SOUTH AFRICAN CIVIL AVIATION AUTHORITY

Section/division **Accident and Incident Investigations Division** Form Number: CA 12-12a

AIRCRAFT ACCIDENT REPORT AND EXECUTIVE SUMMARY

				Reference:	CA18/2/3/9711		
Aircraft Registration	**ZU-FFA**	**Date of Accident**	12 May 2018		**Time of Accident**	0730Z	
Type of Aircraft	Zodiac CH601 HD (Aroplane)		**Type of Operation**		Private (Part 94)		
Pilot-in-command Licence Type		National Pilot Licence	**Age**	43	**Licence Valid**	No	
Pilot-in-command Flying Experience		Total Flying Hours	265,12		Hours on Type	20,8	
Last point of departure	Panorama AerodromeAerodrome, Gauteng Province						
Next point of intended landing	Rand Aerodrome (FAGM) Germiston, Gauteng Province						
Location of the accident site with reference to easily defined geographical points (GPS readings if possible)							
260 meters from the threshold of runway 11 at FAGM, (GPS position 26°14'33.06" South 028°8'16.84" East at an elevation of 5383 ft AMSL.							
Meteorological Information	Surface wind 350° variable between 330° and 030° at 10 kt, temp 17 °C, dew point 3 °C,CAVOK						
Number of people on board	1+0	**No. of people injured**	1		**No. of people killed**	0	
Synopsis							

A pilot, being the sole occupant on board the aircraft, departed from Panorama aerodrome on a ferry flight to FAGM. The flight was conducted under visual flight rules (VFR). Good weather conditions prevailed at the time leading up to the accident. According to the air traffic control (ATC) transcripts, the pilot reported his position while he was overhead Silver Ball (GPS 26°15'24.47" 028°04'53.99", which is located 3.29 nm from the threshold of runway 11 at FAGM. The ATC cleared the pilot to join on a left base for runway 35. The pilot acknowledged the transmission and reported that he would join on a left hand downwind for runway 35. He also stated that he had radio problems.

According to the transcripts, there were two aircraft in the circuit, when suddenly the tower spotted ZU FFA on finals for runway 11. The tower advised the other traffic to remain south of runway 11, as aircraft ZU-FFA was approaching runway 11. The ATC further cleared and gave priority to ZU-FFA to continue approach on runway 11. There was no reply from ZU-FFA, and the ATC observed it disappearing before the threshold of runway 11. The ATC requested one of the aircraft that had been requested to hold to the south to fly over the area and look out for ZU-FFA on the ground. The aircraft reported that ZU-FFA was on the ground short of runway 11 with a person standing next to it. The aircraft was substantially damaged. The pilot sustained serious injuries to his left shoulder.

During an interview with the pilot he revealed that after take-off from FAVV the aircraft experienced radio problems. He then diverted to Panorama aerodrome in order to get the radio rectified. The pilot stated that he called the authorised person (AP) and informed him of the situation, and the AP came and brought him a hand-held radio. The pilot stated that he then took-off from Panorama aerodrome and flew to FAGM. As he was abeam theGosforth offramp toll gate the engine stopped. He did not attempt a restart but continue with a forced landing short of threshold of runway 11.

Investigation revealed that the aircraft executed unsuccessful forced landing on grass short of runway 11 following an inflight engine stoppage due to fuel starvation, which was attributed to a vapour lock inside the fuel pipes.

Probable Cause

Engine stoppage in flight resulting in an unsuccessful forced landing.

Contributory factors:

Fuel starvation due to vapour lock developed inside the fuel pipes.

Fuel lines running close to exhaust pipe.

Fuel lines not shielded against local heat from exhaust pipe.

Fitting of an engine not recommended by the manufacturer which resulted in modification of the fuel system and a propeller.

Use of aluminium pipes interconnecting the two pumps and non-aviation-standard fuel hose.

SRP Date	12 February 2019	Release Date	17 April 2019

Name of Owner	**: Coenraad de Beer**
Name of Operator	**:** Jaco Neethling
Manufacturer	**:** Zenith Aircraft
Model	**:** Zodiac CH 601 HD
Nationality	**:** South African
Registration Marks	**:** ZU-FFA
Place	**:** Rand Aerodrome (FAGM)
Date	**:** 12 May 2018
Time	**:** 0730Z

All times given in this report are Coordinated Universal Time (UTC) and will be denoted by (Z). South African Standard Time is UTC plus 2 hours.

Purpose of the Investigation:

In terms of Regulation 12.03.1 of the Civil Aviation Regulations (2011), this report was compiled in the interest of the promotion of aviation safety and the reduction of the risk of aviation accidents or incidents and ***not to apportion blame or liability.***

Disclaimer:

This report is produced without prejudice to the rights of the CAA, which are reserved.

1. FACTUAL INFORMATION

1.1 History of Flight

1.1.1 On Saturday 12 May 2108 at 0620Z the pilot, being the sole occupant on board the aircraft, took off on a ferry flight from Vereeniging aerodrome (FAVV) with the intention to land at Rand Airport (FAGM). The flight was conducted under the provisions of Part 94. Fine weather conditions prevailed at the time leading to the accident.

1.1.2 The purpose of the flight was to ferry the aircraft to FAGM, where modification at an Aircraft Mantenance Organisation (AMO) was going to be carried out. According to the pilot's interview, he experienced radio problems during the cruise and elected to divert to Panorama aerodrome, where he collected a hand held radio.

1.1.3 The pilot then took off from Panorama and continued with the flight to FAGM. He then contacted the tower and stated that he was at Silver Ball and experiencing radio problems. The tower advised him to join on a left base for runway 35, which he didn't acknowledge. He further stated that when he was overhead the industrial area near Gosforth ramp toll plaza at a height of 6500 feet above mean sea level (AMSL), the engine started spluttering and losing power. He adjusted the mixture, but the engine was still losing power. Shortly after the engine splutter, the engine shut down. The pilot further stated that when he realised that he would not make it to runway 35, he elected to turn the aircraft and aim

for the spot that he identified to carry out an emergency landing on an open field short of runway 11. He noted that the indicated airspeed was ±110 kts when the engine stopped.

1.1.4 According to the ATC transcripts the pilot did not broadcast any distress call (i.e., MAYDAY call or a PAN-PAN). The ATC cleared the aircraft to continue with final approach for runway 11. During this transmission there was no response from the pilot. The ATC stated that the aircraft was seen on final approach and then disappeared during short final approach for runway 11. The ATC requested a helicopter that was in a circuit to fly overhead and look for ZU-FFA on the ground. The helicopter pilot reported back that they had the aircraft visual on the ground with a person standing next to it. ATC then activated the crash alarm and the aerodrome rescue and fire-fighting (ARFF) personnel proceeded to the accident site. According to ARFF personnel, when they arrived at the scene they found the pilot standing next to the aircraft. They also stated that fuel was leaking from the tank.

1.1.5 The aircraft was substantially damaged during the accident sequence as it came to rest in an inverted attitude. The pilot sustained injuries and was transported to hospital by road ambulance for further medical check up.

1.1.6 During interview with the pilot, he stated that when he was overhead Gosforth toll plaza the engine started running rough and shortly thereafter the engine stopped. The aircraft started to lose height rapidly. He then elected to land on an open field across on the extended centre line of runway 11. The pilot stated that it was not possible to glide the aircraft to runway 11 due to insufficient height. After realizing that the aircraft was going to undershoot the runway, he then committed to a forced landing in an open field. He further stated that he turned sharply 90° to the left and did an emergency landing short of but perpendicular to the threshold of runway 11. He stated that the aircraft impacted the ground at very low forward speed. After touchdown the aircraft nosed over and came to rest in an inverted attitude. He stated that he managed to crawl out of the cockpit area unassisted and waited for the emergency personnel to arrive at the scene.

1.1.7 The accident occurred during daylight conditions at a geographical position that was determined to be 26°14'33.06" South 028°8'16.84" East at an elevation of 5383 ft above mean sea level (AMSL).

