FINAL REPORT

AAIU Synoptic Report No: 2010-014
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In accordance with the provisions of SI 205 of 1997, the Chief Inspector of Air Accidents, on 15 March 2009, appointed Mr. Paddy Judge as the Investigator-in-Charge to carry out a Field Investigation into this Accident and prepare a Report. The sole purpose of this Investigation is the prevention of aviation Accidents and Incidents. It is not the purpose of the Investigation to apportion blame or liability.

Aircraft Type and Registration:	Cessna 206G Stationair, EI-HOG
No. and Type of Engines:	1 x Rolls Royce Allison 250-C20S
Aircraft Serial Number:	U20605745
Year of Manufacture:	1980
Date and Time (UTC):	15 March 2009 @ 14.20 hrs
Location:	Clonbullogue Airfield (EICL), Co. Offaly N53º 14.59', W007º 07.24'
Type of Flight:	Aerial Work - Parachute drop
Persons on Board:	Crew - 1 Passengers - 0
Injuries:	Crew - 1
Nature of Damage:	Substantial damage to aircraft
Commander's Licence:	Private Pilot Licence (PPL) Aeroplanes
Commander's Details:	Male, aged 68 years
Commander's Flying Experience:	3,500 hours, of which 17 were on type
Notification Source:	Dublin ATC Watch Manager
Information Source:	AAIU Field Investigation

SYNOPSIS

The aircraft, which had recently commenced operation with the parachute club, suffered a temporary partial power loss at 9,000 ft as it climbed to drop its parachutists. On the Pilot's command, the parachutists exited the aircraft. The engine recovered but subsequently stopped during the final approach. This resulted in the aircraft landing short of the runway in a ploughed field and inverting. The Pilot was taken to hospital but was later discharged.

The Investigation found that the engine stopped due to fuel exhaustion, which was caused by an inappropriate method of monitoring the fuel consumption and fuel quantity on board the aircraft. A contributory factor was lack of operational experience with a new aircraft type.

Two Safety Recommendations are issued; one to the Operator regarding its fuel management system and one to the Federal Aviation Administration (FAA) regarding fuel settling post refuelling.

FINAL REPORT

1. FACTUAL INFORMATION

1.1 History of the Flight

The aircraft had been recently certified by Irish Aviation Authority (IAA) for aerial work operation in Ireland, which includes parachuting. It had flown 5 parachute drop flights at EICL earlier on the morning of 15 March 2009 and then refuelled. A calibrated wooden stick was used to check the quantity in the fuel tanks. The aircraft then flew another five drop flights and on the sixth flight it took-off with a single parachutist and two tandem pairs[1] aboard. The aircraft climbed in its normal drop pattern towards 10,000 ft overhead the field, where it was intended that the drop would be made. However, on passing 9,000 ft a partial power loss was experienced. The Pilot lowered the nose and ordered the parachutists to jump. They exited the aircraft and landed near the village of Clonbullogue. The engine recovered power and the Pilot made a circling descent towards the airfield. During the approach the engine stopped and the aircraft landed short in a ploughed field. The nose wheel dug into the soft soil and the aircraft inverted. The Pilot, who sustained minor injuries, was taken to hospital for observation and was later released. The aircraft was substantially damaged.

1.2 Pilot Interview

The Pilot, who was the Chief Pilot of the parachute club, stated that he was on the sixth parachute lift after refuelling and the tenth flight of the day, all of which he had flown. When passing 9,000 ft in the climb the engine suffered a partial power loss. He levelled the aircraft and scanned the engine instruments but they appeared normal. He retarded the engine power lever to flight idle and the engine returned to normal power. He instructed the parachutists to leave the aircraft and trimmed the aircraft for a 80-85 kt descent. After the parachutists exited, the aircraft headed back towards EICL and contacted the airfield to advise of a problem with partial power. The Pilot said that he kept the aircraft within about one mile of the airfield while conducting left hand orbits to lose height. He again scanned the engine instruments, which appeared normal and as the engine was producing power, he decided to conduct a power on approach. As he turned onto finals to Runway (RWY) 27 at about 2,000 ft, he felt the engine surge, observed that the generator light had come on and *"realised that the engine had turned off"*. He did not feather the propeller as he thought he might still have a little power available and believed at that stage that he would be able to make a normal landing. He reduced speed but did not extend flaps and kept the aircraft in a clean configuration, as he said that the flaps on this aircraft type cause high drag and he was afraid the aircraft might stall. The aircraft contacted the ground short of the threshold, in a recently ploughed field. He said that he held the stick back to stall the aircraft on at a low speed but believed that the wheels contacted a ridge and the aircraft tumbled over. He switched off the master switch and people assisted him to exit the aircraft.

The Pilot informed the Investigation that, prior to the final refuelling operation, he estimated that there were 165 litres (L) of fuel remaining in the aircraft and that during refuelling 165 L was uplifted, split evenly into each wing tank, giving a total of 330 L or 87.1 US gallons (USG) on board. He said that the refueller, using a wooden stick that had been previously marked for the purpose, *"dipped each tank at the time"*.

[1] **Tandem Pairs:** Initial parachute jumps are flown with the student strapped in front of an experienced qualified tandem master; the combination is called a tandem pair.

The Pilot said that he visually checked the stained dipstick at the time, which was shown to him by the refueller and the dipstick reading coincided with the totaliser fuel flow meter reading (**Section 1.4.4**). Before he took off on the accident flight, he had 34.2 USG showing on the flow meter. He was satisfied at that time that there was sufficient fuel on board for the flight. He said that the fuel burn-off was between 6.2 to 6.4 USG per lift, according to the flow meter. Each lift took 14 to 15 minutes.

