COMANDO DA AERONÁUTICA

CENTRO DE INVESTIGAÇÃO E PREVENÇÃO DE ACIDENTES AERONÁUTICOS

FINAL REPORT
IG-133/CENIPA/2019

OCCURRENCE:	**SERIOUS INCIDENT**
AIRCRAFT:	**PR-MPY**
MODEL:	**ATR-72 202**
DATE:	**16SET2019**

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 considering 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 distinct 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 Final Report has been made available to the ANAC and the DECEA so that the technical-scientific analyses of this investigation can be used as a source of data and information, aiming at identifying hazards and assessing risks, as set forth in the Brazilian Program for Civil Aviation Operational Safety (PSO-BR).

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. Considering 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 16 September 2019 serious incident with the ATR-72 202 aircraft, registration PR-MPY. The occurrence received the typification of “[FUEL] Fuel related”.

While the aircraft was on the approach to SBIH (Aerodrome of *Itaituba*, State of *Pará)*, the left-hand engine shut down at an altitude of approximately 1,446 ft AGL. After the landing, the right-hand engine also shut down.

Once the aircraft stopped in the parking area, one found that there was no usable fuel in its wing tanks.

The aircraft suffered no damage.

None of the occupants of the aircraft was injured.

Being France the State of design/manufacture of the aircraft, *the Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile* (BEA) designated an Accredited Representative for participation in the investigation of the occurrence.

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GLOSSARY OF TECHNICAL TERMS AND ABBREVIATIONS

AFIS	Aerodrome Flight Information Service
AGL	Above Ground Level
ANAC	Brazil's National Civil Aviation Agency
ATC	Air Traffic Control
BEA	*Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile* (France)
CENIPA	Brazil's Aeronautical Accidents Investigation and Prevention Center
CA	Certificate of Airworthiness
CAP	Central Alerting Panel
CMA	Aeronautical Medical Certificate
CMM	Component Maintenance Manual
COM	Maintenance Organization Certificate
CVR	Cockpit Voice Recorder
ETA	Air Transport Company
EO	Operating Specifications
FCOM	Flight Crew Operations Manual
FDR	Flight Data Recorder
FQI	Fuel Quantity Indicator
IFR	Instrument Flight Rules
IFRA	IFR Flight Rating (Airplane)
JIC	Job Instruction Card
LO LVL	Low Level Light
MC	Master Caution
MGM	General Maintenance Manual
MOM	Maintenance Organization Manual
PF	Pilot Flying
PIC	Pilot in Command
PLA	Airline Transport Pilot License (Airplane)
P/N	Part Number
PM	Pilot Monitoring
PPR	Private Pilot License (Airplane)
QAR	Quick Access Recorder
QAV	Aviation Kerosene
RCP	Refuel Control Panel
RBAC	Brazilian Civil Aviation Regulation
RELPREV	Prevention Report

SBBE	ICAO location designator - *Val de Cans* (*Júlio Cezar Ribeiro*) Aerodrome, *Belém*, State of *Pará*
SBEG	ICAO location designator - *Eduardo Gomes* Aerodrome, *Manaus*, State of *Amazonas*
SBHT	ICAO location designator - Aerodrome of *Altamira*, State of *Pará*
SBIH	ICAO location designator – Aerodrome of *Itaituba*, State of *Pará*
SBTF	ICAO location designator - Aerodrome of *Tefé*, State of *Amazonas*
SIC	Second in Command
S/N	Serial Number
TPR	Regular Public Air Transport Registration Category
UTC	Universal Time Coordinated
WPS	Words per Second
VFR	Visual Flight Rules

1. FACTUAL INFORMATION.

Aircraft	**Model:** ATR-72 202 **Registration:** PR-MPY **Manufacturer:** Aerospatiale and Alenia	**Operator:** *MAP Linhas Aéreas Ltda*.
Occurrence	**Date/time**: 16SET2019 - 20:35 UTC **Location:** Aerodrome of *Itaituba* (SBIH). **Lat.** 04°14'32"S **Long.** 056°00'03"W **Municipality – State:** *Itatituba - Pará*	**Type(s):** [FUEL] Fuel related

1.1. History of the flight.

At around 17:49 UTC, the aircraft took off from SBIH (Aerodrome of *Itaituba*, State of *Pará*), bound for SBEG (*Eduardo Gomes* Aerodrome, *Manaus*, State of *Amazonas*), on a regular public air transport flight, with four crew and thirty-nine passengers on board.

During the flight, the aircraft returned to SBIH, after an aeronautical occurrence involving another aircraft (registration PT-MHC) in SBEG, rendering the aerodrome inoperative.

With the PR-MPY in the traffic circuit for landing in SBIH, the left-hand engine shut down and, after landing, during the taxi, the right-hand engine also stopped working. The crew managed to restart the right-hand engine, and the aircraft continued taxiing to the parking area.

The aircraft sustained no damage.

None of the occupants of the aircraft was injured.

1.2. Injuries to persons.

Injuries	Crew	Passengers	Others
Fatal	-	-	-
Serious	-	-	-
Minor	-	-	-
None	4	39	-

1.3. Damage to the aircraft.

The aircraft sustained no damage.

1.4. Other damage.

NIL.

1.5. Personnel information.

1.5.1. Crew's flight experience.

Flight Experience		
	PIC	SIC
Total	13,324:55	8,448:05
Total in the last 30 days	15:20	15:50
Total in the last 24 hours	09:55	09:55
In this type of aircraft	3,200:25	4,169:30
In this type in the last 30 days	15:20	15:50
In this type in the last 24 hours	09:55	09:55

NB.: Data concerning the pilots' flight time provided by *MAP Linhas Aéreas Ltda*.

1.5.2. Personnel training.

The PIC (Pilot in Command) did the PPR (Private Pilot - Airplane) course at *Aeroclube do Amazonas*, *Manaus*, State of Amazonas, in 1994.

The SIC (pilot Second in Command) did the PPR course at the *Aeroclube de Nova Iguaçu*, State of *Rio de Janeiro*, in 1993.

1.5.3. Category of licenses and validity of certificates.

The PIC and SIC held Airline Transport Pilot (Airplane) licenses and had valid AT47 type aircraft ratings, which included the airplane of the occurrence. They also held IFRA (IFR Flight Airplane) ratings.

1.5.4. Qualification and flight experience.

The pilots had qualification and experience for the type of flight.

The SIC was the Pilot Flying, whereas the PIC was the Pilot Monitoring.

1.5.5. Validity of medical certificate.

The four crewmembers of the flight held valid aeronautical medical certificates.

1.6. Aircraft information.

The S/N 519 aircraft was an Aerospatiale and Alenia (actually named AIRBUS and Leonardo) product built in 1998, and registered in the Regular Public Air Transport Registration Category.

The Certificate of Airworthiness (CA) of the aircraft was valid.

The technical maintenance records were up to date.

The last scheduled maintenance of the aircraft (following an annual scheduling criteria), named by the manufacturer as “Inspection 1YE”, took place on 20 August 2019.

The very MAP Linhas Aéreas Ltda. performed the last scheduled maintenance (type “1A, in accordance with utilization criteria) on 15 July 2019. The aircraft flew 99 hours and 50 minutes after the inspection.

There were not any records of difficulties in service related to the fuel system.

The maintenance records showed that the aircraft was airworthy. The records did not contain any reports of failures related to the fuel system, nor was the crew aware of any failures (whatever their nature) other than the ones logged in the pertinent logbooks.

Due to the characteristics of the occurrence, the investigation commission considered it necessary to describe the functioning of the fuel indication system, as follows:

1.6.1 Composition of the fuel indication system

The fuel system consisted of:

- an electrical fuel quantity indicator system composed of six probes in each tank and a double digital indicator - Fuel Quantity Indicator (FQI) located on the upper central instrument panel in the aircraft's cockpit (Figures 1 and 2);

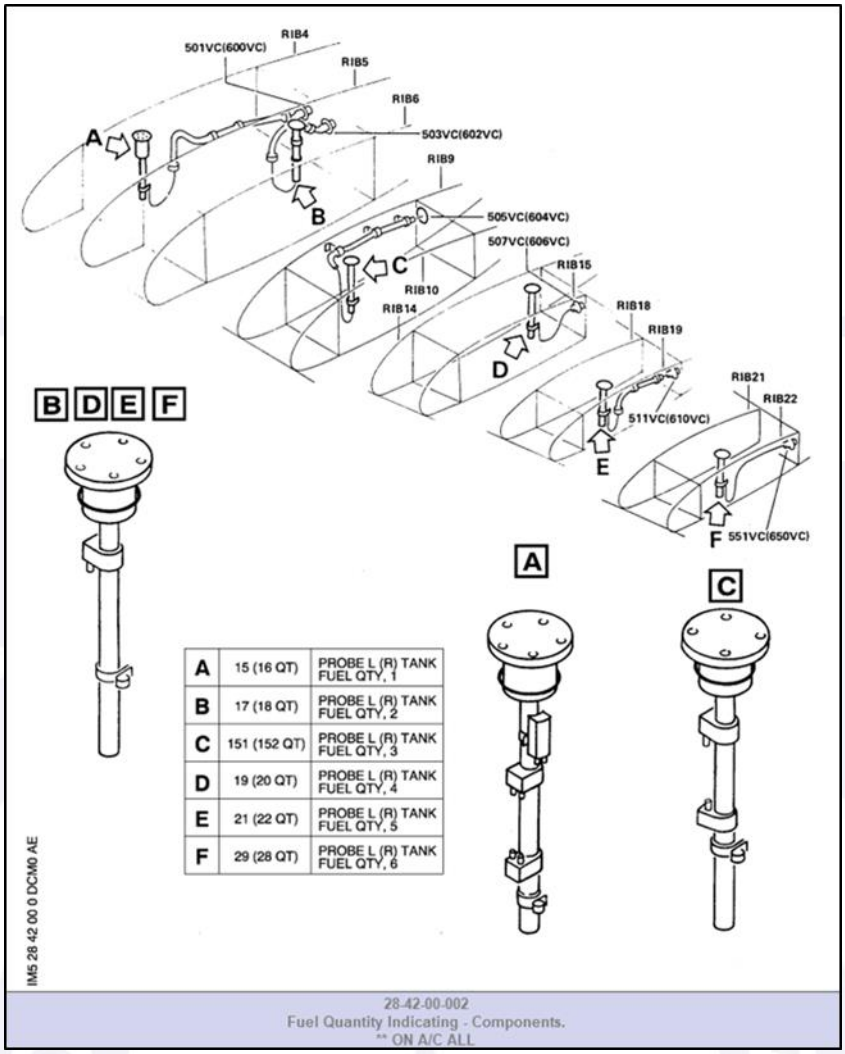


Figure 1 - Components of the ATR-72 202 Fuel Quantity Indicator System.
Source: ATR Maintenance Training Notes, ATA 28 Fuel.

