Cessna 152, G-MASS

AAIB Bulletin No: 3/2004	Ref: EW/C2002/09/04	Category: 1.3
INCIDENT		
Aircraft Type and Registration:	Cessna 152, G-MASS	
No & Type of Engines:	1 Lycoming O-235-L2C piston engine	
Year of Manufacture:	1979	
Date & Time (UTC):	28 September 2002 at 1340 hrs	
Location:	Chenies, Buckinghamshire	
Type of Flight:	Training	
Persons on Board:	Crew - 2	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Nil	
Commander's Licence:	Commercial Pilot's Licence	
Commander's Age:	41 years	
Commander's Flying Experience:	601 hours (of which 226 were on type)	
	Last 90 days - 43 hours	
	Last 28 days - 19 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot, Telephone discussions with aircraft maintenance company, aftercast and other information from the Met Office. Results of tests carried out on a similar aircraft	

History of flight

The commander of the aircraft, a flying instructor, reported that he departed from Denham, with the student pilot handling, on a dual training flight. The aircraft climbed initially to 1,000 feet on the Denham QNH before initiating a further climb at Chalfont St Giles (approximately 5 nm from Denham), levelling at 1,900 feet over Amersham, (some 8 nm NNW of Denham). The aircraft was turned right towards Maple Cross and Denham Information/Radio was called for rejoin information.

The Instructor stated that carburettor air was selected hot and power reduced from 2,100 RPM to 1,800 RPM to commence a descent towards Maple Cross. A routine check (FREDA) was then carried out and all engine indications appeared to be normal. The Denham QFE was set and at a point some 5 nm north of Denham, the instructor remarked to the student that the aircraft was slightly high. The student therefore reduced power to approximately 1,700 RPM. Shortly afterwards the engine lost power, its speed decreasing to about 1,000 - 1,100 RPM.

The student opened the throttle but obtained no response from the engine. The instructor then operated the throttle with little effect; the engine spluttered and its speed increased by 50 - 100 RPM.

The instructor therefore took over control and turned the aircraft away from a built-up area. He tried the effect of various throttle settings with the carburettor air control in both the hot and cold positions but was unable to obtain any increase in engine power and subsequently transmitted a distress call. He then selected a field, established the aircraft on a right hand base leg and desisted from making further attempts to obtain power from the engine. He selected 20 degrees of flap on the base leg and made a right hand turn onto a final approach, before selecting full flap.

The instructor noticed a low fence, half way along the field, which he was able to fly over. He stated that crash drills were carried out; however, he did not consider, or have time, to switch off the fuel or the battery master switch. Seat belts were tightened and both doors opened. A normal touch-down was made with the stall warner sounding and the Instructor brought the aircraft to a halt despite the downslope of the chosen field. The engine was then found to be operating at idle power so the instructor shut it down and the aircraft was vacated.

Meteorological Conditions

An after-cast supplied by the Meteorological Office showed that the estimated surface conditions in the Amersham /Maple Cross area at the time of the event were; Wind Variable 3 - 5 kts, temperature +18°C, dewpoint +11°C, giving a relative humidity of 64%. Dewpoint figures at higher levels were not available but the significant estimated temperatures and winds were +14 VRB 8 kt at 1,000 feet, +10 VRB 10 kt at 2,000 feet and +05 VRB 05 kt at 5,000 feet. Cloud base was estimated to be between 3,000 and 3,500 feet amsl.

The relevant METARs for Northolt, 8 nm SE of the point where the engine problem first manifested itself, showed a cloud base rising from 2,000 feet to 2,600 feet amsl up to a time just after the event, ie a somewhat lower cloud base than that estimated in the aftercast for the area where the power loss occurred. (The METARs constitute observed weather, whereas the aftercast is an estimate of weather based on recordings made at a variety of locations remote from the point of interest.)

Examination of the aircraft and engine testing

The maintenance organisation reported that, after a preliminary examination the engine was extensively ground run, in the field where the aircraft had been landed, without initial problems. After some 40 minutes operation, however, the engine began to run roughly whilst set at about 1,800 RPM. The grass around the aircraft was long and wet at the time; the conditions being such that, before the aircraft could readily be moved, the grass ahead of it needed to be cut.

