FINAL REPORT

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In accordance with the provisions of SI 205 of 1997, the Chief Inspector of Air Accidents, on 29 July 2007, appointed Mr Frank Russell as the Investigator-in-Charge to carry out a Field Investigation into this Accident and prepare a Synoptic Report.

Aircraft Type and Registration:	Steen Skybolt, EI-CIZ
No. And Type of Engines:	1 x Lycoming IO-360-A1B 6D (Modified)
Aircraft Serial Number:	001
Year of Manufacture:	1980
Date and Time (UTC):	29 July 2007 @ 15.26 hrs approximately
Location:	Ardfert Private Airfield, Co. Kerry
Type of Flight:	Private
Persons on Board:	Crew - One
Injuries:	Crew - One (Fatal)
Nature of Damage:	Aircraft Destroyed
Commander's Licence:	PPL (A)
Commander's Details:	Male, aged 57 years
Commander's Flying Experience:	1,600 hours (of which approximately 500 were on type)
Notification Source:	A member of Coonagh Flying Club notified the AAIU
Information Source:	AAIU Field Investigation

SYNOPSIS

The Pilot flew from Coonagh Airfield, near Limerick City, to Ardfert, Co. Kerry, where he carried out a pre-arranged aerobatics display for the Ardfert Festival. This display lasted about 18 minutes in good clear weather conditions. On completion, the Pilot flew to the nearby Ardfert Airfield where he landed on Runway (RWY) 33 and spent a relaxed 20 minutes in the company of some of his pilot colleagues from Coonagh Flying Club.

On departure from this airfield, the Pilot carried out a number of aerobatic manoeuvres along the axis of RWY 15 and, in the final roll manoeuvre, the aircraft's engine was heard to 'bang' and 'splutter', as it cut out. The Pilot, who was in a climbing roll to the right at the time, managed to straighten the aircraft's wings but, as it rapidly lost height, the aircraft initially impacted in the corner of a field and then it's hedge covered stone boundary wall. This field was adjacent to the airfield. There was no fire but the aircraft was destroyed by this double ground impact. Although his seven point harness remained intact, the pilot was fatally injured in the accident.

The Gardaí and Fire Services quickly attended the scene. Once the AAIU Inspectors of Accidents had completed their initial investigation on site, the wreckage of the aircraft was removed the next afternoon to the AAIU facility at Gormanston, Co. Meath, for a detailed technical examination.

1. FACTUAL INFORMATION

1.1 History of the Flight

It is necessary for the Investigation to examine contextual events leading up to the Pilot's penultimate flight on the afternoon of 29 July 2007, as well as his final accident flight itself, as one followed the other in quick succession.

Prior to departure from Coonagh Airfield, the Pilot uplifted 10 litres of Mogas and signed for it in the Flying Club's fuel logbook. He was also observed loading 20 litres of Avgas from a jerry can and said he would be loading another 20 litres from a second jerry can. In all, it is believed that he uploaded 50 litres mixed Mogas/Avgas. Four days earlier he had brought this Avgas in four jerry cans from a fuel truck bowser located at a licensed airfield near Nenagh, Co Tipperary, as there is only Mogas available at Coonagh Airfield itself.

Before his departure, the experienced Pilot would have been conscious of his fuel requirements and planned what amount would be needed for the round trip from Coonagh to Ardfert, a distance of some 107 nautical miles (NM). He mentioned to one of his colleagues that he was considering sending a third Avgas jerry can ahead, in an earlier departing aircraft, to Ardfert Airfield, most likely with the intention of landing and refuelling there prior to the aerobatics display. In the event, however, he did not follow through with this plan and, other than the 50 litres uptake, the exact amount of fuel on board on his departure from Coonagh Airfield cannot be precisely determined by the Investigation.

As his aircraft was not fitted with a transponder, the Pilot avoided the Shannon Control Zone by flying south east of Limerick City and routing towards Ardfert in Class G Airspace, where there was no requirement for him to have radio contact with Shannon Air Traffic Control (ATC). He did, however, have air to air VHF radio contact with a colleague in another aircraft who recalled that the Pilot was delayed on his departure from Coonagh due to problems with another (unrelated) aircraft. As a result, this colleague recalled, the Pilot flew to Ardfert at a higher cruising speed than normal, as he was observed to overtake another aircraft that had departed Coonagh for Ardfert before him (normally both aircraft would have cruised at a similar speed). The flight from Coonagh has a track length of 53.4 NM and was completed in 42 minutes.

While most of this flight was conducted at 2,000 ft, the GPS did record significant airspeed and altitude deviations en route. Allowing for wind, a significant portion of this flight was conducted at or close to maximum speed of 126 kts, as recorded by the GPS.

In addition, he also had air to ground VHF radio contact with another colleague who was in the village of Ardfert. This colleague was there to make the the public commentary on the Pilot's aerobatic display and, because events on the ground were running behind schedule, he asked the Pilot to delay his display by 15 minutes. The Pilot said no to this request and, on arrival over Ardfert, he commenced his aerobatic display, with his colleague commentating. This display lasted for about 18 minutes.

