for the flight. The leg was planned by the airline and the route and condition data of the aircraft were reported to the crew.

Meteorological information for the Salvador Aerodrome – BA, indicated favorable conditions for the visual flight, with the possibility of rain degradation with reduced visibility and operation under IFR. Also, few cumulus clouds of large vertical extension based on 2,000ft and top on FL210 were expected along the aircraft route.

Information available in the last two hours prior to the loss of control of the aircraft did not indicate ice formation conditions on the route and planned flight level.

The normal procedures were performed according to the checklist and the flight proceeded without abnormalities until takeoff. During the climb, PACK 2 FAULT was indicated. The crew turned off that pack and the indication disappeared.

An analysis of the weather conditions showed the presence of indicators that evidenced the conditions for ice formation at the flight level and the PP-PTU route.

During the en-route flight, the crew recognized the low-temperature conditions conducive to icing and performed checklist procedures for Entering Icing Conditions, triggering the aircraft anti-icing systems.

According to the CVR audio, it was found that the crew noticed the presence of ice accretion, however, the engine, wings and stabilizers de-icing systems were not activated, as prevised in the flight manual.

Despite the low Total Air Temperature (TAT), +3.8°C, the aircraft speed reduction (20 kt below expected cruise speed) and water splashing on the windshield, the crew did not recognize such conditions as abnormal.

In this context, although ice accretion conditions were identified, there was no adequate perception of how such conditions could affect air operation. This indicated a low level of situational awareness, which favored the crew maintaining the flight in unfavorable conditions and failing to implement corrective actions provided for the management of the situation (Level 3 defrosting system selection and/or exit from these conditions, according to checklist).

Additionally, it was found that the crew had doubts about the correct adjustment of the range and angle of the aircraft weather radar antenna. Its correct use could have helped the crew avoid the "heavier" weather formations.

During en-route flight there was a progressive reduction of IAS from 202 kt to 184 kt, due to accumulated ice on the aircraft, not eliminated because of the non-selection of the de-icing system.

Then a strong vibration occurred in the aircraft and the power throttle was reduced in both engines. This led to a decrease in IAS from 184 kt to 158 kt (minimum operating speed in freezing conditions was 161 kt), autopilot was decoupled, and actuation on controls led to increased AOA, resulting in the activation of the stick shaker, stick pusher and loss of control of the aircraft.

During the field investigation, it was verified the absence of the Red Bug of the left seat speedometer, which had the function of indicating the minimum flight speed under severe ice conditions to the aircraft captain.

The absence of this BUG may have contributed to the captain not realizing that the speed slowly approached the minimum limit for flight under those conditions.

Crew did not apply the procedure for stall recovery, which were: push on control column, Flaps 15 selection, MCT thrust setting.

During the loss of control, the pilot flying counteracted the stick pusher which generated an uncoupling of both control columns and turning on the PITCH DISCONNECT light in the CCAS.

Considering the DFDR data, it was inferred that the decoupling of the elevator surfaces occurred because of the captain's actuation in the “pitch down” direction (in an attempt to reverse the decrease in pitch angle) associated with the activation of the stick pusher (which causes the nose of the aircraft to "sting").

Due to a recent occurrence of strong vibration in the propellers of another aircraft from the airline (ATR-72-212A, registration PR-TKA on 07JAN2013), until that moment, the crew considered that this condition was the same abnormality and thus, tried to cut the engines.

This fact indicated that there was an inadequate assessment of the situation, which contributed to the crew taking inappropriate action to manage the problem. It is possible that the knowledge of a previous problem with another airline aircraft has influenced the crew's decision making process and impaired recognition of the low energy level of the aircraft.

Analysis of the PP-PTU DFDR data revealed that the APM changed its status from ON to OFF after the completion of the pre-flight stage. Despite the change of status, the crew did not identify any fault or that the equipment was OFF. Thus, the crew followed the procedures provided, adjusting the APM from 15T to 21T, according to the aircraft weight recorded in the load sheet.

