Reims Cessna FA152 Aerobat, G-BIHE

AAIB Bulletin No: 12/2000 Ref: EW/C99/03/04 Category: 1.3

Aircraft Type and Registration:	Reims Cessna FA152 Aerobat, G-BIHE
No & Type of Engines:	1 Lycoming O-235-L2C piston engine
Year of Manufacture:	1981
Date & Time (UTC):	10 March 1999 at 1330 hrs
Location:	Near Sheerness, Isle of Sheppey, Kent
Type of Flight:	Aerial Work (photographic)
Persons on Board:	Crew - 1 - Passengers - None
Injuries:	Crew - Minor - Passengers - N/A
Nature of Damage:	Nose landing gear detached, fuselage distorted, right wing severely damaged
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	42 years
Commander's Flying Experience:	6,970 hours (of which 6,960 were on type) Last 90 days - 40 hours Last 28 days - 19 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and AAIB examination of the aircraft

History of the flight

The aircraft took off from Sibson Airfield, Cambridgeshire, at 1145 hrs. It was fitted with long-range fuel tanks, which had been filled, giving approximately 6 hours endurance. After conducting aerial photographic work in the area of Colchester, Essex, the pilot set course to take further photographs in the Canterbury area, with the intention of then landing at Lashenden Airfield in Kent, routing via Southend to avoid a long overwater crossing of the Thames estuary. He reported the weather generally as similar to the forecast, with the surface wind from 350°M at 3 kt, visibility of around 10 km, a little scattered cloud at 2,500 feet agl and an ambient temperature at the surface of +6°C. However, as G-BIHE approached the Thames the pilot noted that the cloud base reduced to 1,800 feet agl and the visibility deteriorated to around 6 km in haze, although conditions appeared to be better in Kent.

The pilot set out across the Thames at 1,500 feet agl, lower than his preferred level of 2,400 feet agl because of the reduced cloud base, with the engine speed at approximately 2,400 RPM. Shortly after coasting out for the crossing he conducted a check for the presence of carburettor ice by selecting carburettor heat on for 10 to 15 seconds and verifying that the engine note dropped with hot air selected and returned to its previous value when hot air was de-selected. Approximately 3 minutes later, as the pilot was changing the configuration of his photographic equipment, the engine suddenly and smoothly ran down. The aircraft was by then over the mouth of the River Medway, just west of Sheerness, still at 1,500 feet agl. The pilot immediately selected carburettor heat on and carried out the engine failure drill. He reported that the engine seemed to be suffering from intermittent fuel starvation; by pumping the throttle he could keep the engine going and three or four times it burst into life and produced high power for a few seconds.

The pilot transmitted a Mayday call to Southend Airport and turned left towards the shore. He found that his options were very limited because of the aircraft's position and height, with the built-up area of Queensborough extending to the shore on the left, the West Swale river beneath and marshes to the right. He selected an area of open land to the south of Queensborough and attempted to turn 180° left to land into wind, with the engine still producing some power. However, the height and power were insufficient to enable the turn to be completed and he was forced to land straight ahead into a field with a rougher surface. Full flap was selected and, with the engine still producing some power, the pilot aimed at achieving a gentle touchdown. There was insufficient time for him to switch off the fuel, electrics or magnetos before the landing.

The nosewheel dug in on the soft uneven ground and detached, the propeller impacted the bank of a ditch and the aircraft nosed over onto its back and came to rest inverted. The engine, the engine firewall and the instrument panel were displaced aft and the right wing was severely damaged. The aircraft was fitted with a four-point harness but the pilot normally flew with the shoulder straps unfastened when photographing and had managed to refasten only the right shoulder strap before touchdown. He sustained severe bruising to the ribs but was otherwise uninjured and was able to jettison the cockpit left door and vacate the aircraft unaided. There was no fire.

The forced landing occurred at approximately 1330 hrs, giving a flight time from Sibson of around 1.8 hours. It was reported that when the aircraft was dismantled after the forced landing considerable quantities of fuel remained in both wing tanks.

Aircraft examination

G-BIHE had accumulated 8,971 flying hours from new at the time of the accident. Its last maintenance check, a Star Annual Inspection, had been completed on 5 March 1999, 7.2 flying hours prior to the accident.

Examination of the aircraft revealed no signs of a pre-accident problem that would have caused a loss of power. Selection of carburettor heat manually operated a flap that acted to shut-off the normal air supply to the engine and to open an alternate supply path taking air from a muff surrounding one exhaust pipe. No evidence of deficiencies in the carburettor heat system was found.