On completion of the display, he landed for an unplanned tea stop at the nearby Ardfert Airfield where he made one reconnaissance approach and overshoot to RWY 33, before returning to land on the same runway, which is 420 metres in length. This was a non-refuelling stop. Here, he had a cup of tea and met and conversed with his pilot colleagues from the Coonagh Flying Club, a small number of whom also flew in to attend the Festival. He spent about 20 minutes on the ground and, when asked by his friends if he would perform a few aerobatic manoeuvres on his departure, he readily agreed to this request. This was not an unusual request to make to such an experienced aerobatic pilot. His take-off, at about 16.23 hrs, was closely observed by his colleagues and other onlookers on the ground. They saw him first perform a low level roll over the airfield along the axis of RWY 15, then return to perform an inverted fly past, waggle his wings along the same axis and then complete the roll to straight and level flight. Finally, in what appears to have been the Pilot's 'trademark' departure manoeuvre, he initiated a climbing roll to the right, diagonally across the airfield and over the Airfield hangar. It was during this manoeuvre that all witnesses on the ground heard the engine 'bang' or 'splutter', followed by total silence, while the aircraft was banking in the roll. However, as the hangar obscured the witnesses' view of the final moments, most witnesses thought that the Pilot had recovered his wings level before the initial nose down impact with the ground and, some 20 feet further on, the boundary wall of the nearby field. This opinion was subsequently borne out by the flat layout of the aircraft wreckage. These witnesses were at the scene of the accident within one minute to render whatever assistance they could. This included the moving of the main tank fuel selector valve from "MAIN" to "OFF", and switching off the ignition. The Pilot was found slumped over the controls. There was no fire. He was confirmed dead by a local Medical Doctor at about 17.00 hrs. In all, his final flight lasted less than 3 minutes.

1.2 <u>Aircraft Information</u>

The Steen Skybolt is a two-seat aerobatic biplane designed for home-built construction. It is stressd for +12g and –10g. The fuselage is of welded steel construction covered in fabric. The wings are of wood construction, again covered in fabric. The seating is a tandem layout. When flown solo, it is flown from the rear seat. The fixed undercarriage is a tail-wheel configuration. The fuel system consists of a main tank in the fuselage and an optional tank in the wing centre section. Several different designs of tank can be used and these vary in capacity. A variety of engine options can be fitted ranging from 125 to 300 horsepower (hp).

1.3 <u>GPS data</u>

The Pilot's Garmin GPS 296 was recovered from the cockpit of the aircraft. The data on the GPS was downloaded by the AAIU. Tracks for over 310 separate flights were found stored on the unit. These flights included the Pilot's display flight and the accident flight on 29 July. On analysis of this data by the AAIU, it was found that the frequency of the recording interval of the GPS unit was set at 90 seconds i.e. the unit recorded the aircraft's position, heading, altitude and airspeed, among other parameters, every 90 seconds.

1.4 Aircraft Examination

The continuity of the flight and engine controls was checked and it was determined there was no loss of control continuity.

The engine had suffered significant damage in the ground impact. In particular the fuel injector unit and the propeller flange on the crankshaft were damaged to such a degree that it was not feasible to run the engine. The engine was therefore subject to a strip inspection at the AAIU facility in Gormanston.

This inspection found the engine to be in good overall condition, and no defect that would have caused an engine failure was found. The Investigation found that the pistons fitted to the cylinders were a non-standard type, Lycoming Part No LW 11487.

The damage to the propeller was consistent with the engine not running under power at the time of ground impact. The main fuel tank was severely ruptured by ground impact and was split open. The wing tank was removed and inspected. A total of 400 ml of fuel was recovered from the wing tank. This tank suffered some slight buckling at impact, but no fuel leak was found.

Small quantities of fuel were recovered from the various fuel pipes and the engine pump. The quantities recovered were less than would have been expected if the fuel system were fully primed, as in normal operation. Analysis of this fuel, the small quantity recovered from the wreckage of the main tank and the small quantity recovered from the wing tank was found to be free from contamination.

The bolt on the alternator-tensioning bracket was found to be missing. The threaded section of the bolt, which would have been left in the crankcase if the bolt had failed on impact, was not present. The alternator belt was recovered at the accident site.

The dual magneto was checked and found to produce a strong spark. One magneto-blanking cap was missing. This could have been lost during the impact.

The Investigation noted that most of the flexible hoses on the engine bay area bore tags indicating manufacturer in the 3rd quarter 2001. The flop tube did not carry a date or manufacturer tag. However, its condition indicated that it was not the original supplied with the aircraft.

1.5 Fuel System

EI-CIZ had two separate fuel tanks. The main fuel tank was located in the fuselage directly behind the firewall. There was also a small ferry tank in the upper wing, which has a capacity of 37.8 litres. This tank is not stressed for aerobatics and it is recommended that it be empty before commencing aerobatics. Furthermore the piping design of this tank is such that it can't supply fuel to the engine when the aircraft is inverted. The fuselage or main tank was divided horizontally into two smaller sections as shown in **Appendix A**. The purpose of the tank divide was to create an inverted fuel system that allowed sustained inverted flight without starving the engine of fuel. The upper section had a capacity of 69.1 litres and the lower section had capacity of 40.1 litres, giving a total capacity of 109.2 litres. The upper section also had two vertical baffles to prevent fuel sloshing in flight. Fuel was fed to the engine from the lower section, by means of a flop tube located in this section (see **Diagram 1 below**). The upper section is connected to the lower section via a length of 1-inch diameter pipe.

This pipe ensures that, in straight and level flight, while any amount of fuel remains in the upper section, the lower section will always be full. This pipe extends to within 35 mm of the bottom floor of the lower section to ensure that, in inverted flight, only a portion (approximately 9 litres) of the lower section contents would drain into the upper section. Only the upper section was fitted with a fuel measurement transmitter, which was of a float resistance type. The lower section had no fuel transmitter. Thus, the Pilot could only read the contents of the upper section from the cockpit fuel gauge. In addition, prior to flight, the Pilot was known to use a wooden dipstick to measure the upper section's fuel contents. However, it should be noted that there was no access to the lower section and thus it was impossible to measure its contents, even with the dipstick (**Appendix A**). Accordingly, when the fuel gauge in the cockpit reaches zero, the aircraft would still have 40 litres of fuel remaining in the lower section.