1.2 Injuries to Persons

Injuries	Pilot	Crew	Pass.	Other
Fatal	-	-	-	-
Serious	1	-	-	-
Minor	-	-	-	-
None	-	-	-	-

1.3 Damage to Aircraft

1.3.1 Substantial

Figure 1: Aircraft after impact.

1.4 Other Damage

1.4.1 No other damage was caused.

1.5 Personnel Information

Nationality	South African	Gender	Male	Age	43
Licence Number	0279023428	Licence Type	National Pilot		
Licence valid	No	Type Endorsed	Yes		
Ratings	None				
Medical Expiry Date	31 August 2019				
Restrictions	None				
Previous Accidents	None				

Flying Experience:

Total Hours	265,12
Total Past 90 Days	3,41
Total on Type Past 90 Days	1,1
Total on Type	20,8

Note: According to the pilot training file, the pilot did his initial training on a weight shift controlled microlight (WCM) in 2013 and accumulated a total of 19,1 hours dual and 15,1 hours solo. The radiotelephony proficiency test was done in December 2013, after which the pilot was issued with a restricted radiotelephony licence. In December 2016 the pilot did a category rating for light sport

aircraft (LSA) and in May 2017 he applied for an initial recreational pilot licence and upon application he was issued with a national pilot licence.

It was noted that on 01 May 2017 the pilot applied for type rating for conventionally controlled microlight (CCM) as well light sport aircraft (LSA), and upon completion he was issued with a type rating on 01 May 2017 with expiry date of 30 April 2018 on the CCM. At the time of application for LSA on 01 May 2017, the pilot had accumulated a total of of 229,5 hours, of which 31,9 was dual flying.

CARs regulation part 62.03.06 states that: "*the holder of a national pilot licence shall not act as PIC of non-type certificated aircraft, unless he or she meets the maintenance of competency requirements prescribed in this Part for the type of aircraft for which he or she holds a valid category, class or type rating; and has complied with requirements of regulation 62.01.09.*"

1.6 Aircraft Information

Figure 2: Similar type aircraft (Picture courtesy of Zenith Aircraft Company)

Airframe:

Type	Zodiac CH 601 HD	
Serial Number	6-2368	
Manufacturer	Zenith Aircraft	
Year of Manufacture	2009	
Total Airframe Hours (At time of Accident)	102,00	
Last Annual Inspection (Hour and Date)	101,6	25 January 2018
Hours since Last Annual Inspection	0,4	
Authority to fly (Issue Date and expiry date)	25 January 2018	24 January 2019
C of R (Issue Date) (Present owner)	23 January 2018	
Operating Categories	Private Part 94	

Engine:

Type	Lycoming O-235
Serial Number	L-1343-15
Hours since New	102
Hours since Overhaul	TBO not reached yet

Note: According to the last page of the flight folio and defect report serial number 11 obtained at the accident scene, the aircraft last flew on 20 February 2017 with 20 litres of fuel on board. The aircraft flew a total of 1,3 hours with the total of 101,6 airframe hours. No defects were recorded in the flight folio.

The aircraft stood in the hangar for a period of 10 months. The Lycoming manufacturer requires operators/owners of Lycoming O-235 engines to carry out engine preservation in accordance with service letter L180B if the aircraft is not going to be used in the next 31 days. The airframe logbook contains no records of compliance with service letter L180B. The annual inspection was carried out on 25 January 2018 by an approved person, who subsequently issued a certificate of release to service. In the interview, the pilot stated that the fuel added to the aircraft was Mogas (automotive gasoline) fuel. Lycoming's Service Instruction 1070S dated 24 April 2013 for fuels to be used in Lycoming engines states that the automotive fuel approved for use in this engine is 93 AKI (octane level) and NB3 only.

A post-crash interview was conducted with the (AP) who last performed maintenance on the aircraft. He stated that there had been a previous occasion where another pilot had reported that the engine was running rough and there had been an emergency landing (which was successful). This occurrence was not documented in the aircraft's flight folio. The pilot in question requested the AP to clean the carburetor. The AP stated that the carburetor contained residue and sediments before he cleaned it. He further stated that the pilot in question wanted him to fit a bigger propeller on the aircraft. After he fitted the propeller it was discovered that the spinner could not fit properly; the back screws that attach the spinner could not be fastened due to the bigger propeller flange, which caused a misalignment. The AP requested the pilot to test the propeller by taxiing at high speed and returning after the taxi. The pilot taxied the aircraft and he witnessed him lining up on the runway. The pilot took off and completed three circuits overhead the aerodrome, then headed for FAGM. The AP stated that the pilot continued to fly to FAGM with the spinner that was not properly secured on the flange. This was evidenced on the wreckage after the crash.

According to pilot interview there had been a substitution of registration numbers and instruments between ZU-FFA and ZU-CNK. ZU-CNK was converted into ZU-FFA. According to the pilot, the original ZU-FFA was damaged by a hangar door and was transported to an AMO in Durban. During a site visit by the investigator at Springs aerodrome (FASI), it was found that the original ZU-FFA was parked in a hangar with the wings removed. The data plate for the aircraft could not be located;

however, it was noted that the aircraft had stickers with the registration ZU-CNK in the baggage compartment.

According Zenith Aircraft Company, all test and research on the aircraft was done with the Rotax 912 series engine. The fuel system that is supplied with the kit is for the Rotax 912 series engine. The other recommended engines to be fitted are Subaru and Jabiru engines. According to Zenith Aircraft Company, the use of engines other than those the manufacturer has recommended will require the owner to modify the fuel systems. The Rotax engine power output is rated at 80 hp at 5500 rpm. The Lycoming engine that was installed in this aircraft has a take-off power of 115 hp at 2800 rpm.

Note: Modifications 44.01.10(1)

(1) If a person intends to carry out any modifications, including changes to equipment or the installation thereof, which affect, or are likely to affect, the serviceability of the aircraft, or the safety of its occupants or any other persons or property, in relation to an amateur built aircraft or a production built aircraft—

(a) in the case of a minor modification a notification of the modification must be submitted to the Director, or the organisation designated for the purpose in terms of part 149, as the case may be, within 30 days of the modification being performed. All subsequent modifications shall be an amendment to the build standard;

(b) in the case of a major modification an application for the approval of the modification and authority to fly, as prescribed in Document SA-CATS 44, must be submitted to the Director or the organisation designated for the purpose in terms of part 149, as the case may be, before the modification has been performed.

(2) The application referred to in subregulation (1) must be accompanied by the appropriate fee as described in part 187.

(3) All approved modifications shall be entered into the appropriate logbook(s).

(4) An appropriately rated approved AMO, AME or approved person, rated in accordance with subpart 4 of part 66 shall sign in the appropriate logbook(s) that all procedures, as stated in the application for modification, were adhered to and that he or she is satisfied with the quality of the work which was carried out.

Note: SACAA technical guidance material

The SACAA technical guidance material for Amateur built aircraft states in par. 14 that “an amateur built aircraft is not a design approved product in terms of the CAA categorisation and as such all subsequent design changes are the responsibility of the amateur aircraft builder. Therefore, the amateur builder must carry out and certify modification and repair on the aircraft and is fully responsible for the modification and repair of such aircraft. This is supported by the feedback received from airworthiness.

The guidance further give a WARNING: AMATEUR- BUILT AIRCRAFT: THIS AIRCRAFT IS NOT REQUIRED TO COMPLY WITH ALL THE REGULATIONS FOR TYPE CERTIFICATED AIRCRAFT TO BE OPERATED FOR SPORT OR RECREATIONAL PURPOSES ONLY YOU FLY IN THIS AIRCRAFT AT YOUR OWN RISK.

The guidance material further guides that: **NOTE:** In view of the amateur-built aircraft not intended to comply with any prevailing airworthiness design standard, the classification of major or minor modification is not necessarily applicable.