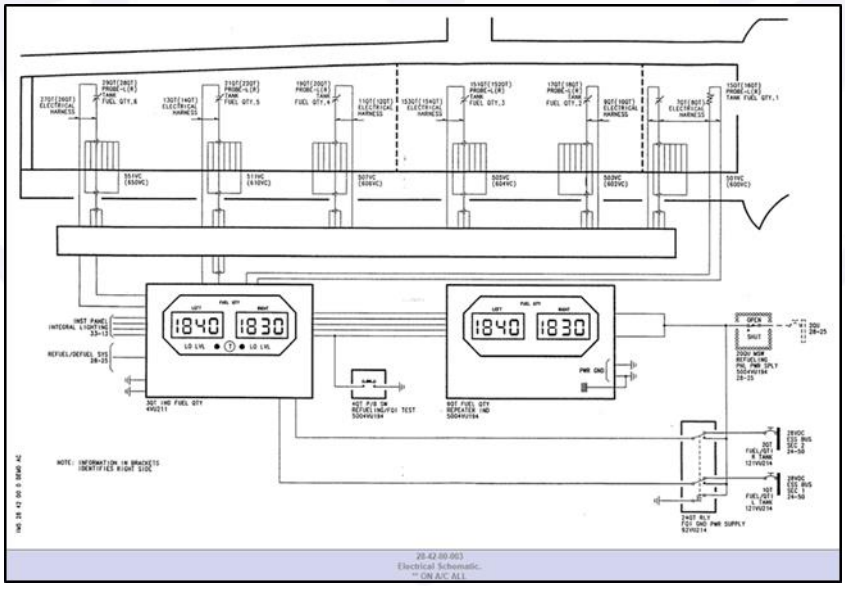


Figure 2 - Wiring diagram of the ATR-72 202 fuel quantity indication and dual indicators.
Source: ATR Maintenance Training Notes, ATA 28 Fuel.

- a fuel quantity repeater indicator and a pre-selector located on the RCP (Refuel Control Panel) on the outer aircraft fuselage (Figure 3);

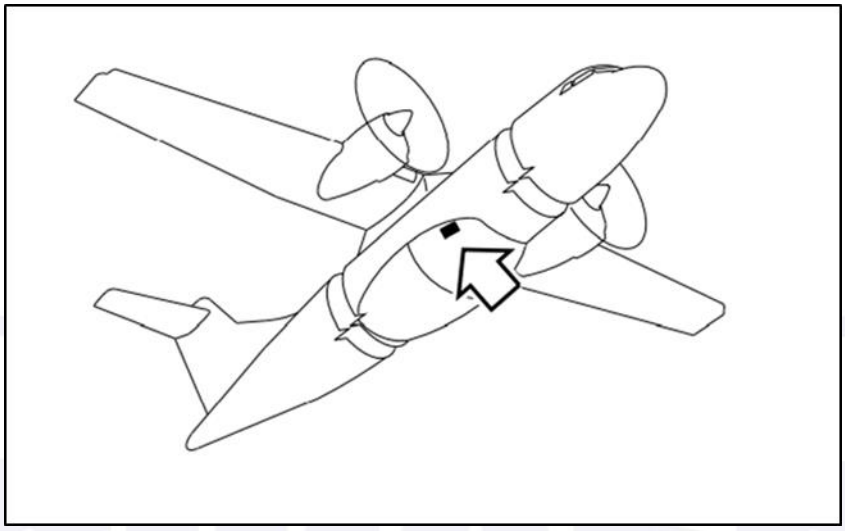


Figure 3 - Refueling panel where the FQI repeater was located.
Source: ATR Maintenance Training Notes, ATA 28 Fuel.

- two manual magnetic fuel level indicators per tank – Manual magnetic fuel level indicators are located on the wings lower surface;

- a high-level detection system, with indicator lights, located on the refueling panel;

- a fuel temperature indicator located on the central instrument panel; and

- A FUEL amber light located on the Crew Alerting Panel (CAP) indicating a fault related to the fuel system.

According to the aircraft manual (item 70.4.3 - *Usable Fuel)*, the amount of usable fuel in each tank was 2,500 kg (Figure 4).

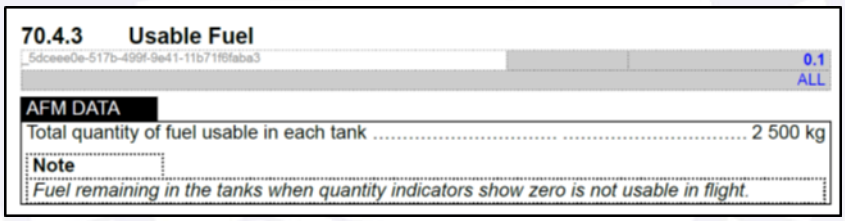


Figure 4 - Usable fuel in each tank.
Source: Flight Crew Operations Manual (FCOM) 72 Rev 1, JAN2018.

1.6.2 Brief description of the fuel quantity indicating system

This system provided the crew with information on the quantity of mass of fuel available in each tank throughout the flight. Such information appeared in digital format on a dual indicator located on the upper central instrument panel.

Fuel mass was measured by means of six capacitance probes installed in each tank. Fuel probes were attached to the tank upper surface and could be removed without defueling the tank. Six electrical harnesses installed inside the tank connected the probes to the fuel quantity indicator through bulkhead connectors and junction boxes. Any change in the quantity of fuel inside the tank resulted in a change of probe's immersion height and consequently a change of its capacitance.

The wing tank fuel quantity was computed by summing the capacitances of the six probes and converting it into a fuel mass. Fuel quantity measurement system accuracy was plus or minus 1% of full tank value (i.e. 25kg) in an empty- tank condition and plus or minus 3% of full tank value (i.e. 75kg) in a full- tank condition when the aircraft attitudes were within -3°/+1° of pitch and -2°/+2° of roll.

The FQI indicated the mass of fuel in each tank. The indications were given in digital format, in pounds or kilograms, according to the aircraft version. This gauge included two amplifiers that processed the electrical signals from the tanks. The two channels, powered by 28 VDC, were completely isolated, and each one of them included a low-level detection system.

The FQI had a Low Level Light (LO LVL) for each tank. Such light would illuminate when the total quantity of fuel in a tank dropped below 160 kg (Figure 5).

Figure 5 - Low-level warning amber light.
Source: ATR Training & Flight Operations Services.

With this value, one would expect the following events:

- illumination of amber warning lights (LO LVL), one for each tank, located on the front face of the indicator;

- illumination of the Master Caution (MC) light with a single sound, and activation of the FUEL light on the Central Alerting Panel (CAP);

- sending of an output signal that was processed by the multifunctional computers; and

- automatic activation of the electric pump.

The dual fuel gauge indicator also included:

- two high fuel-level signal outputs to control the closing of the refueling valve;

- two low fuel-level signal outputs to control the low fuel-level detection system;

- two outputs (optional) for a repeater fuel quantity indicator on the refueling panel;

- a button, named FQI Test, on the face of the indicator to test the two measurement channels; and

- a parallel input-channel intended to receive the signal from the FQI Test button on the refueling panel. These two tests, when triggered, displayed digits “8” on the flight deck indicator. The Fuel Quantity Indicator segments were also tested when the annunciator light test system was activated by the crew.

Figure 6 shows the location of the FQI and FUEL light of the CAP in the cockpit.

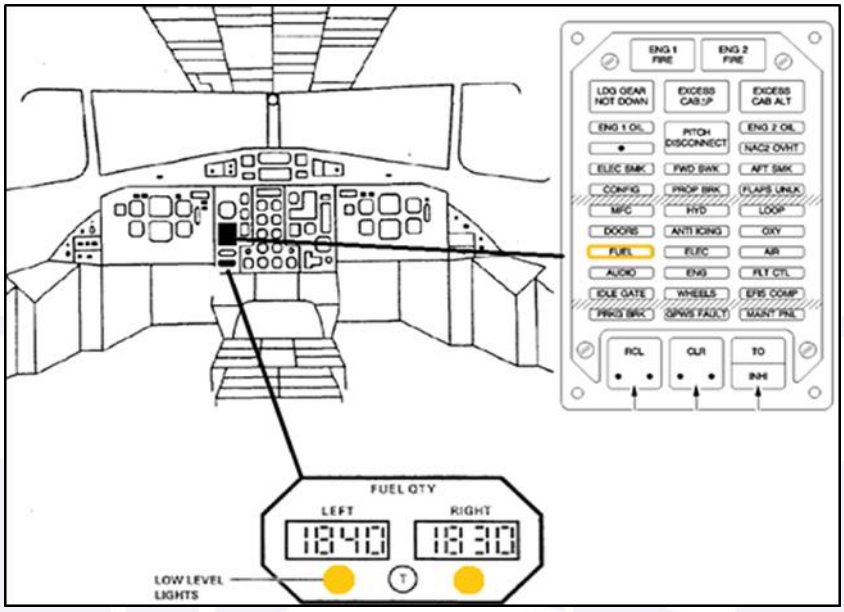


Figure 6 - Location of the FQI in the cockpit.
Source: ATR Maintenance Training Notes, ATA 28 Fuel.

There were also two magnetic fuel-quantity indicators installed on the intrados of each wing, one between the ribs 5 and 6, and another one between the ribs 22 and 23, which could be utilized during refueling operations (Figure 7).

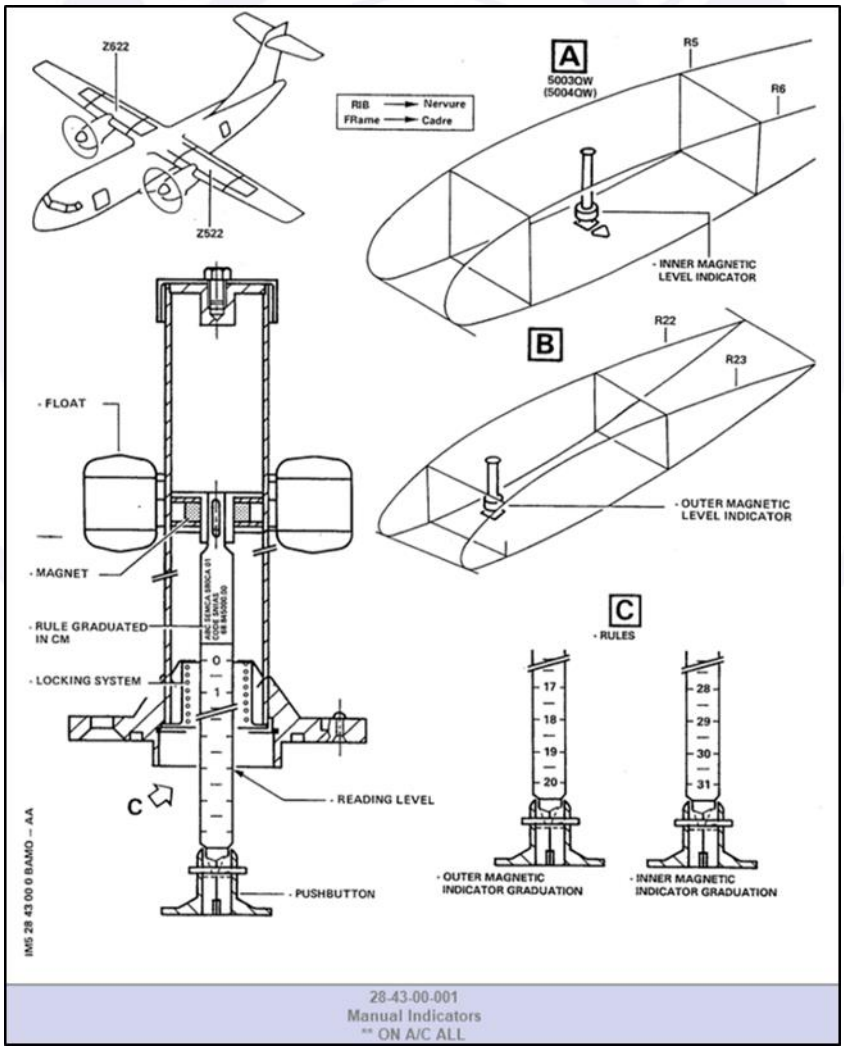


Figure 7 - ATR 72-202 Fuel Level Magnetic Indicators.
Source: ATR Maintenance Training Notes, ATA 28 Fuel.