The aircraft was last fully refuelled the previous December during which the dipstick was calibrated by refuelling the aircraft in increments of 20 L. The Pilot mentioned that he did not trust the gauges nor use them for crosschecks, as he had noticed that they had a large lag; he relied on the fuel totaliser reading to determine the amount of fuel on board.

The Pilot stated that he was certain he had uplifted sufficient fuel and that he did not understand why the fuel totaliser still showed that there was 29.9 USG of fuel on board when no fuel was found on the aircraft after the accident. He also understood that a low fuel warning light was supposed to illuminate below approximately 25 USG but this had not illuminated during the flight. He had previously seen that light on while the aircraft was powered, the engine not running and when the fuel tank selector was being changed slowly from one tank to another. However, he had not checked the fuel low warning light during his pre-flight that day. Although there was a sensor on the engine that detected the burn-off for the fuel totaliser he did not know when this was last calibrated.

With hindsight, the Pilot believed he probably should have feathered the propeller during the descent, but at 2,000 ft on the approach, he still believed that he had partial power. He therefore had an expectation of power for landing, which did not occur. He felt that he did not have enough time to feather the propeller when the engine finally stopped. He said that the propeller was supposed to auto-feather if the oil pressure dropped but he had flight idle selected, which prevented auto-feathering.

He had conducted power off landings as part of his training but had never experienced a landing with the engine shut down. He felt that the power off landing was not at all representative of the glide angle that he had experienced with the engine stopped, as the glide angle was much steeper.

1.3 Accident Site Inspection

The Investigation team arrived at the scene within two hours of the accident occurring. The accident site was 136 m from the threshold of RWY 27 at EICL **(Photo No. 1)**. The Investigation was informed that this field had been ploughed between one and two days previously. The aircraft was found intact but inverted with the nose wheel drag brace and steering linkage fractured. The propeller blades were bent backwards consistent with striking the ploughed earth at low RPM in an unfeathered position.

Photo No. 1: Showing initial impact mark with runway threshold in the background

The aircraft was recovered to an upright position and transported to an adjacent hangar. On inspection, the Investigation found that the integral wing fuel tanks had not been damaged in the accident. The aircraft's electrics were powered up and readings obtained from the Shadin Flow Meter (**Photo No. 2** and **Appendix A)** and the fuel tank gauges (**Photo No. 3**). Whereas the tank gauges showed almost empty, the totaliser showed an estimated 29.9 USG of fuel still on board the aircraft.

Photo No. 2: Shadin Fuel Flow Meter (totaliser) reading post accident

The fuel tank contents indicators showed almost but not quite empty and the fuel low quantity warning lights were found to be inoperative (**Photo No. 3)**. When the Investigation accessed the module containing these lights, it found that the connector at the rear of the module was disconnected from its wiring loom, and that the calibration/normal switch was in the calibration position. It was not possible to say definitively whether the connector had become detached during the impact sequence or had been detached earlier.

Photo No. 3: Fuel Gauges and Annunciator panel

When the loom was re-connected to the module it was found that the warning lights illuminated permanently even though the fuel level in both tanks was well above the low-level threshold. This fault appeared to be caused by an electrical short circuit. Again, it could not be definitively established if this defect was caused by the impact. It should be noted that the position of the calibrate/normal switch does not affect the accuracy of the fuel tank gauges or fuel low level warnings.

The wing tanks were drained; the LH wing integral tanks were found to be empty and the RH tanks contained 2 L. 1.8 L of fuel was found in the left reservoir (collector) tank and 1.6 L in the right reservoir tank. Thus, the Investigation found 5.4 L (1.4 USG) of fuel on board.

A number of soil samples were taken from the area where the aircraft came to rest inverted. These were sent to a laboratory for analysis but tested negative for the presence of fuel.

1.4 Aircraft Information

1.4.1 General

The Cessna U206G is an all-metal six-seat, high-wing, single-engine aircraft equipped with a tricycle landing gear and designed for general utility purposes. EI-HOG was originally manufactured in 1980 and was equipped with a Continental IO-520-F piston engine. It was then registered as N566N. In April 1986, the aircraft was converted to turbine power by Soloy Aviation Solutions in the United States. At that time the aircraft, which was in an amphibious configuration, had a total flying time since new of 1,030.5 hours. In December 2003, the floats were removed and the aircraft was returned to a land plane configuration.

Aircraft Particulars:

Wingspan:	11.0 metres
Length:	9.2 metres
Propeller Diameter:	2.4 metres
Wheel Track:	2.5 metres
Engine Horsepower Rating:	418 SHP[2] @ 101.4 psi[3]
Landing Approach Flaps Up:	75-85 kts
Stalling speed – Power off, Flaps Up:	46-49 kts
Estimated Weight at time of Occurrence:	2,380 lbs
Maximum Take off Weight:	3,600 lbs
Maximum Landing Weight:	3,600 lbs
Certificate of Airworthiness issued:	19 Feb 2009
Certificate of Registration issued:	19 Feb 2009
Airworthiness Review Certificate issued:	19 Feb 2009

At the time of the accident, the Hobbs metre showed 2,677.4 total hours. The aircraft was weighed at EICL on 30 May 2008 and the empty weight with no usable fuel but with full unusable fuel was recorded as 2,200 lbs.

