COMMAND OF AERONAUTICS

AERONAUTICAL ACCIDENT INVESTIGATION AND PREVENTION CENTER

FINAL REPORT
A - 223/CENIPA/2013

OCCURRENCE: ACCIDENT

AIRCRAFT: PT-CNL

MODEL: 172A

DATE: 16DEC2013

NOTICE

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

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

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

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

This Report does not resort to any proof production procedure for the determination of civil or criminal liability, and is in accordance with item 3.1, Annex 13 to the 1944 Chicago Convention, which was incorporated in the Brazilian legal system by virtue of the Decree nº 21713, dated 27 August 1946.

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

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

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

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SYNOPSIS

This is the Final Report of the 16 December accident with the 172A aircraft, registration PT-CNL. The accident was classified as “inflight engine failure”.

The aircraft was being utilized for a training flight in SBTE (Teresina aerodrome).

After the second touch-and-go landing procedure, an engine failure occurred, followed by loss of control in flight.

The aircraft crashed into the ground and caught fire.

The aircraft occupants perished in the crash site.

The aircraft sustained substantial damage.

An Accredited Representative of the National Transportation Safety Board (NTSB – USA) was designated for participation in the investigation.

GLOSSARY OF TECHNICAL TERMS AND ABBREVIATIONS

ACCE	Aeroclube do Ceará
ANAC	(Brazil's) National Civil Aviation Agency
CENIPA	Aeronautical Accident Investigation and Prevention Center
CHT	Technical Qualification Certificate
CHT	Cylinder Head Temperature
CMA	Aeronautical Medical Certificate
DCTA	Department of Science and Airspace Technology
DIVOP	Technical Bulletin
EGT	Exhaust Gas Temperature
CG	Center of Gravity
IAE	Institute of Aeronautics and Space
IFR	Instrument Flight Rules
INVA	Flight Instructor (Airplane)
LAT	Latitude
LONG	Longitude
MLTE	Class certification – Airplane, Multi-Engine, Land
MNTE	Class certification – Airplane, Single-Engine, Land
NTSB	National Transportation Safety Board
OS	Service Order
PCM	Commercial Pilot (Airplane)
PMD	Maximum Take-off Weight
PPR	Private Pilot (Airplane)
SB	Service Bulletin
SBFZ	ICAO location designator – Fortaleza Aerodrome
SBTE	ICAO location designator –Teresina Aerodrome
SIPW	ICAO location designator – Nossa Senhora de Fátima Aerodrome
SERIPA	Regional Aeronautical Accident Investigation and Prevention Service
SIPAER	Aeronautical Accident Investigation and Prevention System
TSN	Time Since New
UTC	Coordinated Universal Time
VFR	Visual Flight Rules

AIRCRAFT	**Model:** 172A **Registration:** PT-CNL **Manufacturer:** CESSNA AIRCRAFT	**Operator:** *Aeroclube do Ceará*
OCCURRENCE	**Date/time:** 16DEC2013 / 21:48 UTC **Location:** Teresina Aerodrome – SBTE **Lat.** 05º03'38"S – **Long.** 042º49'28"W **Municipality – State:** Teresina – Piauí	**Type:** Inflight engine failure

1 FACTUAL INFORMATION

1.1 History of the occurrence

At 21:35 UTC, the aircraft departed from SIPW (Our Lady of Fatima Aerodrome), in the municipality of Teresina, State of Piauí, for a local night-time training flight, with two pilots and two passengers on board.

The aircraft was climbing after the second touch-and-go procedure, when an engine failure occurred, and control of the airplane was lost.

The aircraft crashed into the ground and caught fire.

1.2 Injuries to persons

Injuries	Crew	Passengers	Third parties
Fatal	2	2	-
Serious	-	-	-
Minor	-	-	-
Uninjured	-	-	-

1.3 Damage to the aircraft

The aircraft sustained substantial damage.

1.4 Other damage

Nil.

1.5 Information on the personnel involved

1.5.1 Information on the crew

HOURS FLOWN		
	INSTRUCTOR	STUDENT-PILOT
Total	600:00	37:35
Total in the last 30 days	35:00	10:00
Total in the last 24 hours	01:50	00:00
In this type of aircraft	300:00	37:35
In this type in the last 30 days	35:00	10:00
In this type in the last 24 hours	01:50	00:00

N.B.: The data relative to the hours flown were provided by third parties.

1.5.1.1 Professional formation

The instructor did his Private Pilot course (Airplane category) at the *Aeroclube de Minas* (State of Minas Gerais) in 2010.

The student under training was doing the Private Pilot course (Airplane category) at the *Aeroclube do Ceará*.

1.5.1.2 Validity and category of licenses and certificates

The instructor had a Commercial Pilot license (Airplane category). He had valid qualification certificates concerning airplane/multi-engine/land (AMEL) and airplane/single-engine/land (ASEL), as well as a valid IFR rating.

The student was being trained for earning a Private Pilot license (Airplane category).

1.5.1.3 Qualification and flight experience

The pilot had qualification and enough experience for the flight, in spite of having just a few hours of night-time flight.

1.5.1.4 Validity of medical certificate

The pilots had valid aeronautical medical certificates (CMA).

1.6 Aircraft information

The aircraft (SN 47154) was manufactured by Cessna Aircraft in 1960.

The aircraft had a valid airworthiness certificate (CA).

The airframe, engine, and propeller logbook records were up-to-date.

