COMANDO DA AERONÁUTICA

CENTRO DE INVESTIGAÇÃO E PREVENÇÃO DE ACIDENTES AERONÁUTICOS

FINAL REPORT
IG-053/CENIPA/2022

OCCURRENCE:	SERIOUS INCIDENT
AIRCRAFT:	PS-RJJ
MODEL:	PA-46-600TP
DATE:	19ABR2022

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 19 April 2022 serious incident with the PA-46-600TP airplane, registration marks PS-RJJ. The occurrence was typified as “[SCF-PP] Power Plant failure or malfunction – Engine failure in flight.”

While on cruise flight, the aircraft present abnormal variation of the fuel flow, followed by engine failure and cabin depressurization. The pilot descended the aircraft and made an emergency landing.

A crack was found in the fuel line between the FCU (Fuel Control Unit) and the FFM (Fuel Flow Meter), compromising the performance of the engine in flight.

The aircraft sustained minor damage, while the pilot received no injuries.

Both the USA (State of aircraft manufacture) and Canada (State of engine manufacture), by means of, respectively, the NTSB and the TSB, designated accredited representatives for participation in the investigation of this serious incident.

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GLOSSARY OF TECHNICAL TERMS AND ABBREVIATIONS

ACC-CT	Area Control Center - *Curitiba*
ADC	Air Data Computer
AMM	Aircraft Maintenance Manual
ANAC	Brazil's National Civil Aviation Agency
APP-LO	Approach Control - *Londrina*
CENIPA	Brazil's Aeronautical Accidents Investigation and Prevention Center
CIV	Pilot Logbook
CMA	Aeronautical Medical Certificate
CVA	Airworthiness Verification Certificate
DECEA	Department of Airspace Control
EUA	United States of America
FCU	Fuel Control Unit
FL	Flight Level
HCF	High Cycle Fatigue
IFR	Instrument Flight Rules
IFRA	Instrument Flight Rating - Airplane
ITT	Inter Turbine Temperature
MFD	Multi-Function Display
MNTE	Single-Engine Land Airplane Rating
MOR	Manual Override
NTSB	USA's National Transportation Safety Board
PN	Part Number
PCM	Commercial Pilot License - Airplane
PFD	Primary Flight Display
PIC	Pilot in Command
PPR	Private Pilot License - Airplane
PSO-BR	Brazil's Civil Aviation Safety Program
QAv	Aviation Kerosene
RBAC	Brazilian Civil Aviation Regulation
RPM	Revolutions Per Minute
SBLO	ICAO location designator - *Governador José Richa* Aerodrome, *Londrina*, State of *Paraná*
SD	Secure Digital
SDEN	ICAO location designator - *Costa Esmeralda* Aerodrome, *Porto Belo*, State of *Santa Catarina*
SHP	Shaft Horsepower

SIPAER	Brazilian Aeronautical Accidents Investigation and Prevention System
SN	Serial Number
TPP	Private Air Services Registration Category
SWPY	ICAO location designator – Aerodrome of *Primavera do Leste*, State of *Mato Grosso*
TSB	Canada's Transportation Safety Board
UTC	Universal Time Coordinated

1. FACTUAL INFORMATION.

Aircraft	**Model:** PA-46-600TP **Registration:** PS-RJJ **Manufacturer:** Piper Aircraft.	**Operator:** *Rosecon Jr Empreendimentos Imobiliários Ltda*.
Occurrence	**Date/time**: 19ABR2022 – 11:50 (UTC) **Location:** Municipality of *Cornélio Procópio*. **Lat.** 23°11'43"S **Long.** 050°38'46"W **Municipality – State:** *Cornélio Procópio – Paraná.*	**Type(s):** [SCF-PP] Powerplant failure or malfunction

1.1. History of the flight.

At 10:34 UTC, the airplane took off from SDEN (*Costa Esmeralda* Aerodrome, *Porto Belo*, State of *Santa Catarina*) bound for SWPY (Aerodrome of *Primavera do Leste*, State of *Mato Grosso*) on a private flight with 01 POB (pilot)

While cruising at FL280, the aircraft presented fuel flow variations followed by engine failure.

The pilot chose to perform an emergency descent to land at SBLO (*Governador José Richa* Aerodrome, *Londrina*, State of *Paraná*.

The aircraft sustained minor damage, whereas the pilot suffered no injuries.

Figure 1 - The aircraft stored in a hangar at SBLO.

1.2. Injuries to persons.

Injuries	Crew	Passengers	Others
Fatal	-	-	-
Serious	-	-	-
Minor	-	-	-
None	1	-	-

1.3. Damage to the aircraft.

The aircraft sustained minor damage, restricted to the internal parts of the engine.

1.4. Other damage.

NIL.

1.5. Personnel information.

1.5.1. Crew's flight experience.

FLIGHT EXPERIENCE	
	PIC
Total	3.141:00
Total in the last 30 days	25:15
Total in the last 24 hours	03:55
In this type of aircraft	907:00
In this type in the last 30 days	25:15
In this type in the last 24 hours	03:55

RMK: data on the hours flown obtained by means of PIC's reports and records from in his CIV (pilot logbook).

1.5.2. Personnel training.

The Pilot in Command (PIC) did his PPR course (Private Pilot - Airplane) in 2007, at *Aerocon Escola de Aviação Civil*, *Curitiba*, State of *Paraná*.

1.5.3. Category of licenses and validity of certificates.

The PIC held a PCM License (Commercial Pilot – Airplane), as well as valid ratings for MNTE (Single-Engine Land Airplane) and IFRA (IFR Flight – Airplane).

