FINAL REPORT

ACCIDENT 0981/14

Państwowa Komisja Badania Wypadków Lotniczych

UL. CHAŁUBIŃSKIEGO 4/6, 00-928 WARSZAWA, POLAND
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FINAL REPORT

ACCIDENT

OCCURRENCE NO – 0981/14
AIRCRAFT – Piper PA-31P Navajo aeroplane, N11WB
DATE AND PLACE OF OCCURRENCE – 5 Jul 2014, Topolów, Mykanów municipality, near Częstochowa

This Report is a document presenting the position of the State Commission on Aircraft Accidents Investigation concerning circumstances of the air occurrence, its causes and safety recommendations. The Report was drawn up on the basis of information available on the date of its completion.

The investigation may be reopened if new information becomes available or new investigation techniques are applied, which may affect the wording related to the causes, circumstances and safety recommendations contained in the Report.

Investigation into air the occurrence was carried out in accordance with the applicable international, European Union and domestic legal provisions for prevention purposes only. The investigation was carried out without application of the legal evidential procedure, applicable for proceedings of other authorities required to take action in connection with an air occurrence.

The Commission does not apportion blame or liability.

In accordance with Article 5 paragraph 5 of the Regulation (EU) No 996/2010 of the European Parliament and of the Council on the investigation and prevention of accidents and incidents in civil aviation […] and Article 134 of the Act – Aviation Law, the wording used in this Report may not be considered as an indication of the guilty or responsible for the occurrence.

For the above reasons, any use of this Report for any purpose other than air accidents and incidents prevention can lead to wrong conclusions and interpretations.

This Report was drawn up in the Polish language. Other language versions may be drawn up for information purposes only.

WARSAW 2019

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GENERAL INFORMATION

Occurrence reference number:	**981/14**			
Type of occurrence :	**ACCIDENT**			
Date of occurrence:	5 July 2014			
Place of occurrence	Topolów, Mykanów municipality, near Częstochowa			
Type and model of aircraft:	Piper PA-31P Pressurized Navajo aeroplane			
Aircraft User/Operator:	Szkoła Spadochronowa OMEGA			
Aircraft Commander:	CPL(A)			
Number of victims/injuries	Fatal	Serious	Minor	None
	11	1	-	-
Domestic and international authorities informed about the occurrence	ULC, EASA, NTSB			
Investigator-in-Charge:	Andrzej Pussak			
Investigating Authority:	State Commission on Aircraft Accidents Investigation (SCAAI)			
Accredited Representatives and their advisers:	Kancelaria Prawna K&K Piotr Kasprzyk NTSB Accredited Representative			
Composition of Investigation Team:	(See page 4 of the Report)			
Document containing results:	FINAL REPORT			
Safety recommendations:	YES			
Addressees of the recommendations:	URZĄD LOTNICTWA CYWILNEGO (CAA)			
Date of completion of the investigation:	September 10, 2019			

SYNOPSIS

On 5 July 2014, at about 16:00 hrs[1] Piper PA-31P Pressurized Navajo aeroplane, registration N11WB, took off from Rudniki (EPRU) landing field for a parachute operation. Due to the drop in powerplant power and inability to climb, the pilot decided to perform an emergency landing in a field located about 4 200 meters from the runway threshold. The aircraft in a stall attitude made about 270° roll to the right, and then with a significant nose down pitch and left bank angle collided with the ground.

There was a significant fuel leak from damaged wing tanks on hot engines parts which caused the aircraft caught fire.

[1] all times in the Report, except for the GAMET forecast, are given in LMT.

Residents from the area of impact helped three persons to get out of the cabin but two of them died on the scene due to injuries and burns, and the rest of the aircraft occupants, presenting signs of life, could not have been rescued due to a rapidly spreading fire.

1 – Piper PA-31P Pressurized Navajo, N11WB, after adaptation for parachute operations (additionally mounted step, roller door, handrail above the door, handle behind the door and deflector in front of the door, all seats removed except the pilot's seat, two parallel benches mounted along the cabin, on which skydivers sat astride), photographed in the period preceding the accident [photo: Bartosz Budzisz, Skrzydła.org].
Note: *Unless otherwise stated, all photos made by SCAAI.*

The investigation into the occurrence was conducted by the SCAAI Investigation Team in the following composition:

Andrzej Pussak, Msc (Eng.), test pilot	- Investigator-in-Charge
Jacek Jaworski, Msc (Eng.)	- team member (until 13 Nov 2016)
Stanisław Żurkowski, D. (Eng.)	- team member (until 13 Nov 2015)
Ryszard Rutkowski, Msc, instr pilot	- team member (until 1 Sep 2017)
Jacek Bogatko, Msc, instr pilot	- team member
Tomasz Makowski, Eng	- team member
Krzysztof Pawełek, Msc (Eng.)	- SCAAI expert
Tomasz Pawełek, Msc (Eng.)	- SCAAI expert
Jarosław Olędzki, MA	- SCAAI expert
Marek Flekiewicz, D. (Eng.)	- SCAAI expert.

During the investigation, the State Commission on Aircraft Accidents Investigation (SCAAI) determined the following causes of the accident:

1. **Operation of the aircraft without a valid Airworthiness Certificate.**
2. **Damage and destruction of the dowel pin coupling, what resulted in disconnection of the RH engine crankshaft with the drive shaft of the propeller gear and made the right propeller inoperative and prevented operation of the propeller governor, which caused feathering the propeller blades. The above failures resulted in asymmetry of thrust leading to stall of the aircraft and loss of its controllability.**

   Damage to the dowel pin coupling could have been caused by:

   - **an earlier impact of the propeller with an obstacle in circumstances and time which was impossible to determine;**
   - **a long-term fatigue process due to engine roughness (one of the cylinders in this engine was replaced).**
3. **Stall in the last phase of the emergency landing.**

Factors contributing to the occurrence were:

a) Improper maintenance of the aircraft;

b) Drop in power of the LH engine due to its improper use;

c) Use of fuel which did not comply with the requirements of the engine manufacturer;

d) Adaptation of the aircraft in violation of its Type Certificate;

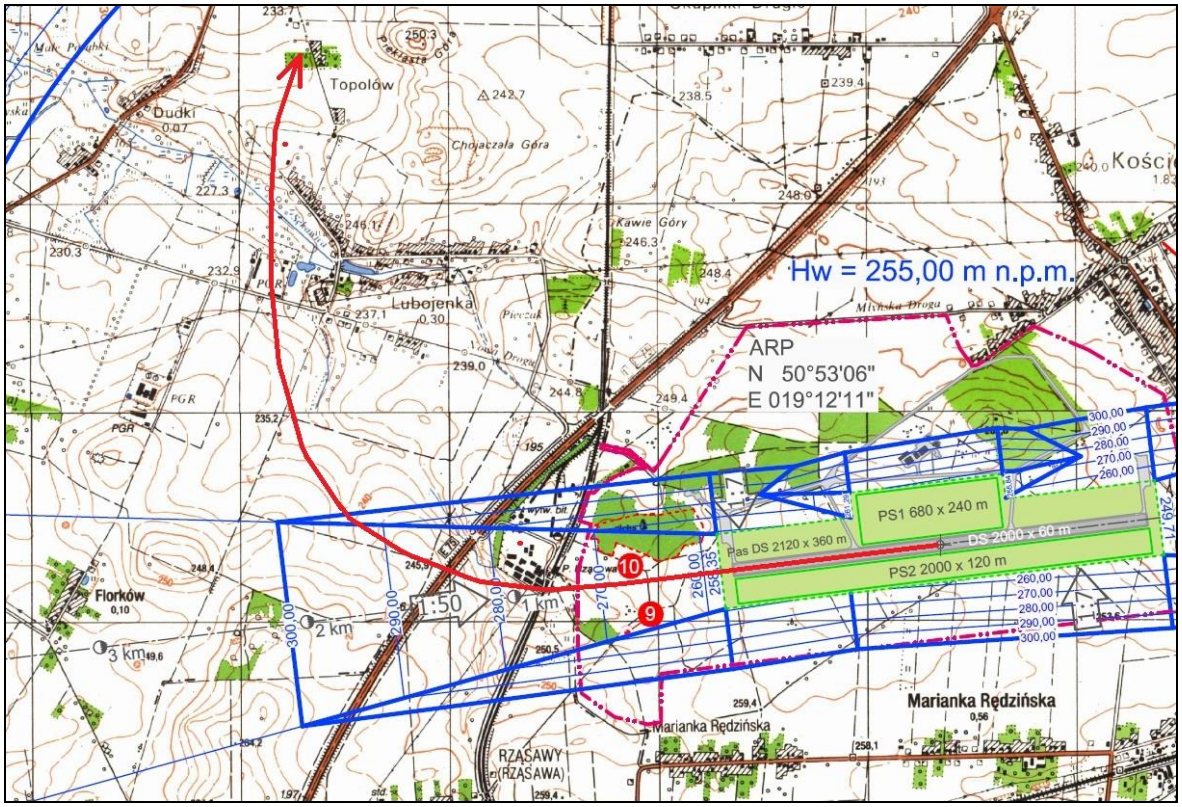
e) Meteorological conditions - high ambient temperature.

After conclusion of the investigation SCAAI formulated one safety recommendation.

1. FACTUAL INFORMATION

1.1. History of the flight

On Saturday, 5 July 2014, at about 16:00 hrs LMT Piper PA-31P Pressurized Navajo aeroplane, registration N11WB, took off from Rudniki (EPRU) landing field for a parachute operation. It was the eighth flight of this plane on that day. There were 11 persons on board, apart from the pilot: 7 skydivers, 2 tandem pilots and 2 tandem passengers.



2 – Approximate route of the last flight of N11WB airplane, plotted on the topographic map of the Rudniki landing field area.

According to the only skydiver who survived the accident, the take-off was normal at the beginning, but shortly after that a drop in power and no climb could have been observed - he estimated that the height at that time was about 100 m.

At a certain time the pilot turned to the persons on board and called out: "*Emergency landing!"* The passengers on board adopted body positions prescribed for such circumstances and immediately afterwards the roll and impact occurred.

At. 16:11 hrs the plane, passing approx. 4200 m from the runway threshold, after reaching about 100 m AGL, in the course of emergency landing, entered the right

autorotation roll, and then, after making about 270° roll to the right, with a significant pitch angle (40-50° nose down) and bank (about 70° to the left), with a significant vertical speed hit a bough of an apple tree with the tip of left wing, breaking it off. The tip of the left wing with the aileron was also broken off. Then the plane hit the ground with the LH engine, the front part of the fuselage and the RH engine. Both propellers were detached together with their gears (the right propeller was driven into the ground in feathered configuration), the wings were separated from the fuselage. The plane fell "on the belly" and was still moving, rotaning around its vertical axis to the left. The right stabilizer collided with the ground, which ultimately led to the separation of the fuselage from the wings and rolling it to the right side, which caused that the door was at the top. The right horizontal stabilizer was also torn off. There was a significant fuel leak from damaged wing tanks and soon after a fire broke out, which took the left wing, partially LH engine and fuselage except the rear part, and partly the RH engine and right wing in the area of fuel tanks.

Residents from the nearest neighborhood of the accident site helped the victims and managed to get out three persons from the fuselage. All of them were seriously injured, and two of them were also severely burned and they died.

The spreading fire of fuel prevented any assistance for other persons in the cabin, who still presented signs of life. At the time of the accident the ambient temperature was high and reached around 30°C.

1.2. Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	11	-	-
Serious	1	-	-
None	-	-	-

1.3. Damage to aircraft

The aircraft was completely destroyed as a result of the collision with the ground and also partially burned due to a fire caused by ignition of fuel which leaked from

damaged wing tanks. The condition of the aircraft after the accident is shown in detail in the Album of Illustrations – Annex 1 to the Report.

1.4. Other damage

Damage to the grass surface on a total area of approx. 450 m^2, local contamination of the ground with petroleum products and products of combustion of the aircraft structure, neutralized by firefighters during the rescue operation. The area of wreckage scattering and area covered by the fire were relatively small.

1.5. Personnel information (crew data)

Commander of the aircraft (PIC) – male, aged 29, holder of CPL(A) issued by the Polish Civil Aviation Authority. Entries in the licence:

- SEP (L), valid until 31 Aug 2015;
- SEP (L) - IR, valid until 31 Dec, 2014;
- MEP (L), valid until 31 Dec, 2014;
- MEP (L) - IR, valid until 31 Dec, 2014.

In addition, the pilot had in his licence an entry authorizing him to conduct radiotelephony communication in English and stating English proficiency level 5, valid until 18 Jan 2019.

Flight experience as of 5 Jul 2014:

- Total: 996 hrs 26 min;
- On type: first flight (first entry) on 15 May 2014, last entry 22 Jun 2014 – total 19 hrs 15 min. For the next 13 days the pilot performed flights but they were not recorded – the flight time for that period was assessed as approx. 20 hours, which makes approximately 40 hours of flight time on the accident type.

PIC was a holder of Class 1 Medical Assessment without limitation valid until 02/08/2018.

1.6. Aircraft information

Twin-engine, 8-seat, low-wing semi-monocoque, all-metal monoplane, tricycle retractable landing gear with the nose wheel; pressurized fuselage; classic empennage.

The airplane is powered by two AVCO-Lycoming TIGO-541-E1A engines - four-stroke, six-cylinder, fuel injected, horizontally opposed turbocharged, rated at 317 kW (425 HP). Propellers – Hartzell, three blade, metal, feathered. Fuel tanks located in the wings and in the engine nacelles. Cable control systems.

Prototype (in PA-31 Navajo version with non-pressurized fuselage) first flown 30 Sep 1964, FAA A-8EA certificate issued in 1967.

PA-31P version with a pressurized fuselage (heavier by approx. 600 kg) was produced since 1970. In total, about 4000 PA-31 aircraft of all versions were manufactured.

The original, factory version of PA-31P featured 8 seats (2 front seats - pilot and co-pilot/passenger and 6 seats for passengers). The baggage and galley area was located in the back of the passenger cabin. The aircraft was designed for operating corporate or commuter flights. In addition, it could have been used for multi-engine and IFR flight training.

3, 4 – Fundamental structural modification of the PA-31P N11WB airplane. On the left – the condition prior to the modification (another plane - visible pressure door); on the right - N11WB after modification (visible roller door, deflector, handrail, handle and step) [photo Bartosz Budzisz, Skrzydła.org + publicly available Internet domain].

In May 2014 in Poland the accident plane (N11WB, serial number 31P-7630005) was modified into 12-seat version to adapt it for parachute operations (one seat for a pilot and two benches along the fuselage for skydivers). During the adaptation the seats were removed and the pressure door was replaced with a roller door, the deflector outside the front edge of the fuselage and the handle, handrail and step for skydivers were added. The result of this adaptation was loss of pressurization and increase in payload by approx. 360-380 kg. The documentation for adaptation was not presented to the investigators.

History of the airplane

Year/date	Registra-tion	Owner/User/*Remarks*
1976	N57531	*Manufactured by Piper Aircraft as 8-seat*
1976-05-28	N57451	*First Certificate of Airworthiness issued*
From 1976-06-03	N57351	Western Automotive Company Inc., Oakland, CA *[first owner]*
From 1977-03-17	N666ER	J.L.Evans and C.W.Reeves *[served as a bank pledge]*
From 1985-03-27	N666ER	E.R. Leasing Co (J.L.Evans and C.W.Reeves)
From 1985-03-28	N666ER	Jobe Ski Corporation, Redmond, WA
1985-10-08	N666ER	*New Certificate of Airworthiness issued*
Until 1987-05-04	N666ER	Jobe Ski Corporation, Redmond, WA
From 1987-05-04	N666ER	Elcon Finans Nord AS
From 1987-05-04	N666ER	Aircraft Sales of California Inc, Hygiena, COLO
1987-05-11	N666ER N11WB	Indiana Texas Aircraft Sales (*According to Airframe Logbook No1 from that date registered as N11WB [discrepancies in entries])*
Jun 1987	N11WB	Baystone Construction Inc. and Brad Razor Buick Inc., IN *[bank pledge]*
1989-02-11	N11WB	Edgewater Financial Group *[Last entry in Airframe Logbook No 1]*
1989-09-18	N11WB	RR Investments Inc DBA Million Air *[date of purchase]*
1990-03-19	N11WB	Corporate Skyways Inc *[date of purchase]*
1990-04-06	N11WB	Land Co Realty NC *[date of purchase]*
1990-06-25	N11WB (N404WB)	Land Co Realty NC (*Registered again(?) – temporary registration as N404WB, bank pledge)*
Apr 1995	N11WB	Ralph Lowry Aircraft Sales Inc, Newton, KS *((this company repeatedly sold the plane to next owners, bought it back and pledged it in various banks)*
Aug 1995	N11WB	Gravlee & Assoc., Tulsa, OK *[Avionics modification]*
1998-10-22	N11WB	Hunsberger Terry R., Garden City
May 2002	N11WB	Sold to ICM Inc, Houma, LA *by* Ralph Lowry Aircraft Sales Inc, Newton, KS
Jan-Nov 2002	N11WB	ICM Inc, Colwich, KS
Mar 2004	N11WB	Ralph Lowry Aircraft Sales Inc, Newton, KS – *one of many ownership changes to* Intrust Bank NA, Wichita, KS
2004-03-16	N11WB	K-Air LLC, Houma, LA
2007-04-14	N11WB	*Registration suspended*
2007-05-04	N11WB	Hicks W.W., Hobbs, NM
Nov 2007	N11WB	TFH LTD Co., Hobbs, NM
2008-08-01	N11WB	*[Last entry in Airframe Logbook No 2]*
2012-06-16	N11WB	*Registration suspended*
2012	N11WB	*Technical review/Review of compliance*
From 2012-05-23	N11WB	Wandoo Aviation LLC, Mount Pleasant, SC
From 2014-04-23	N11WB	Larsen C., Merrimack, NH
Apr 2014	N11WB	ChartAir, Warsaw (user/lessee: OMEGA parachute school) *Sold and imported to Poland by air without re-registration*
May 2014	N11WB	*Modified in Poland to 12-seat version for parachute operations [loss of pressurization, breach of Type Certificate]*
2014-07-05	N11WB	*Destroyed in accident in Topolów, Mykanów municipality near Częstochowa*

Year of manu-facture	Manufacturer	Airframe S/N	Registration marks	Register No	Register date
1976	Piper Aircraft Corporation Lock Haven, PA, USA	31P-7630005	N11WB	-	-

Airframe total flight time since new as of 5 Jul 2014: approx. 4350 hrs

(established based on TTAF and assessment of the operation time after annual inspection effected 19 Jul 2013 in the USA – see below)

Third party liability aviation insurance: signed from 6 Jun 2014 until 31 Mar 2015.