The last inspection of the aircraft ("100 hours") was done on 4 October 2013 by the *Nacional Manutenção Aeronáutica Ltda*. workshop in Teresina, Piauí. After this inspection, the aircraft flew a total of 6 hours.

The last overhaul of the aircraft ("IAM" – annual maintenance inspection) was done on 4 October 2013 by the *Nacional Manutenção Aeronáutica Ltda*. workshop in Teresina, Piauí. After this overhaul, the aircraft flew a total of 6 hours.

The last inspection of the engine ("100 hours") was also done by the *Nacional Manutenção Aeronáutica Ltda*. workshop on 4 October 2013.

The last engine overhaul (to be performed every 1,800 flight hours) was done by the *Goiás Manutenção de Aeronaves Ltda*. workshop on 10 March 2005, in Goiânia, State of Goiás. After this overhaul, the aircraft engine flew a total of 1,061 hours and 48 minutes until the moment of the accident.

1.7 Meteorological information

The prevailing weather conditions were VMC.

1.8 Navigational aids

Nil.

1.9 Communications

The two-way radio communication between the pilot and ATC units was uneventful.

All the ATC frequencies were available for use at the moment of the occurrence.

1.10 Aerodrome information

SBTE is a public aerodrome under INFRAERO administration. It operates VFR and IFR during day- and night-time periods.

It has an asphalt runway, with thresholds 02/20, measuring 2,200m x 45 m, at an elevation of 220 feet.

Normally, runway 20 was more commonly used for take-offs and landings.

At the moment of the occurrence, the runway was dry and unobstructed.

1.11 Flight recorders

Neither required nor installed.

1.12 Impact and wreckage information

After the loss of control, the aircraft entered a downward trajectory, with an approximate pitch-down angle of 45º on a left turn, until crashing into the ground at a distance of 130 meters from the left side of the runway, near the threshold 02, without the occurrence of any previous impact.

After the crash, the aircraft exploded and caught fire.

The crash was seen by the control tower operator.

The distribution of the wreckage was of the concentrated type.

The level of destruction and the charred condition of the aircraft hindered a better observation of the equipment and instruments.

Figure 1 – Aspect of the aircraft wreckage.

1.13 Medical and pathological information

1.13.1 Medical aspects

Not investigated.

1.13.2 Ergonomic information

Nil.

1.13.3 Psychological aspects

1.13.3.1 Individual information

The instructor did his pilot training at the CHB – *Escola de Aviação* (School of Aviation), State of Minas Gerais, concomitantly attending the Course of Aeronautical Sciences at college.

According to data contained in the evaluation sheets of his instructors, some attention and concentration difficulties were identified at the phase of landing during his basic pilot training.

There was a perception that he possessed good theoretical knowledge of the disciplines, but in practice training, the evaluations indicated that his performance in the psychomotor field would not reach the same level, even after several training sessions.

This information was corroborated by one of the instructors at the *Aeroclube do Ceará* (ACCE), who commented on his slowness in making decisions, mainly in emergency situations, when prompter actions were required.

Approximately two months before the accident, the instructor experienced an inflight emergency, in which the aircraft presented a drop of the engine RPM at a height of 500 feet. According to another member of the crew aboard the aircraft on the occasion, his movements were slow in view of the situation.

According to information collected, the instructor's behaviour was characterized by introversion and passivity. He was considered a contained person, unable to adopt an inappropriate attitude towards his peers, or even deny something requested from him.

He seemed to be extremely motivated with his career in aviation, and would not spare efforts to circumvent obstacles. He decided to become a flight instructor in order to accumulate flight hours and progress in his career as a pilot.

In 2010, the instructor did his first health-checkup, and the result was not favourable for flying activities. At the time, he showed signs of instability, as well as tense, unsafe behaviour. He was recommended to follow a psychotherapeutic treatment, which he did for one year and a half.

In the records pertinent to his health-checkups of the following years, nothing was said in this respect.

The instructor had only a few hours of night-time flight. On the flight that culminated in the accident, he allowed two passengers to watch the training aboard the aircraft.

1.13.3.2 Psychosocial information

According to information, there were bonds of friendship between the Director *of Aeroclube do Ceará* and the instructor.

Within the group of instructors, one could observe that there was neither interaction between them, nor exchange of information regarding the instructions delivered. There were signs of an individualized work structure.

1.13.3.3 Organizational information

The ACCE maintained a training aircraft in the city of Teresina, under the responsibility of a flight instructor, in order to accommodate the needs of the students of a local college, which did not have formal bonds with the ACCE.

At the ACCE, it was observed that the pilots' evaluation sheets filled in by the instructors had too little information, making it difficult to evaluate the student's performance.

There was no standardization in terms of the flight instructors' work methodology and of the students' evaluation process.

1.14 Fire

The aircraft caught fire immediately after the impact with the ground. The combustion material was the aircraft fuel, and the ignition source was probably the friction generated by the impact.

The firefighting team stationed at Teresina Airport was immediately summoned after the accident, and went without delay to the place where the aircraft had crashed, following visual clues.

Even with the use of firefighting apparatus appropriate for the category of the airport, the firefighters were not able to extinguish the fire because it spread very quickly. The situation was aggravated by the fact that the tanks were almost full of fuel.

1.15 Survival aspects

Not applicable.

1.16 Tests and research

According to the technical report issued by the Institute of Aeronautics and Space (IAE) of the Aerospace Technology and Science Department (DCTA), at the moment of the impact with the ground, the engine of the aircraft was running, but not developing high power.