1.5.4. Qualification and flight experience.

The records of the PIC's electronic CIV indicated that, since 13 March 2018, he operated P46T airplanes manufactured by Piper Aircraft, including the model involved in the incident. The records also showed that he had operated the PS-RJJ since 09 March 2018, having performed 28 flights in the referred airplane in the 30 days before the incident in question.

He was qualified and had experience in the type of flight.

1.5.5. Validity of medical certificate.

The pilot held a valid CMA (Aeronautical Medical Certificate).

1.6. Aircraft information.

The SN 4698038 aircraft was a product manufactured by Piper Aircraft in 2017, and registered in the Private Air Services Registration Category (TPP).

The aircraft had a valid CVA (Airworthiness Verification Certificate).

The records of the airframe, engine, and propeller logbooks were up to date in terms of the Part II (primary records of maintenance, inspection, revision, minor modifications and repairs), Part III (secondary records concerning addition of airworthiness directives, major modifications and repairs); and Part IV (records relative to the installation and removal of controlled components).

However, the records relative to Part I (monthly records of hours) were out of date.

The latest inspection of the aircraft ("Event 2" type) took place on 04 March 2022 on the premises of *Aeromecânica Ltda.* maintenance organization in *Curitiba*, State of *Paraná*. The aircraft flew 48 hours and 40 minutes after the referred inspection.

The airframe, engine, and propeller logbooks contained records of the maintenance activities and inspections performed on the airplane during its operational history both in the USA and in Brazil. Such records included a service relative to the disassembly of the engine on 02 August 2019, when the aircraft still operated in the USA, which had the purpose of replacing a few blades of the compressor turbine. There were no details in the records about the origin of the damage to the blades.

The Aircraft Maintenance Manual (AMM) 767-617, revision PR20210331, dated 10 May 2021, in force at the time of this incident, contained a program of progressive inspections for the aircraft model. The referred program included, among others, two inspections named “Event 1” and “Event 2”

According to the manual, the cycle of the progressive inspection program consisted of two 100-hour events, which provided a thorough inspection of the aircraft every 200 hours flown. The full inspection cycle (Events 1 and 2) had to be carried out within an interval of twelve calendar months.

The records of the maintenance logbooks had been logged as provided for by the aeronautical legislation in force, and complied with the intervals specified by the manufacturer’s maintenance manual.

No inconsistencies were found concerning the frequency of inspections and of the maintenance activities performed during the period of operation of the airplane, from the time of its manufacture until the date of the incident.

The “Event 2” inspection comprised verification of different components and systems, including the FCU, flow meter, fuel lines, and the Fuel Pump Outlet Filter.

According to the aircraft maintenance records, on five different occasions since the manufacture of the airplane, the Fuel Pump Outlet Filter of the PS-RJJ had undergone maintenance services, being four times in the period that the aircraft still operated in the USA and once, the latest one, in Brazil, when the fuel filter was replaced 46 days before the incident in question.

The Fuel Pump Outlet Filter location was close to the PN 3033981 fuel line, which connected the FCU to the Flow Meter (Figure 2).

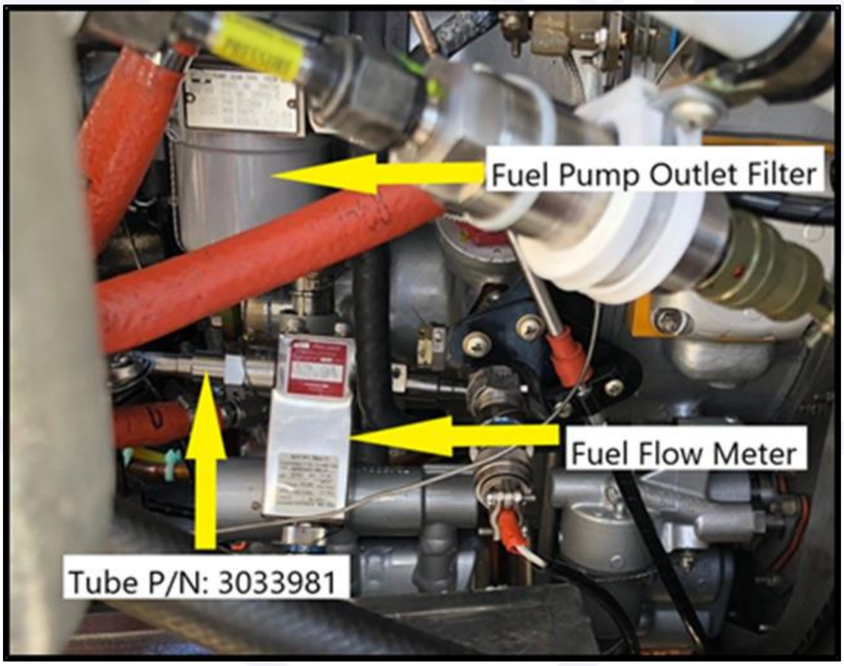

Figure 2 - Image of the engine compartment showing the layout of the Fuel Pump Outlet Filter and the PN 3033981 fuel line.

The PS-RJJ airplane was equipped with Garmin G3000 Integrated Avionics System. The G3000 consisted of an avionics interface featuring colored digital displays that provided information on flight parameters, systems of communication, in addition to data coming from the engine.