Engines: Two piston engines, turbocharged, fuel injected, six-cylinder, horizontally opposed, air-cooled, fuel: 100/130 aviation fuel.

Left engine:

Year of manufacture	Manufacturer	Model	Serial number
-	AVCO Lycoming, Williamsport	TIGO-541-E1A	L-264-62

Right engine:

Year of manufacture	Manufacturer	Model	Serial number
-	AVCO Lycoming, Williamsport	TIGO-541-E1A	L-762-62

Maximum take-off power of each engine: 425 HP

Total time of operation since new: approx. 3660 hrs
(established based on HOBBS and assessment of the operation time after annual inspection effected 19 Jul 2013 in the USA – see below)

Propellers

Two metal propellers, three-blade, controllable pitch.

Left propeller:

Year of manufacture	Manu-facturer	Model	Serial Numbers
Jul 22, 1975	Hartzell Propeller Inc.	HC-C3YN-2LUF/FJC9684B-3R	Assembly: DG 503, Hub: 55891 Blades: L1-K11080, L2-K11081, L3-K11082,

Right propeller:

Year of manufacture	Manu-facturer	Model	Serial Numbers
Sep 17, 1975	Hartzell Propeller Inc.	HC-C3YN-2LUF/FJC9684B-3R	Assembly: DG 508, Hub: 53750 Blades: R1-J97441, R2-K09678, R3-J93493

Note:
1. The absence of shot peening on the pitch change knobs suggests the propeller had not been overhauled per Hartzell Propeller procedures since approximately 2004.
2. The blade S/Ns in both propellers are not the S/Ns in the original/new build, indicating the blades had been replaced sometime after manufacture of the propellers in 1975.

Flight time since new: approx. 3660 hrs
(established based on HOBBS and assessment of the operation time after annual inspection effected 19 Jul 2013 in the USA – see below)

Information, data and documents such as: Airworthiness Review Certificate, number of cycles since new, flight time since last overhaul or inspection, flight time until the next overhaul or inspection (100 H), date of the last periodic

operations (50H) for the airframe, engines and propellers were not available because the basic maintenance and operational documentation of the aircraft was probably burned on board during the accident.

Fragmentary data on the aircraft maintenance (obtained in the form of photocopies made in the USA before its sale to Poland, and provided by the OMEGA Parachute School) were briefly summarized and are presented in the table below.

Date/Provider [A, B, C, D]	Scope of works/operations
03.04.2008/A	Annual/100H inspection, engine operation check, necessary replacement of parts, oil changed and airworthiness confirmed.
04.06.2008/B	LH engine repair after cylinder No 5 overheat.
23.06.2008/A	Replacing the left motor starter drive for another (used but operative).
23.06.2008/A	Oil change, oil filters check and taking a sample of used oil for analysis, tightness check.
28.06.2008/A	Oil change in the LH engine, oil filter check and taking a sample of used oil for analysis, tightness check, fuel nozzles cleaning.
11.07.2008/C	Replacement of a compressor valve and oil change.
28.07.2008/A	Oil change, oil filters check and taking a sample of used oil for analysis, tightness check, fuel nozzles cleaning, new rate generator installed.
26.09.2008/A	Oil change, oil filters check and taking a sample of used oil for analysis, tightness check, fuel nozzles cleaning.
16.09.2008/A	Oil change, oil filters check and taking a sample of used oil for analysis, tightness check.
...	
07.06.2012/A	Scheduled works on the LH engine, inspection of a propeller hub, paint repairs, confirmation of a propeller airworthiness.
...	
15.04.2013/D	LH engine: oil and oil filter changed.
25.04.2013/D	Repaired cylinder No. 3 of the LH engine reinstalled.
19.07.2013/D	**RH engine: annual inspection in accordance with Piper MM, new pushrod installed for proper operation of valve, lever cover replaced, oil changed and oil filter checked, tightness of the fuel pump checked, engine airworthiness confirmed.**
19.07.2013/D	**LH engine: annual inspection in accordance with Piper MM, replacement and adjustment of engine components and systems, oil changed, oil filter checked, oil filter replaced, confirmed airworthiness of the engine. Inspection of propellers and confirmation of their airworthiness.**
19.07.2013/D	**Annual inspection of the aircraft in accordance with Piper MM. Replaced components of electrical and anti-icing systems and landing gear, local airframe repairs (replacement of rivets). Airworthiness of the aircraft confirmed.**
11.09.2013/D	Both engines: oil changed, oil filters checked and replaced.
21.09.2013/D	Altitude controller changed. Removal of radar equipment for repair.
03.10.2013/D	RH engine: Lubrication of the waste gate and verification of its full Travel. Cleaning all waste gate oil lines and checking the system operation.
25.10.2013/D	Re-installing of radar equipment after repair. Replacement of air filters.
08.01.2014/D	Both engines: oil change and oil filters check and replacement. Installation of new mounts of engines cowlings.

Maintenance service providers:

A – *Aero Clinic Inc. (Seminole, TX)*
B – *Broadle's Aircraft Inc. (Meacham Field, Worth, TX)*
C – *Pacific Aircare Inc.*
D – *Interstate Turbine Management (North Charleston, SC)*

Annual inspection report (photocopy of the document) effected 19/07/2013 in the USA by Interstate Turbine Management shows that until the inspection the aircraft had:

- **Total Time Air Frame (TTAF) - 4147,4 hrs**
- **engines working time (HOBBS) - 3460,7 hrs**

The above data (TTAF and HOBBS) plus operation time after this inspection (estimated at 200 hrs) served for estimation of total time since new for airframe, engines and propellers.

On 23 April 2014, due to the sale of the aircraft to Poland, the FAA issued a temporary certificate of registration without changing the registration marks, valid until 23 May 2014.

The above document shows that on the day of the accident (5 July 2014) the registration of aircraft in the US was not valid.

Fuel & Lubricants prior to the flight (according to a witness statement - Aircraft Technical Log from the accident day was not found):

fuel: Verva 98 (should be 100/130), approx. 120 litres
(50 liters of Verva 98 fuel was supplied to each wing tank prior to the last flight)

oil: W80 (12+12) - 24 litres.

Airplane load (mass data):

– empty airplane mass (prior to adaptation):	2268,0 kg
– empty airplane mass after adaptation (approx. 380 kg less):	1888,0 kg
– fuel mass (120 l):	80,0 kg
– oil mass (24 l):	20,4 kg
– pilot and passengers' mass:	865,94 kg
– parachutes, helmets, cameras and altimeters mass (approx):	127,0 kg
– **Total actual take-off mass :**	**2981,34 kg**

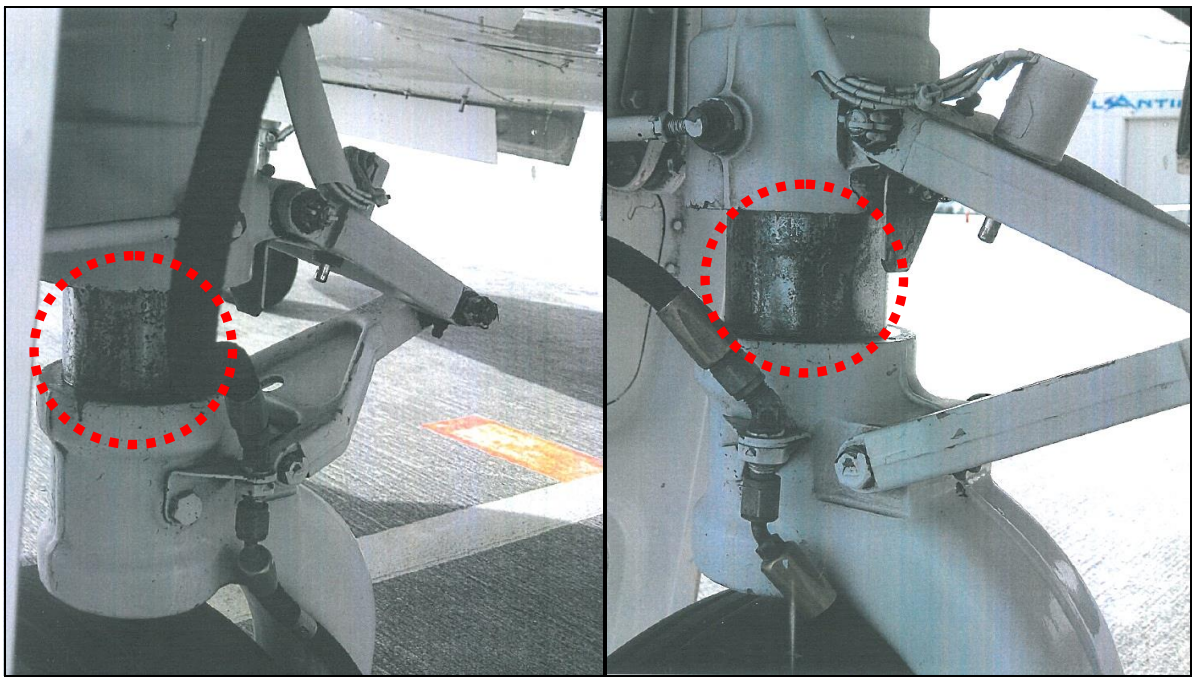
Maximum Take-off Mass (MTOW) 3538,00 kg

The mass of the aircraft during the accident take-off was lower than MTOW prior to the adaptation.

The location of the center of gravity during the accident could have changed because the skydivers might have moved along the cabin since they did not have possibility to use seat belts or handles which were not in the cabin after adaptation.

5 – Piper PA-31P N11WB airplane photographed on 13 May 2014 during landing on Rudniki aerodrome. The significant amount of smoke from the LH engine indicates its improper operation. The cabin door still in the original state (pressurized), i.e. prior to the adaptation, which was made in the second half of May 2014. [photo Bartosz Budzisz, Skrzydła.org].

The general technical condition of the aircraft indicated a long-term maintenance negligence, the consequences of which were not eliminated effectively prior to the transatlantic flight to Poland (a failure in the electrical system during the flight) and after its completion (subsequent occurrences related to engine failures), and which may have resulted from irregular operation and improper service of the aircraft in the USA.



6, 7 – Left and right main landing gears of the aircraft with signs of advanced corrosion [photo via OMEGA].

The Investigation Team did not have access to the records related to operation of the aircraft in Poland, maintenance and service works carried out and adaptations (probably burned on board the aircraft).

Noticeable advanced and extensive corrosion on the landing gears (see Figures 6 and 7) could have been caused by a prolonged parking of the aircraft in water with a depth of about 50-60 cm (e.g. at a place affected by flooding, which could not have taken place in Poland).

1.7. Meteorological information

The weather conditions at the time and place of the accident were determined based on the analysis of:

- satellite images from the NOAA satellite taken during a session closest to the occurrence time;
- satellite images from a geostationary satellite;
- radiosonde data from meteorological stations: 12374 Legionowo, 12424 Wrocław and 11747 Prostejov near Olomouc;
- data from the IMGW 12550 Częstochowa station in the SYNOP code;
- data from IMGW meteorological radar Ramża near Katowice.

The data were obtained from IMGW archival resources and from publicly available archival data from foreign Internet servers: CHMI (Czech Republic), University of Wyoming (USA), wetterzentrale.de (Germany) and OGIMET (Spain).

12550, Częstochowa (Poland) ICAO index: ----. Latitude 50-49N. Longitude 019-06E. Altitude 293 m.			
SYNOPS from 12550, Częstochowa (Poland)			
SM	05/07/2014 18:00->	AAXX 05181	12550 11970 61801 10217 20133 39767 40107 51003 69902 72522 84072 333 10267 20202 91109 93097=
SN	05/07/2014 17:00->	AAXX 05171	12550 41670 71903 10225 20127 39767 40106 52005 78022 8337/ 333 91008 91109=
SN	05/07/2014 16:00->	AAXX 05161	12550 42970 62202 10249 20131 39761 40097 57002 84066=
SI	05/07/2014 15:00->	AAXX 05151	12550 42670 62003 10254 20116 39764 40099 52004 82231 333 91108=
SN	05/07/2014 14:00->	AAXX 05141	12550 42670 62002 10266 20133 39762 40096 57001 81138=
SN	05/07/2014 13:00->	AAXX 05131	12550 41670 62103 10258 20112 39763 40098 55002 70333 81138 333 91108 555 57206=
SM	05/07/2014 12:00->	AAXX 05121	12550 12970 61903 10261 20111 39760 40094 58002 60001 83038 333 91108 93000=
SN	05/07/2014 11:00->	AAXX 05111	12550 42970 61703 10252 20106 39763 40098 57007 83038=
SN	05/07/2014 10:00->	AAXX 05101	12550 42970 61803 10235 20109 39765 40102 55007 83038 333 91108=
SI	05/07/2014 09:00->	AAXX 05091	12550 42970 61603 10244 20107 39762 40098 57013 83038=
SN	05/07/2014 08:00->	AAXX 05081	12550 42970 61803 10225 20112 39770 40109 56009 83038=

18.00 – Tmax 26,7ºC;

15.00 – N 2/8 Cu h 1000-1500 m and 6/8 Ac, Ci, vv 20 km, wind 200/3 m/s, T 25,4°C, T_d 11,6ºC, Q 1009,9 hPa, increase 0,4 hPa/3 hrs.

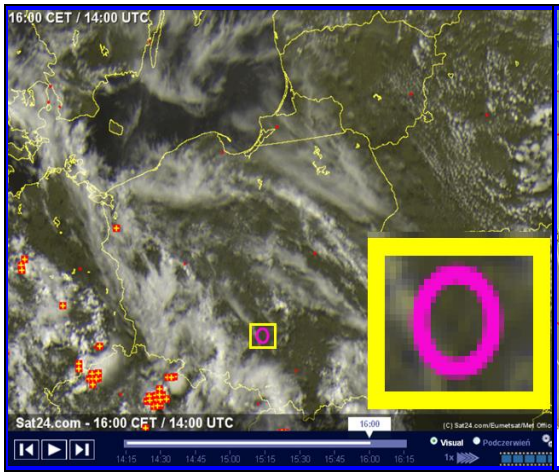
14.00 – N 1/8 Cu h 1000-1500 m and 6/8 Ac, Cs, vv 20 km, wind 200/3 m/s, T 26,6°C, T_d 13,3ºC, Q 1009,6 hPa, decrease 0,1 hPa/3 hrs.

13.00 – N 1/8 Cu h 1000-1500 m and 6/8 Ac, Cs, vv 20 km, wind 210/3 m/s, T 25,8°C, T_d 11,2ºC, Q 1009,8 hPa, decrease 0,2 hPa/3 hrs.

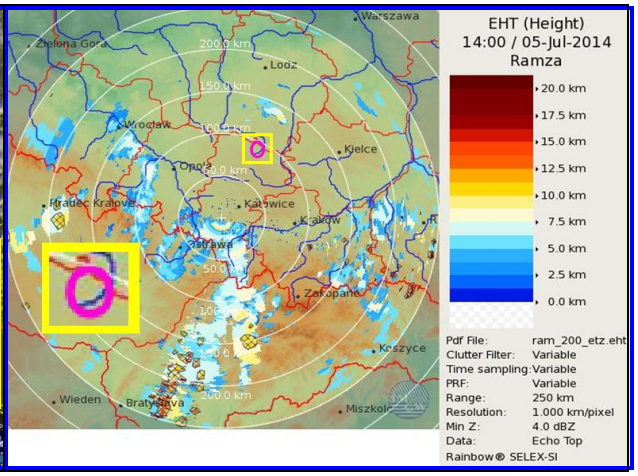
Due to a small distance from the take-off and accident place to the meteorological station in Częstochowa, the results of observations made at this station in the SYNOP code were used to determine the weather conditions at the accident site. The SYNOP code of that station is presented in the above table and the decrypted data below the table.

A satellite image as of 14.00 hrs UTC was used to determine the cloud cover in the accident area. When determining the cloud cover, a meteorological observer is looking at the clouds from the bottom and/or from the side, observing them all over the horizon in all directions, and not just above the observation point, therefore the observation field resembles a flat cone, whose tip is in the eyes of the observer.