It should be considered, however, that when the APM was OFF, calculations were performed normally but alerts were inhibited, that is, no CRUISE SPEED LOW, DEGRADED PERFORMANCE, or INCREASE SPEED alerts were issued.

The fact that the DFDR data indicate that the APM remained in OFF status contradicts the crew's claim that they did not observe any indication that the equipment was OFF, as this indication would appear on the APM panel (Figure 10). Similarly, six other flight captains in which the APM was OFF stated that the equipment was “set” according to the checklist, that it remained ON and that there was no indication that it was OFF or in FAULT.

Although pilots did not receive the APM alerts (CRUISE SPEED LOW, DEGRADED PERFORMANCE or INCREASE SPEED), there was a full range of information available to the crew that could indicate a stall caused by ice accumulation: aircraft flying in an area with ice-forming features; degraded aircraft performance; stick shaker and stick pusher acting; low speed and high angle of attack.

The aircraft lost 10 kt prior to the activation of anti-icing and lost 10 kt prior to the PLA reduction. At 180 kt, the PLA were reduced to 20% TQ with AP still engaged in altitude tracking, leading the IAS to reduce down to 148 kt.

Thus, both the inaccurate perception of the consequences of ice accumulation, as well as the failure to properly analyze the aircraft abnormal behavior, contributed to the crew's failure to apply the intended corrective actions at two different times.

It was also verified that there was inefficiency in the utilization of available human resources for the operation of the aircraft, due to inadequate management of the tasks assigned to each crewmember due to confusion in communication, considering the misinterpretation regarding the need to cut the engines during the occurrence.

3. CONCLUSIONS.

3.1 Facts.

a) the pilots had valid CMAs;

b) the pilots had valid AT47 aircraft type (which included the ATR-72-212A model) and IFRA Ratings;

c) the pilots were qualified and had experience in the kind of flight;

d) the aircraft had valid Airworthiness Certificate (CA);

e) the aircraft was within the weight and balance limits;

f) the aircraft maintenance records were updated;

g) there was no report of the absence of the Red Bug of the left-hand speedometer in the aircraft logbook;

h) the weather forecast did not indicate the possibility of ice formation on the aircraft route;

i) at the end of the stage prior to the occurrence flight, the APM changed its status from ON to OFF;

j) the crew reported not having observed any indication that the APM was OFF;

k) the crew had doubts about the correct adjustment of the range and angle of the aircraft weather radar antenna;

l) the crew recognized the low temperature conditions conducive to ice formation;

m) the crew activated the anti-icing systems of the aircraft;

n) the crew noticed the presence of ice accretion; however, the engine, wings and stabilizers de-icing systems were not activated;

o) the crew did not recognize the aircraft low energy level, which required specific procedures for such conditions;

p) there was a progressive reduction of the Indicated Airspeed (IAS), Indicated Speed, from 202 kt to 184 kt, due to the accumulated ice on the aircraft;

q) despite the low TAT (+3.8ºC), the aircraft speed reduction (20 kt below expected cruise speed) and water splashing on the windshield, the crew did not recognize such conditions as abnormal;

r) there were no CRUISE SPEED LOW, DEGRADED PERFORMANCE or INCREASE SPEED alerts issued by the APM;

s) there was a strong vibration in the aircraft and the power throttle was reduced in both engines, causing the IAS decrease from 184 kt to 158 kt;

t) there was loss of control of the aircraft associated with wide variations in attitude and speed;

u) the stick shaker and stick pusher were triggered at several times during the event, consistently with the situation of high angles of attack;

v) stick pusher was counteracted by the captain. That led to a pitch up (pitch angle up to +20°) when the pitch disconnect occurred;

w) aircraft control was retaken and the landing was made without major problems;

x) the aircraft had minor damage; and

y) the occupants of the aircraft left unharmed.

3.2 Contributing factors.

- **Control skills – a contributor.**

The reduction in power in both engines, associated with the attempt to maintain level flight resulted in the decrease of the IAS to values below the minimum operating speed under the conditions encountered; increased angle of attack; and the subsequent activation of stall protection systems.