The engine was removed and examined by an overhaul agency. It was run on a test bed, following rectification of accident damage, including the replacement of the ignition harness, carburettor and oil filter and the sealing of a sump and induction system leak. The engine ran satisfactorily, with a maximum output power close to the requirement. Magneto settings were correct, sparking plugs tested normally and tests on the damaged carburettor revealed no evidence of pre-accident anomaly.

Weather

An aftercast from the Meteorological Office indicated that there was a moderate north-northeasterly airstream over the area of the accident associated with an area of high pressure centred over the Isle of Mann. Cloud was reported as 7 oktas of stratus with a base at 1,200 feet. Wind, ambient temperature and humidity were:

HEIGHT **ft amsl**	**WIND** **°T/kt**	**TEMPERATURE** **°C**	**DEWPOINT** **°C**	**RELATIVE HUMIDITY** **%**
Surface	360/10	5	2	81
500	010/13	3	2	93
1,000	010/15	2	1	93
1,500	020/17	1	1	100
2,000	020/18	0	-2	86

Analysis

No reason for the sudden loss of engine power was apparent from the aircraft and engine examination. There was plenty of fuel on board, the carburettor appeared to have been serviceable prior to the accident and, after the repair of identifiable impact damage, the engine operated normally after the accident. The possibility was therefore considered that the power loss had resulted from induction system icing. The reported conditions between the surface and 2,000 feet, in the area where G-BIHE experienced its problems, were in the region of the CAA Induction System Icing Chart (see below), designated 'Serious icing - any power'. Given the available evidence and in the absence of any other identifiable pre-crash defect with the power plant, it was concluded that G-BIHE's power loss had probably resulted from induction system icing.

Engine induction system icing

The accretion of ice in a piston engine induction system, causing constriction of the airflow to the engine, disturbance of the fuel/air ratio and power loss or engine stoppage, is described in CAA Aeronautical Information Circular (AIC) 145/1997 (Pink 161) of 30 December 1997. The AIC describes three types of induction system icing, the most common being Carburettor Icing where the temperature drop due to pressure reduction and fuel vaporisation at the carburettor venturi (up to 30°C) can cause moisture to condense and freeze and build up around the venturi and the throttle butterfly. The other types are Fuel Icing, where water suspended in the fuel can precipitate and freeze on the flow passage surfaces, and Impact Icing where ice can build up on air intakes and filters at sub-zero temperatures in precipitation or cloud. The AIC includes a chart showing the 'range of ambient conditions conducive to the formation of induction system icing for a typical light aircraft piston engine operating in clear air' at various power settings (Figure 1). CAA Safety Sense Leaflet 14A (Piston Engine Icing, published 1997) provides similar information.

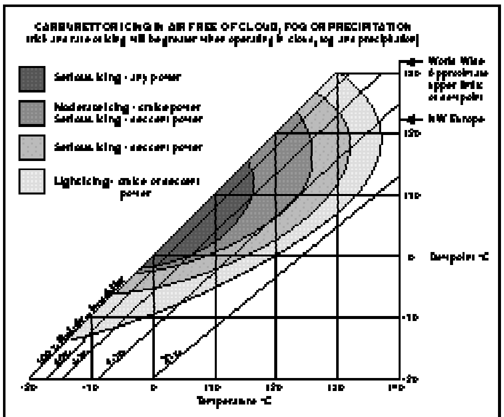

Figure 1
AIC 146/1997 Chart of Ambient Conditions
Conducive to the Formation of Induction System Icing
for a Typical Light Aircraft Piston Engine

British Civil Airworthiness Requirements (BCAR K5-5) required demonstration 'that air intake systems will permit the supply and maintenance of an adequate supply of air to each engine under all conditions of operation for which the aircraft is to be certificated in a manner that will permit the continued safe functioning of the engines, components and accessories.' In this context BCARs required a means of protection against induction system ice accumulation for piston engine installations. For aircraft with unsupercharged engines using conventional venturi type carburettors this is required to provide a 50°C rise in the intake air temperature when operating in moisture-free air at -1°C at 75% of Maximum Continuous Power (MCP). Compliance is generally achieved by using an exhaust gas heat exchanger to warm air taken from an alternate intake manually selectable by the pilot. Satisfactory system function is checked by confirming an engine RPM drop when hot air is selected. However, the RPM or manifold pressure drop to be expected during a Ground Run-Up Check as an indication that the hot air system is functioning adequately is generally not quantified in Operating Handbooks. The AIC and SSL suggest 'about 75 to 100 RPM and 3 to 5" of manifold pressure'.