The system had two Primary Flight Displays (PFD), a Multi-Function Display (MFD), touch-sensitive controllers and two Air Data Computers (ADC). There was also a system that stored a variety of flight parameters, which included altitude, speed, torque, and fuel flow in cards of the Secure Digital (SD) type (Figure 3).

Figure 3 - Panel of the PS-RJJ airplane. Highlighted in red, the position of the SD card slots beside the MFD.

The cabin altitude data was not among the parameters recorded by the G3000 system.

The PS-RJJ airplane was equipped with a Pratt & Whitney PT6A-42A engine (SN PCE-RM0734) manufactured in 2017. This engine had a total 793 hours and 35 minutes of operation at the moment of the incident in question. It had not undergone any overhaul since its manufacture. After the latest inspection, the engine operated 48 hours and 40 minutes. (Figure 4).

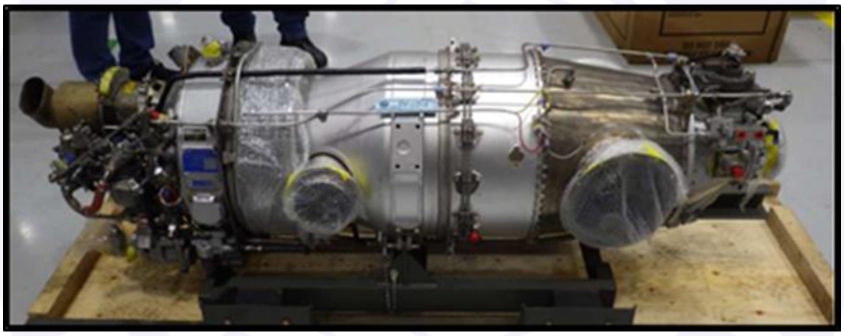

Figure 4 - Overview of the PS-RJJ airplane's engine.

This engine developed a maximum power of 600 Shaft Horsepower (SHP), and was fitted with a propeller whose maximum prescribed rotation was 2,000 RPM.

The PT6A-42A ran on Aviation Kerosene (QAv), and consisted of a free reverse flow turbine and two sections. One of the turbines was connected to the compressor, in the gas-generating section, and the other one was connected to the propeller shaft by means of a reduction box. The engine accessories included a generator, which also acted as a starter, an alternator, and an air conditioner compressor.

The engine was controlled by the pilot by means of three levers, a Power lever, a Condition lever, and a Manual Override (MOR) lever.

The Power lever actuated on the FCU and enabled the pilot to activate the propeller's beta and reverse positions.

The Condition lever, in turn, activated the FCU for the *run* and/or *cut-off* modes. When positioned fully forward, it placed the FCU in a normal operating condition, allowing the fuel flow to the engine in accordance with the position of the power lever. When retracted, it placed the FCU in the cut-off condition, interrupting the fuel flow to the engine and feathering the propeller.

Lastly, the MOR lever consisted of an emergency device, which allowed the pilot to manually override the automatic controls of fuel flow toward the engine, with the objective of providing favorable conditions to the flight in case of FCU failure or loss of control of the power lever. (Figure 5).

Figure 5 - Lever pedestal of the PS-RJJ airplane.

The aircraft manual described the decrease of fuel flow and torque as a characteristic sign of failure or malfunctioning of the FCU, and warned that quick movements of the power lever might result in compressor stall and excessive values of Inter Turbine Temperature (ITT).

The airplane ambient control was responsible for providing air conditioning, ventilation and pressurization of the cabin through the utilization of bleed air from the engine.

The airplane had a hydraulic system that enabled to extend and retract the landing gear. A hydraulic fluid reservoir was located in the rear baggage compartment, and contained a hydraulic pump which was activated electrically. The pump had a reversible functioning, so that it could be commanded in two different directions, one for extension and the other for retraction of the landing gear.

The fuel system consisted of two main tanks located in the wings, a fuel pump located at the outlet of each tank, supply and return lines, in addition to five drains.

The fuel came out of the tanks simultaneously and passed through the respective pump. After the pumps, fuel pressure measuring devices were installed. The QAv then passed through the filter of the system and moved toward the low pressure pump of the engine, where there was another pressure measuring device. Finally, the fuel was directed toward a heat-exchanger, responsible for its heating, and moved to the high pressure pump of the engine, arriving at the FCU.

After passing by the FCU, the fuel traveled by means of a metal rigid line (PN 3033981) to the flow meter, a component that was responsible for measuring the fuel flow that was being consumed so that this piece of information was transmitted to the pilot by means of the system of avionics. After passing by the flow meter, the QAv passed through the fuel divider before proceeding to the injection nozzles of the engine combustion chamber.

1.7. Meteorological information.

The meteorological conditions were above the minima required for the conduction of the proposed flight.

1.8. Aids to navigation.

NIL.

1.9. Communications.

According to the audio transcripts of the communications between the PS-RJJ and the ATC agencies, one verified that the PIC maintained radio contact with the Area Control Center of *Curitiba* (ACC-CT).

There were no recordings of radio contact between the airplane and the Approach Control of *Londrina* (APP-LO).

The recordings showed that ACC-CT called the PS-RJJ after observing that the airplane was departing from the planned route, but did not receive an answer at first.

Subsequently, the ATC agency observed that the aircraft was heading for SBLO while descending to lower levels. By means of coordination via telephone, APP-LO initially informed having no contact with the airplane.

ACC-CT advised APP-LO that the airplane was flying toward *Londrina*, and sometime later, the PS-RJJ called ACC-CT, informing to be heading for *Londrina*. ACC-CT instructed the aircraft to make radio contact with APP-LO.