However, a satellite "can see" the clouds from above, thus having a satellite image, it is possible to determine precisely whether or not the clouds were above a particular place. Also, the radar image as of 16.00 hrs shows no reflections.



8 - Satellite image of clouds as of 14.00 hrs UTC on 05/07/2014.



9 - Fragments of radar images from 14.00 hrs UTC on 05/07/2014.

In the light of the presented data, it may be assumed that there were no clouds at the time and place of the accident. The visibility was very good, definitely above 10 kilometers. Wind from SSW direction (200-210 degrees), speed about 3 m/s. QNH about 1010 hPa showing slight fluctuations. According to the State Fire Service, conducting the rescue operation, the air temperature was 28ºC and this value should be assumed as the right one for the place of the accident.

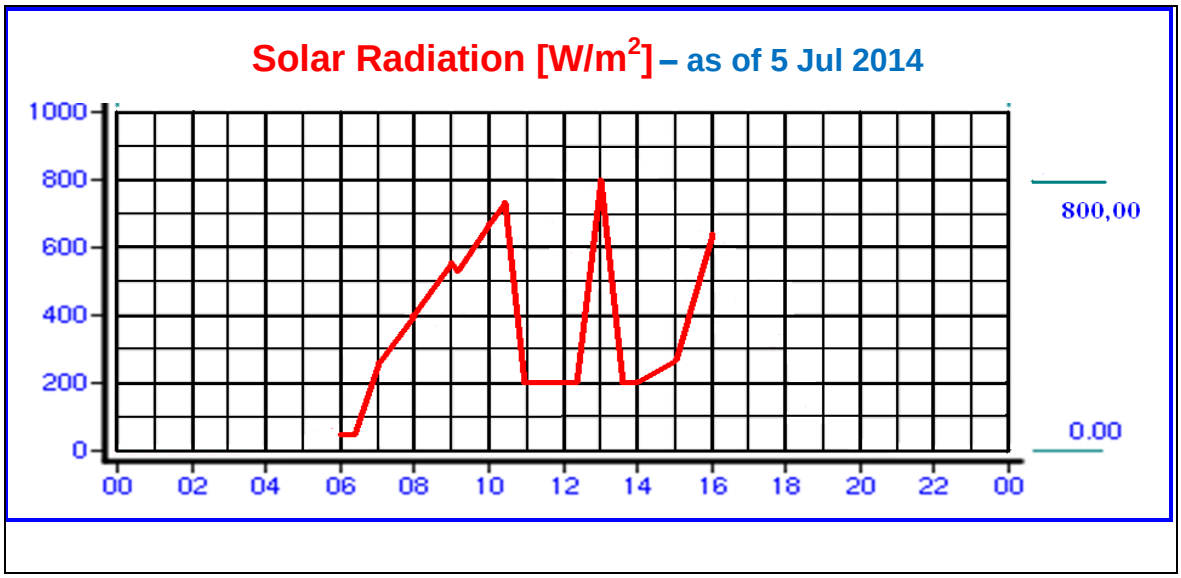
The power of the solar radiation is 1353 W/m2 when vertically reaching the outer layer of the atmosphere. This value is called Total Solar Irradiance and is subject to only slight annual fluctuations. When passing through the Earth's atmosphere the solar radiation is partially reflected, dispersed and absorbed, and therefore only a part of the original radiation gets to the Earth. This part is the effective power of solar radiation.

For the assessment of the power of solar radiation, the courses of this radiation, recorded during the entire day of 5 July 2014 at the meteorological stations Konin and Podkowa Leśna near Grodzisk Mazowiecki were analysed. Due to the fact that the coud cover in the places of the measurement and on the occurrence site were similar, it allows us to assume that the power of solar radiation in this locations was similar or even the same.

In order to determine the cloud cover, satellite images from the geostationary MSG meteorological satellite were used, starting from 06:00 hrs and finishing at 16.00 hrs.

After the analysis consisting in comparing the cloud cover from satellite images and types of clouds from both satellite images, as well as from the meteorological stations in Koło, Warsaw and Częstochowa and taking into account the duration of cloud cover on Rudniki aerodrome, the probable course of solar radiation on Rudniki aerodrome was determined .

From 6:20 hrs to 10:20 hrs, the radiation increased steadily from 50 to about 730 W/m², later due to cloud cover it decreased to about 200 W/m² and was at this level from 11:00 hrs to 12:20 hrs, and later, when the clouds moved, for a short time it increased to about 800 W/m², reaching its maximum. It then fell again to around 200 W/m² and remained at that value for about 20 minutes between 13:40hrs and 14:00hrs and then it was raising again to around 670 W/m² at 16:00hrs.



10 - Probable course of solar radiation on 5 July 2014 in the area of Rudniki aerodrome near Częstochowa

Regardless of whether the aircraft remained on the aerodrome or it was flying, it was equally exposed to solar radiation. The significant reduction in radiation was in the period just before noon, when the sun approached its top position, was at the top, and then lowered its position. In this situation, it is estimated that solar radiation did not have a significant impact on increasing the temperature of the aircraft.

1.8. Aids to navigation

Not applicable.

1.9. Communications

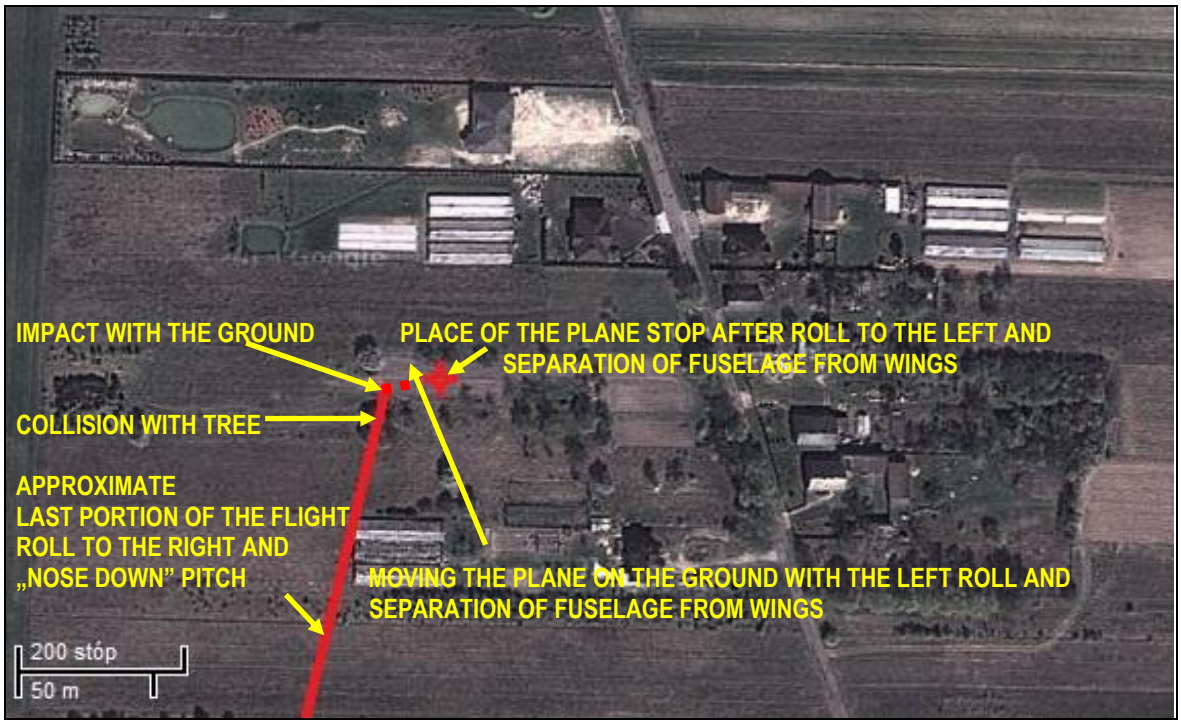
The plane was equipped with two on-board communication radio stations.

Due to the fact that the accident occurred during climb and the pilot did not maintain communication with the aerodrome, the Commission was not able to assess the quality of communication between the aircraft and potential recipients.

1.10. Place of occurrence information

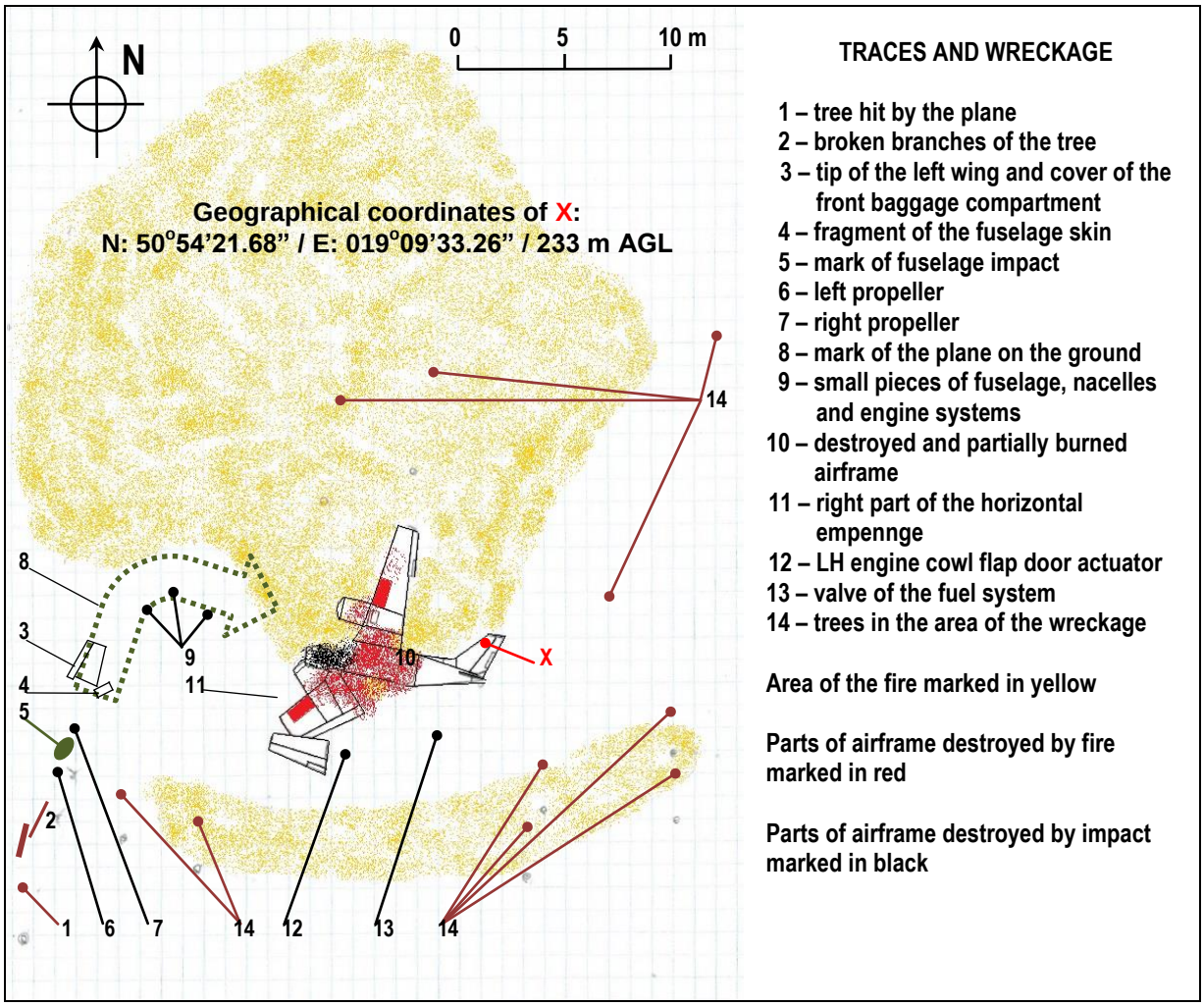
The plane impacted with the ground within the boundaries of a private property at Topolów village, ul. Częstochowska 36, Mykanów municipality near Częstochowa.

Geographical coordinates of the accident site (where the wreck came to rest): **50°54’21.68”N/019°09’33.26”N/233 m AGL** (point "X" in figures 12 and 13). Agricultural land, flat, slightly rolling.



11 – The vicinity of the accident site with sequence of the occurrence marked [background: geoportal.gov.pl]

12 – Piper PA-31P N11WB airplane on the accident site photographed on 6 July 2014 in the morning. Fuselage with a burned cabin separated from the wings lies on the right side. The right flap is not visible, folded under the right wing [photo TVN24/internet].



13 – Sketch of the accident site.

1.11. Flight recorders

The plane was not equipped with on-board flight recorders.

Automatic Activation Device (AAD) of one of the skydivers initiated opening of the parachute - it was set to the descent value of 35 m/s. In addition, on the helmet of one of the skydivers a video camera was installed, which recorded the initial phase of the take-off (the recording ends before the accident, however, it served as a comparative material with similar recordings from earlier take-offs).

1.12. Wreckage and impact information

No evidence was found that any part of the aircraft separated prior to the impact with the ground. The wreckage distribution is shown above in figures 12 and 13.

1.13. Medical and pathological information

The pilot died on the scene. The cause of his death was a blunt chest injury and multi-organ injuries. Toxicological examination did not show any presence of psychoactive substances or narcotic, psychotropic or pharmacological agents. The

pilot blood test did not show the presence of ethyl alcohol. In addition to the pilot, seven skydivers, two tandem pilots and two tandem passengers died on the scene due to extensive multi-organ injuries and burns.

1.14. Fire

When the aircraft was moving on the ground, its structure was gradually destroyed and its fuel system was unsealed in several places including fuel lines on the airframe and fuel tanks in the wings. The contact of the spilled fuel with hot engine elements and possible sparking due to short-circuits in the destroyed electrical system led to a fire which destroyed a major part of the fuselage and a significant parts of the wings. A fire brigade used heavy foam to extinguish the fire.

1.15. Survival aspects

The dynamic contact of the nose part of the aircraft with the ground during its rotation caused complete destruction of the nose part of the fuselage. It exposed the pilot to significant overload and the impact of structure elements on his body. Those circumstances caused immediate death of the pilot at the scene. Skydivers occupying the nearest places behind the pilot were in the same situation.

In case of other skydivers, their parachutes separated them from each other, limiting to some extent the direct impact of the collision with the ground. However, the impact force was so great that all on board who survived the collision, suffered bone fractures and multi-organ injuries limiting their ability to move. This circumstance, as well as the presence of parachutes (impeding the possibility to move inside the cabin) and the position of the fuselage (right side down with the cabin door upwards) constituted a major difficulty in evacuation.

The only skydiver who survived was in the back of the cabin and was closest to the door. It was possible to evacuate only him and the next two persons, who died due to injuries and burns before the ambulance arrived.

The rapid development of the fire made it impossible to help the other skydivers - some of them gave signs of life. The aircraft was not equipped with seat belts or handles for skydivers.

1.16. Tests and research

- A detailed visual inspection of the wreckage was carried out on the scene.

- Photos of the aircraft wreckage and the vicinity of the accident site were taken.
- The kinematic continuity of the airplane control systems was checked on the scene – the continuity was preserved. The elevator and rudder movements were possible. Movement of ailerons was blocked due to extensive deformations and damages to the wings in the places where ailerons were attached.
- An analysis of all available technical and operational records of the aircraft was carried out.
- An analysis of the available pilot's records was carried out.
- The results of autopsy, toxicological tests and tests for alcohol in pilot's body were reviewed.
- Photographic and video documentation (own and obtained from other sources) was analysed.
- Operation, maintenance as well as flying of the airplane during the accident flight were analyzed.
- Accidents to other aircraft of the same type, which had similar course, and whose descriptions and reports were available in the Internet were analyzed.

The Investigation Team carried out a multi-stage technical examination of the wreckage (airframe, engines, propellers) with the participation of the Polish maintenance organization certified according to Part 145 and with the assistance of NTSB (USA) which is summarized below:

- 02-05 September 2014 (disassembly of engines and their verification);
- 25 October 2014 (examination of the propellers with participation and assistance of a representative of their manufacturer - Hartzell Propeller);
- 14 January 2015, shipment of aircraft components to the USA for examinations, which were supervised and authorized by NTSB;
- main components of the engines were sent to Lycoming;
- propeller governors were sent to Ontic Engineering & FG;
- turbochargers were sent to Hartzell Engine;
- 28 April 2015, after the examination, the turbochargers were sent back;

- 31 May 2016, after the examination, the main engine components and the propeller governors were sent back;
- 12 August 2016, a contract was signed with PPHU Royal Star maintenance organization certified according to PART-145 on technical examination of both engines and both propellers under SCAAI supervision;
- 15-17 March 2017 in the above-mentioned maintenance organization an assessment of the technical condition of N11WB powerplants was effected and writing of the Draft Final Report began;
- fuel and ground pump examination was performed at the Air Force Institute of Technology (Poland) before 25 September 2015;
- NTSB has been supervising technical examinations on a current basis until May 2018 (determination of flaps deflection based on the positions of their drives).

1.17. Organizational and management information

The accident was noticed and reported to the rescue services by witnesses. The first rescue unit arrived at the scene almost immediately after the notification. When Rescue and Fire Fighting Unit arrived, two water currents and two currents of heavy foam were applied.