1.4.2 Aircraft Modification History

The Soloy Turbine PAC engine[4] was installed in accordance with Supplementary Type Certificate (STC) SA2353NM. Soloy's records show that a Shadin Digiflow digital fuel flow computer part number 700-1030-1 was also installed at that time. The aircraft was delivered from Soloy to the owner, a USA corporation, with the standard Cessna 88 USG fuel tanks.

The Investigation obtained a copy of a FAA Form 337, dated 25 February 1987, certifying the installation of three Sierra auxiliary bladder type fuel tanks in each wing. This installation was carried out in-house by the then owner's flight department and was in accordance with STC SA3634SW.

The fuel selector and low fuel warning annunciator panel are recorded in the aircraft logbook as having been installed by a maintenance organisation in the USA in September 2006. This equipment was supplied by Soloy and the installation instructions are detailed in Soloy Service Instruction (S.I.) No. 763-12.

[2] **SHP:** Shaft Horse Power.
[3] **psi:** Pounds per Square Inch.
[4] **Soloy Turbine PAC:** The engine was produced by Rolls Royce Allison as an Allison 250. Significant powerplant modifications are made by Soloy. The principal modification was the fitting of a proprietary gearbox and propeller mount to the upper front of the engine.

1.4.3 Aircraft Fuel System

The aircraft fuel system consists of vented fuel tanks, located in each wing, from which fuel flows by gravity to two small fuel reservoir tanks located in the lower fuselage. A four-position fuel tank selector valve (Off, L, R, Both) selects fuel from either or both of the wing tanks. Downstream of the selector valve fuel pressure is augmented by an electrical auxiliary fuel pump which provides fuel to the engine driven fuel pump via a fuel strainer. The fuel then flows to the fuel/air control unit, which supplies fuel to the fuel injectors.

Two fuel gauges and a low-fuel warning annunciator panel were installed in EI-HOG **(Photo No. 3)**. The low-fuel warning panel consisted of two independent circuits for left and right tanks and was calibrated to illuminate when the fuel level dropped to 13 USG on either side. The annunciator unit incorporated a test switch which, if pressed during normal flight operations, caused the warning light to blink until the fuel quantity dropped to a low enough level to illuminate continuously.

The original fuel system fitted to this aircraft consisted of just two vented integral fuel tanks (one in each wing). The Cessna Pilot's Operating Handbook (POH) at the time of original manufacture gave a total fuel volume of 92 USG (46 each side) of which 4 USG were unusable. Thus, the total usable fuel in the original configuration was 88 USG. This later changed with the installation of additional fuel tanks.

The later Sierra fuel tank installation is a gravity-fed system consisting of three integral fuel bladders installed in each wing outboard of the original integral fuel tank. As part of this modification, the original fuel filling point in the integral tank was blanked off. A new fuel filling point was fitted into the first bladder tank, outboard of the integral tank in the top of each wing. At the rib where the inboard Sierra bladder tank connects to the existing integral tank, there are four interconnects between the tanks. These consist of:

- Two 1-inch outer diameter (OD) interconnects located at the front and rear of the tank (approximately 0.5 inches up from the bottom of the tank).
- One 2-inch OD interconnect with a flapper valve, which is centred four inches above the bottom of the tank, and
- One 1-inch OD interconnect located at the top of the tank.

The flapper valve permits fuel to flow only from the bladder tank inboard into the original integral tank and not in the reverse direction. There are similar interconnect arrangements between the three bladder tanks, but without flapper valves.

1.4.4 Shadin Fuel Flowmeter

The Shadin fuel flowmeter system does not sense fuel quantity but rather fuel consumption. The pilot initially sets the total quantity of fuel on board the aircraft. Thereafter, as the engine burns fuel, the total fuel quantity is decremented and can then be displayed as fuel remaining. This process is achieved by a fuel flow transducer, mounted in the fuel line, that measures the rate of fuel flow. The transducer generates electrical pulses that are proportional to the flow rate and which are transmitted to the panel-mounted instrument.

The Shadin operating manual states that the system *".... is a fuel measuring system and NOT a quantity-sensing device. A visual inspection and positive determination of the usable fuel in the fuel tanks is a necessity. Therefore, it is imperative that the determined available usable fuel be manually entered into the system"*.

Shadin advised that, "*On initial installation, the indicator must be configured to match the transducer. The programming that takes place in the indicator is the setup of the k-factor*". The k-factor, which is expressed in pulses per unit volume, is used to electronically provide an indication of volumetric throughput in engineering units.

A logbook entry in September 2006 recorded the installation of a *"Shadin fuel flow gauge (p/n*[5] *910531P) and transducer (p/n 680526A)"*. The Investigation established that this gauge p/n was not approved by Soloy for this installation. The approved gauge (Soloy p/n 700-1030-1 or 700-1030-3 with the equivalent Shadin p/n 910517 or 910517P) included a read-out of fuel temperature and indicated fuel quantity in pounds rather than USG. The presence of an unapproved gauge was not identified in the United States Export Certificate of Airworthiness (C of A) or by the IAA prior to issue of the C of A.

On further examination, the Investigation found that the fuel flow transducer, Shadin p/n 680526AS was not the actual flow transducer installed on EI-HOG. P/n 660526AS was actually installed. This was the correct transducer and the logbook entry was incorrect. However, the gauge was incorrect and not Soloy approved. The operating manual for the p/n 910517P flow meter states that the instrument includes a temperature compensation feature that adjusts fuel flow measurement for greater accuracy, however the 910531P does not have this feature. Furthermore, there was no entry in the logbook or records available to the Investigation to confirm that a k-factor calibration had ever been carried out.