1.10. Aerodrome information.

The engine failure occurred when the aircraft was on cruise flight.

Following the failure, the aircraft made an emergency landing in SBLO (*Governador José Richa* Aerodrome, *Londrina*, State of *Paraná*).

It was a public aerodrome under the administration of *CCR Aeroportos*, operating VFR and IFR during day- and night-time.

The asphalt-sealed runway with thresholds 13/31 measured 2,100 m x 45 m at an elevation of 1,867 ft.

1.11. Flight recorders.

Although flight recorders were neither required nor installed, the aircraft avionics system recorded flight parameters in SD-type cards and stored data relative to the serious incident flight. The flight parameters were successfully retrieved later.

The information obtained revealed that, during the cruise-phase of the flight, the Fuel Flow toward the engine was stable at a rate of 38.20 Gallons per Hour (GPH) with variations of ± 0.15 GPH.

At 11:30:04 UTC, the fuel flow started increasing slowly, reaching an average of 38.70 GPH with larger variations**.**

At 11:32:50 UTC, there was an increase to 41.83 GPH.

At 11:43:12 UTC, this parameter increased to 51.84 GPH.

At 11:43:39 UTC, the fuel flow decreased to 41.61 GPH, a value that was above the average obtained earlier on cruise flight. It should be noted that during the whole cruise flight, the altitude and external air temperature remained constant.

At 11:47:17 UTC, when the aircraft was flying over the municipality of *Cornélio Procópio*, State of *Paraná*, the engine torque value started decreasing from 1,166 ft. lb. until reaching 35 ft. lb. in an interval of 43 seconds.

At 11:48:54 UTC, a peak in fuel flow was recorded, whose value reached 65.59 GPH. From this point until the end of the flight, the values diminished to an average of 7.48 GPH.

Before the failure, still during the cruise phase, the ITT value was around 757°C. After the engine failure, the temperature decreased to 491°C and, immediately after that, two peaks were recorded: one of 1.061°C and another one of 1.046°C, already during the descent.

1.12. Wreckage and impact information.

NIL.

1.13. Medical and pathological information.

1.13.1. Medical aspects.

NIL.

1.13.2. Ergonomic information.

NIL,

1.13.3. Psychological aspects.

NIL.

1.14. Fire.

There was no evidence of fire either in flight or after the aircraft landed.

1.15. Survival aspects.

Nil.

1.16. Tests and research.

In order to identify the factors that contributed to the experienced failure, the engine and its components were subjected to laboratory examinations and tests.

The engine was found with the power section seized. It was observed that there was rubbing between the tips of the second stage turbine blades and the sealing ring, signs that were consistent with a condition of interference between these parts of the engine.

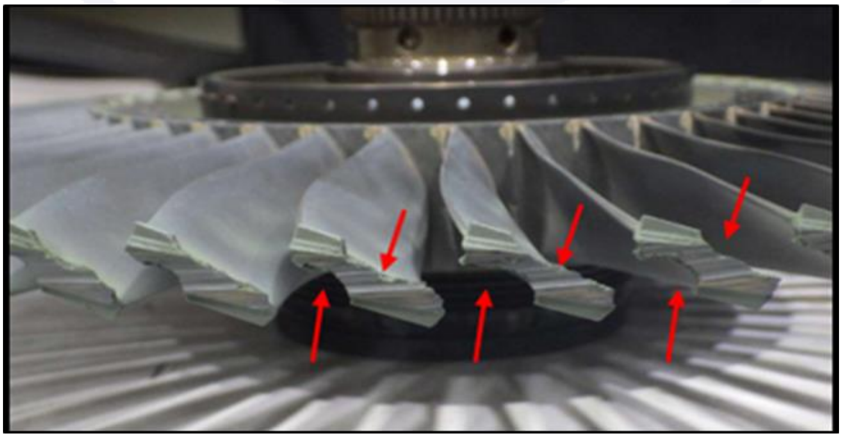

Figure 6 - Power turbine blades with rubbing marks.

The ITT sensors, as well as the power turbine itself, showed damage, deformations, and discoloration consistent with exposure to excessive heat.

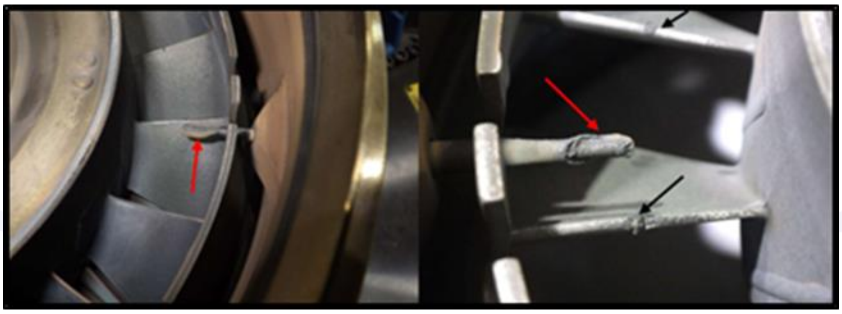

Figure 7 - Inter turbine temperature sensors showing deformations compatible with exposure to high temperatures.

Figure 8 – turbine with discoloration compatible with exposure to high temperatures.

There were no metallic particles on the chip detectors' magnets of the reduction gearbox, nor in the engine's main oil filter.