When the fire was extinguished, the medical service together with the State Fire Service went to the wreck and found in the cabin nine bodies without any signs of life. Two of the three persons removed earlier from the plane were declared dead by a physician and the third one was transported by a helicopter to the hospital.

Rescuers from the State Fire Service searched the area three times for other possible victims. Those actions were repeated by the police with the participation of the dog, but nobody was found. In the evening the accident site was illuminated and nine bodies of the victims were removed from the aircraft wreck. The body of one victim was under engine, therefore the engine was lifted by a winch.

On the days of 5-7July, the accident site was secured.

Actions of the State Fire Service and the police consisted in securing the accident site to support actions of the State Commission on Aircraft Accidents Investigation. Further actions of the State Fire Service and the police consisted in fire protection and cleaning of the accident area, assisting the Commission in visual examination

by cutting the airplane structure and lifting and moving its parts. The following actions were accomplished by the State Fire Service in co-operation with the Commission:

- the left propeller assembly with a fragment of its gear partially driven into the ground was moved to an indicated place;
- the right propeller assembly with the fragment of its gear was excavated from the ground and moved to an indicated place (the unit was located in the ground at a depth of about 0,5 m);
- both engines were separated from the wreckage and moved to an indicated place;
- parts of the left wing and other elements were separated from the wreckage to facilitate access to the cockpit;
- individual components of the aircraft separated by hydraulic and demolishing equipment were moved to indicated places.

1.18. Additional information

In accordance with §15 of the Regulation of the Minister of Transport, dated 18 January 2007 (Dz.U.35 poz.225), the flight organizer was notified about the opportunity of getting acquainted with the Draft Final Report. Representatives of the flight organizer made comments to the Draft Final Report and signed an applicable protocol. The Commission partially took the comments into account and amended the Draft Final Report. The amended Draft Final Report was again presented to representatives of the flight organizer.

The Draft Final Report accepted by the SCAAI Resolution and translated into English is being sent to the USA National Transportation Safety Board (NTSB), inviting their significant and substantiated comments to the content of the Draft Final Report and the cause of the occurrence with a proper rationale not later than within 60 days.

NTSB comments were taken into account and in accordance with Art. 15 para. 5 of Regulation (EU) No 996/2010 of the European Parliament and of the Council of 20 October 2010 on the investigation and prevention of accidents and incidents in civil aviation, SCAAI, prior to releasing the Final Report have informed the families of the victims and their association on the content of the Report.

1.19. Useful or effective investigation techniques

Standard investigation techniques were used.

2. ANALYSIS

2.1. Flying analysis and pilot's training level

The level of the pilot's training on the day of the accident was considered to be sufficient to complete the task. It met all the formal requirements that a pilot should comply with in order to perform parachute operations.

Analysis of accidents to other airplanes of the same type which had similar course, and whose descriptions and reports were available in the Internet led to the conclusion that in case of failure of one engine Piper PA-31 Navajo creates considerable problems even for pilots with wide experience and attempts to land in such a situation undertaken in time deficit by pilots with average skills and experience usually ended in crash of an aircraft. The cause of such outcome was a dramatic drop in performance and a significant deterioration of flying characteristics in the event of thrust asymmetry (especially in case of critical engine failure), leading to loss of controlability. In many cases of this kind, the aircraft turned over on its back during the last phase of the flight.

2.2. Technical analysis

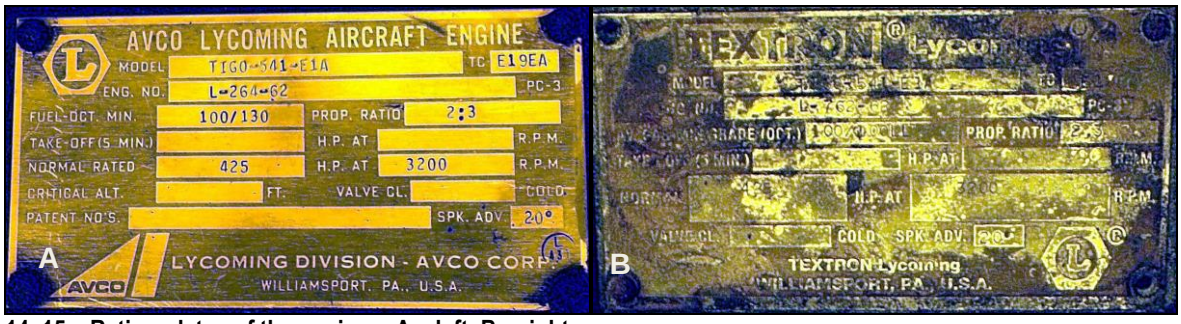
Technical analysis was performed to determine the technical condition of the powerplant and the cause of its failure which was found in the course of the investigation.

Part of this analysis was a comparison of video recordings made from the cabin during previous take-offs of this aircraft with the recording of the last take-off, which ended in accident. The recording (which ends before announcement of emergency landing by the pilot) showed that **the airplane climb was obviously worse than during previous flights.**

High ambient temperature reduced the thermodynamic efficiency of engines and, due to the reduction in air density, it also reduced the aerodynamic performance of the aircraft.

2.2.1. Identification of examined items

The examined items – the aircraft engines - were identified based on their rating plates removed from the aircraft:



14, 15 – Rating plates of the engines: A – left, B – right.

Based on the information from the rating plates, it was possible to determine specifications of TIGO-541-E1A engines manufactured by AVCO Lycoming Aircraft Engines. They are presented in the table below:

TIGO-541-E1A engine specifications

FAA Type Certificate	E 19EA
Rated max. continuous HP	425
Engine Rated speed, RPM	3200
Propeller Rated speed, RPM	2133
Critical altitude, feet	15000
Bore, inches	5,125
Stroke, inches	4,375
Displacement, cubic inches	541,5
Compression ratio	7,30:1
Firing order	1-4-5-2-3-6
Spark occurs	20^{0} BTC
Propeller drive ratio	2:3
Propeller drive rotation	Counter-clockwise (viewed from rear)
Crankshaft rotation	Clockwise (viewed from rear)
Fuel Injection System	Fuel Injector, Bendix RSA-1ODBB
Fuel Pump,	Lear Siegler RG9080J4
Turbocharger,	AiResearch T-18A21
Magnetos	Left - Scintilla S6 LN-1208 / Right-Scintilla S6 RN- 1209
Dimensions, inches	Height x Width x Lenght : 22,65 x 34,86 x 57,57 cali
Required fuel	Aviation Grade Fuel
Required fuel octane rating	**100/130 - The manufacturer prohibits the use of automotive gasoline, regardless of octane rating**

The AVCO-Lycoming TIGO-541-E1A engine is equipped with a dynamic counterweight system and requires proper operation and, above all, avoiding operation with:

— high engine speed and;

— low manifold pressure.

It is also required to ensure a constant throttle position (i.e. possibility of locking), minimizing the rapid change of its opening or closing, in other words limiting the rapid changes in the engine load. The manufacturer warns that failure to comply with the above rquirements may result in severe damage to the counterweights, rollers and bushings.

Another feature of the TIGO-541 engine is its considerable difficult adjustment, resulting from its complexity and interaction of many adjustable parameters.

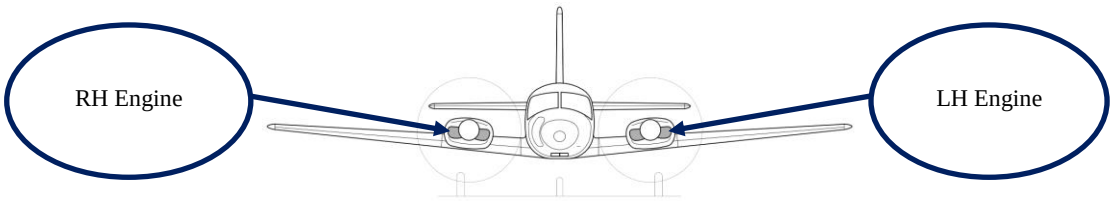
The manufacturer allows only aviation grade fuel 100/130 minimum octane for TIGO-541 engine. Regarding other fuels, the Lycoming service documentation contains the following cautions:

⚠ CAUTION

ANY MIXTURE OF UNAPPROVED FUELS AND ADDITIVE MATERIALS THAT MAKES A LOWER THAN SPECIFIED OCTANE RATING, CAN CAUSE ENGINE DAMAGE. USE OF LOWER-THAN-SPECIFIED OCTANE FUEL COULD CAUSE DETONATION AND MECHANICAL DAMAGE TO THE ENGINE.

⚠ CAUTION

IF INCORRECT FUEL OR ADDITIVES ARE USED, REFER TO THE LATEST REVISION OF SERVICE BULLETIN NO. 398 FOR INSTRUCTIONS TO CORRECT THE FUEL CONTAMINATION.



16 – Identification of AVCO-Lycoming TIGO-541-E1A engines on PA-31 airplane

2.2.2. Analysis of the technical condition of the engines components

The analysis was carried out on the basis of:

1. The report No. 3-3 / 2014 of October 2014, titled „Post-accident survey of powerplants installed on Piper-PA Navajo aiprplane, N11WB registration

marks, involved in the accident on July 5, 2014 in Topolów near Częstochowa; SCAAI reference 981/14".

2. Album of Illustrations showing teardown of the Lycoming TIGO-541-E1A engines removed from Piper PA-31P Navajo N11WB after the accident on 5 July 2014 in Topolów, Poland.
3. Digital photo documentation of the torn down engines removed from the Piper PA-31P, N211WB airplane.
4. Visual examination of engines parts and components, including cylinder barrels, piston-crank assemblies and crankshafts, dowel pin couplings connecting crankshaft with propeller driving gear. The examination was carried out on 17 March 2017 in the presence of the SCAAI members and expert.
5. Presentation by Andrzej Pussak explaining the course of the accident to Piper PA-31P, N11WB, on 5 July 2014 in Topolów near Częstochowa, and the course of SCCAI works and findings until 17 March 2017.
6. Manufacturer's technical documentation, including:
   - OVERHAUL MANUAL AVCO LYCOMING INTEGRAL ACCESSORY DRIVE AIRCRAFT ENGINES 2nd Edition, October, 1975;
   - ATP Grid Index to Manufacturer's Publications: Textron Lycoming TIGO-541 Series Engines Parts Catalog, Aircraft Technical Publishers, 2006;
   - ATP Grid Index to Manufacturer's Publications: Textron Lycoming TIGO-541-E1A Aircraft Engines for Piper Navajo PA-31P Operator's Manual, 2006.

Based on analysis of the photographic documentation provided, visual inspection and measurements, the following condition of the piston-crank system and timing gear was found:

LH engine, serial number L-264-62	**RH engine, serial number L-762-62**
• The forward part of the engine block in the area of single-stage reduction gear - damaged. The upper part of the block - torn out, marks of the gear teeth on the bottom. The shaft, totheed wheel and propeller separated (Album, figure 97). • One of the holes of the turbocharger brace was ovalized and fixing screw bolt destroyed, indicating	• The front part of the engine block in the area of single-stage reduction gear - damaged. The upper part of the block - torn out, marks of the gear teeth on the bottom. The shaft, totheed wheel and propeller separated (Album, Fig. 98). • Oil pump with visible traces of scratches on the inner surface and visible signs of impellers wear (Album, Fig. 118, 119).

a long-lasting degradation process of the screw joint (Album, Fig.100, 101).

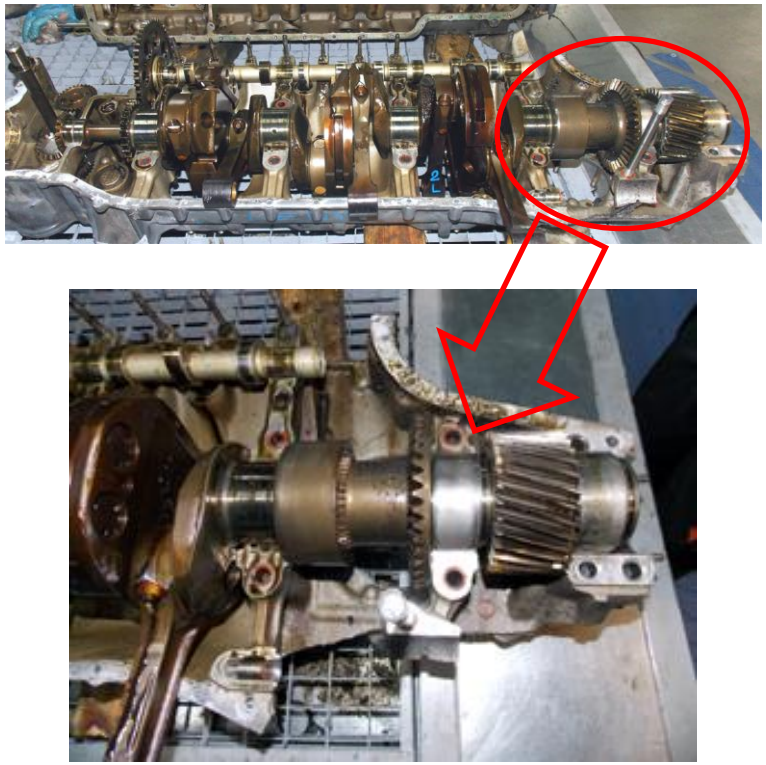
- Oil pump with visible traces of scratches on the inner surface and a damaged impeller (Album, Fig. 102,103).
- Piston of the first cylinder covered with black moist carbon deposit, with visible scratches on the side surface. Hard carbon deposit in the groove of the first ring, in the second groove visible oil carbon deposit (album, Fig. 104, 105).
- Visible traces of excessive combustion temperatures on the pistons heads of cylinders No. 1, 2, 4, 5 and 6 (Album, Fig. 108).
- Spark plugs covered with carbon deposit on both positive and mass electrodes as well as on the ceramic insulator (Album, Fig. 112, 113, 114).
- Exhaust valve of the first cylinder – head with traces of an even temperature distribution, covered with carbon deposit from both the combustion chamber and the inlet sides. Deposit on the valve head from the inlet side indicated a high temperature of the valve during engine operation (Album, Fig.106, 107)
- The seat of the first cylinder exhaust valve was contaminated with carbon deposits (Album, Fig. 104,105).
- Camshaft - visible excessive wear of cams and journals. Vsible effects of peeling, chipping, adhesive and heat wear on the cams. The measured cam throw values were different from each other and varied from 41.9 mm to 43.23 mm (Table 1 and Album, Fig. 116).
- Hydraulic lifters surfaces mating with cams showed effects of peeling, chipping, adhesive and thermal wear (Album, Fig. 117).
- Tests of hydraulic lifters showed their proper operation.
- Tightness tests of the cylinders on the assembled engine, carried out with the differential method, at 80 psi pressure, showed that the cylinder was leaking both through valves and piston rings. Stand tests carried out on the cylinders disassembled from the engine showed the same places of leakage, but smaller values of pressure loss. The full tightness of the cylinders was not achieved despite grinding the valves, lubricating the rings and cylinder barrels and heating cylinders to 80^{O} C, Table 2 and Album, Fig. 124).
- Measured values of crankpins and main pins diameters did not show significant deviations from the maximum admissible values recommended by the engine manufacturer. However, backslash in the bearings exceed the maximum value specified by the engine manufacturer.
- The piston of the first cylinder without signs of seizures, oil leaks traces in the bottom of the piston, piston head covered with hard carbon deposit. Rings fitted correctly, with the correct positions of locks, no signs of galling (Album, Fig. 122).
- Sliding surface of the first cylinder with no traces of honing, with visible discolourations (Album, Fig. 122).
- The valves of the first cylinder free of carbon deposit, the seats evenly worn without deposits or traces of corrosion (Album, Fig. 121).
- The head of the second cylinder piston covered with black soft carbon deposit around the lower spark plug. Piston surface scratched on its top and on the guide part. Piston pin with traces of high temperature. Rings fitted correctly. Compression ring with oil on the inside. Compression ring with visible number 14H21950. Traces of honing and high temperature impact visible on the sliding surface. Cylinder surface scratched longitudinally. The signs of abrasion corresponded with the signs on the piston guide (Album, Fig. 122).
- Suction and exhaust valves of the second cylinder without carbon deposit. Carbon deposit visible on the exhaust valve seat (Album, Fig. 120).
- The third cylinder piston was new, with visible hard, oil-covered carbon deposit located on the circumference of its head. Piston pin with no visible signs of wear. New piston rings, correctly mounted. Ring grooves covered with hard carbon deposit. The cylinder was new, with visible honing signs and a visible blowthrough around the lower spark plug (SCAAI evidence).
- Suction and exhaust valves of the third cylinder without carbon deposit (SCAAI evidence).
- Piston of the fourth cylinder – the head covered with easily removable deposit, small amount of sediment in the grooves, the other side of the head covered with a dark sediment. Rings fitted correctly, the second compression ring covered with oil (SCAAI evidence).
- The fourth cylinder - no visible honing traces, high temperature impact traces (SCAAI evidence).
- Suction and exhaust valves of the fourth cylinder without deposit or sediment. Exhaust valve seat covered with carbon deposit (SCAAI evidence).
- The fifth cylinder piston head - covered with black carbon deposit, a guide part and a piston crown covered with a thick layer of black carbon deposit and oil. Ring grooves filled with oil and carbon deposit. The locks of the second compression ring and the oil regulating ring overlapped (SCAAI evidence).
- The fifth cylinder - no traces of honing, visible traces of high temperature impact (SCAAI evidence).
- Suction valve - covered with carbon deposit, no carbon deposit on exhaust valve. Burned oil on exhaust duct (SCAAI evidence).
- Sixth cylinder – no traces of honing, properly assembled, carbon deposit soaked in oil on the lower leading part. Rings arranged correctly, covered with a large amount of oil.