Propeller:

Type	P Prop (fixed pitch wooden propeller) 69/54
Serial Number	N3938 FEG4R
Hours since New	Unknown
Hours since Overhaul	Unknown

Note: According to available information, the propeller with serial number N3173 FEC2G4 (64/48) was removed from the aircraft and was replaced with a P Prop propeller with serial number N3938 FEG4R. No documented evidence (i.e., logbooks, jobcards) were found relating to the removal and installation for these propellers. According to the AP, the previous owner requested the fitment of P Prop with serial number N3938 FEG4R. The AP further state that the size of the new propeller made it difficult for the spinner to fit properly around the flange area; the screws that attach the spinner could not be secured due to misalignment. This was evidenced on the aircraft after the impact.

Fuel System

The aircraft fuel system was modified with two electrical pumps that were connected in series via aluminium tubing similar to pipes used for hydraulic systems. The pumps were mounted on the forward fire wall with blind fasteners. It was discovered that the outlet pipe from the pump was a normal hardware rubber hose used and not a standard fuel hose, as seen in figure 2 below. In this modification both pumps, including the aluminium pipes, were not shielded against heat from the exhaust pipe.

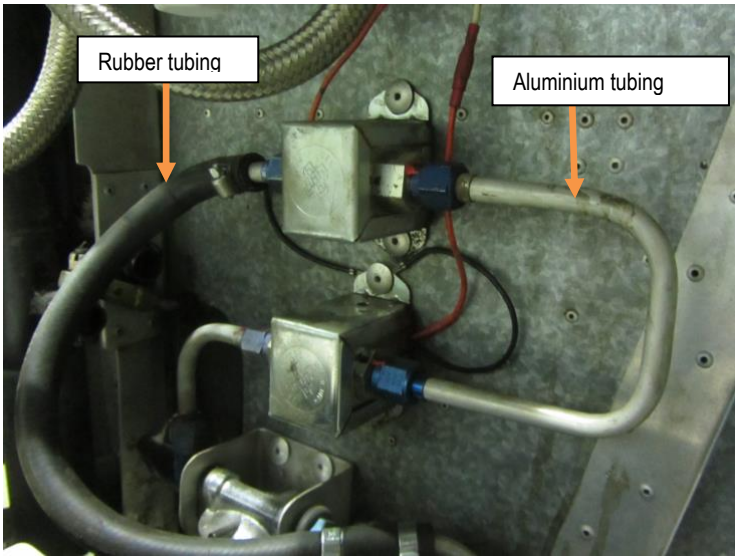

Figure 3: Fuel plumbing layout

1.7 Meteorological Information

1.7.1 An official weather report was obtained from the South African Weather Services (SAWS).

Wind direction	350° variable between 330° and 030°	Wind speed	10 kt	Visibility	9999 m
Temperature	17 °C	Cloud cover	N/A	Cloud base	N/A
Dew point	3 °C				

1.8 Aids to Navigation

1.8.1 The aircraft was equipped with the standard kit build navigational equipment approved by the regulator. No defects of this equipment were recorded prior to the flight. A portable navigation device was retrieved from the aircraft after the accident. On board the aircraft was a portable Garmin zumo 660 which is a device used in the automotive industry. The unit did not have a downloadable memory that could be used to extract data.

1.9 Communications

1.9.1 The aircraft was equipped with one VHF (very high frequency) radio, as approved by the regulator. According to the pilot statement, he reported that he was having radio problems en route to FAGM. He diverted to Panorama aerodrome in order to get the radio problem sorted out. The AP arrived from Vereeniging and gave the pilot a hand-held radio. The pilot took off and continued to FAGM using a hand held radio. According to available records (transcripts), the pilot contacted the tower when he was overhead Silver Ball. The tower cleared the aircraft to join left base runway 35. It was noted that the aircraft was fitted with a transponder, but the pilot failed to enter the code 7600, which is international standard to indicate that you are experiencing a communication failure on board the aircraft.

1.10 Aerodrome Information

Aerodrome Location	Germiston, Gauteng	
Aerodrome Coordinates	26°14'31.12" South 028°9'04.88" East	
Aerodrome Elevation	5483 feet	
Runway Designations	11/29	17/35
Runway Dimensions	1714x15	1463x15
Runway Used	11	
Runway Surface	Asphalt	
Approach Facilities	VOR/DME	

Note: The following NOTAM was issued for FAGM:

C3332/18 NOTAMN Q) FAJA/QNMAS/IV/BO/A/000/999/2615S02809E025 A) FAGM B) 1809130847 C) 1812100900 EST E) VOR/DME RAV 117.7 MHZ/CH 124X U/S. ALL ASSOCIATED PROC SUSPENDED.

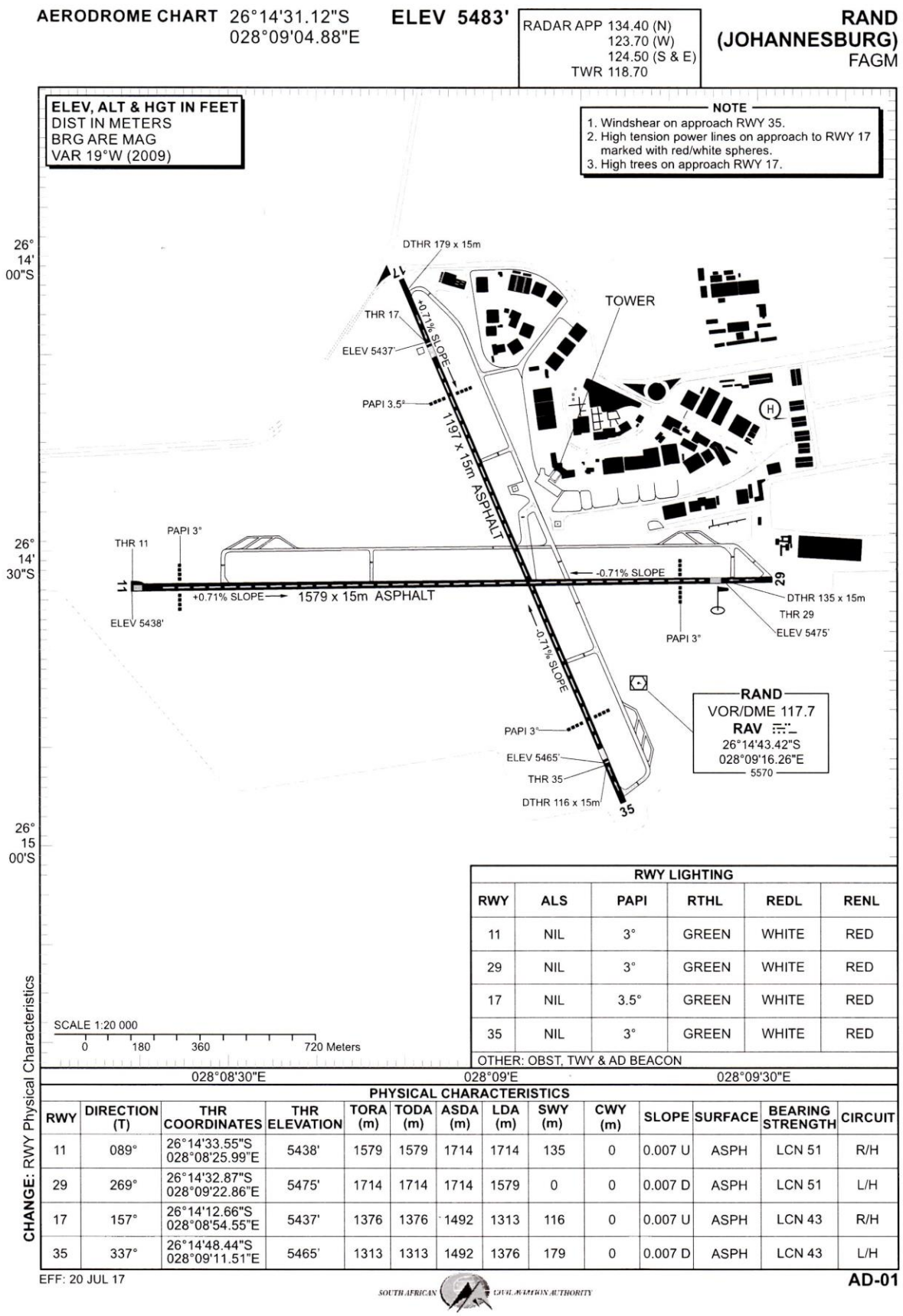

Figure 4: The layout of the aerodrome.