A United States Export C of A was issued for the aircraft on 24 January 2008. The Irish Operator acquired the aircraft and applied to the IAA for Certificates of Registration and Airworthiness on 20 March 2008. A Soloy turbine converted Cessna 206 had not previously been registered in Ireland and therefore numerous queries arose concerning the STC and modification history of the aircraft. The IAA issued the appropriate certificates on 19 February 2009.

1.4.5 Technical Log

The aircraft's technical log was provided to the Investigation **(Appendix B)**. It showed that, on the day of the accident the aircraft initially completed 5 drop flights, each of which climbed to 10,000 ft with either 4 or 5 parachutists aboard. It then logged a refuelling of 165 litres after which another 5 drop flights were recorded. It did not contain any record of the fuel on board the aircraft, either before or after refuelling, nor any record of fuel consumption

1.5 <u>Operator's Fuel Management</u>

The fuel log records at EICL shows that 480 L (126.65 USG) of fuel was put into the aircraft on 2 June 2008, before which point the aircraft contained no usable fuel. On that day fuel was slowly added, incrementally in quantities of 20 L, to each side of the aircraft. A wooden dipstick was calibrated during this process and graduation marks were put on the dipstick at intervals of 80, 120, 160, 200 and 240 L **(Photo No. 4)**.

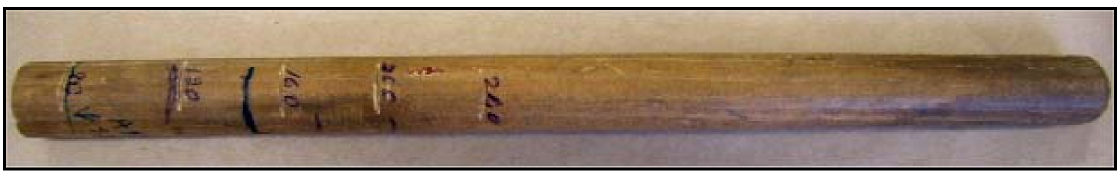

Photo No. 4: Fuel tank dipstick

[5] **p/n**: Part Number.

The 80 L mark is 15 mm from the bottom of the dipstick while the other marks, representing 40 L increases in fuel quantity, are between 30 and 35 mm apart.

The Investigation was informed that the aircraft was regularly started and taxied at EICL subsequent to this calibration but that it did not receive a C of A until 19 February 2009 (8 months later). The technical log shows that it first flew as EI-HOG on 21 February 2009 for 1.1 hours. Thereafter it flew for 1.9 hours on 28 February 2009 and for approximately 2.5 hours on the 15 March 2009, which was the day of the accident.

The fuel log for the airfield showed fuel uplifts of 100 L on 21 February 2009, 60 L on 1 March 2009 and that 150 L of fuel was dispensed into EI-HOG on the day of the accident using the airfield's refuelling facility.

No record was kept of the engine runs and taxiing times during the period between 2 June 2008 and 21 February 2009. The Operator did not keep a record of fuel guage readings, either before or after refuelling. However, the primary method of fuel quantity measurement was a visual check of the marked wooden baton, employed as a fuel tank dipstick, but this too was not recorded.

One of the operator's personnel told the Investigation that he had been advised, during familiarisation training on the aircraft in Germany, that time should be allowed for the fuel to settle during refuelling operations prior to dipping the tanks.

1.6 Post Accident Fuel Tank Calibration

Following the accident, the Investigation calibrated the fuel tank system in EI-HOG. The total fuel in the aircraft at the commencement of calibration was 1.8 L in the left reservoir tank and 1.6 L in the right reservoir tank.

80 L of fuel were added to the left tank system at a rate of 30 L/min, the rate at which the airfield's fuel facility was found to dispense fuel. When the Operator's dipstick was used to measure the quantity of fuel immediately afterwards, it read 145 L. When the level was checked again five minutes later, it was found to have settled to a level of 80 L on the dipstick. This left tank system was then filled to capacity and took a total of 259.5 L (68.5 USG). The aircraft fuel gauge appeared reasonably accurate up to ¼ full. However, when the tank was full, the gauge read 2/3 full. The dipstick calibration was found to be accurate.

80 L of fuel were then added to the right tank again at a rate of 30 L/min. In this case, when the dipstick was used to measure the quantity of fuel immediately after the fuel input, it read 175 L. Again, when fuel level was measured five minutes later, it was found to have settled to the 80 L mark on the dipstick again confirming the accuracy of the dipstick.

The Investigation requested Sierra to provide any data they had concerning fuel flow rate from the auxiliary bladder tanks into the original integral tanks. Sierra responded that their *"... design data does not show the transfer rate of the fuel from the long range fuel bladders to the existing main fuel tank, but it was shown by design to be able to transfer fuel at a rate significantly higher than the main fuel tank could transfer to the engine"*.

The United States Code of Federal Regulations Part 23 Paragraph 955 "Fuel Flow" states in sub-paragraph (b) *"Gravity systems. The fuel flow rate for gravity systems (main and reserve supply) must be 150 percent of the takeoff fuel consumption of the engine"*.