• Slide bearings - connecting rods bearings showed visible wear of the sliding surfaces and overheating (Album, Fig. 126).	Compression rings grooves filled with oil (SCAAI evidence). • Suction and exhaust valves of this cylinder without carbon deposit; deposit and embedded hard lumps present on exhaust valve seat (SCAAI evidence). • Camshaft - no excessive wear of journals or cams. The measured cam throw values varied from 43.11 mm to 43.20 mm, (Table 1). • Hydraulic lifters operated correctly. • Tightness tests of the cylinders on the assembled engine, carried out with the differential method, at 80 psi pressure, showed lack of tightness of the cylinders 1, 5, and 6. Tightness of the cylinders was obtained after lubricating the rings and sliding surfaces and heating cylinder 5 to the temperature of 80°C, (Table 1). • Slide bearings - connecting rod bearings with traces of normal wear of sliding surface, sliding surface abraded, crankpins with visible abrasions (Album Fig. 126). • Crankpins and journal diameters did not show significant deviations from admissible values recommended by the engine manufacturer. The backslash in bearings exceed the value specified by the engine manufacturer.
Summary ▪ The engine maintenance was not carried out systematically and not to the full extent required by the engine manufacturer. ▪ The engine lubrication system did not ensure the effectiveness required by the manufacturer, contributing to excessive wear of the slide bearings, components of the timing system, cams and hydraulic tappets. The way of the engine operation, in particular its frequent start-ups and short intervals of operation under constant load also contributed to excessive wear of the engine. ▪ Excessively advanced wear of the timing cams, with visible traces of their galling and corrosion and fatigue cracks of hydraulic tappets could adversely affect the cylinder filling process and lead to disturbances in the combustion process. ▪ The leaks in the piston-cylinder assemblies caused blowthrough to the crankcase and could cause overheating of cylinder walls. As a consequence, the oil temperature increased, leading to the loss of its lubricating properties, resulting inter alia from accelerated oxidation of oil. ▪ The technical condition of the engine did not ensure its performance guaranteed by the manufacturer. However it was not possible to determine the degree of power loss without test on a dynamometer.	**Summary** ▪ The engine maintenance was not carried out systematically and not to the full extent required by the engine manufacturer. ▪ The engine lubrication system did not ensure the effectiveness required by the manufacturer, contributing to excessive wear of the slide bearings. The way of the engine operation, in particular its frequent start-ups and short intervals of operation under constant load also contributed to excessive wear of the engine. ▪ The leaks in the piston-cylinder assemblies caused blowthrough to the crankcase and could cause overheating of cylinder walls. As a consequence, the oil temperature increased, leading to the loss of its lubricating properties, resulting inter alia from accelerated oxidation of oil. ▪ The technical condition of the engine did not ensure its performance guaranteed by the manufacturer, but it was not possible to determine the degree of power loss without test on a dynamometer. ▪ The tests showed that the technical condition of this engine was slightly better than the left one.

***NOTE:* the enumeration of figures in the table above corresponds with the enumeration in Annex 1 to this Report (Album of Illustrations).**

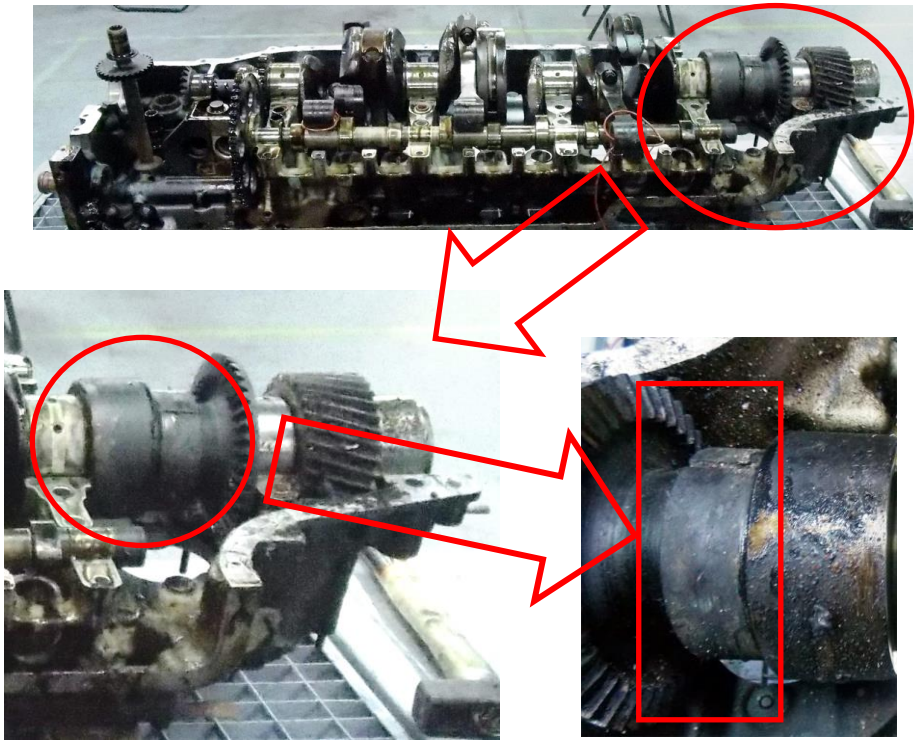
The condition of the toothed gears driving propellers of Piper-PA31P Pressurized Navajo, N11WB registration marks

17, 18 – LH engine gear



LH engine crankshaft and toothed gear components connected to the crankshaft

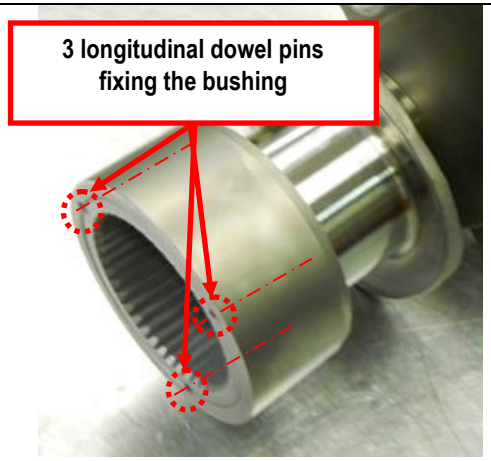
19, 20, 21 – RH engine gear



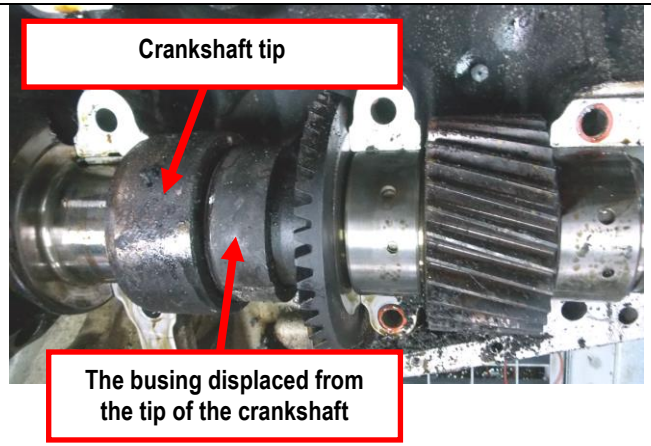
RH engine crankshaft, toothed gear components connected to the crankshaft and displaced bushing connecting the gear shaft to the crankshaft

The drive shaft of the LH engine gear properly joined with the engine crankshaft by a longitudinal dowel pin joint.
In the RH engine, the bushing connecting the crankshaft with the gear shaft is displaced outwards, which prevents the transmission of torque from the engine to the propeller.

RH engine - condition of the bushing with spline mounted on the crankshaft with a longitudinal dowel pin joint



22 - Correct connection of the bushing with the crankshaft, the dashed red lines show the axes of the dowel pins locking the bushing relative to the crankshaft

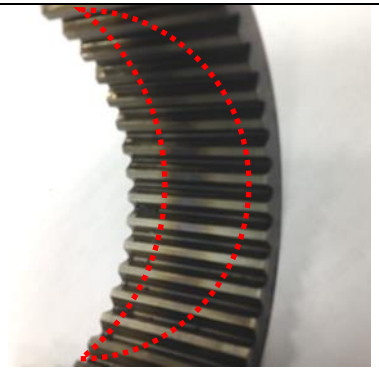


23 - View of the gear drive shaft with the bushing displaced

27, 28 – The tip of the crankshaft with visible deep seizures, the remains of pins pressed into the crankshaft material and signs of high temperature

24 - View of the splined bushing in which the drive shaft of the gear was mounted. Dowel pin groove is visible.

25 - View of the outer surface of the bushing with signs of seizure. One of the dowel pin grooves is visible.



26 - View of the inner part of the bushing and spline with a visible signs of high temperature

The bushing shown in Figures 23 and 26 could have moved only as a result of the damage to the longitudinal dowel pin joint. Damaged edges of the grooves for embedding pins in the bushing (see Figures 24 and 25), pressed material chips both in the grooves of the crankshaft tip and on its inside surfaces (Figures 27, 28) and a significant amount of metal filings on the inside surfaces of the gear housing indicate that the process of the destruction of the joint was lasting for a relatively long time and could have covered up to several hundred hours of engine operation. The total destruction of the pins caused the displacement of the bushing relative to the crankshaft and, as a consequence, a significant increase in temperature of both mating elements due to their friction. Signs of high temperature effects are visible on both the bushing and the crankshaft tip (see Figures 24 and 25 and 27 and 28). A significant loss of material as a result of its abrasion caused the bushing to displace and completely interrupt the transmission of drive from the engine to the right propeller shaft.

2.2.3. Analysis of the technical condition of the propellers

After teardown of the propellers their technical condition was assessed by a representative of their manufacturer (i.e. Hartzell company) and his report is at the SCAAI disposal. The condition of the propellers immediately after the accident is shown in the photos below. The components of the reduction gear are also visible, i.e. the toothed wheel mounted on the propeller drive shaft.

29, 30 - The left and right propeller (driven into the ground) found at the scene of the accident. In both cases the propeller shaft torn out of the gear also visible.

For the purpose of this analysis, only the details relevant to the cause and effect of the occurrence have been taken into account:

Left propeller	Right propeller
• no signs of fire impact • damage to the blades indicating that the propeller was rotating when colliding with an obstacle • blade pitch angle 21/23^{O} (which corresponds to cruising RPM)	• no signs of fire impact • the propeller did not rotate when colliding with an obstacle • at the moment of collision with the ground the propeller blades were in feathered configuration

2.2.4. Summary of the technical analysis

Based on the analysis of technical records, the results of complete teardown of the engines and assessment of their components, organoleptic tests combined with verification of dimensions and bench tests, it was justified to formulate the following conclusions:

- The aircraft was not used in accordance with its original design;
- Frequent take-offs, short flights with full power climb and fast descent caused by this change of the nature of operations resulted in excessive and accelerated wear of most of the powerplant components;
- Verva 98 automotive fuel was used, which the manufacturer defined **in a clear way** as unacceptable for operations - as the only permitted fuel for the engines manufacturer approved aviation grade fuel 100/130 minimum octane (effects - see page 28 of this report);
- Although there were no signs of detonations, the use of automotive gasoline contributed to both an increase in engine temperature and a reduction in powerplant performance;
- The condition of both engines indicates long-term operational negligence, primarily in the scope of required maintenance;
- The visible advanced wear of components of the pistons, crankshafts and camshafts indicates that the wear process was long-lasting and covered not less than a few hundred hours of engines operation;
- It can be assumed with a high probability that the repairs carried out on the engines, e.g. the replacement of the cylinder barrel or the replacement of entire cylinders were aimed only at removal of an immediate cause of the malfunction, and not at improving their general condition;

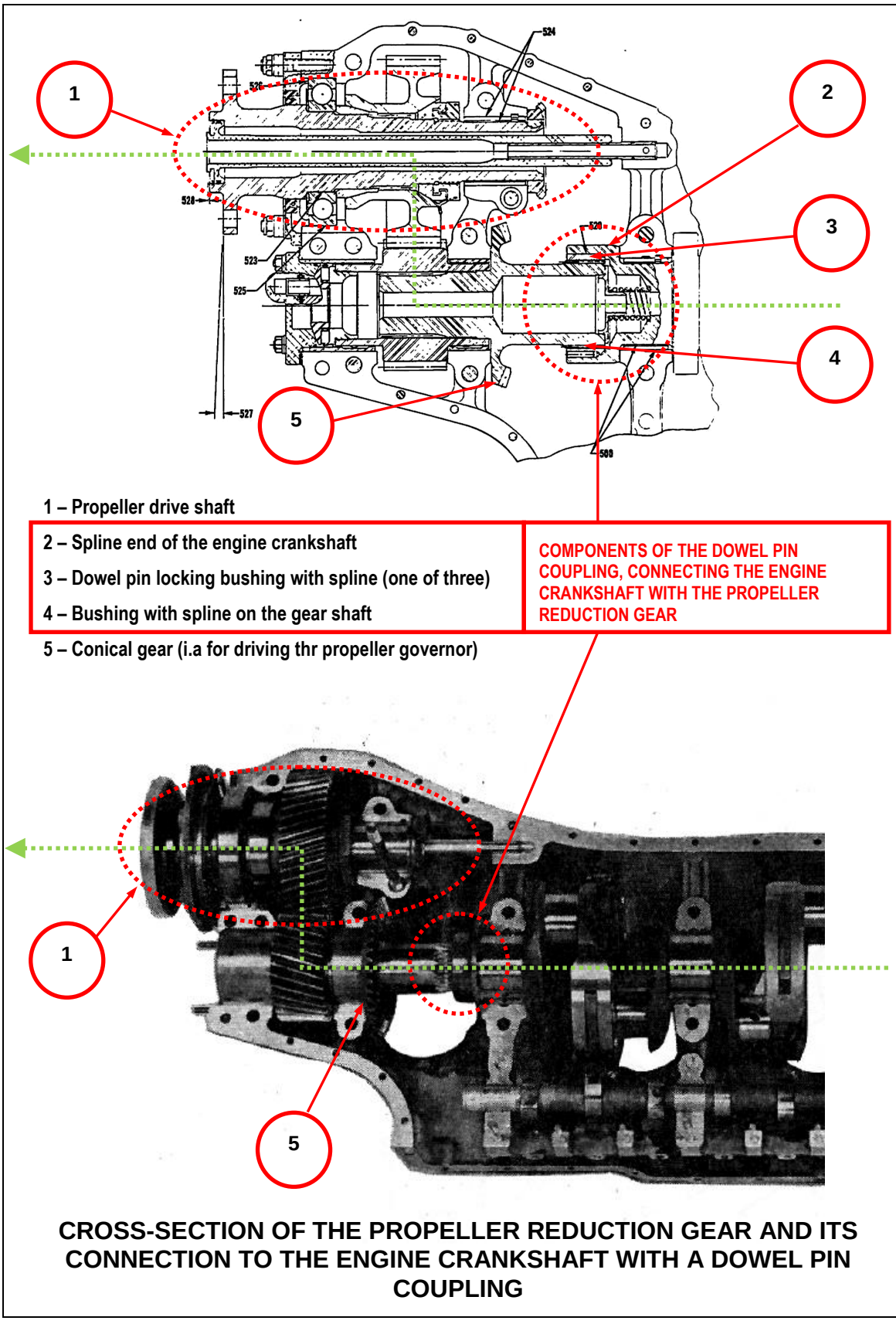
- The condition of the engines, as described in this analysis, significantly limited their performance (and thus the performance of the aircraft), contributed to the increase in fuel and oil consumption, influenced the combustion process, including the running smoothness;
- **The nature of destruction of the longitudinal dowel pin coupling in the right-hand propeller drive indicated that the transmission of torque from the engine to the gear had been interrupted, and as a consequence, the right propeller suddenly lost drive, which caused the asymmetry of the propulsion system as a whole.**

2.2.5. Cause-effect analysis of the powerplant failure

The cause-and-effect analysis is illustrated by the power flow through the aircraft powerplant (marked with the green dotted line in Figure 31). The figure shows the cross-section of the propeller reduction gear, which is located in the front of the power unit (from the propeller side).