What caused the loss of engine power was a failure of the exhaust-valve head of the cylinder number 6. The valve head was expelled from the cylinder through the exhaust duct. After a period of operation, the valve rod was displaced into the combustion chamber due to the effort made by the rocker arm on its foot. Such displacement was facilitated by high temperature to which it that was exposed, and especially due to the wear sustained by the valve locks.

The large amount of soot found in the combustion chamber, in addition to the plastic deformation of the engine muffler, were indications that the engine had already been operating with reduced power.

The IAE analyses also showed that the engine was functioning abnormally at the moment of impact with the ground.

A deeper research showed that the piston of the cylinder number 6 had marks of impact on its head. After disassembly, a fracture in the cylinder exhaust valve was observed, according to Figures 2 and 3.

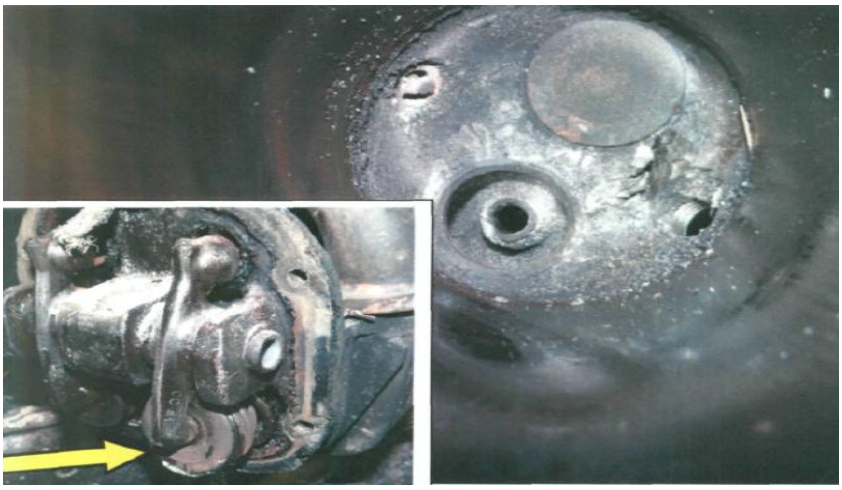

Figure 2 – View of the cylinder number 6, without the exhaust valve, and with the exhaust spring caught by the rocker arm.

Figure 3 – Cylinder number 6 without the exhaust valve.

There were marks of impact both on the piston head (cylinder number 6) and on the wall of the respective combustion chamber.

It was possible to observe that the exhaust-valve guide was also deformed.

Figure 4 – General view of the piston-head of cylinder number 6.

The exhaust-valve rod and the head of the referred valve were not found.

The exhaust-valve rod, upon being expelled, passed through the exhaust duct of the cylinder number 6.

The locks aimed at catching the exhaust-valve rod of the cylinder had signs of wear (without the projection that allow them to connect with the valve rod), in addition to being fractured, as seen in Figure 5.

Figure 5 - Wear/fracture observed in the locks of the cylinder number 6 exhaust valve.

There was deformation inside the cylinder number 6, in the region where the gas escapes from the cylinder. Residues were found, and later analysed at a laboratory. The results confirmed the presence of stainless steel and lead, materials compatible with what is utilized in the metal plate of the engine exhaust pipe and in aviation gasoline, respectively.

The blades of the propeller assembly had transversal scratches, an indication that they were rotating at the moment of impact with the ground (Figure 6).

Figure 6 – Transversal marks on the propeller blade.

The deformations and bending observed in the propeller blades indicated that the engine was not developing high power at the time of collision.

Due to the action of the raging fire, and on account of the fractures in the external components of the engine, it was not possible to perform a functional testing on the parts of the ignition and fuel system.

The SIPAER investigators analysed the aircraft engine maintenance records concerning the overhaul and 100-hour inspection, as well as the calibration of the cylinders compression ratio, and verified that the following services had been provided:

- On 10 March 2005 (TSN: 5,373.9 flight hours): overhaul and 12-month engine inspection.

- On 12 September 2012 (TSN: 5,863.6 flight hours: Annual Maintenance Inspection (AMI) and 100-hour engine inspection. On that occasion, in addition to other services, the cylinder compression ratios were measured, with replacement of the engine lubricating oil and the filtering element of the engine lubrication system, according to the service order (OS) no. 058/12.

- On 17 January 2013 (TSN: 6,057.7 flight hours): 100-hour engine inspection, in addition to calibration of the compression ratios of the cylinders, replacement of the filtering element of the lubrication system and engine oil (OS no. 079/12).

- On 4 October 2013 (TSN: 6,275.5h): Annual Maintenance Inspection (AMI) and 100-hour engine inspection, in addition to measurement of the compression ratios of the cylinders, and replacement of the engine oil. According to the pertinent service order (OS no. 055/13), the cylinder compression ratios were expressed in percentage, and the values found were 70% (for the cylinder no. 1); 75% (for the cylinder no. 2); 75% (for the cylinder no. 3); 70% (for the cylinder no. 4); 75% (for the cylinder no. 5) and 75% (for the cylinder no. 6).

In relation to the last overhaul of the aircraft engine, the company responsible for the maintenance was asked to present the service order no. 321/2005, as well as the 8130 FORM's related to the items of mandatory replacement during the provision of this maintenance. However, given the prolonged period of time between the completion of the overhaul and the day of the accident (approximately 9 years), the company said that they did not have the aforementioned documents in their archives any longer.