1.7 Flight Manual Data

A Soloy produced Pilot's Operating Handbook Supplement (POHS) and FAA Approved Airplane Flight Manual were issued for EI-HOG after its conversion to turbine engine configuration. Figure 5-10 of the Manual provides performance data including fuel quantity used for climb to various altitudes. At an aircraft weight of 3,000 lb, for a torque setting of 78 PSI on a standard temperature day, the average fuel burn rate for a climb to 10,000 ft is calculated as 31.6 USG/hr. The Manual also notes that 3 USG of fuel should be added for engine start, taxi and take-off.

1.7.1 Emergency Landing without Power

The POHS contains the following checklist for an engine failure in flight:

1) *Airspeed 80 KIAS Flaps up, 70 KIAS Flaps 40°*
2) *Propeller Control - FEATHER (OUT)*
3) *Fuel Cut-off Contro - CUTOFF (OUT)*
4) *Fuel selector - OFF*
5) *Flaps - AS REQUIRED (40° recommended)*
6) *Battery and Generator - OFF*
7) *Doors - UNLATCH PRIOR TO TOUCHDOWN*
8) *Touchdown - SLIGHTLY TAIL LOW*
9) *Brakes - APPLY HEAVILY*

1.7.2 Fuel Indicating System

The POHS, Section 7, states the fuel quantity indicators cannot be relied upon for accurate readings during skids, slips, climbs, descents, or unusual attitudes. It further states that,

> *A minimum of 1/8 tank* (5.5 USG) *of usable fuel is required in each wing prior to take off. An inaccurate indicator could give an erroneous indication of fuel quantity.*

The Soloy POHS also states:

> *Connected to the fuel quantity transmitter in each tank of some aircraft is a low fuel warning circuit. When the transmitter is in the 10 gallon position, the fuel low circuit is activated and the respective FUEL LOW light on the warning panel will illuminate.*

1.7.3 Fuel Totaliser

The POHS, Page 7-24, contains procedures for operating the fuel totaliser and states inter alia:

> *A fuel totaliser is also installed. The totaliser displays a continuous readout of total fuel flow in pounds per hour, time remaining in hours and minutes and fuel temperature in degrees F. Other features of the system include fuel remaining in pounds, fuel used in pounds, fuel temperature in degrees C and a low fuel warning system set at 30 minutes.*
>
> <u>*Note:*</u> *The accuracy of the fuel totalising system is totally dependent on the accurate entry of data by the pilot…*

1.7.4 Propeller Information

The POHS, Page 7-18, states

To feather the propeller blades, the propeller control on the control panel must be placed in the feather position (OUT).

An auto-feathering system provides for automatic reduction in propeller RPM in the event of the loss of engine power. This system is not a total feathering device. It is intended to reduce propeller drag due to an engine failure. The system is controlled by a pressure sensor that automatically reduces the propeller RPM (Np) to 1450 RPM with the propeller overspeed governor if the engine torquemeter oil pressure drops below 4 PSI.

1.8 Pilot Licence

The Pilot operated this parachute drop flight on behalf of the parachute club on a Private Pilot Licence (PPL). The IAA informed the Investigation that such operations are categorised as aerial work and accordingly should require a Commercial Pilot Licence (CPL). However, the club had previously held that its operations were club activities, as all novice parachutists were required to join the club before parachuting and that payments were to cover aircraft costs. The club, which has been operational since 1956, had historically interpreted regulations as indicating that a pilot who had a PPL could fly a parachute drop flight. The IAA more recently did not accept that argument and required that pilots of aircraft conducting this activity should have a CPL. In the meantime the IAA granted a temporary concession to allow a pilot with a PPL, who had been flying parachute flights, to continue operation for a fixed period - until the pilot obtained a CPL.

On the date of the accident, the Pilot held a valid IAA issued national PPL. His licence included a condition that permitted him to act as Pilot-in-Command in the club's parachute operations for hire or reward within Irish airspace until 31 March 2009.

1.9 Weather

At the time stable weather conditions existed over Ireland with little hourly change. The actual weather conditions reported at Dublin Airport (EIDW), the nearest weather reporting station, was:

EIDW 151400Z 23011KT 9999 FEW030 SCT150 BKN250 12/05 Q1030 NOSIG.

The local weather at EICL was reported to be similar, with good visibility but without any cloud at lower levels.

2 ANALYSIS

2.1 General

The parachute club acquired the aircraft in 2008 in order to use it as a parachute drop aircraft and as such, it required an Irish C of A. As a result, the aircraft did not commence operation until February 2009. The accident happened on the aircraft's third day flying as a parachute drop aircraft with the club. Initially the engine suffered a temporary power loss at 9,000 ft and, on the Pilot's appropriate command, the parachutists safely exited the aircraft. The Pilot reported that the engine then recovered but subsequently stopped during the final approach. This resulted in the aircraft landing short of the runway in a recently ploughed field.

Weather was not a factor and therefore two aspects of this accident are considered; the reason why the engine lost power and stopped in the first place and then why a successful forced landing did not result, since the engine initially lost power at sufficient altitude and at such a location that a successful forced landing should have been achievable.

On checking the accident site the witness marks revealed that, having touched on at a low speed, the nose wheel dug in to the soft soil. The resulting retarding force on the nose leg assembly was sufficiently below the centre of gravity to invert the aircraft. Consequently, the damage to the aircraft was less than might be expected. Witness marks on the propeller indicated that the propeller was rotating at low speed. As the propeller had not been manually feathered and was consequently freely rotating, the propeller witness marks are consistent with the Pilot's report that the engine had stopped before impact.