The transmission structure shown in Figure 31 combined with the propeller pitch control system allow to draw the following conclusions:

- **Disconnection of the dowel pin coupling (due to damage to the dowel pins) which connected the engine crankshaft with the propeller reduction gear prevented transmission of power to the propeller and to the propeller governor.**
- **As a consequence of the above disconnection the propeller lost its drive and its blades were automatically feathered.**

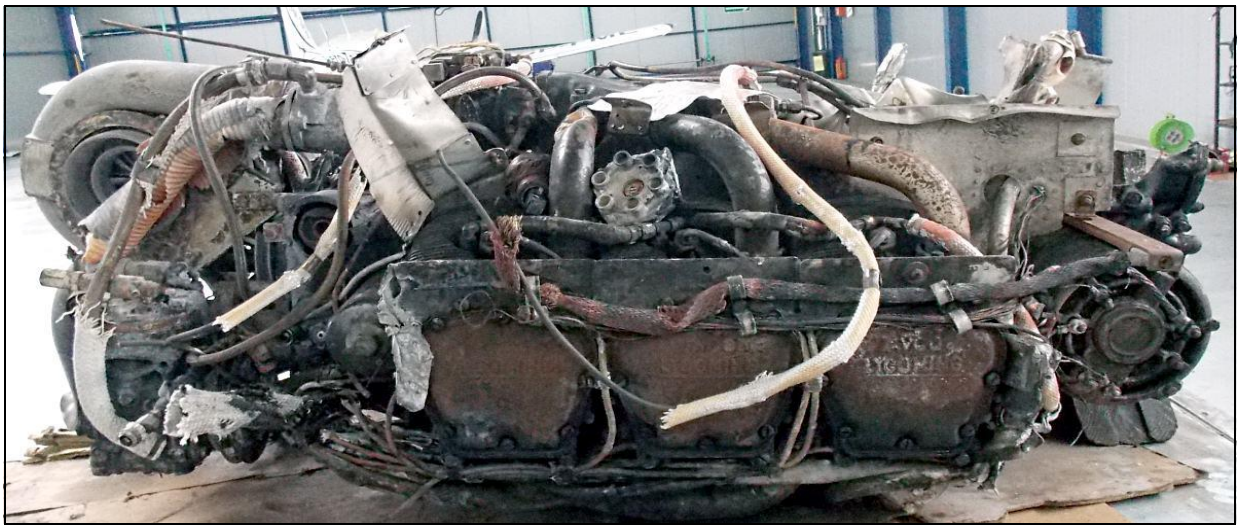


31 - Cross-section of the propeller reduction gear in the AVCO-Lycoming TIGO-541-E1A engine

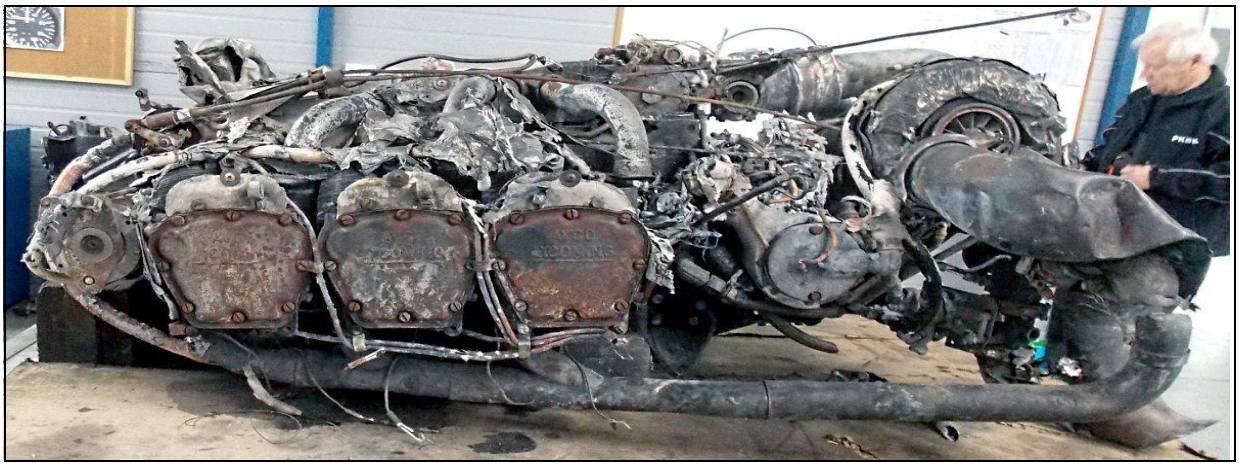
2.2.6. Presentation of the engines (condition in the course of teardown)

32 – LH engine, right side

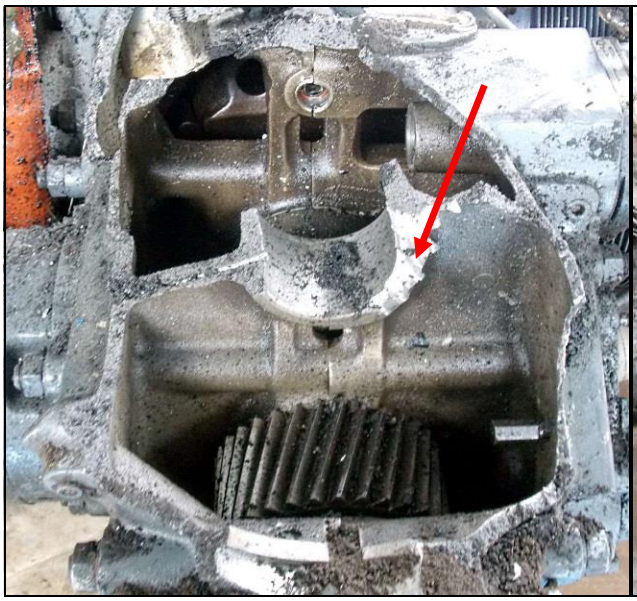
33 – LH engine, left side [photo. Marian Sławiński]



34 - RH engine, right side

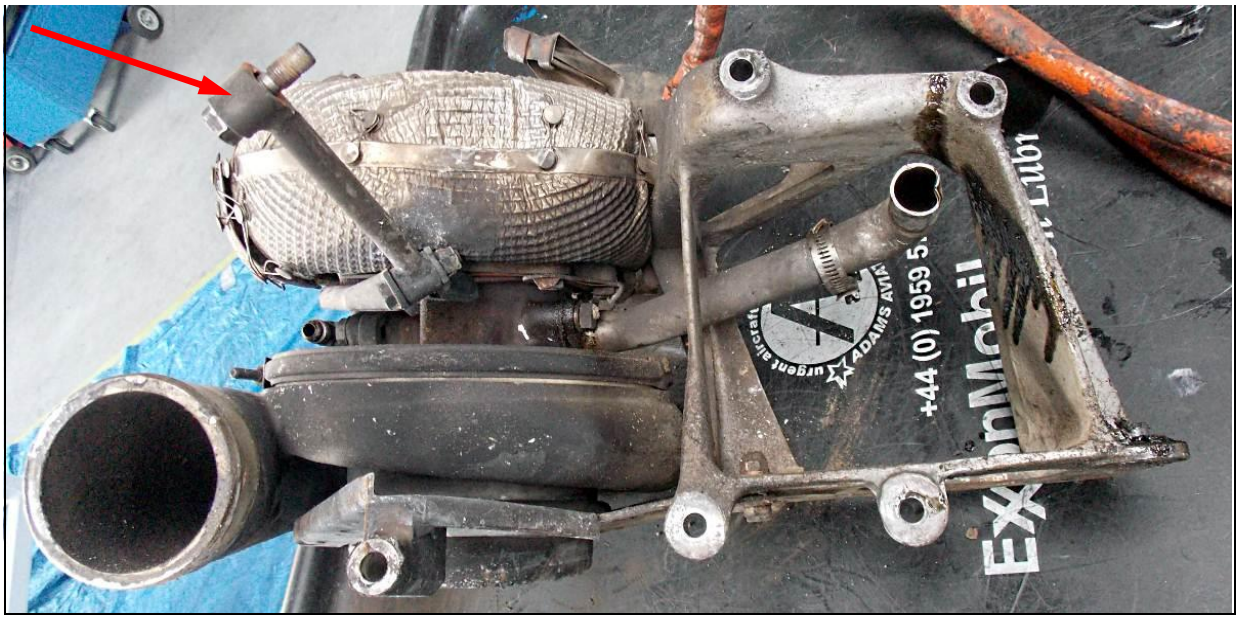


35 - RH engine, left side



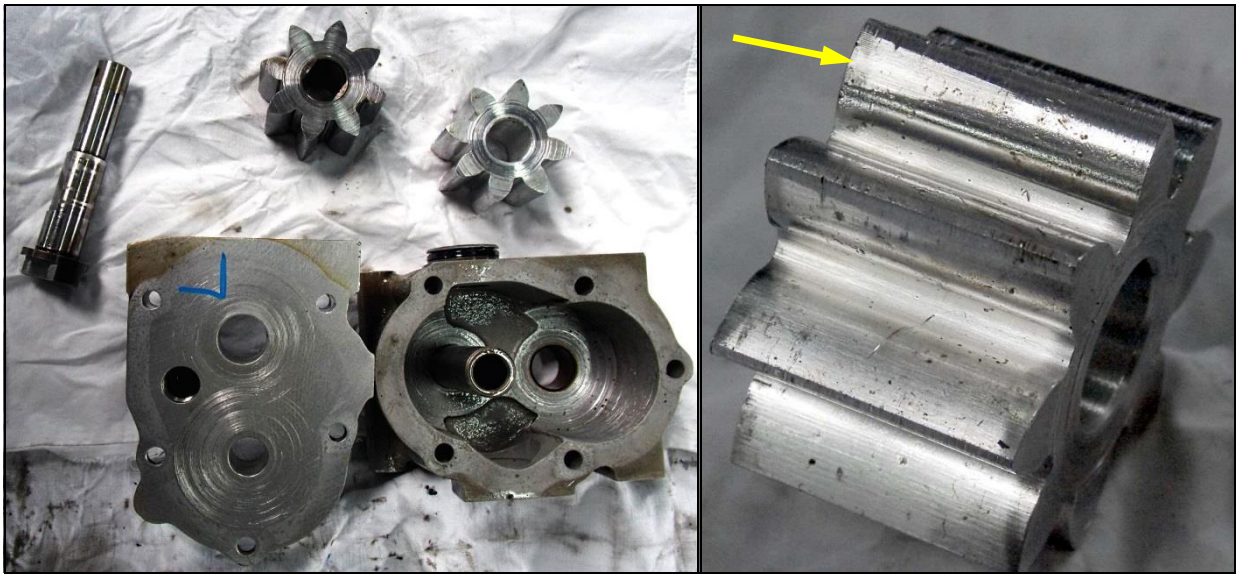
36 – Forward part of the LH engine block – visible fracture of the gearbox casing after separation of part of gearbox. The arrow indicates the dents made by toothed wheel of the gearbox detached together with the propeller

37 - Front the RH engine block – visible fracture of the gearbox casing after separation of part of gearbox and signs of the intensive fire effects

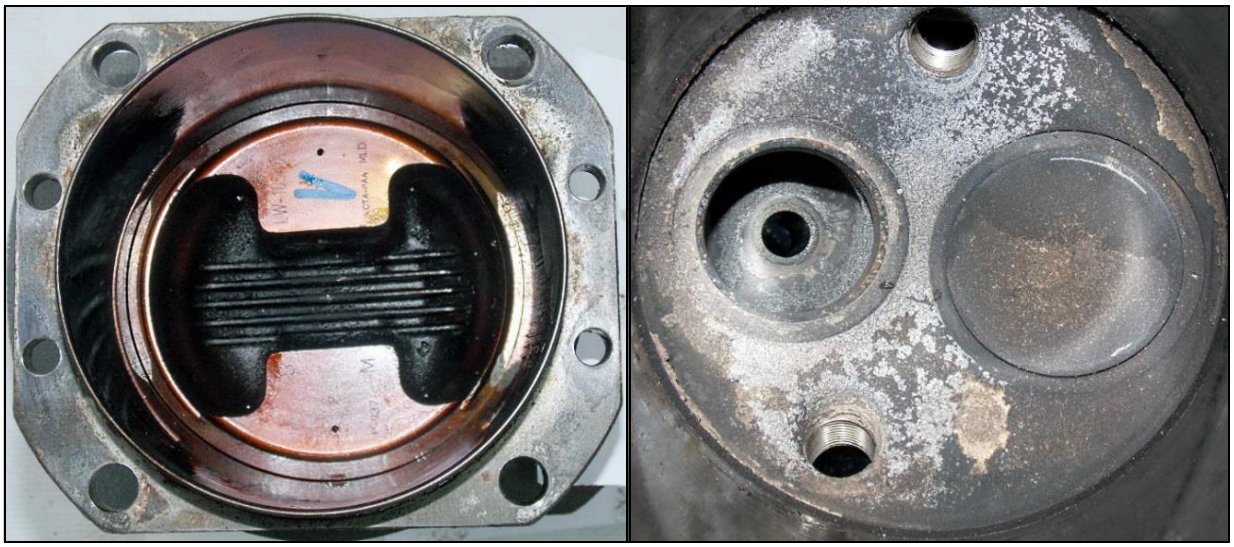


38 – Turbocharger assembly after removal from the LH engine. The arrow indicates a brace with a screw bolt (one of the turbocharger fittings to the engine, the screw bolt shown in a close-up below in the illustrations 39 and 40).

39, 40- The end of the LH engine turbocharger brace with a significantly ovalized hole and substantially damaged screw bolt mating with this hole. The condition of both components showed that the process of their degradation was long-lasting, caused by vibrations and not detected for a long time.



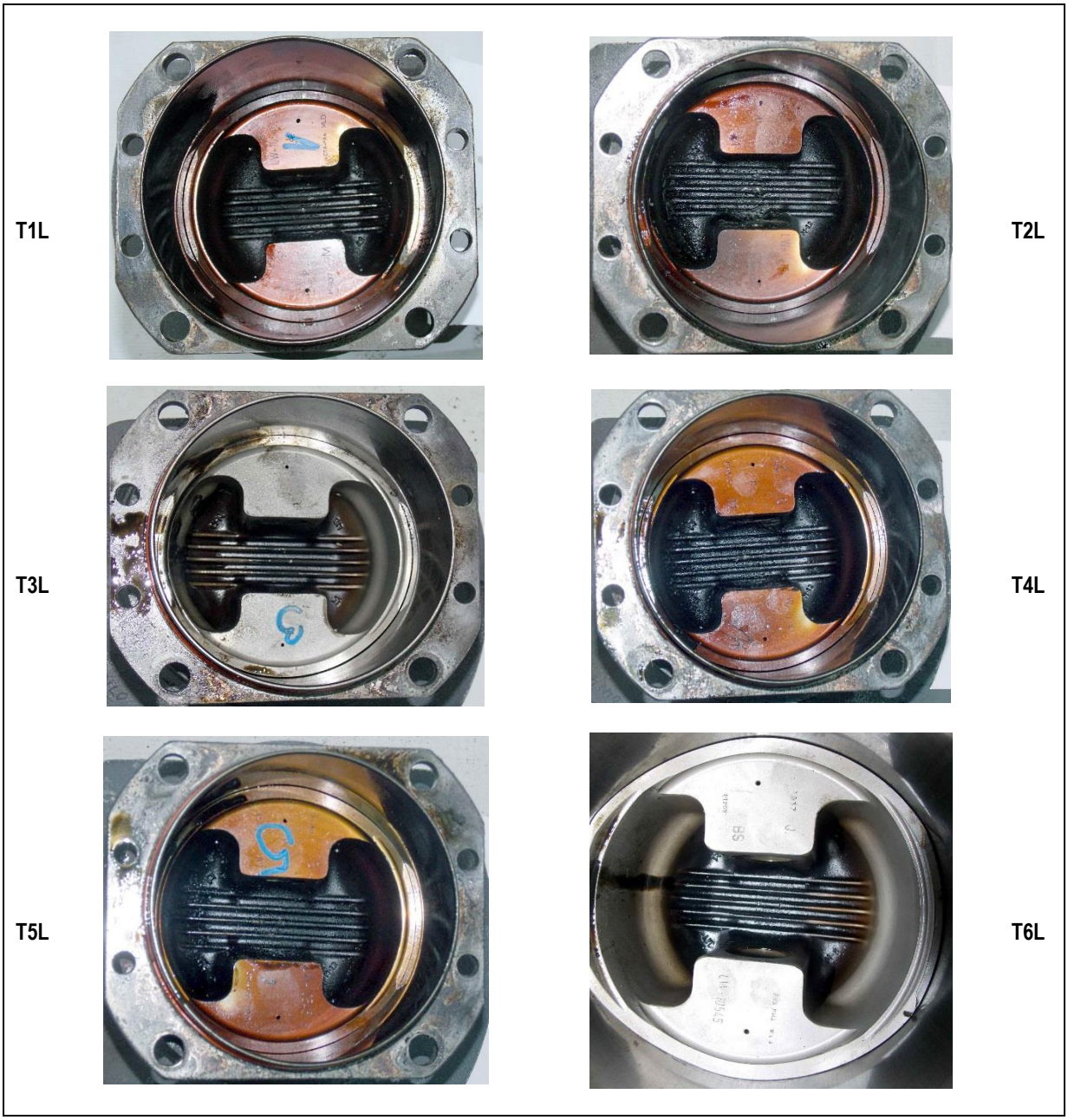
41, 42 - LH engine oil pump with visible scratches on the inside surfaces and close-up on the damaged impeller.



43, 44- Cylinder No 1 with the piston inside removed from the LH engine and a view of the cylinder head inside after removal of the piston, visible exhaust valve and intake valve seat.

45, 46- Intake valve removed from cylinder No. 1 of the LH engine. Clearly visible condition of the headl surface and significant sediment on the stem side.