After consulting the company responsible for the last 100-hour engine inspection, the investigation commission learned that they did not keep in their possession a tool for testing the pressure differential in the cylinders, as recommended by the aircraft engine manufacturer [Service Bulletin SB 03-3 of 28 March 2003, Teledyne Continental Motors (TCM)].

Extending the research to the maintenance services provided to Continental engines, the commission found out that several workshops did not possess the "calibrated hole" (PN: 646953), as recommended in the TCM SB 03-3, of 28 March 2003.

It was also verified that there were no technical publications, issued by Continental Motors, mentioning the minimum nominal values of reference for the calibration of the compression ratios of the engine cylinders. To carry out such a task, the workshops used the Lycoming Textron SI 1191A of 28 September 2008.

1.17 Organizational and management information

At the time of the accident, the administrative headquarters of the *Ceará Aeroclube* was located in the General Aviation Terminal of *Pinto Martins* International Airport (SBFZ), in Fortaleza.

Founded on 7 April 1929, the ACCE had discontinued its activities in the year 2000, and resumed them with the incorporation of the Piauí Aero Club aircraft fleet.

The ACCE operated AB115 Aeroboero and 172C Cessna aircraft.

It was observed that the training delivered away from headquarters did not have the presence of a course coordinator, as recommended by the Brazilian Aeronautical Certification Regulation 147.

1.18 Operational information

The student pilot involved in the accident was doing a training flight as part of his private pilot course. He was also a college student of a superior course for pilots at the Educational Center of Teresina - CET.

The instructor pilot was certified as an instructor in May 2012, and had only four hours of night-time flight.

According to information provided by the ACCE management, the coordinator of the practice training flight sessions held in Teresina was the very instructor pilot involved in the accident.

The aircraft crew filed a flight notification, informing that the local flight had a planned duration of 2 hours. Shortly after take-off, they requested authorization for touch-and-go landings at Teresina Airport, and were granted clearance.

The engine failure occurred when the aircraft was at a height of approximately 150ft, in the climb after the second touch-and-go procedure.

The calculation of the take-off weight showed that the aircraft weighed 1,056kg, i.e., 58kg above the Maximum Take-off Weight (998kg) prescribed by the manufacturer.

For local flights, the ACCE instructors and students were advised to maintain a rich mixture regime in their aircraft.

The aircraft involved in the accident was not equipped with instruments for indication of the temperature of both the cylinder head (CHT) and exhaust gases (EGT).

The student pilot was doing his second night-time training flight (VFR) in order to meet the requirements established by Amendment no. 3 of the RBHA 61.81 for the obtainment of a private pilot license.

As for the correction of the air-fuel mixture, the aircraft operations manual, on its page 1-1, section 1, states that in operations related to start-up, take-off, and climb, the mixture must be set to "rich".

1.19 Additional information

According to eyewitnesses' reports, at the time of the accident, the engine of the aircraft made a noise characteristic of loss of power.

According to information provided by the ANAC, the ACCE had not requested authorization for the delivering of practice training of the Private Pilot*, Commercial Pilot*, and Instructor Pilot* (*airplane category) courses away from headquarters or operational base (RBHA 141.87), nor authorization for establishing a base of operations in the city of Teresina [RBHA 141 (c) (f)].

The name of the flight instructor involved in the accident did not appear in the ANAC records as a course coordinator for the ACCE.

Concerning the operation of a civil aviation school, the RBHA 141 reads:

141.25 – ADMINISTRATIVE HEADQUARTERS AND OPERATIONAL BASE(S)

(...)

(c) In addition to the administrative office, the civil aviation school must have at least an operational base with the facilities required for theoretical and/or practice training.

(...)

(f) An administrative office and/or one or more operational bases located in other municipalities away from headquarters are considered as branches, and each one of them must be authorized in accordance with the section 141.13 of this Regulation, except for operational bases intended for flight training, provided that they are located in the area of the same SERAC.

For the delivery of training away from headquarters by a civil aviation school, the RBHA 141 makes the following provisions:

141.87 – SPECIAL AUTHORIZATION FOR COURSE AWAY FROM HQ

The civil aviation school authorized to operate is allowed to deliver theoretical or practice training in a municipality away from headquarters by meeting the requirements listed below:

(a) the applicant must submit a request to the IAC, at least sixty (60) days before the forecast commencement of the training, to the attention of the Honourable Director General of the DAC (Department of Civil Aviation), informing the period of training delivery, and include the following Documents: proof of ownership of the real property (or lease agreement with assignment of rights for running a civil aviation school), or any other document concerning the assignment of rights of utilization of the real property, duly registered, proving the powers of the signatories in the referred document for the proposed period;

(b) The aerodrome, installations, facilities, and the personnel involved with the course away from headquarters shall meet the requirements laid down in the course manuals, confirmed by means of an inspection done by the IAC;

(c) The instructors shall stay under the direct supervision of the course coordinator or of his assistant.

With regards to the qualification of the course coordinator, the RBHA 141 reads:

141.35 – QUALIFICATION OF THE COURSE COORDINATOR

(a) In order to be designated coordinator or assistant coordinator of the courses, the professional must prove experience as an instructor within the aviation industry for at least two years, by means of a proper document.

(b) In order to be a coordinator or assistant coordinator of practice training of a pilot course, in addition to what is required in the paragraph (a) of this section, the professional must be certified as a flight instructor, as provided by the RBHA 61, and have the licenses and/or certificates for the course to be delivered.

As for the granting of a private pilot license, the RBAC 61.81 (Amendment no. 03) provides that:

Experience requirements for the granting of a private pilot license

(1) Airplane category

(...)