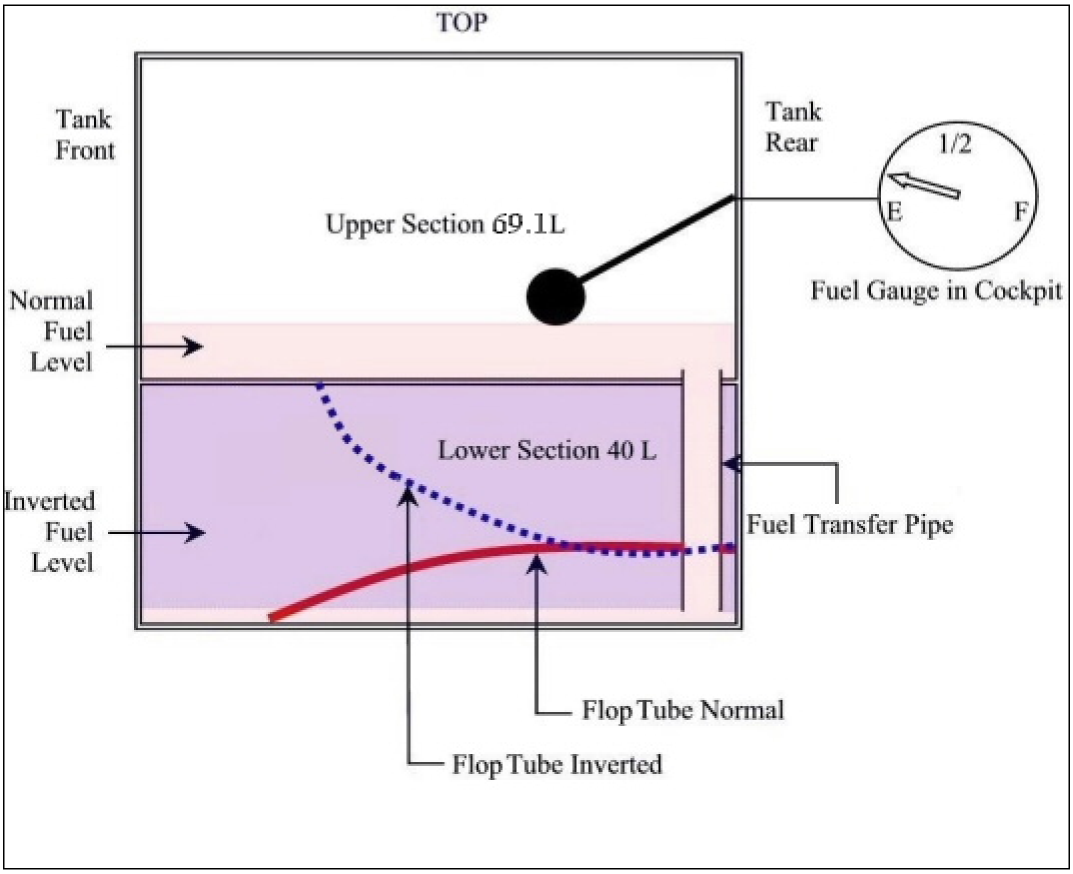

Diagram No. 1: Main Fuel tank

The flop tube fitted to EI-CIZ was a 3/4-inch diameter hose, with its fixed end mounted on the rear of the wall of the lower section of the tank. The flop tube was a length of semi rigid rubber hose, with an outer covering of braided steel, and a long brass weight (a 'clunk') on its free end. The clunk ensured that the free end of the flop tube moved about the tank so as to constantly stay close to the lowest point in the tank and was thus always submerged in fuel. The Investigation noted that it was not very flexible. When the tank was positioned, as it would be if the aircraft were in a vertical climb, it was noted that the flop tube did not fall to the side of the tank. It remained aligned along the forward/aft axis, due to the rigidity imposed by the braided steel hose, rather than fall to the side of the tank.

However, if the tank was positioned vertically and simultaneously rotated vigorously so as to simulate a climbing roll, it was noted that the flop tube fell against the side of the tank about half way up the wall. An arc-shaped mark was clearly visible on the inside of the tank where the clunk had, over a period of time, rubbed against the top, bottom and side walls of the lower section. The Investigation also noted that the combined length of the hose and the clunk was 38.5 cm. Thus the fuel intake, located at the end of the clunk, came to within 6.5 cm of the front wall of the tank.

The Investigation spoke to an experienced pilot who flew this aircraft. Specifically, he was asked about the fuel gauge. He stated that the gauge was 'notoriously unreliable' and that he had flown the aircraft with the fuel gauge reading zero on occasion. He was unaware of the compartmental design of the tank and of the fact that there was significant fuel in the tank when the gauge was reading zero. The Investigation searched the available records of EI-CIZ. These contained no details of the construction or capacities of the main fuel tank.

Research by the Investigation showed that there are several different designs of fuel tank available for the Skybolt. The capacities of these various designs vary considerably. The Investigation found that documentation of another Skybolt operated in Ireland had an upper section capacity of 28 US gallons (106 litres) and lower section capacity of 8 US gallons (30 litres). Many Skybolt tanks also have the flop tube mounted on the front end of the lower section, so the clunk is located to the rear of the tank, whereas that of EI-CIZ was to the front of the tank. It should be noted that the internal configuration of the lower tank couldn't be seen except by removing the tank from the aircraft, removing the flop tube attachment, and then inspecting the innards through this hole.

Further research by the Investigation found that the problem of no fuel measurement system in the lower section was recognised by some Skybolt operators. One solution was to measure the total fuel contents via an external sight glass. However some difficulties were reported with this system. Other installations had a sight glass that only showed the upper section contents. Another recent solution was to fit an electronic capacitance gauge. It may be noted that because of the possibility of interference with the flop tube, the fitting of a float gauge, similar to that fitted in the upper section, is not feasible.