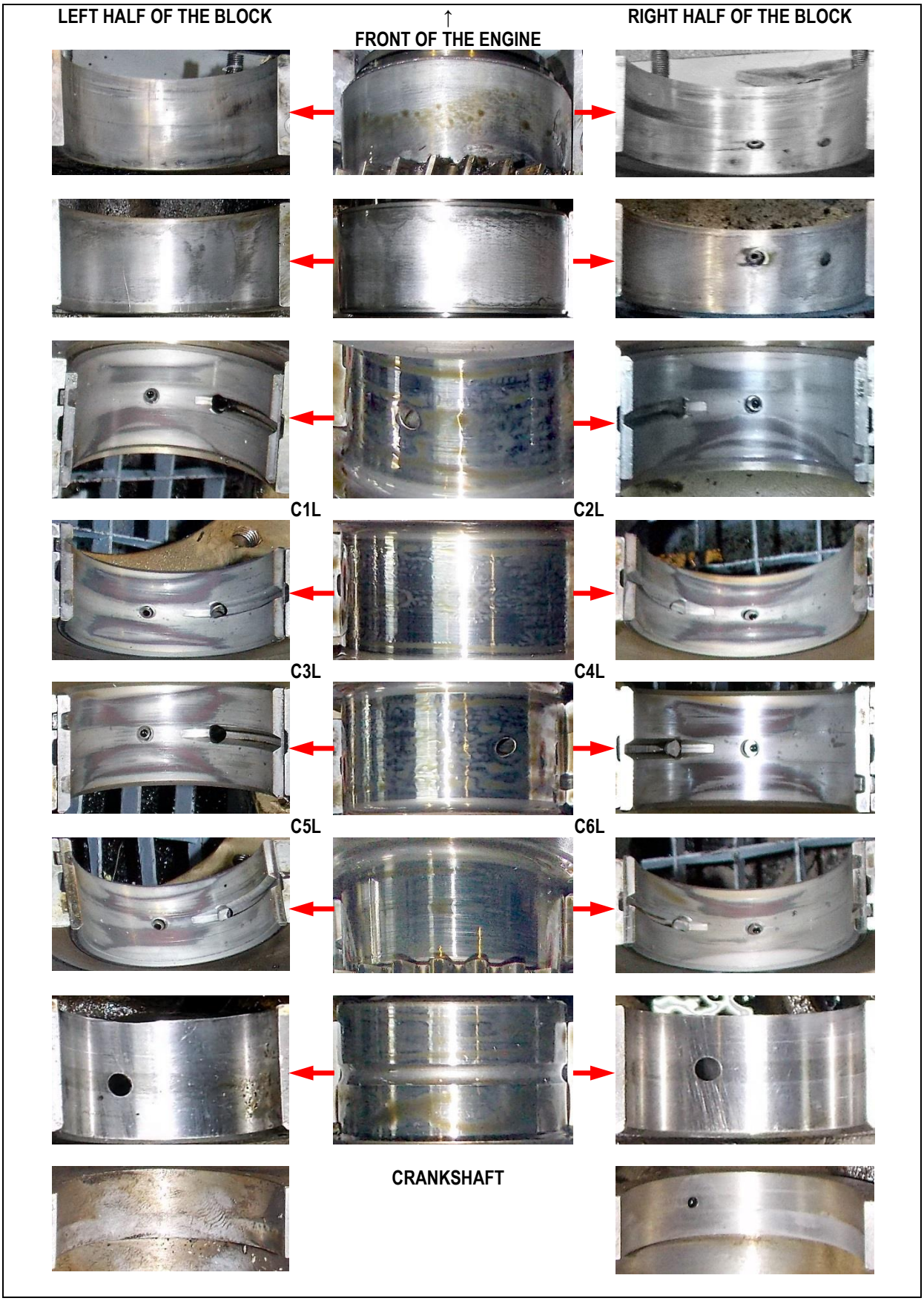
47 - LH engine block disassembled - in the foreground the right half of the block with crankshaft and camshaft.



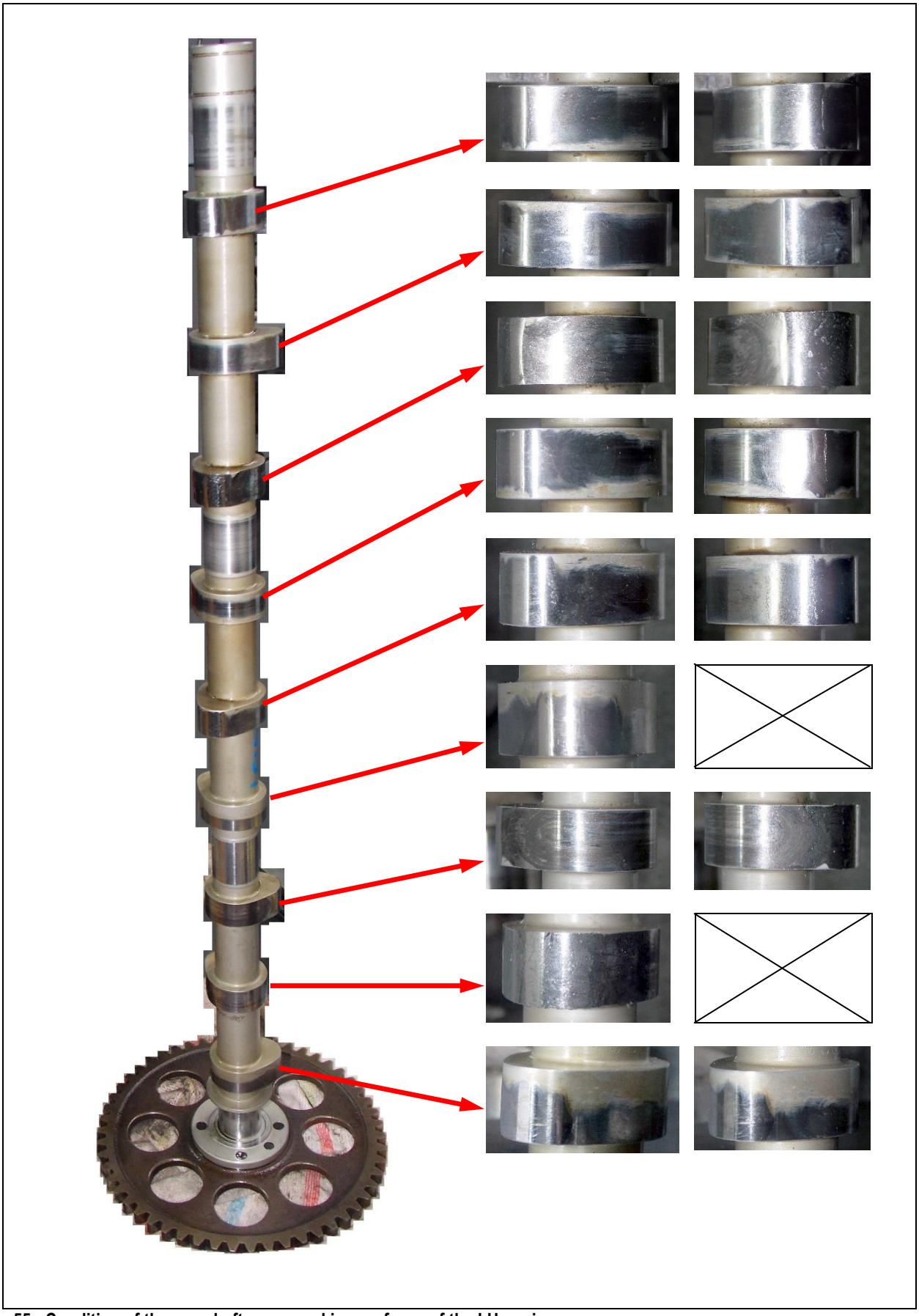
48 - Condition of the lower surfaces of pistons in the LH engine - pistons in cylinders.

49, 50- Components and parts of the RH engine after disassembly.

51, 52, 53- Spark plugs removed from the LH engine.



54 - The condition of the working surfaces of the crankshaft journals and the corresponding surfaces of the journal bearings in the LH engine block. Marked location of the cylinders relative to the journals and bearings.



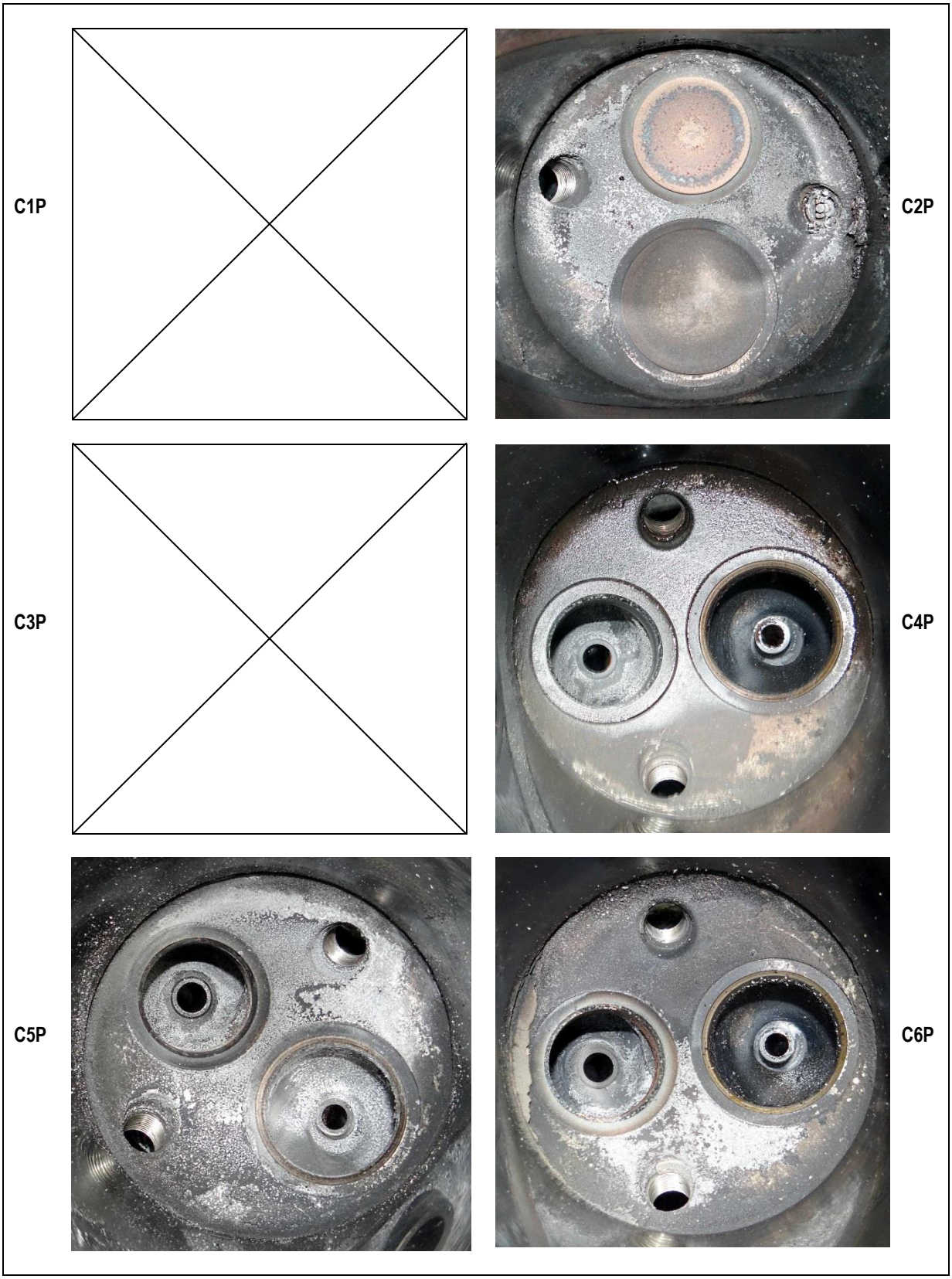
55 - Condition of the camshaft cams working surfaces of the LH engine

Cylinder No 1L			**Cylinder No 2L**
INTAKE			**INTAKE**
EXHAUST			**EXHAUST**
Cylinder No 3L			**Cylinder No 4L**
INTAKE			**INTAKE**
EXHAUST			**EXHAUST**
Cylinder No 5L			**Cylinder No 6L**
INTAKE			**INTAKE**
EXHAUST			**EXHAUST**

56 - Condition of the head surfaces of the hydraulic lifters from the LH engine.

57, 58– Components and parts of the RH engine after disassembly.

59 - RH engine oil pump - visible scratches on the inside surfaces.

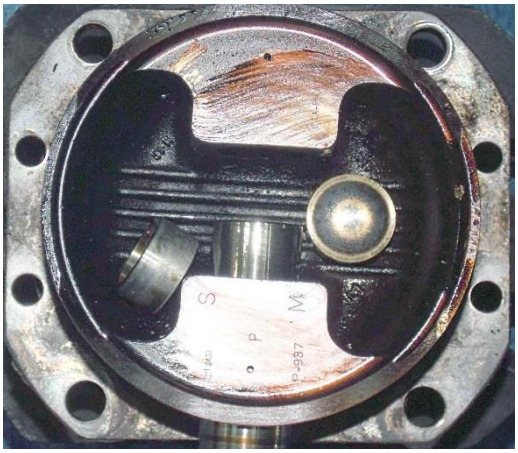


60 – The condition of some cylinder heads, valve seats and valves from the RH engine.

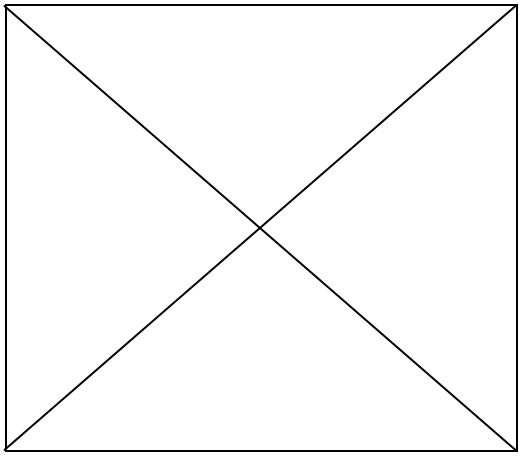
61 – Valves heads of cylinder No 1 of the RH engine. Left - intake valve, right – exhaust valve.

62 - The condition of the head and side surfaces of some pistons from the RH engine.