(E) Three (3) hours of night-time flight training, including ten (10) take-offs and ten (10) complete landings, with the aircraft flying the aerodrome traffic pattern before each landing;

As for the presence of passengers on board training flights, the Internal Rules (Chapter 7 - General) for Students, Pilots and Members of the Ceará Flying School reads:

- It is expressly forbidden:

(...)

To carry people/third parties/passengers??? on board the aircraft on training flights.

Likewise, the paragraph "C" of the RBAC 61, item 61.237, prohibits the presence of passengers on board the aircraft on training flights.

The RBAC 43, paragraph "B43.1", item 4, states that copies of the records of large repairs and major alterations to the aircraft must be kept for at least five years.

The engine installed in the Cessna 172A aircraft was developed by Teledyne Continental Motors (TCM), and had six opposed cylinders, with a power ratio of 145hp at 2,700 RPM.

During normal operation of the engine, the burning of the fuel-air mixture causes expansion of the gases inside the cylinder, compressing the piston head downward, in a steady and cadenced manner, without an excessively powerful stroke.

When the combustion produces high temperature and pressure, to the point of generating spontaneous ignition, we have a detonation problem. This uncontrolled burning of the mixture generates a characteristic noise known as "knocking". The noise comes from the resonance of the combustion chamber transmitted to the block under severe conditions.

The most likely causes for the onset of detonation or knocking are:

- Utilization of fuel with low anti-knocking capacity
- Increase of the cylinder-head temperature
- Increase of the cylinder-head compression ratio
- Utilization of poor mixture throughout the operation of the engine.

The main consequences of engine detonation/knocking are:

- Overheating and loss of engine power;
- Excessive engine oil consumption; and
- Factures or damages in the ring segments, pistons and valves.

The use of fuel in accordance with the engine manufacturer's specifications, and the appropriate correction of air-fuel mixture in the various phases of flight are important aspects related to the performance of engines.

During the phases of flight, the air-fuel ratio must be corrected in accordance with according to the aircraft operation manuals.

A poor or economic mixture will make the engine operate with relative shortage of fuel, hindering the propagation of combustion within the cylinder and generating high temperature in the combustion chamber and in the exhaust collector, as well as formation of solid components in the combustion chamber.

In such cases, the engine will develop less power, due to the smaller amount of fuel delivered for burning, although with better efficiency. Nevertheless, such condition will favour the onset of a phenomenon known as detonation or knocking.

The aircraft Operations Manual, in the chapter on Operating Instructions (pages 4 and 5, items 4-5-6) warns of the importance of not letting the cylinder head temperature extrapolate.

The manual also stresses that when the engine is operated with a poor air-fuel mixture, temperature of the cylinder head will rise, triggering the detonation/knocking phenomenon.

The adjustment of the air-fuel mixture in order to make it more economical is directly related to the increase of the cylinder head temperature and, therefore, to premature damage to the valves of aircraft reciprocating engines.

The exhaust valve locking assembly consists of three mutually concentrical springs (items 20, 21 and 22), a washer (item 23) and two retention latches (key 24), as shown in Figure 7.

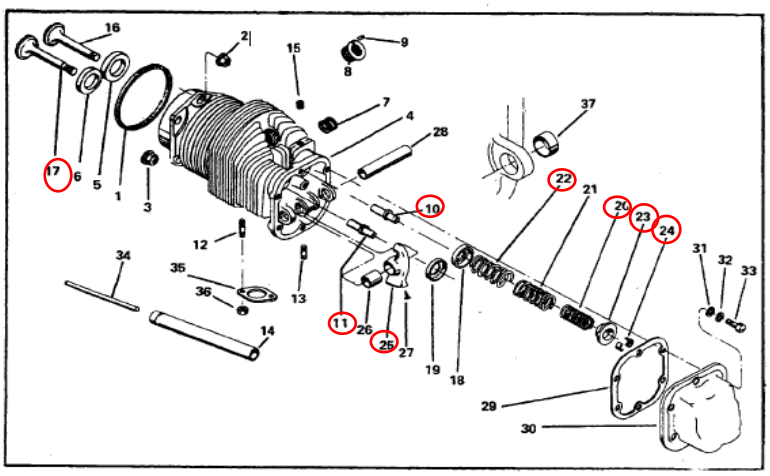

Figure 7 – Exploded view of the cylinder, showing the exhaust valve, rocker arm, and exhaust valve guide with the respective valve retention assembly.

The intake and exhaust valves are the components most exposed to high temperatures as they are directly in contact with the combustion gases.

The highest elevation of temperature in the exhaust valves takes place on the head and neck of the valve. The concentration of the temperature increase in these points of the valve may foster, among other things, the appearance of corrosion mechanisms, since high temperature can affect the mechanical properties of the valve material.

For this reason, the aircraft engine manufacturer recommends by means of the Service Bulletin 97-6B of 18 Nov 2009 (item 9, page 1), that on the occasion of the overhaul the retention locks of the intake and exhaust valves be replaced, as well as all engine exhaust valves (item 17, Figure 7).

For operators of aircraft equipped with reciprocating engines, it is essential to ensure the adoption of procedures to prevent cylinder head overheating (Cylinder Head Temperature - CHT).

The fact that some aircraft equipped with reciprocating engines do not have instruments to monitor the temperature of the cylinder head and of the exhaust gases (Exhaust Gas Temperature - EGT), just like the aircraft involved in this accident, contributes to the engines being often operated without proper correction of the air-fuel mixture.