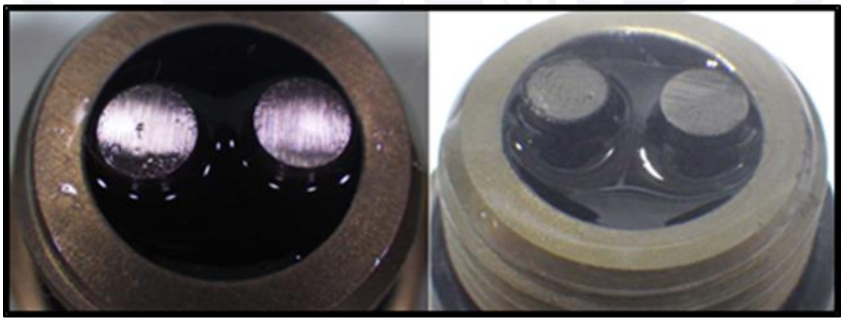

Figure 9 - Chip detectors of the reduction gear box (on the left) and of the accessory gearbox (on the right).

Figure 10 – Engine oil filter.

The fuel filter showed no signs of contamination of the QAv.


Figure 11 – Fuel filter.

The FCU was bench tested, and during this test, small deviations were observed in relation to the parameters defined in the manufacturer's manual, which did not compromise the performance of this unit.

The examination of the engine's pneumatic line connections revealed that all of them were secured and with the correct torque applied.

However, during the inspection of the PN 3033981 fuel line, a leak was found at the point where it connected to the fuel flow meter, an area where a crack was discovered.

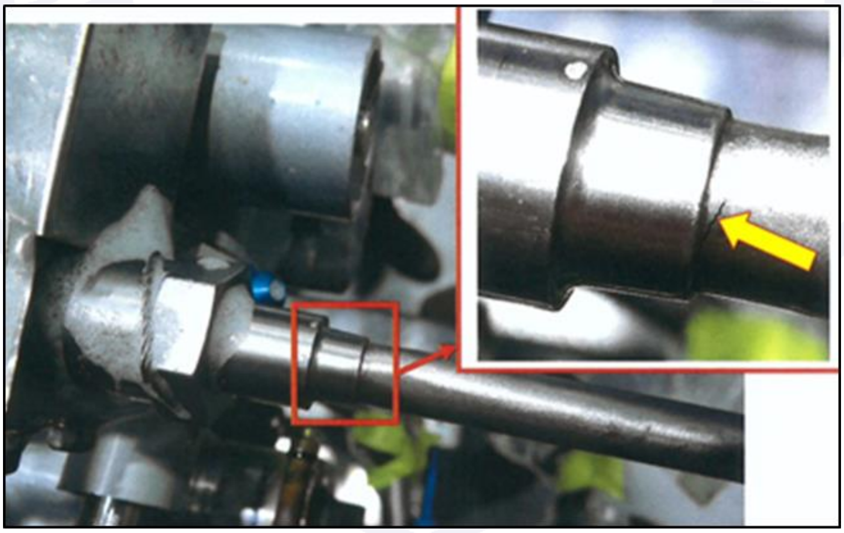
Figure 12 – A crack in the fuel line.

This component was disassembled to be sent for laboratory examination. During the disassembly, a misalignment between the fuel line and its connection to the FCU was observed, on the opposite end of the area where the fracture was found.

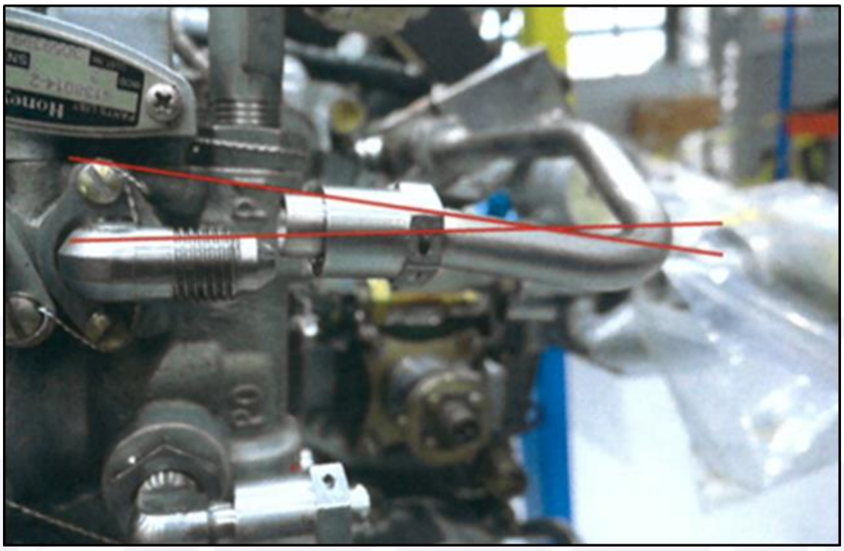

Figure 13 – Misalignment between the fuel line and its connection to the FCU.

Laboratory examinations of the PN 3033981 fuel line showed that the fracture found at the connection to the fuel flow meter propagated approximately 150° around the circumference of the tube.