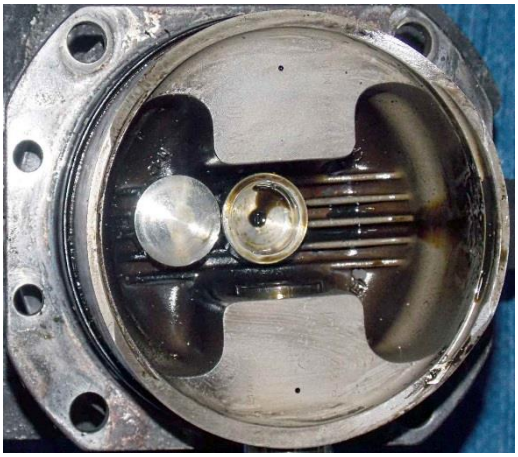
T1P



T2P

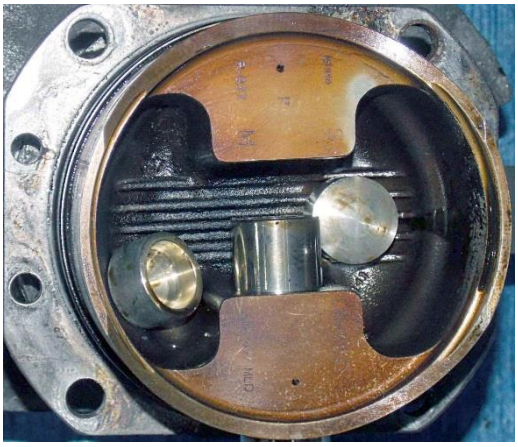


T3P

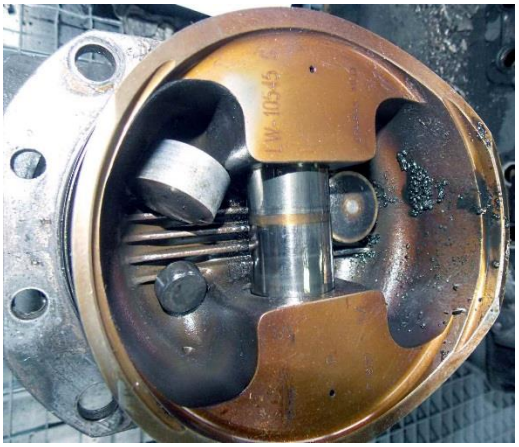


T4P

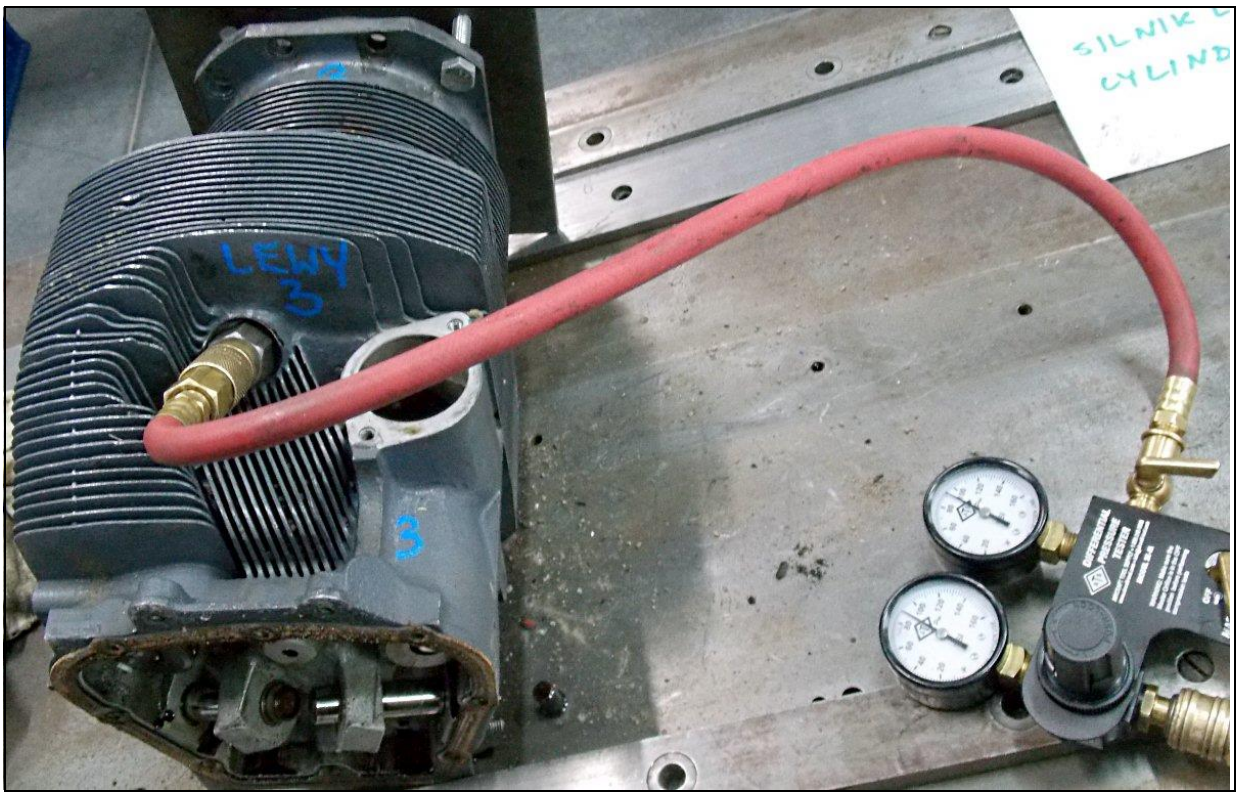
T5P



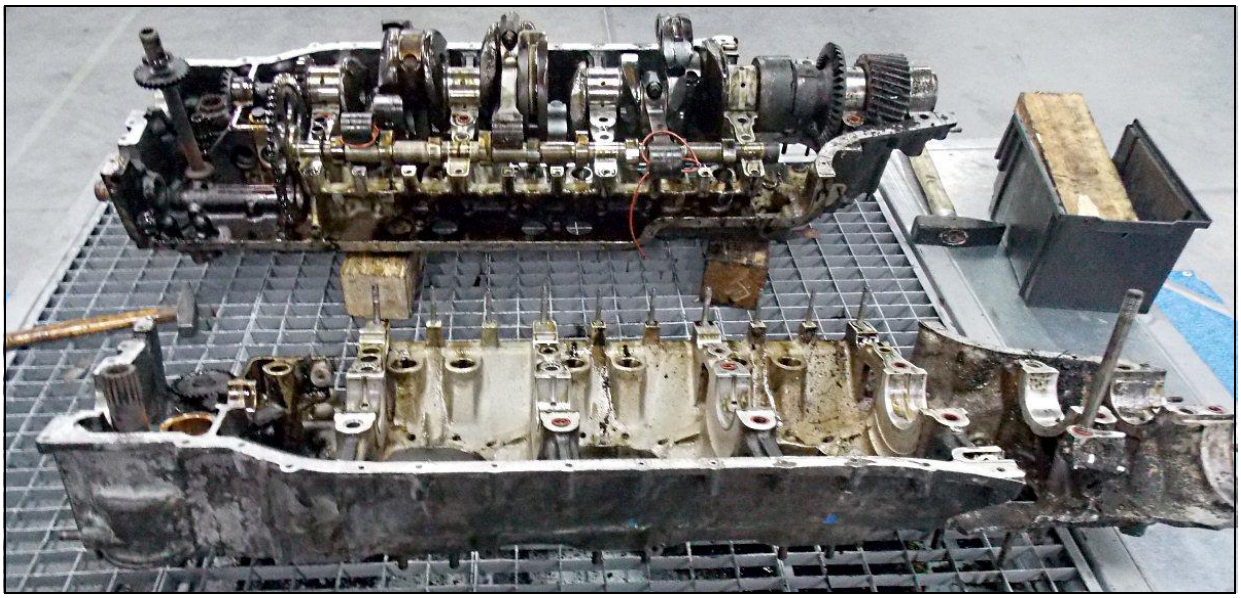
T6P



63 - Condition of the lower surfaces of pistons from the RH engine.

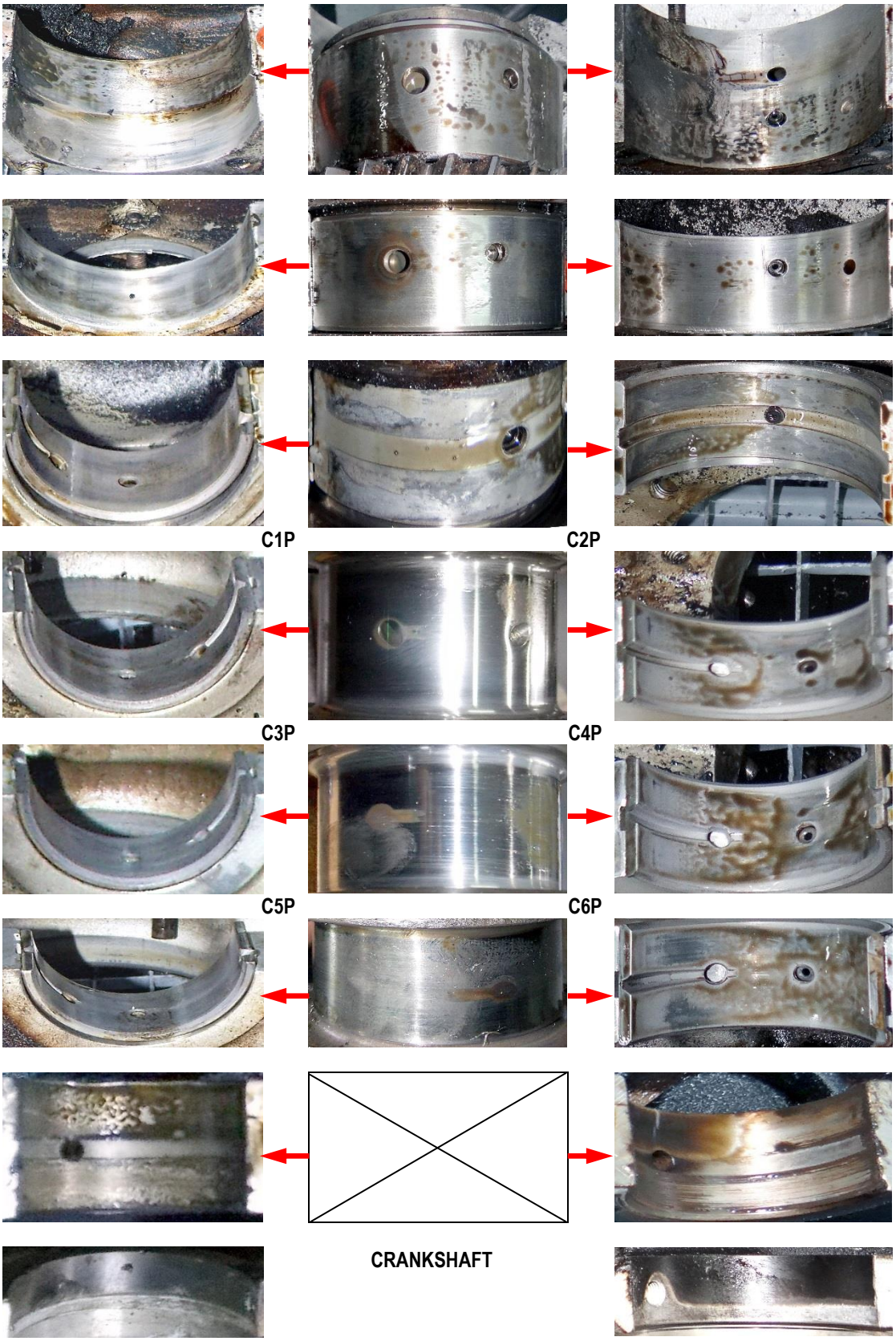


64 – Checking the cylinder-piston-valve assembly for tightness (cylinder removed from engine).



65 - RH engine block disassembled - in the foreground the right half of the block, behind the left half with the crankshaft and camshaft.

LEFT HALF OF THE BLOCK ↑ **RIGHT HALF OF THE BLOCK**
FRONT OF THE ENGINE



66 - The condition of the working surfaces of the crankshaft journals and the corresponding surfaces of the journal bearings in the RH engine block. Marked location of the cylinders relative to the journals and bearings.

Tables with measurement results

Table 1
Measurements of cam throw of the LH and RH engine camshafts (see Figure 55)

LH engine		RH engine	
Cam No	**Throw [mm]**	**Cam No**	**Throw [mm]**
1	**43,23**	**1**	**43,20**
2	**41,90**	**2**	**43,20**
3	**43,00**	**3**	**43,18**
4	**43,15**	**4**	**43,17**
5	**43,12**	**5**	**43,12**
6	**43,08**	**6**	**43,12**
7	**42,40**	**7**	**43,11**
8	**43,18**	**8**	**43,18**
9	**43,13**	**9**	**43,20**

Table 2
Measurement of cylinder tightness with differential method, at the pressure of 80 psi and top dead center piston position

LH engine		RH engine	
Cylinder No	**Pressure [PSI], Remarks**	**Cylinder No**	**Pressure [PSI], Remarks**
1	**18** Leak at exhaust valve and rings	**1**	**51**
2	**10** Leak at both valves and rings	**2**	**59**
3	**19** Leak at exhaust valve	**3**	**42**
4	**16** Leak at both valves	**4**	**62**
5	**20** Leak at intake valve	**5**	**18**
6	**18** Leak at both valves	**6**	**24**

Table 3
Measurements of cylinder tightness with differential method, at the pressure of 80 psi and top dead center piston position, bench test, cylinders warmed up (150^0 C).

LH engine		RH engine	
Cylinder No	**Pressure [PSI], Remarks**	**Cylinder No**	**Pressure [PSI], Remarks**
1	**36** Leak at exhaust valve	**1**	Leak at exhaust valve
2	**44** Leak at rings	**2**	**30**
3	**48** Leak at rings	**3**	**55**
4	**34** Leak at rings	**4**	**60**
5	**44** Leak at intake valve and rings	**5**	Leak at intake valve and rings
6	**38** Leak at rings	**6**	**27**

3. CONCLUSIONS

3.1. Commission findings

1) The Pilot-in-Command (PiC) had a valid CPL(A) with a valid MEP(L) rating and a valid medical assessment, which authorized him to fly parachute operations.
2) The Commission did not find any certificate as well as no entry in the PiC's book related to training for the type of the accident airplane.
3) PiC's blood test did not show the presence of ethanol or psychoactive substances.
4) The aircraft was purchased in April 2014 by a Polish business entity (broker - ChartAir sp.z o.o., Warsaw) and brought to Poland by flight.
5) The sale of the aircraft was reported by the previous owner to the FAA for the purpose of flying the aircraft to the State of purchaser without removal from the USA civil aircraft register.
6) On 23 April 2014, the FAA issued a provisional aircraft registration certificate (for existing registration marks N11WB), valid until 23 May 2014.
7) Operation of the aircraft in Poland by the OMEGA Parachute School (as a lessee) was undertaken without re-registration of the aircraft and was continued despite the expiration of validity of the provisional registration certificate issued by the FAA on 23 April 2014.
8) On the day of the accident (5 July 2014), the USA provisional certificate of aircraft registration issued by FAA was not valid - its validity expired on 23 May 2014.
9) The operation of the aircraft in the USA was irregular, the validity of its registration was periodically suspended, and it was used as a bank pledge by numerous previous owners.
10) The total flight time of the aircraft from the moment of handing it over to the Polish purchaser to the time of the accident can be estimated at about 100 flight hours (including transatlantic flight).
11) At the time of the sale and flight to Poland, the airworthiness of the aircraft was confirmed by the Certificate of Airworthiness issued for indefinite period of time by the FAA on 28 May 1976, and the entry confirming annual

inspection of the airframe, engines and propellers effected in the USA on 19 July 2013 by InterstateTurbine Management (North Charleston, SC).

12) On the day of the accident, the Airworthiness Certificate issued for indefinite period of time by the FAA on 28 May 1976 was not valid due to failure to comply with its conditions (expiration of the deadline for temporary registration of the aircraft in the USA and adaptation of the aircraft which breached its Type Certificate).

13) Aviation insurance was concluded for the period from 6 June 2014 to 31 March 2015.

14) In the second half of May 2014 in Poland the aircraft was modified into a 12-seat variant for parachute operations.

15) It was not possible to determine what documentation was used for the abovementioned adaptation (such scope of adaptation should be specified in the Supplemental Type Certificate approved by FAA).

16) After the adaptation for parachute operations the operation of the aircraft was very intensive (the nature of parachute operations requires energetic control of engine power, which is not recommended in the Flight Manual of the accident aircraft).

17) The accident flight was performed for OMEGA Parachute School, which was the user / lessee of the aircraft.

18) The accident flight was carried out according to VFR, the pilot did not file the flight plan prior to the take-off (it was not required).

19) Incorrect fuel was used for the airplane - at the moment of the take-off for the accident flight about 120 liters of Verva 98 automotive gasoline was in the aircraft tanks instead of 100/130 aviation gasoline. The manufacturer explicitly warns that the use of fuel other than recommended could cause mechanical damage to the engine.

20) Powerplants working on automotive fuel had worse performance, which was reflected in the aircraft performance.

21) Both the aircraft and its engines were neglected in the process of their long-term operation prior to bringing the aircraft to Poland, which adversely affected their performance; incorrect operation in Poland deepened the effects of those neglects.

22) As a result of the failure of the right powerplant, an abrupt asymmetry of thrust occurred, leading to a sudden loss of stability, which resulted in limitation and subsequently loss of control.

23) The analysis of the powerplant configuration on the accident aircraft showed that its RH engine is a critical engine.

24) At the time of loss of control, the aircraft was at a height of about 100 m AGL.

25) As a result of stalling and loss of control, the aircraft entered the right autorotation (towards the critical engine) and until the collision with the ground made about 270 deg rotation around its longitudinal axis.

26) Probably at the beginning of the uncontrolled phase of flight a displacement of the skydivers along the cabin occurred (due to the way they were sitting and the lack of seat belts or handles), which could have resulted in an adverse displacement of the center of mass of the aircraft.

27) The aircraft collided with obstacles and the ground after about 270° roll to the right, with the left bank about 70° and about 40-50^{o} nose down pitch.

28) At the time of the collision with the ground the right propeller did not rotate (or rotated at minimum speed) and its blades were in feathered configuration.

29) At the time of collision with the ground the left propeller was rotating, however, it received much lower power than the rated power of the engine.

30) The pilot and 10 other perons on board died at the scene as a result of injuries suffered during the collision with the ground and fire.

31) No earlier occurrences in Poland affecting the safety of flights of the accident aircraft were reported to SCAAI, which resulted in the lack of their analysis (they involved, inter alia, stoppages of its engines in flight).

32) Weather conditions had an impact on the occurrence of the accident due to high ambient temperatures (reducing the performance of the powerplants due to a decrease in thermodynamic efficiency and lowering the aerodynamic performance of the airframe due to a decrease in air density).

3.2. Causes of the accident

During the investigation SCAAI determined the following causes of the accident:

1. **Operation of the aircraft without a valid Airworthiness Certificate.**
2. **Damage and destruction of the dowel pin coupling, what resulted in disconnection of the right engine crankshaft with the drive shaft of the propeller gear and made the right propeller inoperative and prevented operation of the propeller governor, which caused feathering the propeller blades. The above failures resulted in asymmetry of thrust leading to stall of the aircraft and loss of its controllability.**

   Damage to the dowel pin coupling could have been caused by:

   - **an earlier impact of the propeller with an obstacle in circumstances and time which was impossible to determine;**
   - **a long-term fatigue process due to engine roughness (one of the cylinders in this engine was replaced).**
3. **Stall in the last phase of the emergency landing.**

Factors contributing to the occurrence were:

a) Improper maintenance of the aircraft;

b) Drop in power of the left engine due to its improper use;

c) Use of fuel which did not comply with the requirements of the engine manufacturer;

d) Modification of the aircraft in violation of its Type Certificate;

e) Meteorological conditions - high ambient temperature.

4. SAFETY RECOMMENDATIONS

After analysis of the materials collected during the investigation, SCAAI proposed one safety recommendation to be implemented by the Civil Aviation Authority of Poland:

1. Strengthen oversight and detail procedures for supervision of aircraft registered in other countries but used in Poland for commercial/aviation operations, in particular those used for training skydivers and transporting other kinds of passengers.

5. ANNEXES

1. Album of Illustrations

THE END

Investigator-in-Charge

Andrzej Pussak