- **Adverse meteorological conditions – a contributor.**

The weather conditions observed on the level and route of the PP-PTU, without the aircraft having the de-ice system activated, caused ice accumulation and a significant loss of airspeed. This condition, aggravated by inadequate actuation in flight controls, led the aircraft to a stall condition.

- **Crew Resource Management – a contributor.**

It was found that there was inefficiency in the use of available human resources for aircraft operation, due to inadequate management of tasks affecting each crewmember because of the confusion in communication, given the misinterpretation regarding the need for engine shutdown during the occurrence.

- **Piloting judgment – a contributor.**

There was an inadequate assessment by the crew of the parameters related to the operation of the aircraft, regarding the non-activation of the de-icing system for the presented ice formation conditions, as well as regarding the use of flight commands when trying to counteract the stick pusher performance in a stall situation.

- **Aircraft maintenance – undetermined.**

The absence of the Red Bug from the left-hand speedometer, which was not recorded in the technical logbook, indicated that, at the time of the serious incident, there was no perception by crews and maintenance crews about the importance of observing the minimum operating limits at icing conditions, which may have contributed to this speed limit not being respected in this operation.

- **Perception – a contributor.**

During the flight, there was an inaccurate perception of the impact of ice accretion conditions on the air operation, which favored the crew to keep the flight in unfavorable conditions and not realize the occurrence of stall caused by ice accumulation.

- **Decision-making process – a contributor.**

There was an inadequate assessment of the factors that impacted in the aircraft performance, which undermined the recognition of the severe icing condition and resulted in the adoption of wrong measures to manage that adverse situation.

4. SAFETY RECOMMENDATION.

A proposal of an accident investigation authority based on information derived from an investigation, made with the intention of preventing accidents or incidents and which in no case has the purpose of creating a presumption of blame or liability for an accident or incident. In

addition to safety recommendations arising from accident and incident investigations, safety recommendations may result from diverse sources, including safety studies.

In consonance with the Law n°7565/1986, recommendations are made solely for the benefit of the air activity operational safety, and shall be treated as established in the NSCA 3-13 "Protocols for the Investigation of Civil Aviation Aeronautical Occurrences conducted by the Brazilian State".

To the Brazil's National Civil Aviation Agency (ANAC):

IG-136/CENIPA/2013 - 01 Issued on 10/04/2021

Work with the ATR aircraft operators to ensure that theoretical, simulated and practical training is sufficient for crews to acquire the knowledge and skills necessary to recognize and perform appropriate actions on a flight under training conditions as well as recognizing and performing appropriate actions on a flight under icing conditions.

IG-136/CENIPA/2013 - 02 Issued on 10/04/2021

Work with the ATR aircraft operators to ensure that ATR UPRT philosophy is properly implemented in airline operating manual and associated training.

5. CORRECTIVE OR PREVENTATIVE ACTION ALREADY TAKEN.

The aircraft manufacturer has carried out an extensive search for possible failures that could lead to APM failure without this condition being indicated to the crew. The only condition identified, however, would be the hypothesis of an APM push button failure (208TU push button) as the single failure capable of disabling the APM without any indication.

Daily testing, however, would detect this failure. If the OFF light had failed, such a failure could be evidenced during the lamp test prevised in the cockpit preliminary preparation checklist.

Additionally, the manufacturer made a technical visit to the Airline, in order to exchange information and clarify any issues related to the execution of flight procedures in ice accretion conditions.

The Airline issued a warning to the crew that they had to be aware of the aircraft flight parameters and that the procedures envisaged in case of ice accretion were strictly followed.

The pilots' periodic training has been redesigned, with greater emphasis placed on flight management under aircraft icing conditions.

ATR procedures associated to icing condition, including AFM emergency and normal procedures (Severe Icing and Operating in Icing Condition) have been extensively reworked. With the contribution of different experts and based on in-service experience, ATR has identified areas of improvement in terms of wording, formatting, and presentation to facilitate flight crew decision making and retrieval of essential information in flight.