2.2 Engine Power Loss

2.2.1 General

On checking the aircraft after the accident, the Investigation found only 1.43 USG of fuel on board, less than the 4 USG listed in the POHS as unusable fuel[6]. In addition, the fuel tank gauges indicated almost empty. Soil analysis of the accident site revealed no evidence of fuel spillage. Therefore, the Investigation concluded that no usable fuel remained on the aircraft at the time the engine stopped. Thus, engine stoppage was due to fuel exhaustion.

However, when interviewed, the Pilot appeared convinced that he had uploaded sufficient fuel for the flight. He stated that he did not trust the fuel gauges, as they appeared unreliable, and preferred to physically measure the quantity of fuel on the aircraft by checking the actual depth of fuel in each tank with the dipstick, a procedure that had been satisfactory in the past, and then crosschecking against the fuel totaliser. In addition, the low fuel warning lights did not illuminate and, as the totaliser displayed ample fuel still on board when power was lost, he did not understand how he could have run out of fuel.

2.2.2 Fuel Usage

The aircraft fuel tanks were initially filled full of fuel on 2 June 2008 by a fuel delivery of 480 L. However, no subsequent record was kept of engine runs and taxiing times during the next 8 months – the period up to 21 February 2009. Also since the Operator kept no record of the fuel tank contents at any time, it is therefore not possible to state with any certainty what quantity of fuel may have been onboard the aircraft at any time after the initial fuelling on 8 June 2008.

The Investigation found that, when the dipstick was used to measure fuel quantity immediately after refuelling, it grossly over-read. When 80 L was dispensed into each tank, the immediate dipstick reading showed 145 L in one case and 175 L in the other. Some minutes were required to allow the fuel to settle throughout the tank system before correct readings were recorded by the dipstick.

The Pilot stated that he was definite that the fuel low quantity warning lights did not illuminate during the final flight. However, he stated that he had not checked them using the press-to-test button prior to his first flight of the day and as such did not know if they were serviceable.

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[6] **Unusable fuel:** The POHS figure of 4 USG is based on a worst-case scenario. Normally the amount of unusable fuel on an aircraft is considerably less than the manufacturer's figure.

The Investigation found that, on post-accident inspection, the connector on the rear of the low quantity-warning module was disconnected. Although it was not possible to ascertain when the disconnection occurred, the fact that the Pilot did not observe a low quantity warning prior to or following the initial engine power loss lends credence to the probability that the module was disconnected before the accident.

2.2.3 Fuel Migration

The original fuel tankage, including unusable fuel, on either the left or right side was 46 USG as per the Cessna POH. Following the Sierra fuel bladder modification, this was increased to 73 USG on each side, including unusable fuel, an increase of 27 USG per side. During fuelling, fuel is dispensed into the bladder tank closest to the original Cessna integral tank. It then migrates inboard and outboard into the other tanks through connecting pipes and settles throughout the tanks to its final level over a number of minutes. The fuel slowly migrates from the bladder tank due to the relatively small (1 inch OD) pipe work at the bottom of the tank and the low-pressure head. Consequently, the initial fuel level in the bladder tanks into which fuel is dispensed (and from where the dipstick readings were taken) rises to a level that is substantially higher than the level in the adjoining tanks.

The Investigation examined the time required for the fuel to transfer from the bladder tanks into the original Cessna integral tank to verify if it complied with the FAA certification requirements for fuel flow rates.

The Soloy POH gives an engine horsepower rating at takeoff power of 418 SHP. At a specific fuel consumption of 0.630 lb/shp/hr, this equates to fuel consumption at take-off of 263.34 lb/hr, or 43.89 USG/hr.

Due to the tank configuration described above, a quantity of 46/73 or 63% of the fuel will migrate into the original Cessna tank as the fuel settles to its final level. Therefore, when 80 L of fuel is added to an empty tank system, 50.4 L of that fuel will have migrated into the original tank when the fuel level has finally settled. The Investigation found that after 5 minutes this settling had occurred; an additional 2.67 minutes were required to dispense the 80 L into the aircraft. Thus, the transfer rate from the Sierra bladder tanks into the original Cessna tank was approximately 394 L/hr, equivalent to 104 USG/hr or about 237% of the peak engine take-off fuel consumption. Therefore, the Investigation is satisfied that the fuel transfer rate from the Sierra bladder tank system into the original Cessna tank exceeds the FAA requirement of 150% and complies with certification specifications.

2.2.4 Fuel Totaliser

An incorrect fuel flow transducer was recorded in a logbook entry as having been fitted to the aircraft. On examination of the aircraft, the Investigation found that the correct transducer but an unapproved gauge were actually installed on EI-HOG. Although the incorrect logbook entry record was not a factor in the occurrence, there was an unapproved and inaccurate totaliser gauge installed. This incorrect installation had not been identified during various airworthiness inspections.

Following the accident the Investigation found that the totaliser displayed 29.9 USG although the tanks were empty. The Shadin fuel flowmeter system relies on the pilot inputting the fuel quantity on board the aircraft and, after the engine is started, this fuel quantity is reduced by the fuel flow to the engine, which is measured by rate and time.

Therefore, it relies on an accurate initial fuel quantity input by the pilot and subsequently on accurate calibration of the sensor k-factor, or the rate of fuel flow to the engine. Accordingly, the flow meter totaliser became more inaccurate the longer the engine was running, as it under read fuel consumption by 19%. The installation of an unapproved totaliser gauge, in addition to the lack of k-factor calibration, is likely to have caused this gross under-reading fuel consumption.