1.11 Flight Recorders

1.11.1 The aircraft was not equipped with a flight data recorder (FDR) or a cockpit voice recorder (CVR), nor was it required by the regulations to be fitted to this type of aircraft.

1.12 Wreckage and Impact Information

1.12.1 According to the witness marks observed on the ground, the aircraft impacted the ground with all three wheels. The aircraft skidded for approximately 2 m, when the nose gear dug in and the aircraft nosed over, coming to rest in an inverted attitude.

Figure 5: The aircraft as it came to rest

Figure 6: The hand-held radio that was used by the pilot during the flight.

1.12.2 Two of the instruments became dislodged during the accident sequence (i) the directional indicator and the (ii) attitude indicator.

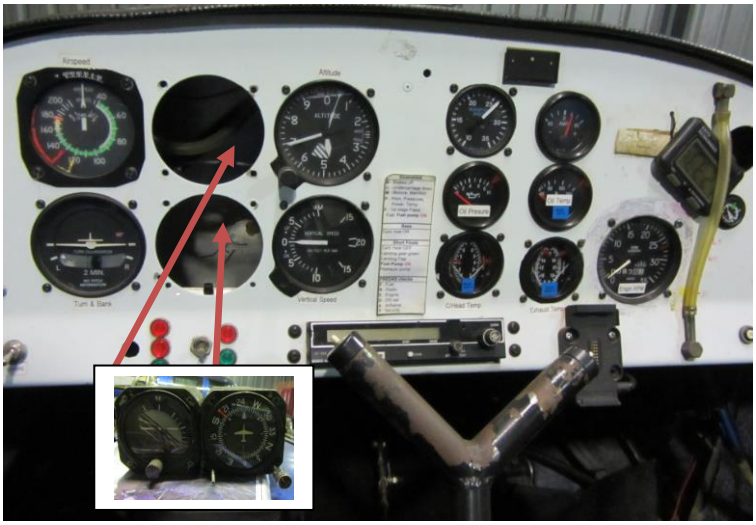

Figure 7: The instrument panel. (photo taken after recovery)

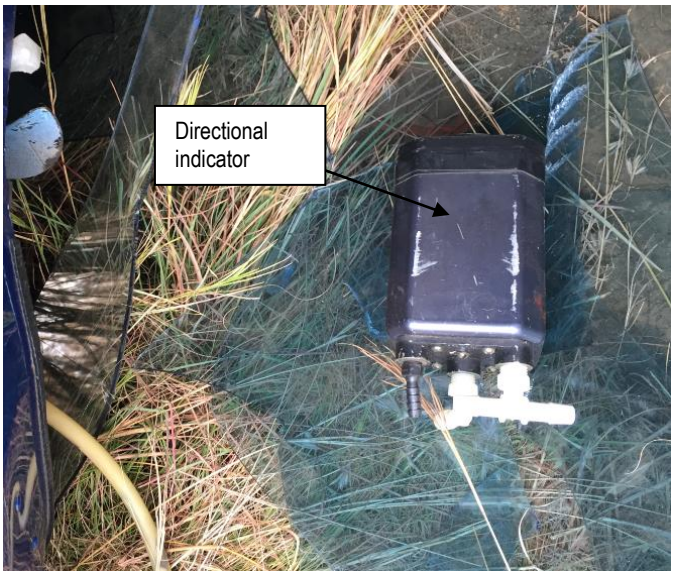

Figure 8: The directional indicator instrument.

1.12.3 One of the propeller blades was broken in mid section. The other propeller blade was still intact, with no signs of rotational damage. The spinner was observed having scratch marks from the nose towards the back. The screws that attach the spinner on the flange were all missing. The engine thrust mounts were still intact.

Figure 9: A propeller (picture taken after removal)

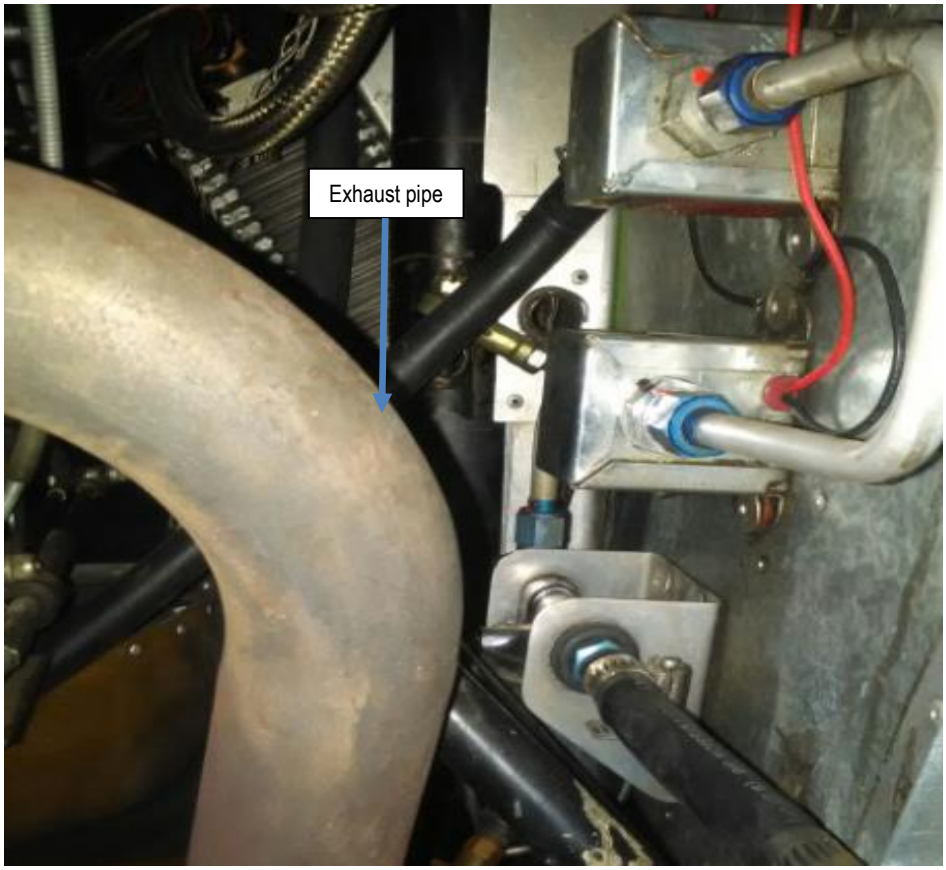

Figure 10: Exhaust pipe position

1.12.5 Both wings were still intact and attached to the fuselage. The flaps were observed to be in the up position. The empennage was deformed underneath with compression stress signature in the area close to where it attaches to the fuselage. The vertical fin was bent as the result of impact with the ground after the aircraft nosed over.

1.13 Medical and Pathological Information

1.13.1 None

1.14 Fire

1.14.1 There was no evidence of pre- or post-impact fire.

1.15 Survival Aspects

1.15.1 The accident was considered to be survivable, with limited damage caused to the cockpit/cabin area. The pilot managed to crawl from underneath the wreckage and free himself.

1.16 Tests and Research

1.16.1 The engine was removed from the wreckage and was found to be in an overall good condition, which allowed for a bench test. The bench test was conducted at an approved engine maintenance facility in the presence of the investigator-in-charge. Prior to commencing with the test it was noted that the engine's crankshaft was slightly bent. A loaner propeller was fitted to the crankshaft flange for the purpose of the bench test. The engine started without difficulty and was operated at idle speed for some time before the throttle was advanced to full throttle setting for approximately 5 minutes. Both magnetos were also tested during the test run and was found to be within its operating limitations. . The instruments were showing normal engine operation, the oil pressure was 65 psi and the manifold pressure was 250 psi while the engine rpm was at 2200 rpm.

Figure 11: Engine on the test bench running at full throttle.