Each indicator contained:

- a sealed tube, installed vertically in the tank;

- a rod, graded in centimeters, which would slid vertically in the tube; and

- an annular float, which would slid would vertically on the outside of the tube.

When the fuel level magnetic indicator rod was unlocked, it dropped under its own weight, and stayed magnetically linked to the float. The fuel level was read in centimeters on the section of the rod which protudes from the lower surface of the wing.

A chart, provided in the Flight Crew Operations Manual (item NSU.28.3.4 – Use of Manual Magnetic Indicators) was used to convert centimeters into liters and units of weight (kg or lbs) as a function of the aircraft's roll attitude and fuel density.

To check the roll attitude, one would make use of a clinometer located in the main landing gear compartment.

1.7. Meteorological information.

At the final landing of the aircraft on runway 05, the SBIH AFIS reported wind of 150° at 7 KT, QNH 1006 hPa, temperature 34°C, with thunderstorms and rain showers in the southeast and east sectors of the aerodrome.

One verified that the conditions were favorable for VFR flights, despite cloud formations near the aerodrome (thunderstorm and cumulonimbus).

Visibility was above 10 KM, cloud cover was FEW between 2,000 and 2,500 ft. There was presence of rain and formations of clouds near the airfield, more specifically in the eastern and southeastern sectors (Figure 8).

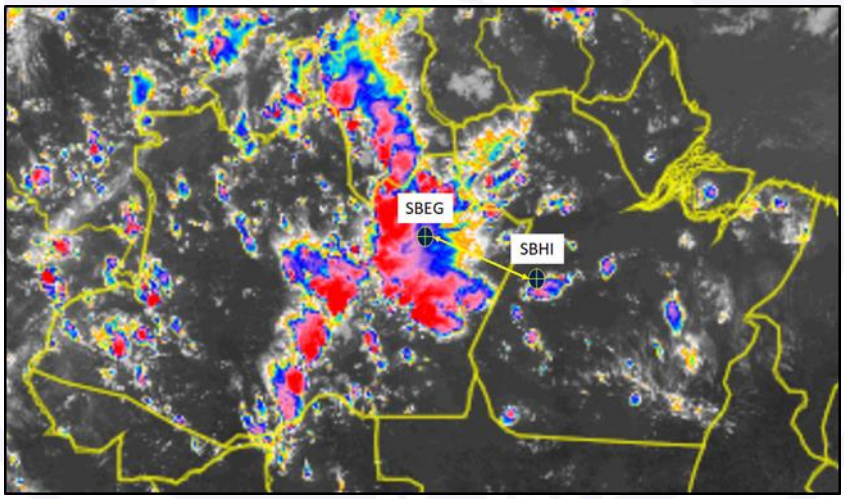


Figure 8 - Enhanced Satellite Image at 20:30 UTC.
Source: REDEMET.

1.8. Aids to navigation.

NIL.

1.9. Communications.

The crew maintained radio contact with the ATC agencies, and no technical abnormalities affected the communication equipment during the flight.

1.10. Aerodrome information.

SBIH was a public aerodrome under the administration of the municipality of *Itaituba*, State of *Pará*. It operated VFR and IFR during day- and night-time

Its asphalt-paved runway, with thresholds 05/23, measured 1,605 m x 30 m, and had an elevation of 108 ft.

The dimensions of the aerodrome were adequate for the safe operation of the aircraft in question.

1.11. Flight recorders.

The aircraft had an L3Harris FA2100 Flight Data Recorder (P/N 2100-4043-00, S/N 592728), with a solid-state memory capable of recording up to 25 hours of flight time at a speed of 128 WPS (words per second).

Additionally, it was also equipped with a model L3Harris FA2100 Cockpit Voice Recorder (P/N 2100-1020-02, S/N 669745) featuring a solid-state memory with a recording capacity of two hours, and 4 high-quality input channels.

Both recorders (CVR and FDR) recorded data related to the occurrence.

The investigators also recovered data from the QAR (Quick Access Recording) device.

1.12. Wreckage and impact information.

NIL.

1.13. Medical and pathological information.

1.13.1. Medical aspects.

There was no evidence that considerations of physiological nature or disability might have affected the performance of the crew.

1.13.2. Ergonomic information.

NIL.

1.13.3. Psychological aspects.

On 15 September 2019, the crew stayed overnight in *Belém*, State of *Pará*. According to information collected in interviews, they considered their rest period sufficient and appropriate.

Around 13:25 UTC, the crew reported for the scheduled flight between SBBE and SBEG, with stopovers in SBHT and SBIH.

The PIC and SIC had already had the opportunity of flying together on a number of occasions. There were no reports of conflicts between them, and, according to interviews, they also had a good interpersonal relationship with the other professionals of the company.

Both pilots joined *Manaus Aerotáxi* in 2010, and started to fly for *MAP Linhas Aéreas* sometime later. The two companies belonged to the same owner, and, according to reports, it was common practice to select pilots for *MAP Linhas Aéreas* after they had worked for a period at the *Manaus Aerotáxi* company.

The PIC began his activities at *MAP Linhas Aéreas Ltda*. in October 2014. In his professional career, he had worked in another regional company of the aeronautical sector. He was familiar with public air transport operations, pursuant to the requirements of the Brazilian Civil Aviation Regulation (RBAC) nº 121 - “Public Air Transport Operations with Airplanes with Maximum Certified Passenger Seat Configuration of More than 19 Seats, or Maximum Payload Capacity above 3,400 kg”.

His co-workers considered him a reserved and calm person, who demonstrated focus on good professional performance. From the chief pilot's perspective, the PIC was a committed and efficient professional, respected by the other pilots for his experience. According to reports, *MAP Linhas Aéreas* had thought of him for joining the company’s board of instructors, but he ended up declining the offer.

The SIC had been with the company since 2012. That was his first contract for flying public air transport aircraft. Previously, he had worked as a flight instructor at the Aeroclube do *Amazonas* and at air-taxi companies, including the aforementioned *Manaus Aerotáxi* company.

His colleagues described him as a shy and introspective person, who maintained good relations within the company. According to the chief-pilot, he showed interest in progressing in the company and becoming an aircraft captain. However, due to some performance difficulties presented by him in the periodic training, that promotion had not taken place yet.

1.14. Fire.

There was no fire.

1.15. Survival aspects.

The crew and passengers disembarked normally via the doors of the aircraft..

1.16. Tests and research.

The tests and research for the identification of factors that could have contributed either directly or indirectly to the occurrence started on 17 September 2019 in the parking area of SBIH, the same place at which the aircraft had stopped the day before.

The information obtained shortly after the occurrence revealed that the quantity of fuel indicated in the FQI corresponding to the left-hand wing tank was 230 kg, and 180 kg in the right-hand wing tank. In such condition, the Fuel-Level Magnetic Indicators indication was *zero fuel* (Figure 9).

Figure 9 - Indication of the PR-MPY FQI and Fuel-Level Magnetic Indicators measured after the landing in SBIH.

On 18 September 2019, the PR-MPY received 2,537 liters of QAV-1 (aviation kerosene), which represented a weight of 1,935.73 kg (2,537 liters x 0.763), after verification of the respective density (*weight to volume* ratio).

After this refueling, the FQI data indicated 1,190 kg in the left-hand wing tank, and 1,200 kg on the right-hand wing tank, i.e. a total of 2,390 kg.

On the other hand, the Fuel-Level Magnetic Indicators showed that the left-hand wing tank had 1,350 liters, while the right-hand one had 1,550 liters, representing a weight of 1,039.5 kg on the left-hand wing, and 1,193.5 kg on the right-hand wing, a total of 2,233 kg, considering a density of 0.77.

Those numbers represented a difference of 157 kg between the indications of the FQI and the Fuel-Level Magnetic Indicators. The accuracy of the magnetic level indicator is ±200 liters/tank.

In order to check other maintenance procedures and the operating condition of the aircraft's engines, one put the engines to operate. They consumed approximately 80 kg of fuel during the time they were in operation.

In the sequence, with the aircraft maintaining the same previous position, 983 more liters of QAV were put in the tanks, which meant an addition of 754 kg, after application of the respective correction of density.

Thus, on 18 September 2019, the aircraft received a total of 2,689.69 kg of fuel. However, at the end of the refueling, the data available in the FQI indicated 1,500 kg on the left-hand wing tank, as well as 1,500 kg on the right-hand wing tank, that is, a total of 3,000 kg.

On 19 September 2019, after the ferrying of the aircraft to SBEG with due authorization by ANAC, tests were carried out in the hangar of *MAP Linhas Aéreas Ltda.* for comparison between the information provided by the FQI and the numbers provided by the Fuel-Level Magnetic Indicators located on the left- and right-hand wing tanks of the PR-MPY.

At that moment of the investigation, the electrical condition of the fuel probes and cabling had not yet been checked. Only transference of fuel between the wings was carried out in order to check the behavior of the fuel-quantity indication system.

The initial information presented in the FQI was 1,110 kg in the left-hand wing tank, and 1,070 kg in the right-hand wing tank.

The aircraft had its wings level, and one made several transfers of fuel between the tanks through a hose that connected the engine of one wing to the fueling nozzle of the opposite wing. One made use of the electric fuel-pump for pulling the fuel until the moment the fuel-pump ceased to be efficient.

During the transfer of fuel from the left-hand wing tank to the right-hand wing tank, one collected a number of pieces of information, among which the following ones stand out:

- with the FQI of the left-hand wing tank indicating 310 kg, the Fuel-Level Magnetic Indicators of the same wing tank indicated *0* (zero) fuel;

- even after removing the whole remaining fuel from the left-hand wing tank (75 liters) through a drain located near the wing root, the FQI of the left-hand wing tank indicated the presence of 230 kg of QAV-1; and

- with no more fuel remaining in the left-hand wing tank, but with 230kg of fuel quantity displayed on the left- hand tank, the low level light did not illuminate, indicating that fuel low level alert triggering conditions were not met.