No information on the effectiveness of this type of system at power settings below MCP and in dynamic situations has been found, including situations where ice formation causes both a power loss and a restriction in the flow of hot air through the induction system. Because of the range of variables involved, the frequency and duration of hot air application necessary to prevent the accretion of excessive induction system icing apparently cannot be fully defined. The SSL recommends a hot air check every 10 minutes in the cruise, or "more frequently if conditions are conducive to icing". Similarly, the procedure for warming the engine at height increments during a low power descent, intended to generate sufficient heat to prevent excessive induction system icing, is only partially specified. The SSL recommends increasing power to cruise setting every 500 feet height interval during descent, but also recommends this "more frequently if conditions require", and makes no suggestion as to time for which the cruise power setting should be maintained. However, if the power application is too short, and there may well be an incentive to minimise it in order to expedite the descent, it will not generate sufficient heat to eliminate excessive ice. Wide variation in reported typical practice was found among a small sample of pilots, with the power increase duration generally reported as a maximum of a few seconds only but ranging up to 30 seconds. Views on the purpose of warming were varied, frequently relating to prevention of supercooling of oil or cylinders.

The AIC and SSL also note that partial application of hot air may actually promote induction system icing and should not be used unless an intake temperature gauge is fitted and allows the effect to be assessed and that use of MOGAS increases the possibility of carburettor icing. They mention that 'the use of hot air after ice has formed may at first appear to make the situation worse because of the reduction in power due to the use of hot air and to an increase in rough running as the ice melts and passes through the engine. The SSL notes that (red text in the SSL is here represented in bold) "If this happens the **temptation to return to cold air must be resisted** so that the hot air has time to clear the ice. **This time may be in the region of 15 seconds,** which will, in the event, feel like a very long time!"

The AIC and the Safety Sense Leaflet (SSL) note that carburettor or fuel icing can occur in clear air and is therefore particularly insidious. The SSL notes that "Specific warnings of induction system icing are not normally included in aviation weather forecasts and you must be prepared to deal with it on the basis of your knowledge and experience." However, some confusion is evident in the statements, "Carb icing is **not** restricted to cold weather, and will occur on **warm days** if the **humidity is high,** especially at **low power settings.** Flight tests have produced serious icing at descent power with the ambient (not surface) temperature over 25°C, even with relative humidity as low as 30%."

Available information suggests that ambient conditions pertaining in the UK for most of the time are conducive to carburettor icing. The AIC and SSL note that the onset of induction system ice may be recognised by a slight drop in rpm, for an engine driving a fixed pitch propeller; or by a reduction in manifold pressure for an engine driving a constant speed propeller or helicopter rotor system. Some information suggests that the rpm or manifold pressure drop experienced, before the fuel/air ratio disturbance is sufficient to cause a major power loss, may be very small in some circumstances.

Previous cases of induction system icing

AIC 145/1997 notes that statistics continue to show an average of 10 occurrences, including 7 accidents, per year which were probably caused by engine induction icing. SSL 14A notes that every year there are several accidents where induction system icing may have been a factor.

Accidents and incidents in the UK suspected as having been caused by induction system icing in a recent 14 year period (January 1985 to December 1998 inclusive) were identified from analysis of information from previous AAIB investigations and data supplied by the CAA. The cases attributed to this cause were characterised by severe power loss for which no explanation other than induction system icing could subsequently be found. The number could not be established with certainty because the evidence is almost invariably circumstantial, the ice melting away before the cause of the power loss is investigated, generally leaving no direct evidence. Additionally, the evidence was not comprehensive in many cases. It was therefore possible that the assessment attributed some accidents to induction system icing that had in fact resulted from other causes. On the other hand, a considerable number of cases of unexplained power loss where induction system icing could have been a cause or contributor were not attributed to this cause because of lack of evidence. It was therefore judged that the assessment provided a reasonable estimate of the number of reported cases. It was also considered likely that there had been other occurrences of significant power loss due to induction system icing which had hazarded the aircraft but had not been reported.

The assessment indicated that induction system icing had led to a total of 111 reported forced landings in the 14 year period, plus other cases where aircraft damage resulted from terrain contact while recovering from engine power loss, resulting in 96 Reportable Accidents reported in the UK. Among the 96 damaged aircraft, 59 were severely damaged and a further 20 were destroyed. 52 persons were injured, including 7 seriously and 13 fatally.