Fuel burn calculations using POHS data indicate that the average flow rate in a climb to 10,000 ft is 31.6 USG/hr (under conditions similar to those on the day of the accident). The Pilot informed the Investigation that the Shadin flow meter was indicating a fuel burn rate of 26.4 USG/hr during his climbs to 10,000 ft. This suggests that the flow meter was under-reading by a factor of approximately 19.7%. The Pilot also stated that the average fuel burn per lift was approximately 6.4 USG. If this quantity is factored by 19.7%, then it is probable that the actual fuel burn per lift was 7.66 USG. The aircraft was on its sixth lift following refuelling and therefore the total fuel burn is likely to have been approximately 46 USG if 3 USG for start, taxi and take-off is taken into account. The airfield fuel records that 150 L (40 USG) was dispensed into the tanks prior to the final six lifts. It is very likely that the fuel quantity in the tanks prior to the refuelling was only 23 L (6 USG) and not the 165 L (44 USG) estimated by the Pilot. Although the Pilot recorded the fuel uplift as 165 L and the airfield recorded that it dispensed 150 L this inaccuracy is not considered a contributory factor to the accident and the Investigation considers that the more likely amount is 150 L.

During refuelling 150 L (40 USG) were dispensed between the LH and RH tank systems and it was reported that dipstick readings were taken that indicated 165 L on each side. The Pilot and the refuelling operator both confirmed these readings immediately after refuelling and the Pilot added this uplift to the fuel totaliser. However, the fuel was not allowed time to settle after refuelling and consequently the dipstick readings seen by the Pilot and the refueller were erroneous. The quantity of fuel in the tanks following the refuelling was only in the region of 173 L (150 L + 23 L) or 46 USG.

As was demonstrated in the subsequent checks by the Investigation, sufficient time should have been allowed for the fuel level to settle before a fuel tank quantity reading could be taken, whether by dipstick or by reading the fuel tank gauges. The Investigation found the fuel tank gauges under read by 1/3 at higher quantity levels. This coupled with the POHS statement that the fuel quantity indicators cannot be relied upon for accurate readings during skids, slips, climbs, descents, or unusual attitudes probably gave rise to the Pilot's over reliance on the fuel totaliser. In addition, the Investigation found no caution on the aircraft or in the operational documentation of the aircraft, which indicated that time must be taken to allow the fuel to settle before tank readings are recorded. Accordingly, a Safety Recommendation to the FAA is issued on this matter.

Although the POHS warns, *"An inaccurate indicator could give an erroneous indication of fuel quantity"* in this case the inaccurate indicator was also ignored. However, the fuel tank gauges should have been properly calibrated and would have been consequently more accurate and reliable.

The Shadin operating manual states that the system is not a quantity-sensing device and that a *"visual inspection and positive determination of the usable fuel in the fuel tanks is a necessity"*. Although the Pilot inspected the dipstick after refuelling this occurred in the middle of a series of drop flights and consequently an erroneous reading was taken before the fuel had time to settle.

Therefore, the Pilot overestimated the amount of fuel on board on departure, which co-incidentally happened to be confirmed by the inaccurate totaliser reading and thus his suspicions were not raised.

As a result, when the engine lost power and later stopped, the Pilot did not realise why and became confused - confusion that was evident in his subsequent interview with the Investigation. The post refuelling dipping the level of fuel in the wing tanks, which he had theretofore implicitly relied on, had failed to prevent fuel exhaustion.

2.2.5 Operator Fuel Records

The technical log of EI-HOG on the day of the accident **(Appendix B)** contained a record of the quantity of fuel uplifted on the day of the accident but did not contain any record of the fuel on board the aircraft, either before or after flight. Although the technical log recorded the amount of fuel put on board the aircraft, it did not monitor fuel consumption or quantity of fuel on board the aircraft. Consequently, the initial fuel loaded on 2 June 2008 inadvertently became a depleting resource since fuel consumption was not matched by fuel uplift. Therefore, the Operator's fuel management system is considered by the Investigation to be deficient and a Safety Recommendation is issued accordingly.

2.3 Forced Landing

After the initial power loss, the Pilot instructed the parachutists to leave the aircraft and trimmed the aircraft for an 80-85 kt descent, keeping the aircraft within about one mile of the airfield while conducting left hand orbits to lose height. The reason for this power loss was not evident to the Pilot who saw all the instruments as normal, including the illuminated red digits of the fuel totaliser display, which indicated there was an adequate quantity of fuel remaining. There was no evidence in the Pilot's interview that he had looked at the fuel tank gauges at the time, and if he had it is likely that he would not have believed their indications since the low fuel warning lights were not illuminated. Having levelled the aircraft after the initial power loss the engine recovered, but was then being supplied with the last of the usable fuel on board the aircraft. This recovery lead the Pilot, who had little experience on the aircraft type, to still believe that he had partial power. He planned his descent accordingly while still keeping close to the airfield.

When the engine finally stopped, the Pilot was not prepared as he said that he did not have enough time to feather the propeller; he had flight idle selected, which prevented the propeller from auto-feathering. The Pilot said that with hindsight he believed that he probably should have feathered the propeller. However, it would have been much clearer to the Pilot that a forced landing was necessary had the engine stopped and not recovered at an earlier stage. However, the auto-feather function is a function of power loss and it is probable that the Pilot, when interviewed shortly after the accident, confused auto-feathering, where the propeller does not stop rotating, with feathering where it stops or virtually stops. Whereas no pilot action was required to auto-feather, feathering on the other hand required that the propeller RPM control was manually selected to feather.