Figure 12: Exhaust pipe temperature (photo courtesy of Clack Air)

1.17 Organisational and Management Information

1.17.1 This was a private flight with the aircraft being repositioned for modifiaction to be performed.

1.17.2 According to available records the last annual inspection was carried out on the aircraft prior to the accident flight was on 25 January 2018 at 101,6 airframe hours by an approved AP, who issued a certificate of release to service which lapses at 201,6 hours airframe hours.

1.17.3 The SACAA guidance material states that the amature builder is responsible to carry out and certify modifications and repairs of such aircraft. This should be supported by the feedback received. There were no modification application found under SACAA.

1.18 Additional Information

1.18.1 The following information was extracted from Mogas MSDS (Material Safety Data Sheet) 2014:

INFORMATION ON BASIC PHYSICAL AND CHEMICAL PROPERTIES

Physical State: *Liquid*
Colour: *Pale Yellow*
Odour: *Characteristic*
Odour Threshold: *No data available*
pH: *Not technically feasible*
Melting Point: *No data available*
Freezing Point: *No data available*
Initial Boiling Point / and Boiling Range: *28°C (82°F) - 210°C (410°F) [ASTM D86]*
Flash Point [Method]: *<-35°C (-31°F) [IP 170/70]*
Evaporation Rate (n-butyl acetate = 1): *No data available*
Flammability (Solid, Gas): *Not technically feasible*

Upper/Lower Flammable Limits (Approximate volume % in air): *UEL: 7.6 LEL: 1.4 [test method unavailable]*
Vapour Pressure: *[N/D at 20ºC] | 4 kPa (30 mm Hg) at 37.8 °C - 240 kPa (1800 mm Hg) at 37.8°C [test method unavailable]*
Vapour Density (Air = 1): *> 1 at 101 kPa [test method unavailable]*
Relative Density (at 15 °C): *< 1 [test method unavailable]*
Solubility(ies): water *Moderate*
Partition coefficient (n-Octanol/Water Partition Coefficient): *> 3.5 [test method unavailable]*
Autoignition Temperature: *>250°C (482°F) [test method unavailable]*
Decomposition Temperature: *No data available*
Viscosity: *<1 cSt (1 mm2/sec) at 40ºC [test method unavailable]*
Explosive Properties: *None*
Oxidizing Properties: *None*

1.18.2 The following information was extracted form the Lycoming Operators Manual

OPERATING CONDITIONS (CONT.)

Operation	RPM	HP	Fuel Cons. Gal./Hr.	Max. Oil Cons. Qts./Hr.	*Max. Cyl. Head Temp.
			0-235-C, -E		
Normal Rated	2800	115	10.7	0.52	500°F. (260°C.)
Performance Cruise (75% Rated)	2350	86	7.3	0.29	500°F. (260°C.)
Economy Cruise (65% Rated)	2250	75	5.8	0.25	500°F. (260°C.)
			0-235-F, -G, -J		
Normal Rated	2800	125	10.7	0.56	500°F. (260°C.)
Performance Cruise (75% Rated)	2500	94	7.3	0.31	500°F. (260°C.)
Economy Cruise (65% Rated)	2400	81	5.8	0.27	500°F. (260°C.)
			0-290-D Series		
Take-Off	2800	130	------	------	500°F. (260°C.)
Normal Rated	2600	125	11.9	0.56	500°F. (260°C.)
Performance Cruise (75% Rated)	2350	94	7.5	0.31	500°F. (260°C.)
Economy Cruise (65% Rated)	2250	81	6.5	0.27	500°F. (260°C.)
			0-290-D2 Series		
Take-Off	2800	140	------	------	500°F. (260°C.)
Normal Rated	2600	135	12.6	0.60	500°F. (260°C.)
Performance Cruise (75% Rated)	2350	101	7.2	0.34	500°F. (260°C.)
Economy Cruise (65% Rated)	2200	87	6.3	0.29	500°F. (260°C.)

* - At Bayonet Location - For maximum service life of the engine, maintain cylinder head temperatures between 150°F. (65°C.) and 400°F. (204°C.) during continuous operation.

3-9

Figure 13: Engine manifold temperature

1.18.3 The following information was extracted from Zenith Aircraft Company regarding recommended engines to be installed on these aircraft

ZODIAC CH 601 Series Kit Aircraft:
Summary of Design Features

	ZODIAC XL	CH 601 HD	CH 601 UL	CH 601 HDS
Design Overview:	The newest Zodiac model, developed for increased speed, power and gross weight, yet maintaining a low stall (landing) speed. Optimized for the proposed Sport Pilot category.	The original Zodiac model delivers good performance with low power. Features a high-lift constant-chord wing design with no flaps.	Designed specifically for 'Advanced Ultralight' categories around the world that limit the gross weight of the aircraft. The design is nearly identical to the HD model.	Based on the HD model, the 'Super Zodiac' features tapered and shorter 'speed wings.'
Recommended Power:	100 - 125 HP	65 - 100 HP	50 - 100 HP	80 - 100 HP
Sample Engines:	Rotax 912S Lycoming O-235 Jabiru 3300 Continental O-200	Rotax 912 / 912S Subaru EA-81 Continental O-200	Rotax 912 / 912S	Rotax 912 / 912S Subaru EA-81 Jabiru
Wing Design	New 'conventional' full-length wings.	Three-section wing design with carry-through center wing spar.		
Wing Area	132 sq.ft.	130 sq.ft.	130 sq.ft.	98 sq.ft.
Wing Span	27 feet	27 feet	27 feet	23 feet
Wing Profile	Riblett GA 35-A-415	NACA 605-18	NACA 605-18	modified NACA605-18
Wing Flaps	Electric wing flaps	none	none	none
Landing Gear, Main:	Spring gear, bolted to the fuselage. Wheel size: 5.00x5	Steel gear strut with wheel fork, dual bungee shock absorber, built into center wing. Wheel size: 8.00x4		
Nosewheel	Steel strut with wheel fork, bungee shock absorber, direct linkage steering.			
Fuel System:	Dual wing tanks: 2 x 12 US gallons.	16-gallon header tanks (optional wing tanks available)		
Canopy System:	Forward hinging canopy.	Side hinging canopy (hinges both sides). (Forward hinging canopy available as an option).		
Tail (empennage):	All Zodiac models share the same tail sections, with the full flying rudder.			
Sport-Pilot Category:	**Yes**	Probable	Yes	No (stall speed too high)
	ZODIAC XL	CH 601 HD	CH 601 UL	CH 601 HDS

Figure 14: Engines recommended by the manufacturer

1.18.4 ***Vapour Lock and Hot Fuel Handling Problems*** *(Motor gas technical review, Chevron.com)*

Vapour lock and hot fuel handling problems occur when excessive gasoline vapour accumulates somewhere in the fuel system of a vehicle and reduces or interrupts the fuel supply to the engine. This may take place in the fuel pump, the fuel line, the carburettor, or the fuel injector. When the fuel supply is reduced, the air-fuel ratio becomes too fuel-lean (too much air for the amount of fuel), which may cause loss of power, surging, or backfiring. When the fuel supply is interrupted, the engine stops and may be difficult to restart until the fuel system has cooled and the vapour has recondesed. After a hot soak (engine shutdown), it may be difficult to start the engine if too much vapour has formed in the fuel system. Overheated fuel or overly volatile fuel is the main cause of vapour lock. Fuel temperature depends on several factors: the ambient temperature, how hard the vehicle is working, how well the fuel system is isolated from the heat of the engine, and how effectively the fuel system is cooled.