Calculations show that if the lower section contained approximately 34 litres of fuel (and zero in the upper section) the flop tube inlet can uncover if the tank is pitched into a vertical position, as would occur when the aircraft enters a vertical climb. This condition is shown in **Appendix B.**

1.6 Engine modification

The Standard Lycoming 10-360-AIB 6D engine is rated at 200 hp. The Investigation noted that this was the type of engine fitted to EI-CIZ, but that high compression pistons, carrying Lycoming part number LW11487 were fitted to the aircraft. These pistons, which are taller than the standard pistons increased the compression ratio from 8.7:1 to 10:1, thereby boosting the engine power from 200 horsepower to 230 horsepower. The crown of these pistons featured depressions, which prevent the inlet and exhaust valves from striking the piston.

Lycoming informed the Investigation that these pistons were certified only for use in the helicopter version of this engine. The Investigation noted that a US company is now offering such a modification, but it is not certified for general use.

It has been given a Supplementary Type Certificate, (STC) by the FAA for two specific aircraft. It is noteworthy that both these aircraft are designed for higher altitude cruising, and are not aerobatic.

The engine logbook of EI-CIZ contains no entries relating to the fitting of these high compression pistons. This is not in adherence with the Society of Amateur Aircraft Constructors (SAAC)[1] Procedures Manual. The condition of these pistons, after the accident, would indicate that they had not completed a high number of flying hours and therefore were most likely fitted in recent years. The records of SAAC, recommending the aircraft for a Permit-to-Fly do not refer to the engine modification. The SAAC Inspector who signed the Permit-to-Fly Recommendation informed the Investigation that he was not aware that the engine had been modified. In the SAAC Procdures Manual, the maximum engine size covered under the SAAC system is 180 hp. This manual "defines the organisation and procedures upon which, the IAA approval is based for SAAC to make recommendations to the IAA for the issue/renewal of the Permit to Fly"[2]. However both SAAC and the IAA were aware that the original engine (prior to modification) was rated at 200 hp and the Permit-to-Fly was issued on this basis.

1.7 Fuel system tests

The Investigation noted that in a very steep climb, such as the zoom climb at the end of a low run, fuel could drain from the lower section to the upper section of the main tank through the transfer tube. Because the tank of EI-CIZ was severely damaged and ruptured in the accident, the Investigation made a mock up of the tank to determine the probable rate of flow from the lower section to the upper section in such a climb. These tests showed that the flow rate could be as high as 1.5 litres per second.

1.8 Fuel consumption

The documentation of EI-CIZ obtained by the Investigation gave no details of the fuel consumption of this aircraft. The fuel consumption figures obtained from the manufacturer for the standard Lycoming IO-360-A1B 6D engine are:

Economy Cruise:	36.5 litres per hour	(approximately 105 kts in this aircraft)
High Performance Cruise:	47.2 litres per hour	(approximately 120 kts in this aircraft)
Aerobatics:	59.2 litres per hour	

The effect of the piston modification on the fuel consumption rates is not precisely known. However, it is probable that the fuel consumption was higher, as a richer mixture would be required at high power settings. A source engaged in the technical support of the Skybolt design, informed the Investigation that a fuel consumption of 25 US Gallons per hour (94.6 l) could be experienced while conducting aerobatics at low altitude.

[1] SAAC was founded in 1978 to cater for aviation enthusiasts in Ireland who wanted to build and fly their own aircraft for recreational and educational purposes. SAAC has a formal agreement with the IAA covering its activities.

[2] Page 7, section 1.6.1 of SAAC Procedures Manual, dated 8 March 2006.

1.9 Aircraft Logbooks

The Investigation was only able to locate the current airframe and engine logbooks that cover the period from November 1992 to the date of the accident. The Investigation noted that the engine and airframe log books corresponded exactly. This indicated that the engine was the original engine fitted to the aircraft when it was built in 1980.

The engine logbook contains no record that an overhaul was completed on the engine since 1980. The 'Time Since Top-Overhaul' column contained partly completed data. The aircraft suffered a previous accident on 8 November 1999. The aircraft returned to service in 2002 after this accident. SAAC paperwork, dated 26 November 2002, stated that a Top Overhaul was completed on the 4 June 2001. A SAAC Application for a Permit-to-Fly, dated the 30 December 2003, shows that the engine was overhauled (not just Top-Overhauled)[3] on the 4 June 2001. The logbook does show that the engine was repaired on the 4 June 2001, but the certification is only for a repair, not any kind of overhaul. The Investigation noted that there was an error in the engine logbook records for 2006, in that the entered hours are 100 hours more than the actual hours. The engine logbook certified that the engine received an annual inspection by a SAAC Inspector on the 25 May 2007.

1.10 Engine Overhaul Life

The engine logbook information indicates that the engine was not overhauled since new in 1980. Under Irish Aviation Authority (IAA) Regulations, as per Aeronautical Notice No. A43 of 12 August 1999, there is no fixed period overhaul requirement for piston engines in aircraft operating under a Permit-to-Fly. An annual inspection, or a 100-hour inspection, which certifies that the engine is in a satisfactory condition, is the only requirement for an engine to continue in service. This engine satisfied these requirements, notwithstanding that it had flown for 27 years without a recorded overhaul.

1.11 Recent Repairs

The Investigation found that significant repairs had been recently performed on the aircraft, including replacement of the leading edge of the upper wing centre section, and also the replacement of the auxiliary fuel tank, which is located in the upper wing centre section. These repairs were not noted or certified in the aircraft's logbook. However, these repairs were not a factor in this accident.