During the transfer of fuel from the right-hand wing tank to the left-hand wing tank, one collected several pieces of information, among which the following ones stood out:

- the low-level fuel indication in the FQI of the right-hand wing tank illuminated when the data displayed on the instrument was 170 kg;

- the electric fuel-pump ceased to be effective when the FQI indication of the right-hand wing tank was 160 kg; and

- by means of a drain of right-hand wing tank, one removed approximately 167 liters of fuel.

On 20 September 2019 in the hangar of *MAP Linhas Aéreas*, with the aircraft in the same position of the day before, a functional test was performed on the six fuel probes of the wing tanks. This search action took place, in accordance with the troubleshooting prescriptions of the respective system, listed in the Job Instruction Card (JIC) 28-42-72 FUT 10000.

The number-3 fuel probes (P/N 768-100) of both wings were out of the parameters and were replaced. The same occurred with the Harness (Cabling), P/N 798-078-2, of the number-3 fuel probe of the right-hand wing, which was also out of the parameters and was replaced.

After the replacement actions, the FQIs started indicating a “zero” quantity when the pertinent fuel tank was empty.

However, the indication of low fuel-level in the FQI of the left-hand wing tank was still not appearing, leading to the replacement of the number-1 fuel probe (P/N 766-983-1).

Subsequentially, the components removed were sent to *SAFRAN Aerotechnics* (then responsible for the design and manufacture of these items) for specific bench-tests and identification of any possible compromises (Figure 10).

Figure 10 - Fuel probes and number-3 probe wiring sent for testing.

SAFRAN Aerotechnics inspected the following items:

- Fuel Probe: P/N 768-100, S/N 1358 and 516;
- Fuel Probe: P/N 766-983-1, S/N 1647; and
- Harness: P/N 798-078-2, S/N 563.

The fuel probes were used for measuring the quantity of fuel in the tanks. They were of different shapes and lengths, depending on their location in the tank.

The level of the fuel was measured by means of the capacitance difference obtained when the fuel probe was totally or partially immersed (or not immersed) in the fuel.

A low fuel-level detector was also available in some models, such as the fuel probe P/N 766-983-1, which was located in the number-1 position.

All components were checked in accordance with the prescriptions of the Component Maintenance Manual (CMM) for each item.

As for the Harness P/N 798-078-2, S/N 563, the connectors were in good condition, and there was no visible damage to the respective pins.

However, there was a splice past the label of identification of the component. One clearly verified that several wires for protection of the cabling were broken (Figure 11).

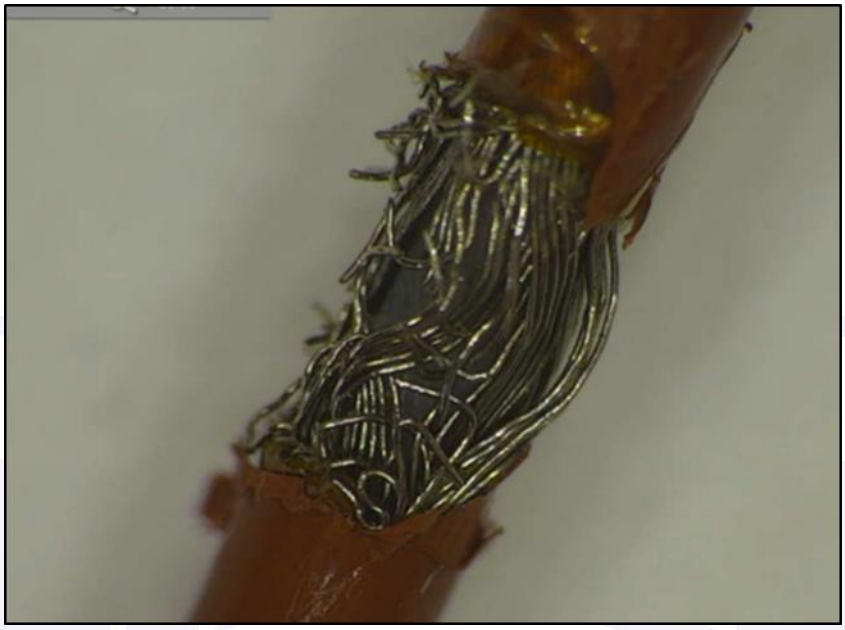


Figure 11 - Wiring protection found damaged.
Source: SAFRAN Investigation Report.

The cabling underwent two electrical tests for resistance, insulation and continuity. The item passed both tests (Figure 12).

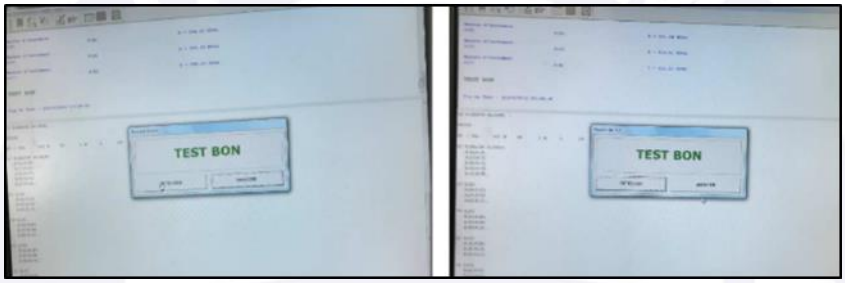


Figure 12 - Result of electrical tests.

Thus, no discrepancies existed that might result in non-conformities, despite the damage found in the cable shielding.

In the P/N 766-983-1 S/N 1647 fuel probe, it was possible to see pollution inside the tube, oxidation in the electrical box, and scratches and shocks on the probe head (Fig. 13).

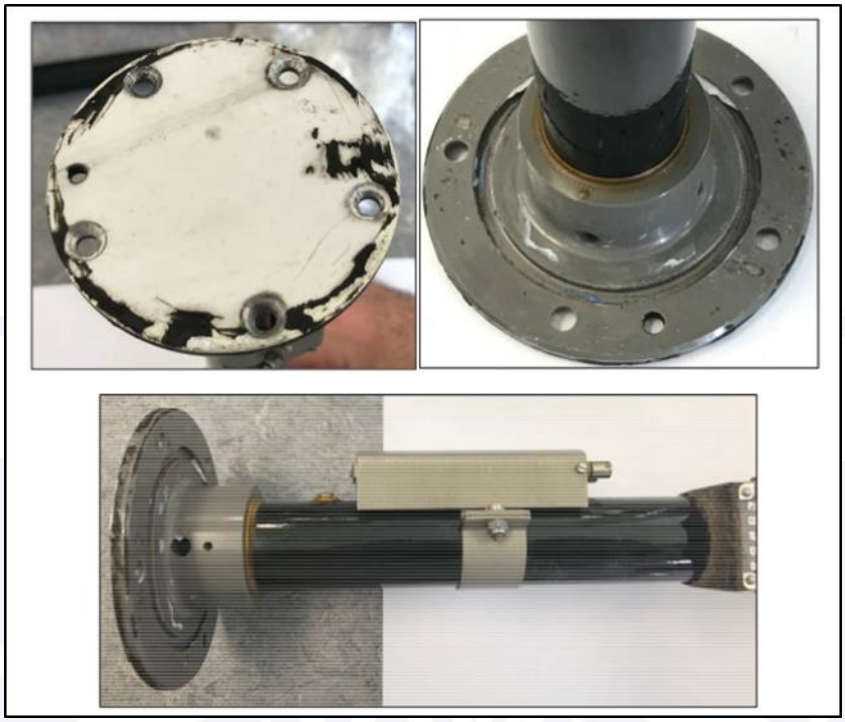


Figure 13 - Damage to the P/N 766-983-1 S/N 1647 fuel probe.
Source: SAFRAN Investigation Report.

On the P/N 768-100 S/N 1358 fuel probe, it was possible to observe scratches, traces of shock, and oxidation of the probe head, along with scratches on the outside of the tube. No oxidation was visible in the electrical box. There were also signs of pollution inside the tube (Figure 14).

Figure 14 - Pollution inside the P/N 768-100 S/N 1358 fuel probe.
Source: SAFRAN Investigation Report.

On the P/N 768-100 S/N 516 fuel probe, one observed scratches, traces of shock, and oxidation on the probe head (Figure 15).

Figure 15 - Damage to the P/N 768-100 S/N 516 7 fuel-probe head.
Source: SAFRAN Investigation Report.

Pollution was visible inside the tube, as well as oxidation in the electrical box (Figure 16).

Figure 16 - Oxidation in the electrical box of the P/N 768-100 S/N 516 7 fuel probe.
Source: SAFRAN Investigation Report.

In all the probes, one verified the presence of varnish on the screws of the respective boxes (Figure 17).

Fig. 17 - Varnish on the screws of the electrical box of P/N 768-100 S/N 516 fuel probe.
Source: SAFRAN Investigation Report.

Despite the damage observed, the tests undergone by the fuel probes did not indicate any abnormalities.

Thus, the exams and tests of the items conducted by *SAFRAN* showed that all such items were subject to verification in accordance with the CMM procedures, and passed the functional tests.

In spite of the results, several pieces of equipment showed signs of aging, such as scratches and corrosion. The analysis conducted by *SAFRAN* also highlighted that the worst damage observed related to the Harness P/N 798-078-2, S/N 563.

1.17. Organizational and management information.

The same family group, owner of *Manaus Aerotáxi*, founded *MAP Linhas Aéreas* in 2011. During the period in which these companies were property of the same owner, they shared the administrative sectors of management and human resources.

With respect to the maintenance sector, although *MAP Linhas Aéreas* had its own team of mechanics, *Manaus Aerotáxi* was in reality the company responsible for the maintenance of the aircraft fleet, since *MAP Linhas Aéreas* had not yet received certification for such activity.

MAP Linhas Aéreas started the process of management change to *Passaredo Linhas Aéreas* in August 2019. From the beginning of the referred process onward, the company underwent organizational changes in all sectors, with the objective of standardizing its procedures with the ones adopted by *Passaredo Linhas Aéreas*, besides separating the sectors shared with *Manaus Aerotáxi* up to that time.

In addition to these organizational changes, the staff of *MAP Linhas Aéreas* also underwent a process of evaluation and adaptation in consonance with the requirements of the new company. The formation of the team occurred through evaluation of the performance of the professionals who worked at *MAP Linhas Aéreas* during the previous management. In addition, the company underwent changes of employees in strategic positions, at the discretion of the new administration.

The professionals not selected by the human resources department of *Passaredo Linhas Aéreas* ended up transferred to *Manaus Aerotáxi* or dismissed from the company.

As for the initial and continued training process, one verified that *MAP Linhas Aéreas* operated in accordance with the requirements established by the ANAC.

Their team of mechanics received capacitation training in 2017 and refresher courses every two years at the company headquarters, with the help of an experienced professional.

The maintenance of the aircraft fleet continued to be under the responsibility of the *Manaus Aerotáxi* team on an outsourced basis. Therefore, the mechanics of both *MAP Linhas Aéreas* and *Passaredo Linhas Aéreas* would participate in the inspection of the aircraft maintenance with the inspectors after provision of the maintenance services by the *Manaus Aerotáxi*'s team of mechanics.