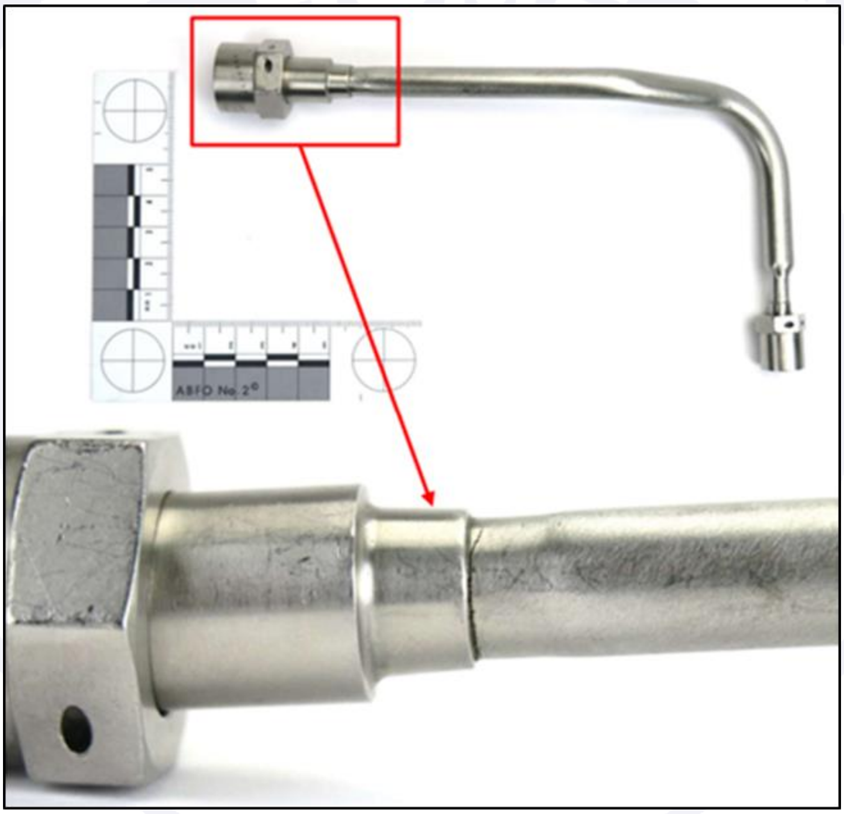

Figure 14 – Detail of the fracture found in the fuel line.

The fracture occurred in only one of the semicircumferences of the fuel line, a condition consistent with a situation of stress on the tube in a specific direction.

The fractured region was sectioned and examined under a microscope in the laboratory.

The yellow arrows in Figures 15 and 16 show multiple ratchet marks, indicating different points of origin for the fracture, a condition consistent with a failure that started in a region of stress concentration.

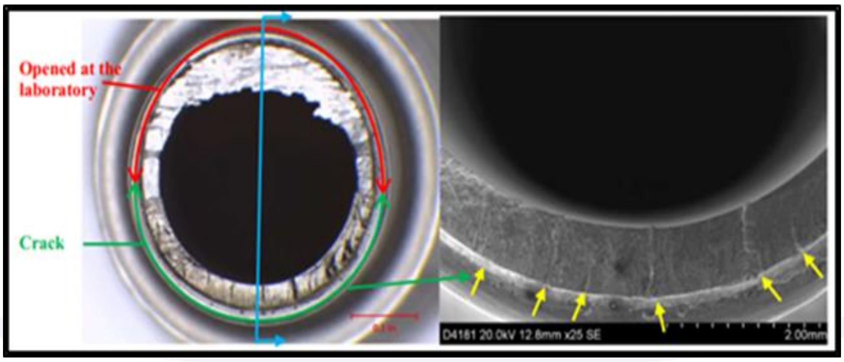

Figure 15 – Image of the laboratory examinations of the fracture.

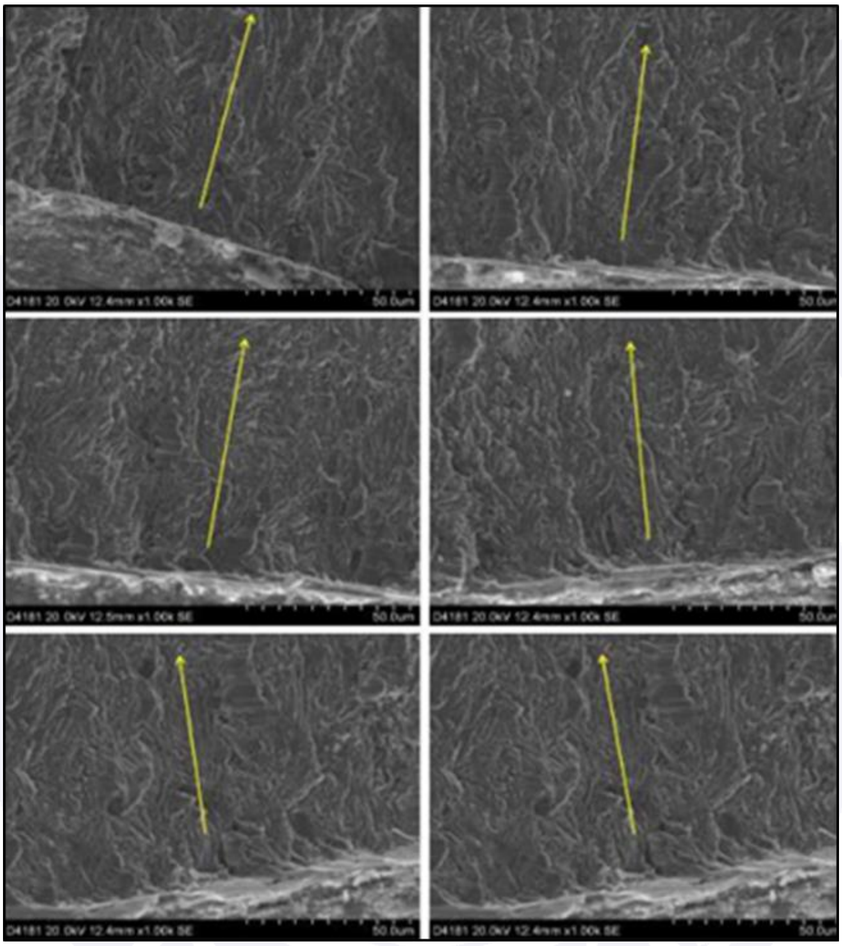

Figure 16 – Image of the fracture examinations under the microscope.