The Engine Operator's Manual issued by Continental Motors in August 2011 mentions [page 9, item (4)], that on the occasion of the 100-hour engine inspection, the covers of the boxes of the rocker arms must be removed for purposed of verification of their general condition and lubrication of all parts contained in that section.

The Service Bulletin SB 03-3 of 28 March 2003 establishes procedures for doing the differential pressure testing and boroscopic inspection of the aircraft engine cylinders, every 100 hours or when cylinder problems are suspected, as well as for the Annual Maintenance Inspection (AMI). This refers to all models of Teledyne Continental engines.

The Service Bulletin further recommends that an E2M tool of the Eastern Technology Corporation be used for the calibration of the compression ratio of the cylinders. According to the SB, the tool incorporates a PN 646 953 calibrated "master hole", which must be purchased from that company separately.

The SB 03-3 also mentions that the differential pressure test equipment used for calibration of the compression ratio of the cylinders must be certified and calibrated. Failure to observe the maintenance and calibration of the test equipment used for that purpose may result in false readings of the differential compression of the engine cylinders

As for the annotation of the readings of the acceptable limits regarding loss of pressure in the cylinders on the occasion of the calibration of the compression ratio in the engine cylinders, it must be done, together with the annotation of the readings of the pressure in individual cylinders, in the engine logbook and in the inspection service order, and these values must be written in the

Pressure Reading in PSI
80 PSI

format.

Days before the date of the accident, some pilots reported to the instructor that the aircraft engine had an abnormal noise.

Videos retrieved from the cell phones of the aircraft occupants, showed images of a defective artificial horizon and passengers on board during training flights.

1.20 Utilization of other investigation techniques

Nil.

2 ANALYSIS

On the night of the accident, the aircraft was on a local training flight in the traffic pattern of Teresina Aerodrome.

During the climb after the second of touch-and-go procedure, an aircraft engine loss of power occurred, followed by loss of control in flight.

The aircraft entered a downward trajectory at a sharp angle of incidence relative to the ground until crashing at a distance of 130 meters from the left side of the runway, near the runway 02 threshold.

The trajectory assumed by the aircraft after the engine failure until crashing into the ground shows that the loss of control of the aircraft in flight may have been the result of loss of lift.

The transversal marks, deformations, and bends found on the propeller blades showed that at the moment of collision with the ground, the engine had rotation, but was not developing high power.

The engine failure was attributed to loss of compression ratio of the cylinder no. 6, on account of a premature collapse of the exhaust-valve head in that cylinder.

After the breakage of the exhaust-valve head there was a strong incidence of combustion gases on the retention lock of the aforementioned valve, contributing to the loss of its mechanical properties. Subsequently, the valve was into the combustion chamber due to the effort made by the rocker arm on the foot on the very valve.

The damage to piston head of the cylinder no. 6 (Figure 4) showed that the head of the exhaust valve was fragmented by the piston of cylinder, and the residues were expelled through the corresponding exhaust duct.

At the opening of the engine, the exhaust-valve rod of the cylinder no. 6 was not found. However, the plastic deformation appearing in the corresponding exhaust duct is evidence that the rod was really expelled.

As for the reasons of the collapse of the exhaust-valve of the cylinder no. 6, one must consider the following:

- Although the Service Bulletin 97-6B established the replacement of retention locks of the intake and exhaust valves, it was not possible to ensure that the procedure was complied with in the last engine overhaul (10 March 2005), since no records of the corresponding maintenance services were presented to the investigation commission;

- It is possible that the premature damage to the exhaust valve of the cylinder no. 6 was a result of the engine being operated throughout its lifetime without proper control of the cylinder head temperature, contributing to the operation under high temperatures. In part, the fact could be related to the procedures used for adjusting the air-fuel mixture, since the aircraft was not equipped with tools to indicate the temperature of the cylinder head (TC) and of the exhaust gases (EGT). Even with the information that the ACCE pilots were instructed to perform local flights using a rich mixture, such evaluation was compromised because it was not possible to establish the history of the operation of engine by the former owner / operator of the accident aircraft;

- The intermediate inspections did not contemplate removal and verification of the specific locks and valves of the engine cylinders, and this could explain why the premature deterioration of these components could not be identified at the 100-hour inspections; and

- The accident occurred when the engine of the aircraft had 1,061 hours and 48 minutes of flight, that is, 738 hours and 12 minutes before the next engine overhaul, with replacement of the intake valves, together with replacement of the exhaust valves and all the valve retention locks.

It seems that the abnormal noise of the engine heard by some pilots days before the accident could be related to detonation (also known as “knocking”).

Although the records of the last 100-hour inspection presented the engine compression ratios of the six cylinder in terms of percentage, in discordance with the SB 03-3, one cannot affirm that there was a problem of this kind in the cylinders at the time of that inspection during the course of that inspection, since for nominal values presented by the workshop responsible for the inspection were adequate.

It was not possible to ascertain whether, contingently, the calibration of the compression ratio of the engine cylinders was really done out without using the E2M tool model. However, this issue did not appear as predominant, since no problem was detected in relation to the compression ratio of cylinders of the aircraft engines.

The execution of the night-time training flight was in accordance with the provisions set in the letter "E", paragraph 1, of the RBAC 61.81 (Amendment no. 03).

The ACCE authorization to operate was up-to-date. However, they had not requested authorization for delivering practice training sessions in a municipality away from headquarters, as established in the RBHA 141.87.