According to reports gathered during the investigation, the maintenance sector, at different times, had difficulties concerning the modernization and updating of procedures, due to the resistance to change and little adherence on the part of the maintenance team.

There were reports from the team of mechanics that important information regarding maintenance and inspection services would end up lost because of the lack of control over the activities performed.

Episodes were mentioned, in which the maintenance processes performed failed to be registered in the pertinent controls, or even aircraft were released without the prescribed inspection.

Still according to the maintenance team's reports, such practices had their origins in the former management of the company. The practices were encouraged by the then head of maintenance, who demanded urgency for the return of aircraft to service, leaving the logging routine procedures to a later date.

One should note that difficulties related to the control of the maintenance services in the organization had already been identified during the investigation of a June 2019 occurrence involving the *MAP Linhas Aéreas'* aircraft registered as PR-MPN. The investigation commission on the occasion became aware of the difficulties on the part of the safety sector concerning the implementation of new processes in the area of operational safety.

In such context, there were accounts that Prevention Reports (RELPREV) were regarded as a punitive and snitching act in the company, and that the safety sector did not have an adequate methodology for dealing with the problems reported in order to sort them out.

In the course of the investigation of this serious incident with the PR-MPY, the investigation commission learned that the pilots involved in the occurrence had been fired by *MAP Linhas Aéreas*.

1.18. Operational information.

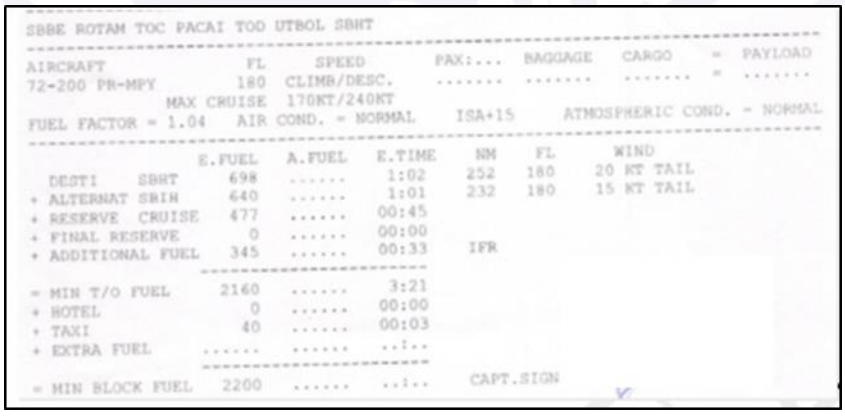
The PIC, who at the time of the occurrence was the Pilot Monitoring, completed his initial training of the ATR72 aircraft on 05 December 2014, and underwent periodic training in the years 2015, 2016, 2017, 2018 and 2019.

The SIC, who at the time of the occurrence was the Pilot Flying, concluded the initial training of the ATR72 aircraft on 27 February 2011, and underwent periodic training in the years 2012, 2013, 2014, 2015, 2016, 2017 and 2019.

On 16 September 2019, at around 13:25 UTC, the crew reported to SBBE for the MAP5913 flight between SBBE and SBEG, with stopovers in SBHT and SBIH.

According to the flight dispatch of the first segment, the aircraft was within the weight and balance limits specified by the manufacturer. In the first segment (SBBE – SBHT), the forecast fuel consumption was 698 kg. If necessary, another 640 kg of fuel were available for the aircraft to proceed to the alternate aerodrome (SBIH).

There were also 477 kg of fuel available to fly from the alternate aerodrome for another 45 minutes, besides an additional extra fuel quantity of 345 kg. The minimum takeoff fuel listed in the dispatch was 2,160 kg, and there was still an additional 40 kg reserved for taxiing, totaling 2,200 kg (Figure 18).



SBBE ROTAM TOC PACAI TOD UTBOL SBHT

AIRCRAFT	FL	SPEED	PAX:...	BAGGAGE	CARGO	=	PAYLOAD
72-200 PR-MPY	180	CLIMB/DESC.	.....	.....	.....	=	.....
	MAX CRUISE	170KT/240KT					

FUEL FACTOR = 1.04 AIR COND. = NORMAL ISA+15 ATMOSPHERIC COND. = NORMAL

	E.FUEL	A.FUEL	E.TIME	NM	FL	WIND
DESTI SBHT	698	.....	1:02	252	180	20 KT TAIL
+ ALTERNAT SBIH	640	.....	1:01	232	180	15 KT TAIL
+ RESERVE CRUISE	477	.....	00:45			
+ FINAL RESERVE	0	.....	00:00			
+ ADDITIONAL FUEL	345	.....	00:33	IFR		
= MIN T/O FUEL	2160	.....	3:21			
+ HOTEL	0	.....	00:00			
+ TAXI	40	.....	00:03			
+ EXTRA FUEL	.....	.....	..:..			
= MIN BLOCK FUEL	2200	.....	..:..	CAPT.SIGN		

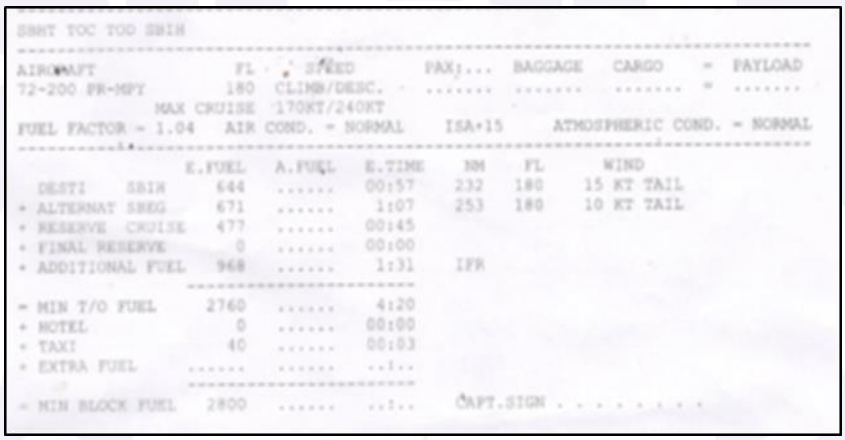
Figure 18 - MAP5913 flight dispatch, segment SBBE/SBHT.

After refueling the aircraft with 906.3 kg of QAV-1 in SBBE, the pilots started up the engines (aircraft fuel was 2,600 kg, according to the logbook). To reach the destination, the aircraft burned 790 kg of fuel.

In SBHT, they refueled the airplane with 1,015.14 kg of fuel, according to the refueling voucher made available to the Investigation Commission. The entire refueling procedure was accompanied by the PIC.

According to the dispatch, the aircraft was within the weight and balance limits specified by the manufacturer for the second segment of the flight, with a forecast consumption of 644 kg of fuel between SBHT and SBIH and, another 671 kg to proceed to the alternate aerodrome (SBEG) if necessary

There was still a quantity of 477 kg of fuel available to fly from the alternate aerodrome for another 45 minutes, besides an additional 968 kg. The minimum take-off fuel according to the dispatch was 2,760 kg, and there were 40 kg of fuel for taxiing, totaling 2,800 kg (Figure 19).



SBHT TOC TOD SBIH

AIRCRAFT	FL	SPEED	PAX/...	BAGGAGE	CARGO	=	PAYLOAD
72-200 PR-MPY	180	CLIMB/DESC.	.....	.....	.....	=	.....

MAX CRUISE 170KT/240KT

FUEL FACTOR = 1.04 AIR COND. = NORMAL ISA+15 ATMOSPHERIC COND. = NORMAL

	E.FUEL	A.FUEL	E.TIME	NM	FL	WIND
DESTI SBIH	644	.....	00:57	232	180	15 KT TAIL
+ ALTERNAT SBEG	671	.....	1:07	253	180	10 KT TAIL
+ RESERVE CRUISE	477	.....	00:45			
+ FINAL RESERVE	0	.....	00:00			
+ ADDITIONAL FUEL	968	.....	1:31	IFR		
= MIN T/O FUEL	2760	.....	4:20			
+ HOTEL	0	.....	00:00			
+ TAXI	40	.....	00:03			
+ EXTRA FUEL	.....	.....	..:..			
= MIN BLOCK FUEL	2800	.....	..:..	CAPT.SIGN		

Figure 19 - MAP5913 flight dispatch, segment SBHT/SBIH.

In this way, the fuel for starting the operation in SBHT expressed in the dispatch, was 2,800 kg, and corresponded to quantity entered in the logbook records. However, by subtracting the fuel used in the previous stage (790 kg) and adding the fuel supplied (1,015.14 kg), the quantity of fuel for takeoff registered in the aircraft logbook should have been 2,825 kg.

After consulting the Flight Crew Operations Manual (FCOM), it was possible to infer that the found difference of 25 kg was compatible with the normal error of indication described in the manual.

The actual fuel consumed in the second segment (SBHT/SBIH) was 778 kg against the forecast quantity of 644 kg included in the planning. The aircraft was not refueled in SBIH.

Thus, although the aircraft was within the weight and balance limits specified by the manufacturer to perform the third segment of the flight, the QAV-1 available for starting the operation of the flight destined to SBEG recorded in the logbook was 2,022 kg (Figure 20).

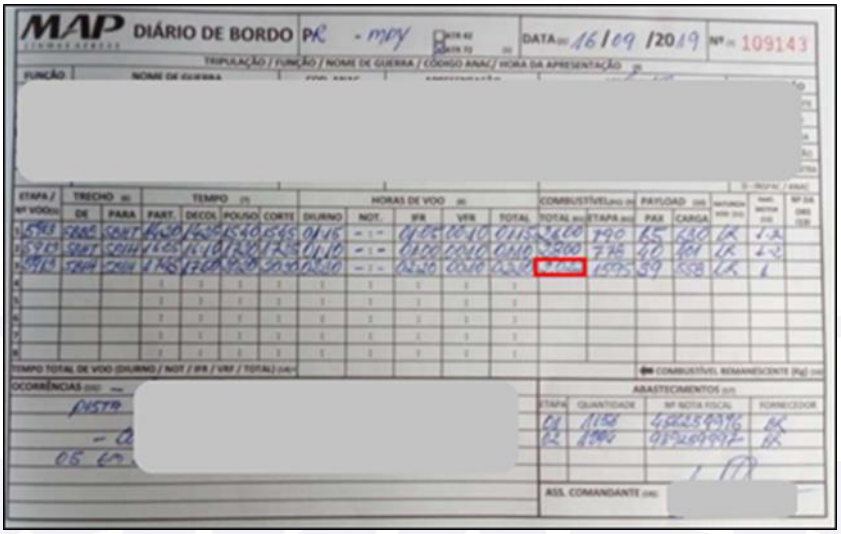


Figure 20 - PR-MPY Logbook of 16 SEPT 2019.

These 2,022 kg of fuel available in the PR-MPY tanks were less than the 2,116 kg established in the planning of the flight bound for SBEG, as shown in Figure 21.