1.18.5 The following information was extracted from the POH. (Engine out glide performance)

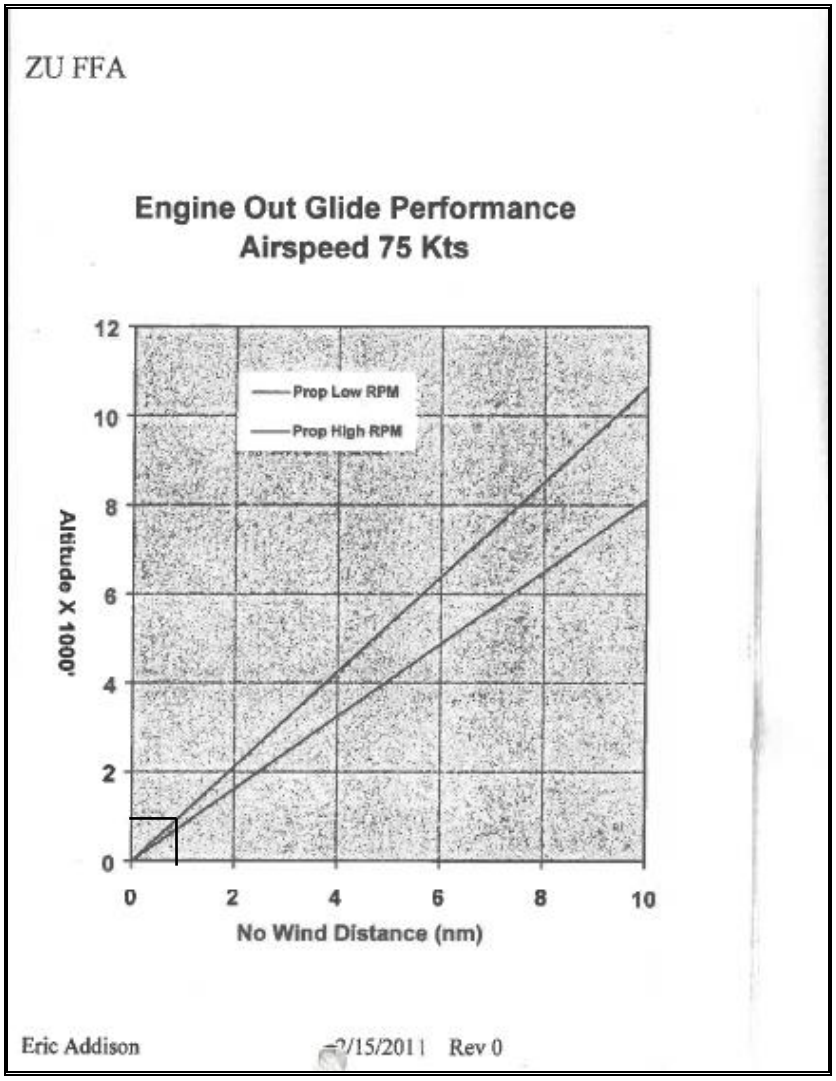

Figure 15: Engine out glide distance graph.

1.18.6 Mogas temperature and pressure lead to vapour lock. Source: http://iopscience.iop.org/article/10.1088/1757-899X/370/1/012008/pdf

Since there is a developing practice of utilizing automotive fuels as flight fuel, there are higher chances of dangerous scenarios, particularly in the operation of piston aircraft engines. The use of motor vehicle gas (MOGAS) or aviation gas (AVGAS) in the operation of aviation piston engine increases the risk of vapour locking. A statistical examination of European aviation industry indicates that around 20,000 aircraft are affected either specifically or conceivably by the different negative impacts of gasoline blended with ethanol. Particularly, for most contemporary carburettor engines, there are risks associated with ethanol-admixed fuels that have potential to upset engine operation. The danger of vapour locking, which is the generation of gas bubbles inside the fuel system causing an impairment of fuel movement in the engine, is well documented particularly by studies on aircraft using MOGAS. Contrasted with AVGAS, MOGAS is inclined to demonstrate this phenomenon. Vapour lock is perhaps the leading serious problem that ought to be addressed if MOGAS is to be used as a substitute for AVGAS. Vapour lock problem

is critical because it causes malfunctions to aircraft engines. Thus, an understanding of vapour handling ability of small aircraft is essential to establish safe operating confines at existing fuel temperature and pressures.

1.19 Useful or Effective Investigation Techniques

1.19.1 None

2. ANALYSIS

2.1 Man (Pilot)

The pilot was on a ferry flight for modification from Panorama to FAGM.The pilot was not licensed for the flight. It was noted that the national pilot licence that was issued on 08 May 2017 expired on 30 April 2018. The pilot was in possession of a valid medical certificate which was issued on 25 August 2016 with an expiry date of 31 August 2019. According to Part 62, a holder of a national pilot licence should maintain the licence as required by the available regulations.

According to the ATC transcripts, the pilot reported when he was overhead Silver Ball, where the ATC gave him joining instructions to maintain 6500 ft and join left base runway 35. The pilot read back and stated that he would join left downwind for runway 35. The aircraft was then observed by ATC on final approach for runway 11 and disappeared short of runway 11. The pilot stated that the engine started running rough when overhead Gosforth toll plaza and then stopped. The indicated air speed at that point was ±100 kt. It was noted that when the engine stopped, the runway that was closer was runway 11, which was situated 0.52 nm from the Gosforth toll plaza. According to the engine out glide performance chart in the POH, at an air speed of 75 kts, with a prop low rpm and a height of 6500 feet AMSL (1017feet AGL), the glide distance would be 1 nm as seen on 1.18.6. With surface wind conditions at the time of the accident being 350° 330V030 at 10 kts, a best glide angle and rate of descent, the aircraft should have made it safely to runway 11. The pilot stated that he did a right 90° bank in a northerly direction and aimed for the open field diagonally with the extended centre line, which was into the wind and 100 m short of the threshold of runway 11.

2.2 Machine (Aircraft)

The aircraft was located short of runway 11 lying inverted with the nose facing south. According to the aircraft logbooks, the aircraft underwent an annual inspection on 25 January 2018 at 101,6 airframe hours, after which a release to service certificate was issued which would expire on 25 January 2019 at 201,6 hours. The aircraft only flew 0,4 hours since the last inspection. The aircraft was issued with an authority to fly on 25 January 2018 which would expire on 24 January 2019. The aircraft was fitted with a Lycoming O-235 C engine and a 69X54 fixed pitch propeller. According to the manufacturer, the engines that are recommended for this type of aircraft are Rotax 912, Subaru EA81 and Continental

O-200. No records as required by the regulator for the modification in which an alternative engine was fitted, were found. According to the manufacturer of the aircraft, the fitting of the alternative engine required the owner to modify the fuel system to accommodate the engine. It was noted that the fuel system was modified to accommodate the fitting of an alternative engine. According to the manufacturer, the test and research on the aircraft were done using a Rotax 912 engine, and the fuel system embedded on the aircraft was for a Rotax 912 engine. It was noted that no STC records were found in the logbook regarding modification of the fuel system and the fitting of the two electrical (automotive) pumps as required by the regulator in part 44. The part number and serial number of the propeller that was fitted on the aircraft did not correspond to the details that were recorded in the airframe logbook.

According to the AP, the propeller in question was fitted on the day before the accident, and the pilot was requested to do high-speed ground runs to test the propeller. It was noted that the removal and installation of the propeller were not recorded in the aircraft logbooks, as required by the regulations. According to the AP the pilot was observed lining up and taking off, whereafter he completed three circuits and then headed for FAGM. The screws on the propeller flange were not fastened properly due to misalignment, as noted on the accident scene. The fuel system integration as found on the aircraft comprised two electrical pumps interconnected by aluminium pipe with non-aviation standard rubber hose for delivery to the engine. It was noted that this modification was done to accommodate a Lycoming engine. No records were found to support this modification. The fuel system was mounted on the firewall, with the exhaust pipe of the left-hand side running close to it. It was noted that the fuel system was not shielded against heat from the exhaust pipe. In the test that was done on the Lycoming O-320-E2D, the temperature of the exhaust at full power was measured as 329 °C. According to the Lycoming O-235 C operator's manual, the cylinder head temperature is 320 °C. Due to the heat being concentrated at one point (exhaust pipe), the fuel inside the pipes reached boiling point, which led to vapour being formed in the pipes. It was noted that the initial boiling point of the Mogas is 28°C.