The fracture propagated through the cross-section of the fuel line. The image produced during the microscopic examinations indicated relatively low cyclic stresses, consistent with a High Cycle Fatigue (HCF) process.

The metallographic examinations did not reveal any material anomalies in the fracture region.

Measurements taken on the fuel line showed the component dimensions were in accordance with the manufacturer's specifications, except for a deformation found in the metal ferrule at the end closest to the FCU (the opposite end from where the fracture was found).

Figure 17 – Deformation at the end of the fuel line closest to the connection with the FCU.

The angle of the deformation encountered (α in Figure 18) was estimated to be 5.62°.

Figure 18 – Angle of deformation (α).

The deformation was consistent with a stress-generating condition in the fuel line that could trigger a high cycle fatigue (HCF) process.

Thus, it was concluded that the condition found (fracture in the fuel line) caused the leakage of aviation kerosene (QAv) and compromised the engine's operation during the flight.

The examinations also concluded that the rubbing of the power turbine blades and the engine seizure were consistent with disproportionate cooling and contraction of the metallic parts, a situation characteristic of a sudden engine flameout in flight.

It is worth noting that, in this situation, the external parts of the engine tend to cool down and contract more rapidly than the internal parts due to contact with the outside air.

It was not possible to determine the origin of the stress concentration process that triggered the HCF fatigue cycle and the resulting crack found in the PN 3033981 fuel line.

1.17. Organizational and management information.

NIL.

1.18. Operational information.

It was a private flight, conducted under the requirements established by the Brazilian Civil Aviation Regulation n°91, Amendment 03, which dealt with the General Operating Requirements for Civil Aircraft.

According to the IFR flight plan filed, the aircraft would take off from SDEN, climbing to flight level FL280, bound for SWPY.

The airplane was within the prescribed weight and balance limits.

The aircraft performed uneventfully during takeoff, climb and levelling off. The PIC later reported having noticed variations in the engine fuel flow while cruising at FL280, at which point he took a picture of the numbers displayed on the aircraft's panel.

Figure 19 – Images obtained by the pilot after the aircraft levelled off, showing fuel-flow indications at two distinct moments highlighted in red ovals.

Approximately five minutes after the picture was taken, the engine sustained performance issues and failed. According to PIC's reports, after noticing the drop in fuel flow associated with a reduction in engine torque, he operated the MOR lever in an attempt to restore power. Subsequently, he performed the inflight engine restart procedure without success in any of his attempts.

Then, the aircraft started losing cabin pressurization.

Under those conditions, the PIC initiated an emergency descent, heading for the aerodrome of *Londrina*. During the descent, he informed ACC-CT that he was in emergency due to engine failure.

According to the PIC, it was not necessary to don the oxygen mask. However, he was not able to inform the maximum cabin altitude reached during the emergency descent procedure.

The aircraft landed in SBLO at 12:01:59 UTC without any damage resulting from the emergency landing.

After the aircraft landed, accumulation of fuel could be observed inside the engine cowling, as well as on the floor of the parking area, as shown in the figure below (Figure 20).

Figure 20 – The aircraft after landing in SBLO.

1.19. Additional information.

NIL.

1.20. Useful or effective investigation techniques.

NIL.

2. ANALYSIS.

The flight was a private operation conducted under the requirements of RBAC-91, Amendment 03, between SDEN and SWPY, with only the pilot on board.

Given the pilot's report of observing variations in the engine's fuel flow while leveling at FL280, and that approximately 5 minutes after taking a photographic record of these fluctuations the engine failed, as well as the data extracted from the G3000 system showing that the fuel flow had dropped to 7.5 GPH and the torque to 35 ft-lb, indicating an engine failure, the investigation focused on this component.

During the examination of the engine internal components, one found that there was rubbing between the tips of the second-stage power turbine blades and the sealing ring, which is consistent with a condition of interference between these parts of the engine.

In addition, there was evidence of overheating, particularly indicated by the persistent deformations of the ITT sensors and the discoloration observed inside the turbines.

It is believed that the seizure of the power section and the overheating damage were secondary effects of the inflight engine shutdown.

Specifically, regarding the rubbing of the power turbine blades and their subsequent seizure when the engine shutdown occurred in flight, its hot section did not cool down as it should, as it would normally happen during a regular shutdown. Consequently, the accumulated heat kept the turbine assembly in an expanded state for a longer period compared to the adjacent parts closer to the engine's outer casing, which contracted, resulting in contact between these parts, as well as in the observed damage.

Considering that the aircraft manual warned about the possibility of rapid movements on the MOR lever causing excessive ITT values, and that the pilot reported having operated this control in his initial attempt to restore power, in conjunction with the peaks in fuel flow (65.59 GPH) and ITT (1,061ºC) recorded by the G3000 after the engine failure, one concluded that such extremes were the result of the action taken by the pilot during the encountered emergency.

Thus, an inadequacy in the handling of the controls, specifically regarding the movement of the MOR lever, resulted in damage that would prevent the restoration of engine control due to the seizure that occurred, had the failure originated in the automatic fuel flow controls, which exacerbated the consequences of the failure.