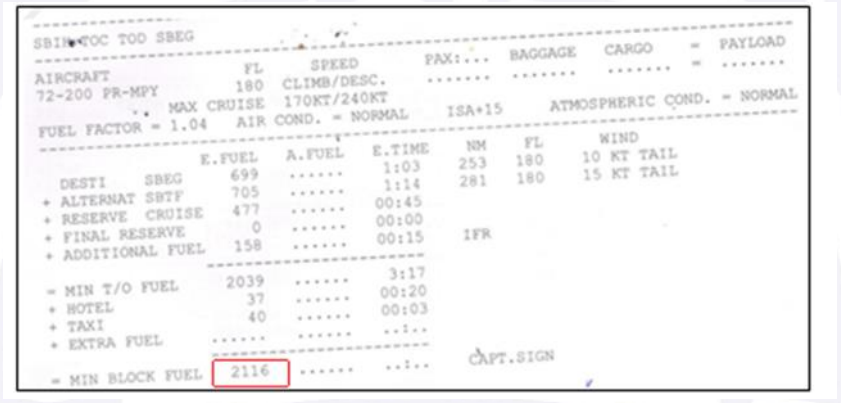


Figure 21 - MAP5913 flight dispatch, segment SBIH/SBEG.

In the SBIH/SBEG segment, the aircraft would consume 699 kg of fuel and, if necessary, another 705 kg were available for the aircraft to proceed to SBTF, the alternate aerodrome.

The aircraft would still have, according to the flight dispatch form, 477 kg of fuel to fly for another 45 minutes from the alternate aerodrome, besides an additional 158 kg to perform a 15-minute holding procedure.

The minimum forecast take-off fuel was 2,039 kg; there was also an amount of 40 kg for taxiing and another 37 kg for the “hotel”, to keep the aircraft with the air conditioning system in operation while on the ground in Itaituba, thus totaling the 2,116 kg shown in Figure 21.

During the en-route phase of the flight toward SBEG, the crew received information that the aerodrome ceased operations due to an accident involving another aircraft.

The PM instructed the PF to reduce speed and maintain flight level FL180. A few moments later, for suspecting the presence of conditions conducive to icing, they chose to descend to FL160.

While approaching SBEG, the crew coordinated with ATC delaying procedures for retarding their arrival in SBEG. However, with no forecast for the reopening of the aerodrome, the crew decided to divert to the alternate airfield.

The information contained in the flight dispatch indicated that the aircraft would need 705 kg of fuel to reach SBTF (Aerodrome of *Tefé*, State of *Amazonas*), besides 477 kg to fly an extra time of 45 minutes, totaling 1,182 kg.

Information available to the crew on the FQI indicated that the aircraft had approximately 1,200 kg of fuel, which was enough to proceed to the diversion aerodrome.

However, the PM suggested changing the alternate aerodrome listed in the flight plan (SBTF) to the aerodrome of origin (SBIH), since the latter was nearer, with weather conditions known to the crew. The crew made VHF contact with the airline, which authorized the change. SBEG was 253 NM away from SBIH and 281 NM from SBTF.

According to statements, after the crew's decision to return to *Itaituba*, they were maintaining FL 190 as their cruise level, when the FUEL light on the CAP illuminated for some time and then went out.

According to pilots' accounts, the FUEL light on the CAP came on, but the LO LVL amber light remained off.

With a fuel quantity of less than 160 kg of QAV-1 in the tank of the corresponding side, the amber MC light would illuminate intermittently, the FUEL alert indication would appear on the CAP, and the LO LVL warning light on the FQI would remain illuminated (Figure 22).

FUEL LO LVL-Alert

_10ae92b0-36e9-46f1-9e0f-56e8b1f04b8f 1.1 ALL

CONDITION	VISUAL	AURAL
Fuel quantity indication below 160 kg (352 lb)	- MC light flashing amber - FUEL amber message on CAP - LO LVL amber light on FUEL QTY indicator	SC

Figure 22 - FCOM 72 Rev 1, JAN2018.

The data extracted from the PCMCIA card revealed five illuminations of the Master Caution light associated with Low Fuel light, with drop of NH and NL in the engines, and with the shutdown of the left-hand side turbine, as follows:

- 23:16:37 UTC: MC, Fuel (1), while holding, 22 NM away from SBEG, FL160;

- 23:48:34 UTC: MC, Fuel (2), 124 nm away from SBEG vertical, FL190;

- 23:54:32 UTC: MC, Fuel (3), 127 nm away from the vertical of SBIH, FL190;

- 00:04:53 UTC: MC, Fuel (4), 85 nm away from the vertical of SBIH, FL190;

- 00:26:11 UTC: Eng-1 NH/NL Drop, 3.35 nm away from the vertical of SBIH, 1,735 ft;

- 00:26:13 UTC: MC, Fuel (5), 3.3 NM away from the vertical of SBIH, 1,708 ft;

- 00:26:28 UTC: Eng-1 Loss, 2.65 NM from SBIH, 1,446 ft; and

- 00:28:55 UTC: Eng-2 NH/NL Drop, on the ground, close to threshold 23.

It is important pointing out that during the tests performed on the aircraft, the illumination of the LO LVL lights was always related to the FQI indication, regardless of the actual quantity of fuel present in the tanks.

In order to expedite the approach, the PF performed a descent to join the VFR traffic pattern of SBIH. When the aircraft was close to the base leg and configured for landing, the ELEC light on the CAP illuminated and the Engine no. 1 (on the left-hand side) shut down at the same time. The PF maintained the landing configuration and a single-engine approach profile, touching down the runway uneventfully.

Already on the runway, after deceleration and below 70 KT, the PM took control of the aircraft steering and, at a reduced speed, started the aircraft's backtrack in order to taxi to

the apron. However, while the aircraft was maneuvering, the Engine no. 2 (on the right-hand side) shut down.

In order to proceed to the apron and disembark the passengers, the crew restarted the right-hand engine. According to the pilots, it was only at that very moment that the LO LVL low fuel-level light on the right-hand side came on in the FQI (Figure 23).

Figure 23 - PR-MPY LO LVL Fuel of Engine no. 2 illuminated in SBIH.

On the power of only the right-hand side engine, the aircraft taxied toward the parking stand where the passengers disembarked.

The data obtained through the QAR revealed that the aircraft remained holding at the vertical of SBEG for about 25 minutes, and that the fuel consumed from the takeoff until the landing back in SBIH was approximately 1,463 kg (Figure 24).

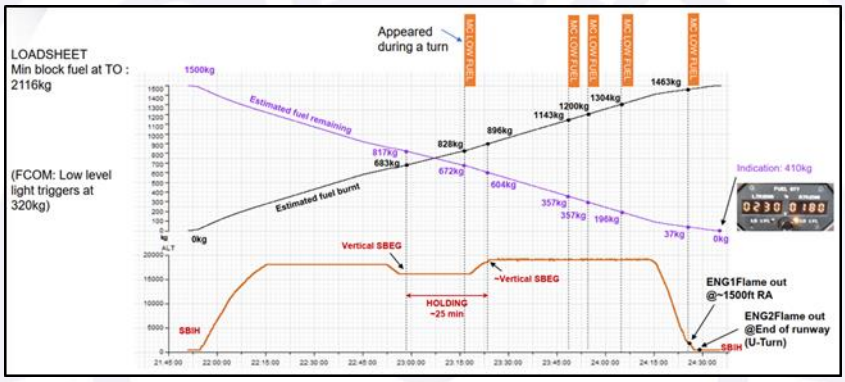


Figure 24 - QAR Reading - Flight Profile & Estimated Fuel Burnt.
Source: ATR.

The first illumination of the MC and FUEL lights, indicating low fuel-level, occurred during a turn performed while the PR-MPY was on a holding pattern in SBEG.

Considering the QAR consumption data, one reached the conclusion that, after departing the vertical of SBEG towards SBIH, the aircraft consumed approximately 567 kg of fuel until the left-hand side engine shut down.

The data extracted from the QAR revealed that the aircraft took off from SBIH with 1,500 kg of fuel. On the other hand, when the PR-MPY left the holding pattern in SBEG in order to proceed to SBIH, the fuel available was 604 kg.

The FQI indications, after the engines shut down in SBIH, were 230 kg of fuel in the left-hand side wing tank and 180 kg in the right-hand side wing tank. At the same time, the information from the Fuel-Level Magnetic Indicators located on the wings indicated that there was no fuel.

In SBIH, the monitoring services concerning the refueling, pre-flight and post-flight were to be conducted by the aircraft's pilots. The PIC would monitor the refueling and perform the checks concerning the initial fuel, fuel consumed, fuel received in the refueling, and the new quantity presented in the FQI.

Control of the refueling was done by means of the RCP (Figure 25).

Figure 25 - ATR-72 Refuel Control Panel (illustrative image).
Source: ATR Systems - Fuel System.

The crewmembers were not in the habit of using the Fuel-Level Magnetic Indicators for checking the actual quantity of fuel in the tanks (Figure 26).

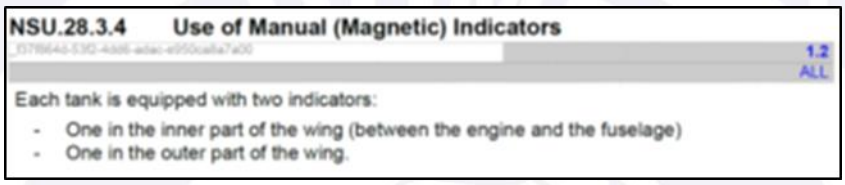


Figure 26 - Use of the magnetic fuel-indicator.
Source: FCOM 72 Rev 1, JAN2018.

1.19. Additional information.

On an accident with another aircraft of the same operator, one observed some conditions referring to processes and control of preventative maintenance services, which fit in the context of the occurrence with the PR-MPY aircraft.

One verified that the operator did not possess a certified maintenance organization in accordance with the Brazilian Civil Aviation Regulation nº 145 (RBAC-145) - “Aeronautical Product Maintenance Organizations”, in force at the time. In the Operator's Operating Specifications, revision nº. 27, dated 16 May 2019, there was the following:

> Part C.2 - Authorized Maintenance Services: Check A maintenance level;
>
> Part C.3 - Authorized Maintenance Service Providers: The operator does not have third-party line maintenance providers”. There are also no authorized maintenance providers for any other level of maintenance;
>
> Part C.4 - Line Stations and National Maintenance Bases: Own maintenance, Check A level, in SBEG”. There are no outsourced maintenance providers, at any other level, in SBEG (the company's headquarters), and at any of the aerodromes where it operates.

However, the *MAP Linhas Aéreas’* General Maintenance Manual (MGM), revision nº. 05, dated 25 April 2018, contained in its item 9.3.1 - "Own Maintenance", among other pieces of information, the following:

> The maintenance performed by the Operator in a primary manner is limited to the execution of line maintenance in accordance with its approved Operational Specification. The other maintenance services corresponding to hangar maintenance items, which require certification in accordance with the RBAC-145, will be carried out by *Manaus Aerotáxi Participações Ltda.*, which is a company certified in consonance with the RBAC 145 of the same economic group to which *MAP* belongs. All services performed by *Manaus Aerotáxi* will be in accordance with

its EO (Operational Specification) in its current version, following the procedures listed in this manual and in its manuals approved by ANAC.