The pilot stated that the engine was running rough, followed by a sudden stoppage. The fuel pressure and temperature influenced vapour lock. Temperature and pressure also affect gasoline's vapour-forming qualities, the capability of the system to hold vapour, in addition to the operating state of the engine. According to research done by Ferrara and Wares (1988), vapour bubbles may crop up at any part of the fuel system. However, the most crucial segments are typically the fuel pump. At the fuel pump, a bulk heat transfer to the gasoline occurs. Here pump suction lessens the pressure, which increases vapour development. The volume of the vapour under fuel-system temperatures is around 160 times the volume of liquid. Based on this, it is apparent that a pump with a maximum volume flow rate will not be able to administer a sufficient mass flow rate of gasoline to the carburettor for maximum power if a large proportion of the fuel has turned into vapour. It was noted that for unknown reasons the aircraft stood in the hangar for a period of 11 months. According to the engine

manufacturer service letter 1534, engines must be preserved for long storage. No evidence of compliance was not found in the aircraft logbook.

2.3 Environment (weather):

The weather conditions prevailing at the time had no influence on this accident. The surface wind was reported by SAWS to be 350° 330V030 at 10 kt, temp 17 °C, dew point 3 °C and visibility 9999 m, CAVOK where the accident took place; this was well within the operating limitations of this aircraft type. The terrain where the accident took place was flat and there was ample space available for an unscheduled or forced landing in the vicinity of the aerodrome.

2.4 Crash Survivability**:**

The pilot suffered serious shoulder injuries during the impact sequence. After impact the aircraft nosed over and came to rest in an inverted attitude. The canopy was crushed, although the cabin area remained intact. The pilot was able to free himself and crawl from underneath the aircraft. This accident was considered survivable.

2.5 Conclusion:

This was intended to be a direct flight flown by the pilot. According to the ATC, the pilot reported that he had radio problems and elected to divert to Panorama aerodrome, which is located 6,5 nm from FAGM. Upon landing at Panorama aerodrome, the pilot called the AP to bring a hand held radio. The pilot took off and continued to FAGM using a hand-held radio. According to the ATC transcript, the pilot was given clearance to maintain 6500 ft and join left base runway 35. During the transmission back to the ATC, the pilot confirmed that he would join left-hand downwind runway 35. The pilot stated that he was familiar with the aerodrome. It is not known why the read-back was incorrect. Shortly thereafter the pilot was observed by ATC on final approach for runway 11. This resulted in ATC having to keep other aircraft that were in a circuit on hold and prioritise ZU-FFA landing on 11. According to the pilot, he stated that when he was overhead the tollgate (Gosforth ramp toll plaza) the engine started spluttering and stopped. The pilot elected to turn the aircraft 90° to the left and aim for runway 11. Excessive banking of the aircraft was likely to cause loss of speed and height. The field elevation for FAGM is 5438,ft,, which gave a height above ground of 1062 ft. It was noted that according to the engine out glide performance at airspeed of 75 kt, a height of 1062 ft and speed of 75 kt, the aircraft had a glide distance of 1 nm (without converting excess airspeed to altitude). The position from the place overhead when the engine stopped to the position where the aircraft landed is 0,55 nm. According to the calculation on the graph in figure 16, the aircraft could have made it safely to runway 11 after the engine stopped, taking the temperature, surface conditions, rate of descent and speed into consideration.

It was noted that the fuel system integration as found on the aircraft comprised two electrical pumps interconnected via aluminium pipe with non-aviation standard rubber hose for delivery to the engine. It was noted that this modification was done to accommodate a Lycoming engine. No records of this modification were found. The fuel system was mounted on the firewall, with the left exhaust pipe situated in close proximity to the fuel pumps and lines. It was noted that the fuel system was not shielded against heat from the exhaust pipe. According to the temperature test that was conducted on the Lycoming O-320-E2D, the temperature of the exhaust at full power was 329 °C.

According to the Lycoming O-235 C operator's manual, the cylinder head temperature is 320°C. Due to the heat being concentrated at one point (exhaust pipe), the fuel inside the pipes reached boiling point, which led to vapour being present in the pipes. It was noted that the initial boiling point of the Mogas is 28 °C. The pilot stated that the engine was running rough, followed by a sudden stoppage. The fuel pressure and temperature influence vapour lock. Temperature and pressure also affect gasoline's vapour forming qualities, the capability of the system to hold vapour, in addition to the operating state of the engine. According to research done by Ferrara and Wares (1988), vapour bubbles may crop up at any part of the fuel system. However, the most crucial segment is typically the fuel pump. At the fuel pump, a bulk heat transfer to the gasoline occurs. Here pump suction lessens the pressure, which increases vapour development. The volume of the vapour at fuel system temperatures is around 160 times the volume of liquid. Based on this, it is apparent that a pump with a maximum volume flow pace will not be able to administer a sufficient mass flow rate of gasoline to the carburettor for maximum power if a bulk of the fuel has turned into vapour. It was noted that the aircraft was fitted with a transponder and that the pilot did not squawk 7600, which is a frequency for radio failure procedure. However the ATC continued to transmit blind on the frequency.

3. CONCLUSION

3.1 Findings

3.1.1 The pilot was a holder of national pilot licence and the aircraft type was endorsed on it. The pilot licence that was issued on 08 May 2017 with expiry date of 30 April 2018 was not valid at the time of the accident.

3.1.2 The pilot was in possession of a valid aviation medical certificate with no restrictions issued on 25 August 2016 with an expiry date of 31 August 2019.

3.1.3 The aircraft was in possession of a valid authority to fly certificate which was issued on 25 January 2018 with an expiry date of 24 January 2019.

3.1.4 The last annual inspection was carried out on 25 January 2018 at 101,6 airframe hours, whereupon a certificate of release to service was issued that would lapse on 25 January 2019 or 201,6 hours

whichever comes first. The accident flight was the first flight after the annual inspection. The aircraft had only accumulated 0,4 hours since the last annual inspection

3.1.5 The prevailing weather conditions at the time of the accident did not have any effect on the psychological and physical state of the pilot.

3.1.6 The manufacturer recommends the use of Rotax 912/912S, Subaru EA85 or Continental O-200 engines, but the aircraft was fitted with a Lycoming O-235-C engine.

3.1.7 No modifications applications were found in the aircraft file regarding the use of an alternative engine not recommended by the manufacture or regarding modification of fuel the system to accommodate this engine, as required by the regulator, or regarding the fitting of a bigger propeller.

3.1.8 The aircraft stood in the hangar for a period of 11 months. No information relating to the preservation of the engine in accordance with the service letter issued by the engine manufacturer was found in the logbook.

3.1.9 The fuel system pumps and fuel lines were not shielded against heat from the exhaust pipe.

3.1.10 The engine out glide distance calculation graph indicated that given the height and the distance to runway 11, the aircraft should have glided safely to runway 11 after the engine ceased working.

3.1.11 The engine stopped due to fuel starvation as result of vapour lock caused by heat from the exhaust pipe, which ran in close proximity to the fuel pumps and fuel lines.

3.1.12 The aircraft was fitted with a transponder, but the pilot did not squawk 7600, which is the radio failure procedure.

3.2 Probable Cause/s

3.2.1 Engine stoppage in flight resulting in an unsuccessful forced landing.

3.3 Contributory factors

3.3.1 Fuel starvation due to vapour lock developed inside the fuel pipes.

3.3.2 Fuel lines running close to exhaust pipe.

3.3.3 Fuel lines not shielded against local heat from exhaust pipe.

3.3.4 Fitting of an engine not recommended by the manufacturer which resulted in modification of the fuel system and a propeller.

3.3.5 Use of aluminium pipes interconnecting the two pumps and non-aviation-standard fuel hose.

4. SAFETY RECOMMENDATIONS

4.1 In the interest of safety, it recommended to the Director of Civil Aviation to enforce measures for non-type certificated aircraft operators to comply with necessary requirements when major modifications which might affect the design and flight characteristics of the aircraft as well as expediting of a form to be used for application of modification for non-type certified aircraft.

4.2 Safety message: It is recommended to the owners of aircraft to install a heat shield in the exhaust pipe to prevent excessive heat transfer to the fuel plumbing.

4.3 Safety message: It is recommended in the name of safety for the pilot to receive remedial training before he can commence with flying again.