1.12 Aircraft Permit-to-Fly

This aircraft operated under a Permit-to-Fly, issued on the 2 July 2007 by the IAA. This Permit was issued on the basis of an inspection completed by a SAAC Inspector and the completed SAAC application.

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[3] A Top-Overhaul is limited to the cylinder heads, pistons and valves, and is normally accomplished with the engine installed in the aircraft. A full overhaul requires that the crankcase be dismantled and the engine to be removed from the aircraft.

1.13 Video Evidence

The Investigation obtained a witness video of the aircraft arriving at Ardfert Airfield after the Festival display. The Investigation noted that the engine made loud bangs (backfires) as the throttle was retarded prior to landing. This video did not include the accident sequence.

1.14 Previous accident

This aircraft suffered an accident on 8 November 1999. The AAIU Investigation of that accident[4] concluded that it was caused by the fuel selector valve not being properly aligned, thereby causing a restricted fuel supply to the engine. The selector valve was changed after that accident. The Investigation is satisfied that the selector valve operation was not a factor in this accident.

1.15 Meteorological Information

The Aviation Division of Met Éireann, Shannon Airport, supplied the following information:

General Situation:	An anticyclone, centred off the northwest coast of Ireland, maintained a north northwesterly airflow over the area.
Wind:	2000ft 360 15 kt Surface 330 08-12kt
Weather:	Nil
Visibility:	10+km
Cloud:	FEW/SCT 2000-3000ft
Temp/Dew Point:	18/08 C
MSL Pressure:	1022 hPa

1.16 Medical Information

A Post Mortem was carried out on the Pilot in Tralee General Hospital on 30 September 2007. His clinical history showed that the Pilot had been fit and healthy, and had no medical history of relevance. He was not on any medication at the time of the accident. The Report found that the Pilot had died from 'multiple injuries' following an air crash.

1.17 NTSB Records Review

The Investigation carried out a website review of NTSB data on Steen Skybolt Accidents/Serious Incidents from 1975 to 2003 (when this data ended). It showed 50 records of accidents/serious incidents, of which 18 were fatal accidents during the period covered. A common causal factor running through the majority of these accidents is impact with terrain following low level manoeuvres.

1.18 Additional Information

The removal of the Pilot from the wreckage prior to the arrival of the Investigation team, the associated displacement of items in the cockpit and the partial destruction of the cockpit area in order to remove the Pilot, impeded the Investigation by virtue of the destruction of this crucial cockpit area evidence.

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[4] The AAIU report of this accident can be found at: http://www.aaiu.ie/upload/general/9638-0.pdf

The Investigation fully understands that the Fire Services priority is the suppression of fire and the expeditious removal of casualities from any accident site. However,in this instance, the Investigation considers that there was no pressing reason that required the removal of the Pilot from the cockpit before the Investigation arrived on scene.

The protocol at an air accident scene is that evidence such as the position of the pilot(s), passenger(s), flap and undercarriage levers, and various other cockpit switches etc needs to be recorded by the Investigation. This can only be done with any fatalities in situ and unmoved until the Investigation completes it's initial findings. The Investigation notes that the AAIU previously issued "*Guidance for An Garda Síochána and the Emergency Services in the aftermath of an air accident*"[5] as an aide-memoire to those two Services at air accident sites. The Investigation understands that the local Fire Service was not aware of the existence of this guidance material at the time of the accident. This is not the first occasion that the removal of fatalities, however well intentioned and motivated, led to the loss of crucial cockpit and airframe evidence as a result of collateral damage to those areas by the Fire Services.

2. ANALYSIS

2.1 GPS Analysis

Aerobatic manoeuvres, such as those that the pilot was engaged in at the time of the accident, result in very rapid changes in heading, airspeed and altitude. Therefore, much of the flight details, which could be expected from the GPS, were lost due to the low frequency recording interval. In the 60-minute flight from Coonagh to the landing at Ardfert Airfield the GPS only plotted data 41 times. This resulted in a very coarse track, especially when the aircraft was engaged in aerobatic manoeuvres. Aerobatic manoeuvres such as loops and barrel rolls were not easily discernable on the data. On the final flight, only the take-off to an altitude of 200 feet was recorded. Again, due to the low frequency recording interval, only 1.5 minutes of flight time were recorded. This indicated that the final flight was of 3 minutes or less duration.

The recording interval of the unit is user-adjustable; it can be varied from once a second to once every few hours. The lower the frequency of the recording interval, the longer duration of data that can be stored on the GPS internal memory. However, this data is less accurate than the data obtained when using a more frequent recording interval. The Investigation was inhibited by the low recording interval selected on this GPS unit.

2.2 Propeller and Engine

On inspection of the propeller blades it was noted that one propeller blade was bent backwards slightly at about two-thirds span. The other propeller blade had some small indentations along the outer quarter of its leading edge. The propeller flange on the crankshaft was fractured and bent at its attachment point to the propeller. The nature of this damage is significant as it is consistent with that of a propeller striking the ground at very low RPM. On analysis of the engine and its ancillary components, the Investigation is confident that the engine was capable of producing rated power at the moment of impact. However, the damage to the propeller suggests that the engine was producing very little, if any power, at the moment of impact.

[5] Over 1,000 copies of this guidance material were posted out to the relavant agencies and it is also available on the AAIU web site www.aaiu.ie

No evidence of aircraft failure or malfunction, or of pilot incapacitation, was found. The evidence of the aural witnesses of loud bangs, or backfires, followed by silence as the aircraft climbed after it's final low run, is consistent with engine stoppage due to fuel starvation. The backfire, as noted in the approach to land when the throttle was retarded (and the fuel and air supply reduced suddenly), is similar to the indications that would be experienced when the fuel supply was lost.