In-service experience has shown that the flight crew may have difficulty to identify the external conditions and manage the flight in accordance with the conditions. Indeed, ice accretion depends on several parameters and the severity of icing conditions on an aircraft is not directly accessible. Moreover, pilots experience and comfort level may also influence their perception of icing intensity. To improve the situational awareness of the flight crew, ATR modified the procedures in line with ICAO UPRT manual, to link the decision making with the objective aircraft performance figures, i.e energy state

The main changes in approach are the following:

- Focus on providing most essential information in a clear and logical manner.

  This is done by improving sequence of actions in the "entering icing conditions" and "when ice accretion observed or detected" in the AFM and harmonize the FCOM and QRH with the AFM by merging the two distinct procedures into one single "atmospheric icing conditions" using the same logic.

- Use factual and verifiable information to aid decision making.

  The "icing conditions" procedure provides clear and factual triggers for identifying "severe icing" and calls for the emergency severe icing procedure: unable to maintain ICING BUG+10 kt –or– unable to maintain a rate of climb of 100 ft/min –or– if abnormal vibrations occur.

- Enhance the situational awareness by guiding the attention of the flight crew to the most critical information while operating in icing condition.

- More emphasis has been made on simple figures (such as 300 ft/min, the minimum residual rate of climb at the maximum operational ceiling) to enable early identification of an abnormal situation (undesired aircraft state).

In line with UPRT philosophy, ATR highlighted key factors to manage efficiently the aircraft energy.

As shown on the graph here below, aircraft energy is split between potential energy (terrain clearance), kinetic energy (Indicated airspeed) and mechanical energy (engine power).

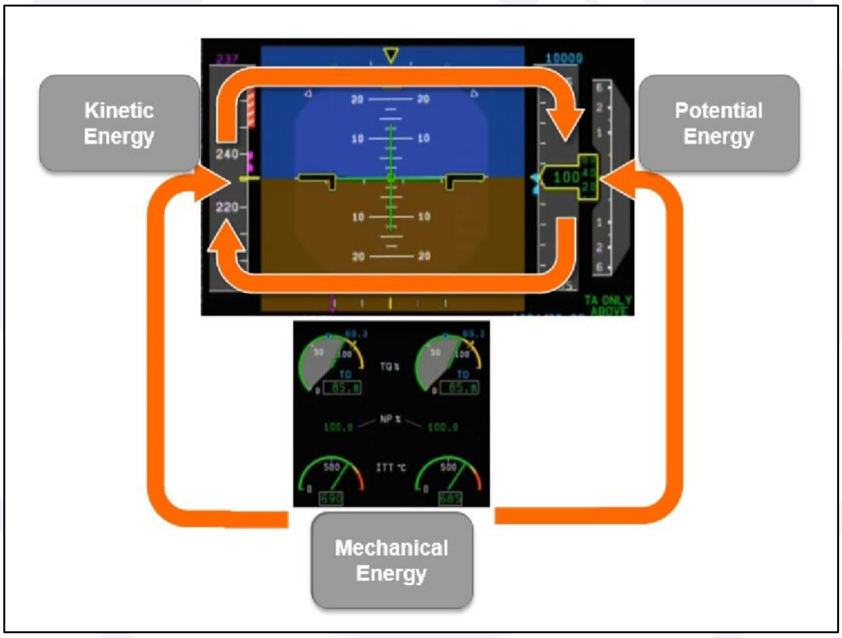

Figure 23 - EFIS ATR-72: BEA.

The pilot, in accordance with the flight conditions, is required to manage total aircraft energy.

ATR emphasize the need to follow carefully the following steps to enhance the flight crew situation awareness:

- Flight preparation: Anticipation is the first step to prevent the flight crew from being put in a difficult position on the first place

- Flight management: The management of aircraft energy during the flight is the keystone of the prevention of upset situations

- Escape: Escape manoeuvers enable the aircraft energy to be kept within acceptable limits.

On October 4th, 2021.