5. APPENDICES

5.1 Service Instruction 1534 (Long-term storage)

5.2 Service Instruction 1070S (Use of alternative fuels)

5.3 Ground runs technical report

5.4 Mogas (automotive gasoline) MSDS

Appendix 1: Service Instruction 1534 (Long-term storage)

LYCOMING

652 Oliver Street
Williamsport, PA. 17701 U.S.A.
Tel. 570-323-6181
Fax. 570-327-7101
www.lycoming.com

SERVICE INSTRUCTION

DATE: January 27, 2011

Service Instruction No. 1534
Engineering Aspects are
FAA (DER) Approved

SUBJECT: Service Recommendations for Long-Term Storage of Engines That Use Automotive Fuel

MODELS AFFECTED: All Lycoming aircraft engines using automotive fuel

TIME OF COMPLIANCE: Before engine storage for a duration of 6-months or longer

NOTE

Incomplete review of all the information in this document can cause errors. Read the entire Service Instruction to make sure you have a complete understanding of the requirements.

The Service Instruction only applies to Lycoming engines that have been operated on automotive fuel (as specified in the latest revision of Service Instruction No. 1070) and are to be stored for 6 or more consecutive months.

Before storing an engine, Lycoming recommends the following:

1. Either operate the engine or drain the aircraft fuel system per the aircraft manufacturer's instruction until the fuel tank contains less than 50% of automotive fuel.
2. Add the specified aviation fuel, as per the latest revision of Service Instruction No. 1070, until the aircraft fuel tanks are full.

NOTE

The aviation fuel can be mixed with the automotive fuel. The goal is to have more than 50% aviation fuel in the fuel tanks during storage to prevent fuel system clogging.

3. Operate the engine for a minimum of 45 minutes with the oil temperature at 180°F (80°C) to work the aviation and automotive fuel mixture through the engine and fuel lines.

WARNING

IF THE 45 MINUTE ENGINE OPERATION PORTION OF THIS SERVICE INSTRUCTION IS DONE ON THE GROUND, DO NOT OPERATE THE ENGINE AT FULL-STATIC FOR MORE THAN 10 SECONDS.

4. Add more aviation fuel to make sure that the aircraft fuel tanks are full.
5. Obey the storage preservation recommendations in the latest revision of Service Letter No. L180.

General Aviation Manufacturers Association

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Appendix 2: Service Instruction 1070S (Use of alternative fuels)

LYCOMING
652 Oliver Street
Williamsport, PA. 17701 U.S.A.
Telephone +1 (800) 258-3279 U.S. and Canada (Toll Free)
Telephone +1 (570) 323-6181 (Direct)
Facsimile +1 (570) 327-7101
www.lycoming.com

SERVICE INSTRUCTION

DATE: April 24, 2013

Service Instruction No. 1070S
(Supersedes Service Instruction No. 1070R)
Engineering Aspects are
FAA Approved

SUBJECT: Specified Fuels for Spark Ignited Gasoline Aircraft Engine Models

MODELS AFFECTED: Lycoming engine models as detailed in Table 3

TIME OF COMPLIANCE: When refueling aircraft

NOTE

Incomplete review of all the information in this document can cause errors. Read the entire Service Instruction to make sure you have a complete understanding of the requirements.

This Service Instruction identifies approved fuels that can be used when refueling aircraft with Lycoming engines. Fuels no longer known to be in production and distribution have been removed from this Service Instruction. For historical information, refer to the engine model Type Certificate Data Sheet or previous revisions of this Service Instruction.

Fuels approved for use in Lycoming engines include the following types:

- Aviation Fuels (Table 1)
- Automotive Fuels (Table 2)

⚠ 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.

General Aviation Manufacturers Association

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Table 3
Fuels Approved for Use in Lycoming Engine Models

Engine Models	Leaded Aviation Fuels (Table 1)				Unleaded Aviation Fuels (Table 1)		Unleaded Automotive Fuels (Table 2)		
	ASTM D910	TU 38	GOST 1012		ASTM D7547	HJELMCO	ASTM D4814		EN228
	100* 100LL 100VLL	91*	B91/115*	B95/130*	UL 91	91/96	91 AKI	93 AKI	NB.3
O-235									
-C, -E, -H	●	●	●	●	●	●		●	●
-F, -G, -J	●			●					
-K, -L, -N	●			●	●			●	●
-M, -P	●				●			●	●
O-290									
-D	●	●	●	●	●	●		●	●
O-320									
-A, -B, -C, -D, -E	●	●	●	●	●	●		●	●
-H	●								
IO-320									
-A, -B, -D, -E	●	●	●	●	●	●		●	●
-C, -F	●			●					
AIO-320									
-A, -B, -C	●	●	●	●	●	●		●	●
LIO-320									
-B	●	●	●	●	●	●		●	●
-C	●			●					
AEIO-320									
-D	●	●	●	●		●			
-E	●	●	●	●	●	●			
O-360									
-A, -B, -C, -D, -F, -G, -J	●	●	●	●	●	●		●	●
-E	●								

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Appendix 3: Ground runs technical report

CLACK AIR cc AMO 1207

REG No: 2011/033932/23

HANGER NO.4 NORTH
SPRINGS AIRFIELD
TEL NO: 011 817 2562
FAX NO: 086 654 2172

EMAIL: brian@clackair.co.za
P.O.BOX 8176
VERWOERD PARK
1453

DATE:	10-Jul-18
TO (COMPANY)	SACAA
ATT:	Tshitso Moroane Accident Investigator
FROM:	BRIAN CLACK
PAGES:	1 OF 1

RE: ENGINE RUN ON LYCOMING O-235-C, ENG S/No: 1343-15

Dear Sir,

I AM, BRIAN CLACK OF CLACK AIRcc , AME LICENCE No: 0252007725, AND I WAS REQUESTED TO TEST RUN AN ENGINE ON THE TEST BENCH.

ENGINE : LYCOMING O-235-C

ENGINE S/No: 1343-15

(1) Engine oil quanty was at 6 Quarts
(2) At 10:20, Prime the engine for start, engine start Normal, engine oil pressure at 70PSI
engine RPM increased to 1800, leaned out mixture for optomin performance, mag check, R/H 100RPM, L/H 100RPM
(3) Throttle response was Normal to max RPM of 2200RPM
(4) Engine RPM reduced to idle 750RPM, Normal
(5) DEAD Mag check at idle, Normal
(6) Engine run did not reveal any abnormalities.

Best Regards

Brian Clack

Appendix 4: Mogas (automotive gasoline) MSDS

SECTION 9 PHYSICAL AND CHEMICAL PROPERTIES

Note: Physical and chemical properties are provided for safety, health and environmental considerations only and may not fully represent product specifications. Contact the Supplier for additional information.

9.1. INFORMATION ON BASIC PHYSICAL AND CHEMICAL PROPERTIES

Physical State: Liquid
Colour: Pale Yellow
Odour: Characteristic
Odour Threshold: No data available
pH: Not technically feasible
Melting Point: No data available
Freezing Point: No data available
Initial Boiling Point / and Boiling Range: 28°C (82°F) - 210°C (410°F) [ASTM D86]
Flash Point [Method]: <-35°C (-31°F) [IP 170/70]
Evaporation Rate (n-butyl acetate = 1): No data available
Flammability (Solid, Gas): Not technically feasible
Upper/Lower Flammable Limits (Approximate volume % in air): UEL: 7.6 LEL: 1.4 [test method unavailable]
Vapour Pressure: [N/D at 20°C] | 4 kPa (30 mm Hg) at 37.8 °C - 240 kPa (1800 mm Hg) at 37.8°C [test method unavailable]
Vapour Density (Air = 1): > 1 at 101 kPa [test method unavailable]
Relative Density (at 15 °C): < 1 [test method unavailable]
Solubility(ies): water Moderate
Partition coefficient (n-Octanol/Water Partition Coefficient): > 3.5 [test method unavailable]
Autoignition Temperature: >250°C (482°F) [test method unavailable]
Decomposition Temperature: No data available
Viscosity: <1 cSt (1 mm2/sec) at 40°C [test method unavailable]
Explosive Properties: None
Oxidizing Properties: None