This fact contributed to the lack of a timely action to be taken by the civil aviation supervisory agency, aimed at verifying whether the flight practice training in Teresina was being done correctly, mainly in relation to the supervision of the air activities conducted by the ACCE.

Based on the calculations performed considering the average weight of each of their four occupants - 80kg - and fuel supplied before the flight (82kg), it was observed that the aircraft was at least 58kg above its MTOW, but within the limits of the center of gravity (CG) specified by the manufacturer.

On account of the limited experience in the operation of night-time flights and of the behaviour described by his colleagues, one cannot rule out the possibility that the instructor was slow in identifying the engine failure, and did not react in a timely manner to prevent the aircraft loss of control.

Apparently, such traits of behaviour were present when the passengers were allowed on board the aircraft on a training flight

According to information provided by the ACCE management, in relation to the flight practice training in Teresina, the instructor accumulated the function of course coordinator. This fact, besides being contrary to the prescription of letter (c) of the RBHA 141.87, considering that the instructor did not have the minimum experience of two years established in the letter (a) of the RBHA 141.35 for working as course coordinator, prevented the ACCE from exercising adequate supervision of the instructional activities in a location distant from the headquarters, since the two tasks were fulfilled by the same person.

The presence of passengers on board the aircraft on training flights conducted in Teresina, contrary to the prescriptions of the ACCE internal regulations and to the letter (c) of the RBAC 61.237, and the operation of the aircraft with a defective artificial horizon crash, were reflexes of an inadequate supervision.

The student pilot involved in the accident was doing flight training aimed at the obtainment of a private pilot license which, in turn, was a prerequisite for the completion of a superior course (college degree) on professional aircraft flying delivered by the Teresina Educational Center college (CET).

The fact that many superior education institutions, responsible for professional aircraft flying courses or aeronautical science courses do not deliver practice training leads to an intense search by his students of schools working with private pilot training, among them, the flying schools.

However, the lack of a regulatory provision establishing the sharing of data between the colleges, the civil aviation pilot training schools, and the ANAC, makes it impossible for the agency to adequately monitor the conditions under which the flight training sessions are delivered to the students, notably in regard to the airworthiness of aircraft, the technical training of the instructors and the supervision of the flight training.

In the case of this aeronautical accident, the lack of a timely and appropriate flow of information the ACCE and the civil aviation supervisory agency may have contributed to the onset of a scenario characterized by the contributing factors identified.

Within the psychological aspect, other variables related to the accident were also identified. The existing friendship between the director of the flying school and the instructor may have contributed to the establishment of an excessive confidence in the instructor’s performance, allowing him to assume the responsibility for the provision of flight training in Teresina even if he did not meet the requirements to be a coordinator of the course and without supervision on the part of the flying school management.

When the collected data were considered, the lack of supervision showed up as a consequence of the work structure established in the flying school, in which the management of the control and accountability systems was not yet fully implemented.

This fact also contributed to the lack of standardization of the training delivered, which, as learned, was a reflection of the culture established among flight instructors, characterized by individualization and informality of the actions taken during the training sessions.

3 CONCLUSIONS

3.1 Facts

a) The pilots had valid aeronautical medical certificates;

b) The instructor had a valid technical qualification certificate (CHT);

c) The instructor had qualification, but not many hours of night-time operation;

d) The aircraft had a valid airworthiness certificate (CA);

e) The aircraft was not within the weight limit but within balance limit;

f) The airframe, engine, and propeller logbooks records were up-to-date;

g) The aircraft was being utilized on a local night-time flight;

h) During the climb after the second touch-and-go landing exercise, there was failure in the left engine of the aircraft;

i) After the engine failure, there was loss of control in flight;

j) The aircraft crashed into the ground at approximately 130 meters from the left side of the runway, near threshold 02;

k) The engine loss of power was caused by breakage of the exhaust valve of the cylinder number 6;

l) The aircraft sustained substantial damage; and

m) The pilots and passengers perished in the crash site.

3.2 Contributing factors

3.2.1 Human Factor

3.2.1.1 Medical Aspect

Not a contributor.

3.2.1.2 Psychological aspect

3.2.1.2.1 Individual information

a) Attitude – undetermined

It is possible that the characteristic passivity of the instructor contributed to his slow reaction in response to the engine failure.

b) Perception – undetermined

The pilot’s situational awareness could be at a lower level on account of his little experience in night-time flights, thus preventing an accurate perception of the factors and conditions which affected the operation.

3.2.1.2.2 Psychosocial information

a) Work group culture – undetermined

The fact that the instructor accepted the responsibility for the execution of air operations in Teresina, without the necessary supervision and without meeting the requirements for the job, may be related to the utilization of informal rules by the team of instructors of the flying school.

b) Interpersonal relationship – undetermined

The existing friendship between the president of the flying school and the instructor may have influenced on his decision to designate the instructor as the person responsible for the delivery of flight training in the city of Teresina, even without meeting all the necessary requirements.

3.2.1.2.3 Organizational information

a) Work organization – a contributor

The management of the flying school activities, as well as the control and responsibility systems, was not yet properly established, allowing the same professional to undertake the tasks of flight instructor and course coordinator at odds with the provisions issued by the regulatory civil aviation agency.

b) Organizational processes – a contributor

The lack of proper monitoring of the flight training activities in the city of Teresina allowed the training to be conducted in the presence of unsafe conditions both in the operational context, with the aircraft being operated with defective artificial horizon, and in the organizational context, by not complying with the prescribes procedures which did not allow passengers on board the aircraft.