According to the company's General Maintenance Manual, line maintenance could be understood as Check A, and it was an adaptation to the nomenclature established by *MAP* of the term used by the Regulatory Agency.

Still in accordance with the contents of *MAP*'s MGM and *Manaus Aerotáxi*'s Maintenance Organization Manual (MOM), the addresses of the organizations were the same. During the phases of the investigation carried out at *MAP*'s headquarters, the investigation commission found out that both companies (*MAP Linhas Aéreas* and *Manaus Aerotáxi*) shared the same hangars and facilities.

In that context, the investigation commission also noted the presence of an ATR 42 aircraft owned by *MAP*, registration marks PR-MPO, under maintenance in one of the hangars shared with *Manaus Aerotáxi*. In the referred hangar, maintenance tasks related to the intervals of 5,000 hours and 1,600 hours were being performed, as well as the ones related to the 2-year and 4-year intervals. Such tasks were outside of the *MAP*'s authorized level of maintenance.

The Maintenance Board of *MAP Linhas Aéreas* attested that *Manaus Aerotáxi* was carrying out the maintenance services on the PR-MPO aircraft, and that the progress of the maintenance activities, as well as the technical monitoring of the tasks performed, were under the responsibility of *MAP Linhas Aéreas*.

During a visit of the facilities shared by the two companies, it was not possible to differentiate the limits of responsibility between *MAP Linhas Aéreas* and *Manaus Aerotáxi*, both with regard to the subordination of supervisors and mechanics who were performing the maintenance activities, and to which organization the sectors established in each hangar belonged. For example: in the supply sector, identified as belonging to *MAP Linhas Aéreas*, there were items and parts marked as property of *Manaus Aerotáxi*.

Thus, the investigation commission found out that there was another organization, namely *Manaus Aerotáxi*, which in fact carried out the maintenance services on *MAP Linhas Aéreas*' aircraft on an outsourced basis at different levels of Check A, in discordance of the provisions contained in the Operational Specifications of *MAP Linhas Aéreas*.

In addition, the investigation commission verified that *MAP Linhas Aéreas* carried out technical monitoring of the services provided by *Manaus Aerotáxi*, at a level that was not consistent with the authorization contained in its Operational Specification.

Likewise, the investigation commission observed that the sharing of facilities and professionals involved in the supervision and execution of the maintenance tasks (no matter scheduled or otherwise), made it difficult to clearly define the levels of responsibility of each one of the companies in maintaining the condition of airworthiness of the entire fleet of ATR-42 and ATR-72 aircraft in service for the regular passenger transport company.

One must take into consideration that *MAP Linhas Aéreas* and *Manaus Aerotáxi*, for the obtainment of their respective *Air Transport Company* and *Maintenance Organization* certificates, demonstrated their capabilities in a separate and independent manner. Within all such context, one has to comprehend the administrative and maintenance personnel, as well as the specific tools, installations and maintenance workshops.

After verifying that the maintenance services of the *MAP Linhas Aéreas*' aircraft fleet were provided in a way that was divergent from the prescriptions contained in the airline company's Operating Specifications, in which there was involvement of a third-party company, which shared physical facilities and technical personnel with the referred airline, the investigation commission identified a potential danger in the fact that it was not possible for one to clearly determine that the services performed by *Manaus Aerotáxi* were compliant with the requirements of the *MAP Linhas Aéreas*' Maintenance Program.

1.20. Useful or effective investigation techniques.

NIL.

2. ANALYSIS.

It was a regular public passenger air-transport flight between the aerodromes of SBBE and SBEG, with stopovers at SBHT and SBIH. All segments were performed by the same crew of the day before.

The maintenance records attested that the aircraft was airworthy, with no reports of failures related to the fuel system.

The aircraft completed all segments within the weight and balance limits specified by the manufacturer. The SBBE/SBHT/SBIH legs were flown in consonance with the operator's planning.

However, on the flight leg between SBIH and SBEG, there was a discrepancy between the quantity of fuel established in the flight planning and the amount effectively logged in the aircraft logbook.

Such divergence originated from the total fuel consumed between *Altamira* and *Itaituba*, since the actual consumption of QAV-1 was higher than planned by the company. Therefore, instead of consuming the expected 644 kg, the airplane burned 778 kg of aviation kerosene, directly affecting the fuel available for the next flight leg.

Thus, for the takeoff from SBIH, while the logbook records were 2,022 kg, the flight dispatch forecast a total of 2,116 kg, to be distributed as follows (Figure 27):

Destino¤	699·kg¤
Alternativa·¤	705·kg¤
Reserva·em·cruzeiro¤	477·kg¤
Adicional·IFR¤	158·kg¤
Hotel·(ar·cond.)¤	39·kg¤
Taxi¤	40·kg¤
Total·Combustível·Requerido¤	2.116·kg¤

Figure 27 - Fuel required for the flight.

While the minimum fuel declared in the flight dispatch to start the operation in SBIH was 2,116 kg, the minimum fuel for takeoff was 2,039 kg.

If the fuel onboard the aircraft for the SBHT/SBIH segment corresponded to the fuel planned, there would be no need to refuel in *Itaituba*, although there was fuel available in that location.

Despite the fact that the PIC signed the flight dispatch listing the total quantity of fuel needed for the segment, the refueling was not carried out at SBIH.

In this regard, it is important pointing out that in *Itaituba* there was no support from ground staff to carry out post-flight and pre-flight checks, as well as refueling, leaving the pilots with the responsibility of monitoring the refueling and performing other tasks. Thus, one cannot rule out the possibility that these aspects have contributed to the reduction of attention and to the lapses associated with automatic processes, since refueling was not commonly carried out in that location.

Although it is not possible to specify whether the crew did not notice, or disregarded the difference between the prescribed mass of fuel and the indicated one, since the PIC

signed the dispatch, it is clear that the operation at SBIH started with an indication of fuel 94 kg short of the quantity recommended in the company's planning.

It is important to highlight that the crewmembers were not in the habit of using the Fuel-Level Magnetic Indicators to check the actual quantity of fuel available. Had this verification been carried out, it would have been possible to identify the discrepancy between the quantity of fuel indicated and the one available in the tanks.

At the take-off from the municipality of *Itaituba* for the flight to *Manaus*, the weather conditions at the departure aerodrome were consistent with VFR flights.

While en route, with the aircraft maintaining FL180, the crewmembers received information that the destination aerodrome was closed, due to an aircraft accident, which would make it impossible to land upon arrival in SBEG.

In order to increase their en-route time, in an attempt to prevent holding close to Manaus, the aircraft reduce speed. At the same time, the cruise-flight level changed from FL180 to FL160, with the purpose of preventing the occurrence of icing.

Even with the reduction in speed, upon arriving in Manaus, the airfield was still unavailable for operations, with holdings taking approximately 25 minutes. As there was no forecast for SBEG to resume operations, the crew, in coordination with the airline office, decided to return to SBIH, which was, at that moment, 28 NM closer than the planned alternate aerodrome of SBTF, besides being operating VFR (Figure 28).

Figure 28 - Distance between aerodromes. Source: Adapted from Google Maps.

The FQI indicators showed that there would be 1,200 kg of QAV-1, enough fuel to proceed to any of the aerodromes.

The crew reported that, while they were cruising at FL 190 on the way back to *Itaituba*, the FUEL light illuminated on the Crew Alerting Panel for the first time. Then, that light went out without identification of any associated light. However, the data obtained from the QAR showed that the first illumination of the MC and of the FUEL light, indicating low level of fuel, occurred still during a turn performed while holding in SBEG. In total, the Master Caution light illuminated on five occasions, all of them associated with low levels of fuel.

The FQI had a Low Level Light (LO LVL) for each tank. It would illuminate if the total quantity of fuel in a tank dropped below 160 kg.

Because of the alert on the CAP concerning the fuel system, the crew performed a profile of descent, seeking to minimize the flight time, and proceed as quickly as possible for the landing. They were still on the final approach when the engine no.1 shut down.

After landing, they maneuvering on the runway to return to the apron when the engine no. 2 of the aircraft shut down. The crew successfully restarted the right-hand engine of the aircraft in order to clear the runway and proceed to the parking area, where the passengers and crew disembarked.

The crew reported that it was only after the start-up of the engine no. 2 that the first light on the LO LVL of the right-hand side of the FQI illuminated, with an indicated amount of 180 kg of fuel. On the left-hand side, the indicated amount was 230 kg. Thus, in such

condition, the Fuel-Level Magnetic Indicators (located under the wings) indicated *zero fuel* after being measured.

The discrepancy between the mass of fuel indicated in the FQI and the measurement of the Fuel-Level Magnetic Indicators led one to investigate the reasons why the engines had shut down.

At a first moment, on 18 September 2019, the PR-MPY received 2,537 liters of QAV-1, which represented a weight of 1,935.73 kg (2,537 liters x 0.763), after verification of the respective density (*weight to volume* ratio).

After this refueling, the data available in the FQI indicated 1,190 kg on the left-hand wing tank and 1,200 kg on the right-hand wing tank, i.e. a total of 2,390 kg.

On the other hand, the Fuel-Level Magnetic Indicators showed that the left-hand wing tank had 1,350 liters of fuel, and the right-hand one had 1,550 liters, which represented a weight of 1,039.5 kg on the left-hand wing tank, and 1,193.5 kg on the right-hand wing tank, considering the density of 0.77, i.e. a total of 2,233 kg.

That was a difference of 157 kg between the indications of the FQI and of the Fuel-Level Magnetic Indicators.

After authorized by ANAC, the aircraft was ferried to SBEG, where tests of higher accuracy found several non-conformities after transference of fuel between the wings for verification of the behavior of the fuel-quantity indication system, as follows

- with the FQI of the left-hand wing tank indicating 310 kg, the Fuel-Level Magnetic Indicators of that wing indicated zero fuel;
- even after removing all the remaining fuel (75 liters) from the left-hand wing tank by means of a drain located near the wing root, the FQI of left-hand wing tank indicated a quantity of 230 kg of QAV-1;
- the low fuel-level indication in the FQI of the right-hand wing tank illuminated when the data shown on the instrument was 170 kg; and
- even when there was no drainable fuel on the left-hand wing tank any longer, the light that would indicate the low fuel-level condition did not illuminate in the respective FQI, evidencing that the alert was inoperative.

These findings corroborate the information that, after the incident, only one of the LO LVL amber lights was on when the aircraft was in the parking area of Itaituba, even with the markings of the Fuel-Level Magnetic Indicators showing zero kg of fuel.

Such differences led the commission to start a research aimed at determining the origin of the failure in the indication, and of the difference existing between the mass of fuel indicated in the FQI and the actual quantity of fuel in the tanks of the aircraft.

Subsequently, as per the JIC 28-42-72 FUT 10000, all six fuel-probes of the tanks were subject to functional tests. The results indicated that the number-3 fuel probes of both wings (P/N 768-100, S/N 1358 and S/N 516, respectively) were out of parameters and requiring replacement. Similarly, the P/N 798-078-2 Harness (Cabling) of the number-3 fuel probe on the right wing was out of parameters and in need of replacement.