2.3 Fuel Contents

The Investigation was unable to determine the fuel contents of the aircraft prior to departure from Coonagh, as the tank contents, prior to the addition of 50 litres by the Pilot, are unknown. It does appear that the Pilot did not put any fuel into the upper wing ferry tank and, in all probability, this tank was almost empty on departure from Coonagh. The Pilot did have a discussion with another pilot about ferrying some fuel in another aircraft to Ardfert, so that he could uplift some fuel there after the display. In the event, this was not done, but this indicates that the Pilot did have some concerns regarding an adequate fuel reserve. In light of this, it is probable that he filled the main tank to capacity, or at least to near maximum capacity, which is 110 litres.

During the flight from Coonagh to Ardfert, EI-CIZ was observed to overtake another aircraft, which indicates that it completed this segment of the flight at high speed and, consequently, at a high power setting. According to the GPS data, this flight, with a track length of 53.5 nm took 42 minutes, which equates to a ground speed of 76 kts. As the wind was across track it would have had little effect on the ground speed. The aircraft had a cruising speed of 113 kts. At this speed, the flight should only have taken 28 minutes for the flight. The significant variations of ground speed and altitude recorded by the GPS in the Abbeyfeale area indicates that the Pilot probably practised some aerobatics at this point. Calculations show that a period of high-speed cruise and 14 minutes of aerobatics could have consumed 42 litres of fuel. The aircraft then performed aerobatics at the Ardfert Festival for approximately 18 minutes. Aerobatics are conducted at high power settings and with frequent throttle movements, which would increase the fuel consumption to as much as 94 litres/hr. therefore about 28 litres of fuel would have been used during the aerobatics display.

The final flight, after take-off from Ardfert Airfield, was again largely aerobatic. During this three-minute flight approximately 4.5 litres of fuel would have been used. Therefore total fuel consumption since departing Coonagh, up to the time of the accident, could have been as high as 75 litres. Based on the foregoing, at the time of the accident, the contents in the upper section were exhausted and approximately 35 litres remained in the lower section, if the tank was full on departure from Coonagh. However, if the tank was not filled to the absolute brim, the lower section fuel level could, at the time of the accident, have reached the critical quantity of approximately 34 litres or less, where the flop tube inlet would momentarily uncover during a vertical climb.

The Investigation is of the opinion that if the aircraft had entered a near-vertical climb, with approximately 34 litres or less fuel in the lower section, and the clunk remained central, the fuel inlet in the clunk would have uncovered and air would have been sucked into the fuel system. During such a steep climb, the fuel level in the lower section would further reduce due to fuel draining into the upper section through the transfer tube.

This is shown in **Appendix B**. In a 3 second climb, as much as 4.5 litres would have transferred in this manner, lowering the fuel level in the lower section, thereby further increasing the uncovering of the clunk (flop tube inlet).

Calculations also showed that in such a 3 second period, the engine would have consumed the contents of the fuel line between the clunk and the fuel injector. Therefore some 3 seconds after the clunk uncovered, air would have entered the fuel injector, and the fuel supply to the cylinders would have ceased. The engine would then have backfired briefly and stopped. From reliable witness reports, it is known that prior to the accident the aircraft climbed near-vertically to a height of approximately 400 feet above ground level (AGL).

This climb would have taken approximate 3 seconds from its initiation. The Investigation therefore considers that it is probable that the flop tube inlet uncovered in the final steep climb and that the entry of air into the engines fuel system caused the engine to stop. It is noteworthy that this condition could have been initiated when there were approximately 34 litres of fuel remaining in the lower section, which in normal circumstances, would have provided sufficient fuel to return to Coonagh at an economy cruise setting, with an additional fuel reserve of approximately 25 minutes.

2.4 Main Fuel Tank Design

Because this was not a certified aircraft, it did not have a parts book. Given the variety of tank designs available for this aircraft, there is no standard flop tube specified for this installation. The Investigation is of the opinion that the location of the Clunk in EI-CIZ, i.e. very close to the front wall of the lower section of the fuel tank, was not the original design intention. A location near the centre or rear of the tank would appear preferable. If this particular flop tube were fitted to a tank with a front wall mounting for the flop tube, the Clunk would have rested near the rear wall of the tank and would not have uncovered in a steep zoom climb. Given that the condition of the flop tube indicated it was not the original, it is possible that the flop tube fitted at the time of the accident was longer than the original and did not conform to the intentions of the designer. Given that no flop tube length or part number is laid down, the fitting of an inappropriately long flop tube could easily occur.

2.5 Engine Modification

The use of a high compression engine configuration would have caused the engine to stop more quickly due to increased braking effect caused by the higher compression ratio. Furthermore, for the same reason, the propeller would be less likely to windmill at lower speeds such as that experienced at the top of the final climbing manoeuvre. In addition, fuel injection engines, such as that fitted to EI-CIZ, are more difficult to restart once air has been allowed to enter the fuel system. The forgoing, allied with the low altitude of the final manoeuvre, precluded a successful restart of the engine.

2.6 Layout of Fuel Tanks

2.6.1 Upper Wing Tank

The non-use of the wing tank can be explained by the fact that this tank must be empty when performing aerobatics, as it does not have a contents gauge and it is not plumbed for inverted flight.

2.6.2 Main Fuel Tank

The main tank is made up of two sections. The upper section of this tank is equipped with a float type fuel gauge, which allows the pilot to monitor his fuel contents in the cockpit. The lower section of this tank is designed to provide fuel for inverted aerobatic flight. It has no fuel gauge nor is it possible to independently measure its contents when the upper section tank is empty. Therefore the Pilot could only determine the remaining fuel by estimating the rate of fuel burn for the aircraft and the elapsed time since the gauge initially read empty. Preforming aerobatic manoeuvres when the upper section tank is empty will produce a situation whereby the flop tube inlet uncovers and the engine is starved of fuel.