However, the examinations conducted on the external components of the engine revealed that the loss of power while the aircraft was in normal cruise flight was due to a leak in the fuel line that connected the FCU to the fuel flow meter.

Thus, it should be noted that there was no way for the pilot to know that the difficulties encountered were not related to the automatic fuel flow controls, and that the actions he took would not allow for the restoration of the engine control.

The mentioned fuel line was analyzed in a laboratory, and the examinations revealed the presence of a crack near the end closest to the flow meter. The crack was concentrated on only one of the tube's semicircumferences, with multiple ratchet marks, characteristics consistent with a failure that originated in a region of stress concentration in a specific direction, and propagated for approximately 150º, that is, nearly half os its circumference.

Microscopic examinations identified characteristics consistent with a high cycle fatigue (HCF) process, which resulted in failure of the material and led to the fuel leakage observed during the investigation process.

Given the proximity of the fractured fuel line to the fuel outlet filter, one considered that the deformation observed in the ferrule at the end of the tube closest to the FCU may have been caused during a maintenance procedure on the mentioned filter.

Such deformation, in turn, could create stress concentration and result in a high cycle fatigue (HCF) process at the other end of the fuel line.

The fuel outlet filter was subject to servicing during “Event 1” and “Event 2” inspections, conducted every 100 flight hours.

According to the aircraft's maintenance records, five services were performed on the Fuel Pump Outlet Filter since its manufacturing, four of which took place while the aircraft was still operating in the United States, and one, the most recent, during its operation in Brazil, when the component was replaced 46 days before the incident in question.

Thus, the deformation in the ferrule may have been the result of either an intentional or unintentional displacement of the PN 3033981 tube during the PS-RJJ airplane's engine maintenance.

However, the absence of any records related to an abnormal condition observed in the PN 3033981 tube prior to the incident under investigation made it impossible to further evaluate the quality of the services performed on the aircraft, whether in the United States or in Brazil.

3. CONCLUSIONS.

3.1. Findings.

a) the pilot held a valid CMA (Aeronautical Medical Certificate);

b) the pilot held valid ratings for MNTE (Single-Engine Land Airplane) and IFRA (IFR Flight – Airplane);

c) the PIC was qualified and had experience in the type of flight;

d) the airplane had a valid CVA (Airworthiness Verification Certificate);

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

f) the records of the airframe, engine, and propeller logbooks were out of date;

g) the meteorological conditions were above the minima required for the conduction of the flight;

h) during the cruise phase of the flight, the PIC observed variations in the fuel flow indications;

i) the engine presented performance issues and failed;

j) the PIC reported that, after noticing the drop of the fuel flow associated with the reduction of the engine torque, he operated the MOR lever in the attempt to restore power;

k) the PIC reported that, after operating the MOR lever, he performed the inflight engine restart procedure without success;

l) the PIC initiated an emergency descent, and landed at the aerodrome of *Londrina*;

m) the examinations conducted during the investigation process revealed that the engine had a seized power section;

n) one verified that there was rubbing between the ends of the second stage power turbine blades and the sealing ring;

o) the ITT sensors, as well as the power turbine itself, were found with damage, deformations, and discoloration consistent with exposure to excessive heat;

p) while examining the fuel system, one verified the existence of a leakage in the PN 3033981 fuel line at the connection end with the fuel flow meter, region where a crack was found;

q) laboratory exams conducted on the PN 3033981 fuel line revealed that the fracture observed at the connecting end of the tube with the fuel flow meter propagated for approximately 150° around the circumference of the tube;

r) during the disassembly of this component, one observed a misalignment between the PN 3033981 tube and its respective connection with the FCU, at the end opposite from the region where the fracture was identified;

s) a deformation was found in the metallic ferrule of the PN 3033981 tube end closest to the FCU (opposite end relative to the position where the fracture was found);

t) such deformation was consistent with a fuel line tension-generating situation that might trigger an HCF process;

u) the airplane sustained damage restricted to the internal parts of the engine; and

v) the PIC suffered no injuries.

3.2. Contributing factors.

- **Handling of aircraft flight controls – a contributor.**

Considering that the aircraft's manual warned about the possibility that rapid movements of the MOR lever could cause excessive ITT values, and that the PIC reported operating this control during his initial attempt to restore power, in association with the fuel flow and ITT spikes recorded by the G3000 after the engine failure, it was concluded that such extremes were the result of the action taken by the pilot during the emergency situation.

Thus, improper handling of the controls, specifically in relation to the movement of the MOR lever, resulted in damage that would prevent the restoration of engine control due to the seizure that occurred, had the malfunction originated in the automatic fuel flow controls (FCU), something that aggravated the consequences of the failure.

- **Aircraft maintenance – undetermined.**

According to the aircraft's maintenance records, five services were performed on the Fuel Pump Outlet Filter of the PS-RJJ since its manufacture, four while the aircraft operated in the United States and one more recent service during its operation in Brazil, when the component was replaced 46 days prior to the serious incident in question.

The deformation observed in the metal ferrule, which could lead to stress concentration and result in a high cycle fatigue (HCF) process, may have been caused by an intentional or unintentional displacement of the PN 3033981 tube during the execution of the aircraft maintenance service.

4. SAFETY RECOMMENDATIONS

None.

5. CORRECTIVE OR PREVENTATIVE ACTION ALREADY TAKEN.

None.

On December 30th, 2024.