The Pilot stated that he had conducted power off landings as part of his training but he had never experienced a landing with the engine shutdown. He felt that the power off landing was not at all representative of the glide angle that he had experienced with the engine stopped, as this was much steeper.

Training for forced landings in turboprop aircraft is normally conducted at a power setting that is representative of the drag induced by a feathered propeller. Such training assumes that an actual forced landing will be conducted according to the POHS emergency checklist, i.e. with the engine shutdown and the propeller feathered. In this case, as the propeller was not fully feathered when the engine stopped, the rate of descent in the glide was greater and the resulting glide angle steeper. Consequently, an undershoot resulted and the aircraft failed to reach the runway.

The Investigation notes that in a significant number of recent single-engine aircraft occurrences in Ireland where the engine stopped, an unsuccessful forced landing resulted. These accidents resulted primarily due to the unrealised expectation that engine power would be recovered. Because of this, pilots' attentions were directed towards restarting the engine and not to executing a forced landing, including completion of the appropriate checklists. Therefore, it is important that if there is any loss of power in a single engine aircraft a pilot should suspect that a complete engine stoppage may occur at any stage. Therefore, a landing should be planned and prepared for based on that assumption. Consequently, this Investigation is of the opinion that single engine pilots should conduct regular practice of forced landings and glide landings at appropriate locations down to and including touchdown.

3. <u>CONCLUSIONS</u>

(a) Findings

1. The Pilot was properly licensed to operate the parachute drop flight.

2. The aircraft had a valid Certificate of Airworthiness at the time of the accident.

3. The accident flight occurred on the third day of the operation by the parachute club of a new aircraft type.

4. Following an initial, partial power loss the Pilot correctly ordered the parachutists to exit the aircraft.

5. The Pilot planned a power-on landing but the engine subsequently stopped on final approach.

6. The propeller was not manually feathered after the engine stopped and the aircraft undershot the runway.

7. The engine stopped due to fuel exhaustion.

8. The low fuel warning system was probably inoperative and the Pilot was unaware of the impending fuel exhaustion.

9. The fuel gauges had not been properly calibrated and were inaccurate.

10. The Shadin fuel flow gauge installed was not a Soloy STC approved part.

11. No record was found for calibration of the Shadin fuel flow sensor, which under read fuel consumption by approximately 19%.

12. The Operator's method of recording fuel on board the aircraft was inadequate.

13. During the final refuelling of the aircraft insufficient time was taken to allow the fuel to settle, consequently the fuel on board the aircraft was grossly overestimated. However, tank fuel migration rates following refuelling complied with certification requirements.

14. The Pilot's fuel management was inadequate as he relied on inaccurate fuel flow information to determine fuel consumption and remaining quantity on board the aircraft.

(b) Probable Cause

Engine stoppage due to fuel exhaustion resulting from inadequate fuel uplift.

(c) Contributory Factors

1. Lack of operational familiarity with a new aircraft type.
2. Inadequate fuel recording procedures.
3. Uncalibrated fuel tank indicators.
4. Unapproved and uncalibrated fuel flow indicator.
5. The low fuel warning system was probably inoperative.

4. SAFETY RECOMMENDATIONS

It is recommended that:

1. The Operator, the Irish Parachute Club review its fuel monitoring, recording and usage tracking system so as to monitor the consumption of fuel and accurately indicate the quantity of fuel on board its aircraft prior to flight. **(IRLD2010021)**
2. The FAA should consider an amendment to STC SA3634SW, which requires the installation of a placard and the introduction of a flight manual supplement, cautioning that fuel should be allowed to settle post refuelling before determining the quantity of fuel on board. **(IRLD2010022)**

Appendix A

Unapproved Shadin Fuel Flow gauge as installed in EI-HOG

Appendix B

Technical log of EI-HOG for the day of the accident.

AIRCRAFT : [illegible] REG : EI-HOG
PRE-FLIGHT INSPECTION : ______ DATE: 15/3/09 TIME : ______

HOBBS FINISH ______ NEXT CHECK: ______ HR
HOBBS START ______
TOTAL ______ TIME TO NEXT CHECK ______ HR

TOTAL TIME BROUGHT FORWARD ______

FLIGHT #	PIC	R/H SEAT	NO OF SKYDIVERS	ALTITUDE	START	FINISH	FLIGHT TIME	TOTAL TIME	FUEL UPLIFT	START (Y/N)	NO. LNDG's	REMARKS
1			6	FL [illegible]					ltrs			[illegible]
2			6	FL [illegible]					ltrs			"
3			6	FL [illegible]					ltrs			"
4			5	FL [illegible]					ltrs			"
5			5	FL [illegible]					165 ltrs			"
6			6	FL [illegible]					ltrs			"
7			4	FL [illegible]					ltrs			"
8			6	FL [illegible]					ltrs			"
9			6	FL [illegible]					ltrs			"
10			6	FL [illegible]					ltrs			
11				FL					ltrs			
12				FL					ltrs			
13				FL					ltrs			
14				FL					ltrs			
15				FL					ltrs			
16				FL					ltrs			
17				FL					ltrs			
18				FL					ltrs			
19				FL					ltrs			
20				FL					ltrs			
TOTAL									ltrs			

POST FLIGHT INSPECTION SIGNED : ______ DATE : ______ TIME: ______

OIL QTY UPLIFT ______ US QTS TECH LOG PAGE NO : ______

- END -