Some of the cases involved engines running on Mogas, but in most cases Avgas was being used. The power loss commonly followed a descent, particularly after a Practice Forced Landing descent, but some cases were found covering virtually every phase of flight. The flying experience of the commanders involved covered a wide spectrum, from a student pilot with 29 hours total on her second solo flight to an airline pilot with around 16,000 hours total. In some of the cases there was evidence that the intake hot air system had not been used in the recommended manner; however, this was not a general feature and in many cases there were positive indications that the system had been used as recommended but had not protected against severe power loss.

Previous AAIB recommendations

Safety recommendations aimed at reducing the accident rate due to induction system icing were made to the CAA on 5 November 1991 following the investigation of a previous accident (Cessna 172 G-AWXV on 21 March 1991, AAIB Bulletin 10/91). The recommendations and a summary of the CAA response were as follows:

1. Publish and diseminate specific advice to pilots on the procedures to be adopted to minimise the risk of induction system icing in piston engined aircraft - CAA accepted.
2. Consider the need for Operating Handbooks and Flight Manuals to include procedures for performance checks of carburettor hot air systems that quantify the minimum acceptable reduction in engine RPM and manifold pressure - CAA rejected, concluding that the wide range of equipment and ambient conditions made it impractical and that the promotion of greater pilot awareness would be the most practical and effective measure.
3. Consider requiring inclusion of relative humidity or dew point in aviation forecasts and weather reports - CAA accepted and noted that discussions were taking place with the Meteorological Office to determine feasibility.
4. Require the fitment of a warning system to alert pilots of induction system icing on future types of aircraft certificated in the UK, and consider a similar requirement for types currently certificated - in its response the CAA noted that, before accepting or rejecting the Recommendation, it was consulting engine manufacturers and their airworthiness authorities regarding the availability of and service experience with induction system icing warning systems. The CAA undertook to review the information and, if beneficial, to initiate a dialogue with its JAA partners with a view to establishing a certification requirement.

Induction system icing warning systems

A number of relatively cheap passive monitoring system that provide a direct audio/visual warning to the pilot of the accretion of induction system ice are available. One example uses an optical probe fitted in the carburettor, generally in a pre-existing, blanked hole in the body, to trigger a warning light and an audio warning in the cockpit when carburettor ice begins to form. A test switch enables system function to be verified. The system has been in use for a number of years and is available in the UK for under £300 (including VAT), plus an estimated 2 manhours for installation.

Recommendation

The phenomenon of sudden severe loss of power from aircraft piston engines due to induction system icing has been known for many years and papers dealing with it as a cause of aircraft accidents have been found dating back almost 80 years, to 1921. The evidence suggests that many widely-used powerplants are susceptible in weather conditions typically prevailing in the UK throughout the year and that some installations may be highly susceptible to rapid ice build-up in certain conditions. The traditional means of avoiding serious effects involves the pilot executing empirically based procedures that are not fully defined and may not prove effective in all circumstances, partially based on his judgement of the susceptibility for icing and partially on the detection of subtle changes in engine operating parameters. Not surprisingly, the evidence shows a continuing incidence of accidents and incidents causing damage and injury, sometimes serious or fatal, resulting from induction system icing. It appears that the likelihood of recurrence of this type of accident could be greatly reduced by a warning system triggered by the early stages of induction system ice build-up. Such systems are available now, relatively cheaply.

Recommendation 2000-55

It is therefore recommended that the CAA assess available induction system icing warning systems and fully consider requiring the fitment of such a system to UK registered aircraft susceptible to sudden major power loss as the result of induction system icing.

During correspondence in connection with the above recommendation the CAA indicated that it has approved a carburettor ice detector, known as the "Iceman", for installation on a wide range of aircraft fitted with certain models of Precision (Marvel Schebler) carburettors. This system is manufactured by Iceman Aviation Supplies of Ontario, Canada and comprises an optical sensor, which is inserted into the airstream of the carburettor. When ice forms on the probe, the system detects a change in light level and triggers an audible alarm and illuminates a red light mounted on the aircraft instrument panel. The CAA has determined that this modification can benefit safety and has therefore agreed that charges for the approval of the modification on each aircraft will be waived to encourage owners and operators to adopt it. This position will be published in an edition of GASIL.

Nevertheless, in view of the lack of any data to substantiate the reliability of this unit and considering the fact that there are other types of carburettor in service for which no similar detector is available, the CAA does not consider it appropriate to make the installation of the Iceman mandatory.

The CAA further emphasised that this modification is seen as a supplement to, and not a replacement of, the need regularly to check for the presence of carburettor ice using the procedures described in their Safety Sense Leaflet 14A, the Aeronautical Information Circular (AIC) 145/1997 and the engine manufacturers' operating instructions.