3.2.2 Operational Factor

3.2.2.1 Concerning the operation of the aircraft

a) Application of the controls – a contributor

The delay or failure of the application of the flight controls to prevent loss of control of the aircraft after the engine failure, contributed to the aircraft entry in the abnormal attitude and to the irreversibility of the accident.

b) Flight indiscipline – undetermined

The operation of a training flight with passengers on board characterized a violation of the rules established by the RBAC 61 and internal ACCE regulations.

It was not possible to quantify or directly relate the presence of passengers on board with the loss of control in flight. However, it is a fact that the presence of passengers increased the number of fatalities and severity of the accident, which would not have occurred if the relevant legislation had been complied with.

c) Aircraft maintenance – undetermined

It was not possible to identify at what stage of the aircraft maintenance program the failure compliance occurred, since the accident occurred in the interval between the engine overhauls, and the affected components (locks and valves of the cylinders) were included as items to be examined at the intermediate inspections of the airplane engine.

d) Flight planning – undetermined

The presence of passengers on board the aircraft showed the inadequate preparation for the flight, since, in addition to disregarding the relevant legislation, it contributed to the excess aircraft weight at the moment of the accident.

e) Managerial planning – a contributor

The designation of the same person for performing the functions of flight instructor and course coordinator highlighted the poor ACCE's management planning.

f) Pilot's short experience – undetermined

It is possible that the limited experience in night-time flights compromised the instructor's situational awareness to the point of hindering a reaction that could prevent the loss of control in flight after the aircraft engine failure.

g) Managerial supervision – a contributor

The presence of passengers onboard the aircraft during the training flight, and the operation of the aircraft with a defective artificial horizon, refer to inadequate supervision of educational activities in Teresina by the ACCE management.

h) Others – undetermined

It is possible that the premature damage to the valve of the cylinder no. 6 resulted from the operation of the engine throughout its useful life, without proper control of the cylinder head temperature.

3.2.2.2 Concerning ATS units

Not a contributor.

3.2.3 Material Factor

3.2.3.1 Concerning the aircraft

Not a contributor.

3.2.3.2 Concerning ATS equipment and technology systems

Not a contributor.

4 SAFETY RECOMMENDATIONS

Safety Recommendation is a measure of preventative or corrective nature issued by the SIPAER Investigation Authority (or by a SIPAER-link) within their respective area of responsibility, aiming at suppressing a hazard or mitigating a risk generated by a latent condition, or an active failure, as a result of the investigation of an aeronautical occurrence, or from a preventative action, which shall never be used for the apportion of blame or civil liability.

In accordance with the Law no. 7565/1986, safety recommendations are issued solely for the benefit of the operational safety of the air activity.

The compliance with the Safety Recommendation will be the responsibility of the holder of the highest executive function of the organization to which recommendation is forwarded. If the recipient judges him/herself to be unable of complying with the safety recommendation shall inform the CENIPA on the reason for the non-compliance.

Safety Recommendations made by the CENIPA:

To the National Civil Aviation Agency (ANAC):

A-223/CENIPA/2013 – 01 Issued on 29/02/2016

Implement a provision for purposes of approval of aeronautical science courses, or the like, establishing sharing of data between the institutions responsible for delivering such courses, the schools pilot practice training, and the ANAC, in order to allow a timely and adequate monitoring of the airworthy of the aircraft, as well as the qualification of personnel involved in flight training.

A-223/CENIPA/2013 – 02 Issued on 29/02/2016

Verify the adequacy of methods utilized in the Managerial Supervision by the ACCE, aiming at the faithful compliance of the RBHA 141.35, mainly in relation to the proven experience required from the Coordinator of the Courses.

A-223/CENIPA/2013 – 03 Issue on 29/02/2016

Verify the adequacy of methods utilized in the Managerial Supervision by the ACCE, aimed at monitoring the flight training delivered away from headquarters, particularly with regard to the prohibition of the presence of passengers on board the aircraft on training flights, as established in the RBAC 61.237, and in relation to the tasks of the course coordinator, as defined by the RBHA 141.87.

A-223/CENIPA/2013 – 04 Issued on 29/02/2016

Verify, by means of internally developed mechanisms, whether the *Nacional Manutenção de Aeronaves Ltda*. workshop utilizes the tool that incorporates a PN646953 calibrated "master hole" for measuring the cylinder compression ratio of the engines manufactured by Teledyne Continental.

A-223/CENIPA/2013 – 05 Issued on 29/02/2016

Verify, during the supervision of flight training activities carried out by civil aviation pilot training schools, including flying schools, the faithful compliance with the RBHA 141.87, which disposes on the Special Authorization for Courses Away from Headquarters.

A-223/CENIPA/2013 – 06 Issued on 29/02/2016Y

Verify, during the supervision of flight training activities carried out by civil aviation pilot training schools, including flying schools, the faithful compliance with the RBHA 141.35, which makes provisions on the Qualification of Course Coordinators.

5 CORRECTIVE OR PREVENTATIVE ACTION ALREADY TAKEN

The Service Bulletin (DIVOP) no. 007/2013, which was available for consultation on the CENIPA website, featured a series of seven contributing factors in aircraft accidents involving flight training activities in the area of civil aviation between the years 2011 and 2013, including the problem related to the absence of a Practice Training Coordinator / Director of Training.

. The study presented by the aforementioned DIVOP shows that the case is recurrent, pointing out the need of strict compliance with the standards established by the civil aviation regulatory agency, by managers of pilot training schools, including flying clubs, as well as for the appropriate supervision of such activities.

On February 29th 2016