2.7 Records

The Investigation was somewhat hampered by the absence of detailed maintenance records in the aircraft's logbooks. The Investigation also noted a recent error in the logbook hours total and the omission of recent major repairs to the aircraft. The Investigation believes that SAAC should require complete logbook records, as prescribed in Section 13 of the Procedures Manual, as a criterion for recommending renewal of Permits-to-Fly.

2.8 Engine Overhaul Period

The Investigation did not find any significant fault with the engine. In fact, the engine bore evidence of good maintenance. However, there are several aspects of an engine's condition that can only be determined during a complete overhaul. The Investigation is concerned that an engine should have completed 27 years service without an overhaul. It should be noted that the engine manufacturer recommends an overhaul every 12 years and the IAA imposes a maximum limit of 20 years between overhauls for aircraft with a certificate of airworthiness.

3. CONCLUSIONS

(a) Findings

1. The Pilot was properly licenced and medically fit in accordance with Joint Aviation Authorities (JAA) requirements.
2. Weather conditions at Ardfert were dry and sunny, with some scattered broken cloud and were not a factor in the accident.
3. The Pilot uplifted 50 litres mixture of Avgas/Mogas fuel prior to his departure for his air display at the Ardfert Festival. However, the Investigation could not ascertain the exact amount of fuel on board EI-CIZ at its point of departure from Coonagh Airfield.
4. The 18-minute air display at Ardfert went off successfully, after which the Pilot made an unplanned landing at the nearby Ardfert Airfield to socialise briefly with some of his pilot colleagues from Coonagh Flying Club.
5. No fuel was uplifted at Ardfert Airfield.
6. The Pilot acceded to a request from his colleagues to perform some aerobatics on his departure for Coonagh. On take-off, he initially carried out two horizontal roll manoeuvres and, during the third and final manoeuvre, which was a climbing roll to the right, the engine was heard by witnesses to bang and splutter, as it stopped.

7. As the aircraft descended towards the ground, witnesses observed that the Pilot attempted to get his wings level but their view of the final ground impact was obscured by the Airfield hangar and some boundary hedges.

8. Impact witness marks at the accident site showed that the aircraft initially hit the ground in a slightly nose down attitude and rebounded a further 20 feet into the field's boundary fence of a stone wall with strongly developed shrubs on top. Here, it came to rest in the horizontal position and partially through this wall. The forward part of the aircraft, its undercarriage and wings were destroyed. There was no fire.

9. The Pilot, still seated in his seven-point harness in the rear cockpit, received fatal injuries, possibly as a result of the first ground impact.

10. The Investigation found no failure on the aircraft that could have contributed to this accident.

11. The Investigation found that in a situation where the upper section tank was empty (gauge reading zero), the detailed configuration of the lower section tank would allow the flop tube inlet to uncover at approximately 34 litres or less.

12. Calculations show that when the flop tube inlet uncovered and the engine stopped, there would have been sufficient fuel in the lower section tank to complete the flight back to Coonagh.

13. The low height at which the engine stopped precluded a successful restart.

14. The high compression pistons fitted to this engine were not approved or certified for this application, but this was not a factor in causing the engine to stop.

15. The engine had been modified without the knowledge of SAAC or the IAA. However, the Investigation was unable to determine when this modification was carried out.

16. The aircraft's logbooks were not complete. This was not a factor in the accident. The aircraft engine appears to have completed 27 years service without overhaul. This was not a factor in the accident.

3.2 (b) Cause

The immediate cause of the accident was the sudden stoppage of the engine due to fuel starvation during the climbing roll to the right.