Due to lack of indication of low fuel-level in the FQI of the left-hand wing tank, the number-1 fuel probe (P/N 766-983-1 S/N 1647) of the referred wing was replaced.

After replacement of the three right-hand side fuel probes and damaged Harness (which had several protection wires broken), the FQI resumed showing correct “zero-fuel” indications, besides turning on the LO LVL amber lights, indicative of low fuel-level. Upon completion of the repairs, the fuel quantity indication of the PR-MPY restarted its normal

operation, confirming that these components had defects that had directly interfered with the PR-MPY fuel system indication.

Thus, although the bench tests did not determine what caused the failure of the aircraft's fuel indication system to work properly, the functional tests (as per JIC 28-42-72 FUT 10000), on the other hand, revealed the non-conformity of the items subject to replacement (three fuel probes and harness, all of which on the right-hand side). That is to say, non-conformity of the fuel indication system of the aircraft right-hand side.

Therefore, the investigation corroborated the existence of non-conformities in the preventative and/or corrective maintenance services performed on the aircraft, since the PR-MPY had a system failure (not identified until then by the crew), which contributed to this serious incident.

Within such context, one should not rule out the possible contribution of the company's organizational support, given the fact that, although *MAP Linhas Aéreas* had its own team of mechanics, it was actually *Manaus Aerotáxi* the organization responsible for the maintenance of the aircraft, since *MAP Linhas Aéreas* did not have authorization to carry out maintenance activities. This particularity may have led to failures in the supervision, or even, in the design of important organizational processes for maintaining operational safety.

Moreover, it was possible to observe that *MAP Linhas Aéreas* was performing technical monitoring of the services provided by *Manaus Aerotáxi* at a level that went beyond the limits established in its Operating Specifications. Besides, one observed the sharing of facilities and professionals involved in the supervision and execution of maintenance tasks, scheduled or otherwise, making it difficult to define clearly the levels of responsibility of each company in maintaining the airworthiness condition of the entire ATR 42 and ATR 72 aircraft fleet of the regular passenger transport company.

Therefore, even though the aircraft took off from SBIH with a quantity of aviation kerosene that fell 94 kg short of the quantity specified in the planning, that fact in isolation would not be enough to cause the engine of the aircraft to shut down in flight, had the information on the fuel available to the pilots been reliable and effective, with real FQI indication of the actual mass of QAV-1 available for the flight.

The discrepancy was such that the QAR reading indicated that the plane had 1,500 kg of fuel when it took off from SBIH towards SBEG. According to the numbers entered by the PIC in the logbook, this amount would be 2,022 kg, that is, a difference of 522 kg.

That difference between the indicated and the actual fuel could only be verified on the ground after the flight, when the crew had information of at least 410 kg of fuel in the tanks, an amount that was in fact unreal, as verified by the measurements of the under-wing Fuel-Level Magnetic Indicators, which showed *zero fuel*.

Despite the survey carried out in the history of the aircraft's fueling information, it was not possible to identify the moment at which the information provided by the FQI diverted from the real expression of the mass of fuel contained in the left- and right-hand wing tanks of the aircraft.

That said, after considering the discrepancy between the FQI indication and the actual amount of fuel in the tanks, resulting from the lack of prior identification of the incongruity by the maintenance staff. In addition, considering the accumulation of tasks performed by the pilots on the ground in SBIH. Moreover, considering the takeoff of the aircraft from SBIH with a quantity of QAV-1 that was lower than the one prescribed in the company's planning. The investigation commission inferred that the abovementioned aspects, in conjunction, acted as factors which contributed to the sequence of events that culminated in the complete failure of both engines on account of fuel exhaustion (dry failure).

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3. CONCLUSIONS.

3.1. Findings.

a) the four crewmembers had valid Aeronautical Medical Certificates;

b) the pilots had valid AT47 type aircraft ratings, which included the aircraft model of the occurrence, and valid IFRA (IFR Flight - Airplane) ratings;

c) the pilots were qualified and experienced in the type of flight;

d) the aircraft had a valid Certificate of Airworthiness;

e) the aircraft was within the weight and balance limits specified by the manufacturer;

f) the records of the maintenance logbook were up to date;

g) the weather conditions were consistent with the conduction of the flight;

h) the aircraft started operations in SBIH with 2,022 kg of fuel, 94 kg less than the minimum forecast in the flight dispatch, which was 2,116 kg;

i) refueling was not provided in SBIH;

j) while flying en route, the crew received information that SBEG was closed due to an aeronautical occurrence;

k) the crew chose to return to the SBIH;

l) at the landing of the aircraft in SBIH, its left-hand engine shut down;

m) while the aircraft was taxiing after landing, the right-hand engine shut down due to lack of fuel;

n) the pilots managed to re-start the engine no. 2, and proceeded to the parking area;

o) on the ground, shortly after the occurrence, one identified a discrepancy between the mass of fuel indicated in the FQI and the numbers of the Fuel-Level Magnetic Indicators of 410 kg in total;

p) the results of the functional tests indicated that the number-3 fuel probes (P/N 768-100, S/N 1358 and S/N 516, respectively) of both wings were out of the prescribed parameters and needed to be replaced;

q) there was replacement of the Harness P/N 798-078-2 of the right-hand wing fuel probe no. 3, which was out of the prescribed parameters;

r) the low fuel-level indicator of the FQI, referring to the left-hand wing tank, was inoperative;

s) the fuel probe (P/N 766-983-1, S/N 1647) on the left-hand wing was replaced;

t) there was no damage to the aircraft; and

u) the crew and the passengers suffered no injuries.

3.2. Contributing factors.

Attention – undetermined.

Due to the multiple tasks performed by the pilots while on the ground in SBIH, there was possibly a reduction in their process of attention, which may have caused lapses related to automatic processes, and distractions concerning the amount of fuel required for starting operations in SBIH, since the PIC signed the flight dispatch, which contained the minimum fuel requirements.

Crew Resource Management – a contributor.

There was inefficiency in the utilization of the human resources available for the operation of the aircraft, due to an inappropriate management of the tasks assigned to each pilot, considering their inobservance of the minimum fuel required for starting operations in SBIH.

Aircraft maintenance – a contributor.

After the occurrence of the serious incident, and upon completion of the aircraft repair work, the fuel quantity indicator of the PR-MPY resumed proper operation anew, evidencing that the FQI components had problems that interfered directly with the fuel system indication. Thus, one verified the non-conformity of the maintenance services previously performed on the aircraft, independently of having been preventive or corrective, since the PR-MPY had remained with a system failure that contributed to the serious incident.

Support personnel – undetermined.

The fact that there was no support staff at SBIH to perform post-flight, pre-flight and refueling tasks may have strongly increased the pilots' workload, which may have resulted in possible distraction as to the need of refueling the aircraft.

Organizational processes – undetermined.

One cannot rule out the possible contribution of the company's organizational support, since, despite the fact that *MAP Linhas Aéreas Ltda.* possessed its own team of mechanics, it was actually Manaus Aerotáxi the company responsible for the maintenance of the aircraft, since *MAP Linhas Aéreas Ltda* did not have certification for the provision of maintenance services. Such state of circumstances may have led to failures in the supervision or, even, in the design of organizational processes important for the preservation of safety.

Managerial oversight – a contributor.

In view of the various non-conformities observed in the components of the fuel indication system after the occurrence, one inferred that there were failures in the monitoring and oversight of the maintenance services of the operating company.

4. SAFETY RECOMMENDATIONS

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 consonance with the Law n°7565/1986, recommendations are made solely for the benefit of 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 Brazil's National Civil Aviation Agency (ANAC), it is recommended:

IG-133/CENIPA/2019 - 01 **Issued on 12/29/2023**

Review its own internal processes so as to verify the establishment of conditions and circumstances under which a regulated entity, pursuant to the RBAC-121 requirements, has to address and solve specific deficiencies in an internal fashion, attesting, before the Agency, the effectiveness of the corrective measures adopted for the re-establishment of the minimum acceptable conditions, as prescribed in the document *Diretrizes para a Qualidade Regulatória* (Guidelines for Regulatory Quality)."

IG-133/CENIPA/2019 - 02 **Issued on 12/29/2023**

Reassess its own internal safety oversight processes, in order to make sure that they are capable of identifying, as applicable, the degradation of a regulated company's technical

and financial conditions required to guarantee the safety of the activities performed by such company, as established in the Art. 27 of the “Specific Safety Program (PSOE-ANAC)”.

5. CORRECTIVE OR PREVENTATIVE ACTION ALREADY TAKEN.

NIL.

On December 29th, 2023.

ANNEX A – COMMENTS BY THE STATES PARTICIPATING IN THE INVESTIGATION

In compliance with the provisions of the Chapter 6, item 6.3, of the Annex 13 to the Convention on International Civil Aviation, the States participating in this investigation had the opportunity to make their comments concerning the content of this final report.

Through the Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile (BEA), France forwarded the document V-56/23, containing comments from the aircraft manufacturer's Avions de Transport Régional (ATR).

All comments deemed pertinent have been included in the body of this report. The following are comments that have not been incorporated or have been partially incorporated.

COMMENT CONTAINED IN THE BODY OF THE DOCUMENT V-56/23

In the body of document V-56, which forwarded ATR's comments on the draft of this Final Report, ATR suggested to CENIPA that a safety recommendation be drafted for all commercial transport operators. This recommendation should aim to implement a fuel policy (FUEL POLICY) in operations (SOP), as well as supporting flight crews in its implementation.

CENIPA´s Opinion

Not incorporated.

CENIPA's Argumentation

The Brazilian Civil Aviation Regulation - RBAC No. 121, established the requirements for public air transport operations with aircraft with a maximum certified passenger seating configuration of more than 19 seats or a maximum payload capacity of more than 3,400 kg.

In this regulation, issues relating to Fuel Supply and In-Flight Fuel Management were established, thus defining the fuel policy that operators should adopt during their operations.

COMMENT 15

Text to be corrected (Chapter 2, Page 30, Line 30)

The FQI had a Low Level Light (LO LVL) for each tank. It would illuminate if the total quantity of fuel in a tank dropped below 160 kg.

Text proposed by ATR

Add a note:

On this aircraft configuration, in case of feeder tank not full, the following alerts on PR-MPY aircraft triggers:

- Master Caution flashing amber

- FUEL amber message on the CAP

- No local alert - LO LVL amber light on Fuel Quantity Indicator (FQI)

ATR identified that it occurred on aircraft equipped with Multi-Function Computer (MFC) standard 4 (or later standards) without having the secondary fuel low fuel function (Feeder tank not full).

ATR recommends modifying this aircraft configuration to introduce the local alert to further aid flight crew. An official retrofit information letter will be sent in January 2024.

ATR72:

Service bulletin for the secondary fuel low level detection will be published in 2024.

CENIPA´s Opinion

Not incorporated

CENIPA's Argumentation

From CENIPA's point of view, the information on how low fuel alerts work is already presented in Figure 22.

The proposed changes regarding the aircraft configuration and the information that a Service Bulletin will be published have not been incorporated as neither the changes nor the information contribute to the aim of that chapter, which is to analyze the sequence of events.