(c) Contributory Factors

1. The uncovering of the flop tube inlet during the final manoeuvre.

2. Conducting aerobatic manoeuvres having exhausted the contents of the upper section of the main fuel tank.

3. Insufficient height above the ground for the Pilot to effect a safe recovery following the engine failure.

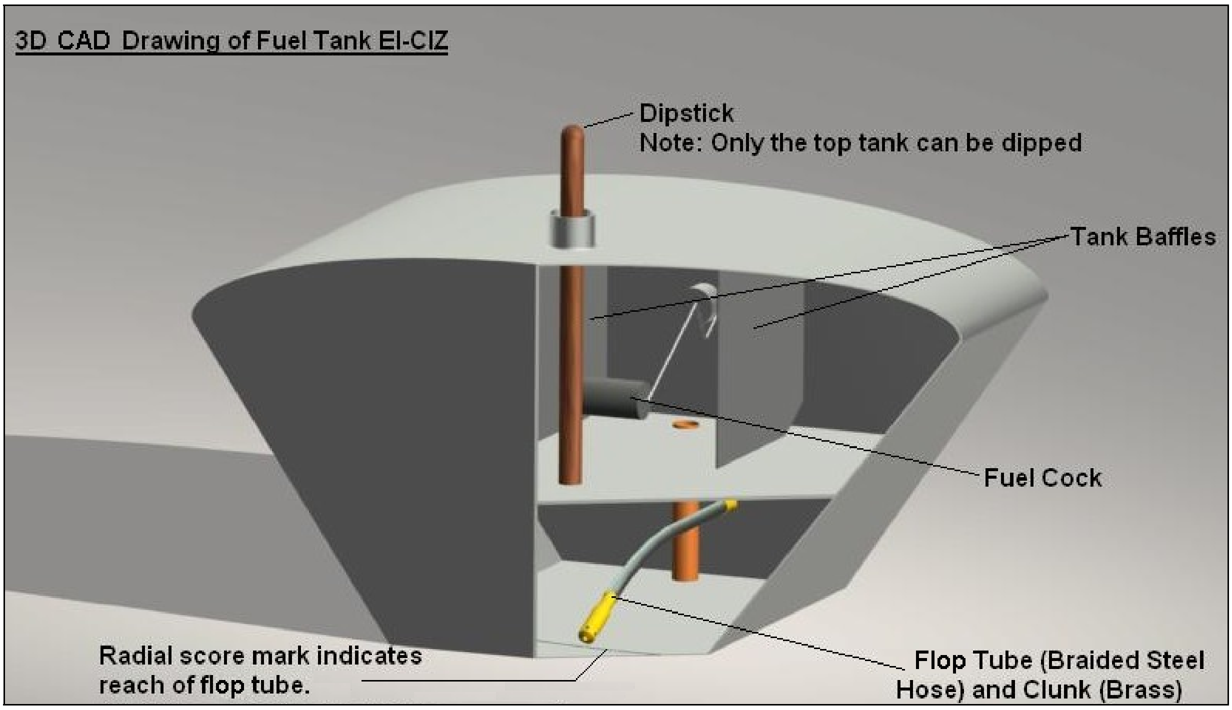
4. <u>SAFETY RECOMMENDATIONS</u>

It is recommended that:

1. The IAA, in conjunction with SAAC, should review the IAA/SAAC Procedures Manual of March 2006, to ensure adherence to it's guidelines and amend where necessary in the light of issues raised in the course of the Investigation. **(SR 22 of 2008)**

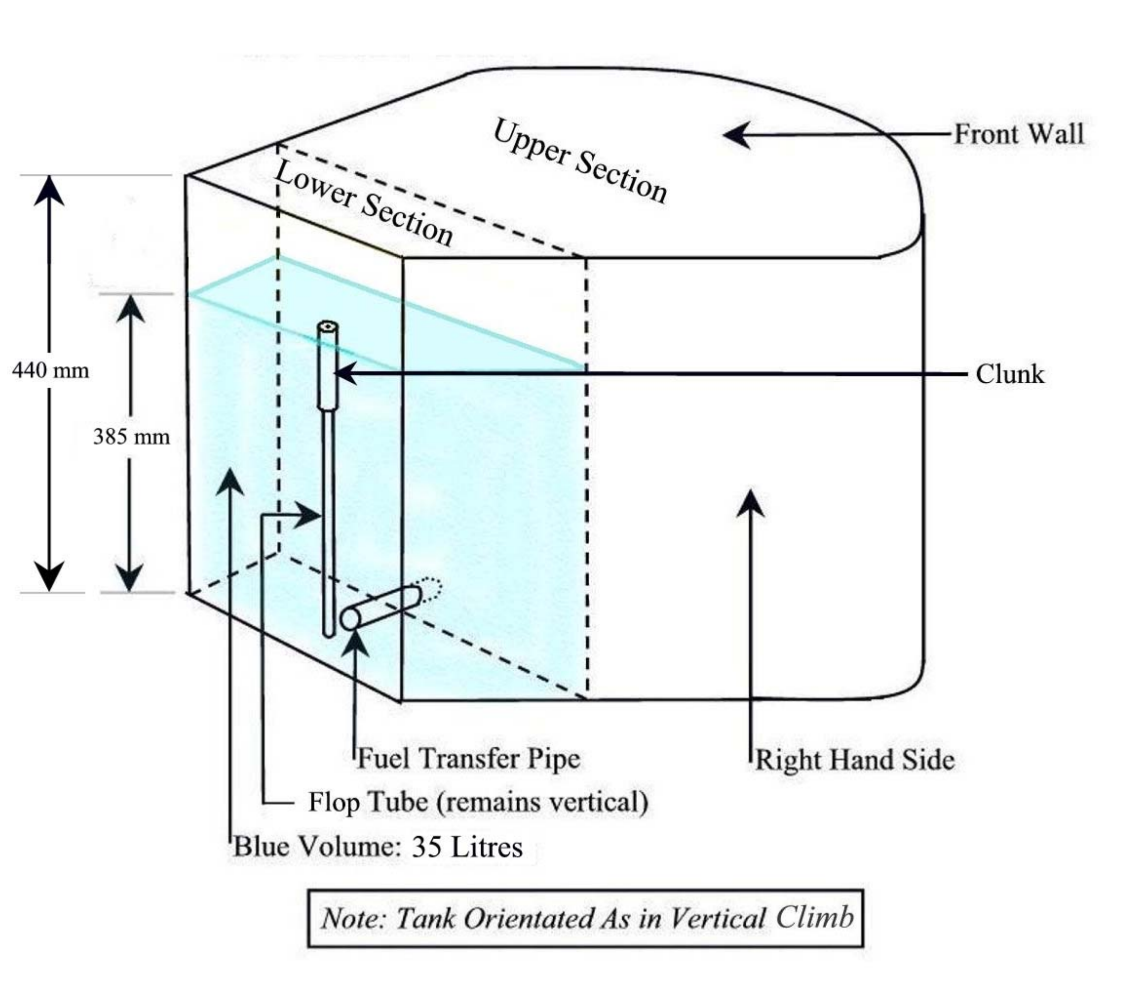
2. The Department of the Environment, Heritage and Local Government should ensure that the AAIU document, *Guidance for An Garda Síochána and the Emergency Services in the aftermath of an air accident*, is available and adhered to by each of the State's 37 Fire Authorities. **(SR 23 of 2008)**

Appendix A



A pictorial representation of the main fuel tank.

Appendix B



A pictorial diagram of the main fuel tank when the aircraft was in a vertical or very steep zoom climb

- END -