During subsequent examination of the aircraft, before flying it out of the field, particular attention was given to the engine induction system. The only significant defect identified was, however, not in the engine but was the deterioration of an O-ring seal in the fuel priming pump. This was replaced by a new seal; the defective seal was not retained. The engine was then started and successfully ground run and subsequently the aircraft was flown out of the field.

Design of the priming system

Engine priming is carried out before starting, using a dedicated pump. This is supplied with fuel via a small diameter pipe from a point upstream of the carburettor and delivers a fuel spray through small diameter nozzles into each of the engine induction ports via individual pipes, also of small bore diameter.

The pump consists of a manifold, incorporating inlet and outlet galleries, terminating in connectors threaded to receive corresponding unions mounted on the ends of the inlet and the (single) delivery pipe respectively. Spring-loaded non return valves are mounted in the inlet and outlet galleries, orientated to ensure that fuel flow can only occur towards the engine cylinder inlet ports. The cylindrical pump body is also mounted on the manifold. A piston within the body is operated by hand via a rod and an operating plunger. The piston to body seal is achieved by means of O-rings mounted in two circular grooves in the piston.

A spring loaded needle valve is mounted on the end of the piston and passes through a close fitting bore in the manifold to bear on a seating. When the primer is locked, the needle bears on the seating, preventing fuel from entering the manifold from the inlet side of the pump, regardless of the condition of the relevant non-return valve. Locking of the piston, rod and plunger, when the pump is not in use is achieved by a means of a bayonet arrangement on the pump body. The presence of the needle in the close fitting bore of the manifold restricts any airflow from the operating cylinder to the exit gallery.

Certification of induction hot air systems

Type certification of induction hot air systems in piston engined aircraft requires demonstration of a specified minimum rise in induction air temperature when the carburettor heat control is moved from 'COLD' to 'HOT'. The requirements to which the Cessna 152 was certificated called for a rise of 90°F (50°C) in induction air temperature whilst operating at 75% power in an atmosphere at 30°F and free of visible moisture. These certification requirements had been established by 1949 and remain essentially the same for normally aspirated, carburetted, induction systems.

75% power is a typical cruise setting and at this figure there is less susceptibility to induction system icing than at lower powers. The certification process does not establish the system effectiveness during prolonged operation in 'HOT' with reduced engine power selected. During in-flight operation, movement of the control to 'HOT' and a further reduction in throttle opening may follow a prolonged period when the engine has been operating at power settings too low to create exhaust heat exchanger temperatures as high as those which were used for the original certification demonstration. Prolonged operation at low power leads to a reduction of exhaust system temperature with a consequent reduction in the induction air heating effected by selecting the carburettor air control to 'HOT' and a reduced ability to prevent ice formation.

The adequacy of induction heating systems to prevent the formation of ice when operating at reduced power in extremely severe conditions is uncertain. In some conditions such systems may either be inadequate or only effective if the best operating procedures are established and rigidly observed. Although correct use of the carburettor heat control normally eliminates induction ice, the effectiveness of that control is a function of the temperature of the exhaust system and is only at a maximum immediately after the engine has carried out sustained running at a high power setting.

Tests

Tests have shown that, during a descent in a Cessna 152, at an airspeed in the region of 85 kt and with a throttle setting giving 1,800 RPM, the throttle angle is similar to that required to produce only approximately 1,300 RPM in a stationary aircraft conducting a ground run. With the greater airflow through the engine compartment in flight, the airborne condition will almost certainly result in a slightly lower exhaust temperature than at 1,300 RPM during a static ground run.

Analysis

The maintenance engineer who examined the aircraft considered that the leakage of air into the priming pipes via the deteriorated seal in the priming pump could have resulted in additional air being drawn into the cylinders without routing through the carburettor. This, he surmised would have resulted in an excessively lean mixture. The instructor also believed this was the cause and discounted carburettor icing as a possible factor. He stated that the pre take-off power checks had been normal, indicating that the carburettor air control was operating correctly.

The engine was ground-run in the field, after the event, for about 40 minutes with no apparent problems before beginning to run roughly. The conditions under which the ground-running was performed were, in themselves, highly conducive to carburettor icing and, thus, after that length of time, some 40 minutes, it is not surprising that symptoms consistent with carburettor icing were noted.

Thus the possibility existed for either the defective seal in the priming pump or induction icing being the primary cause of the engine power loss during the flight.

Priming System

The condition of one of the seals in the priming pump could conceivably have allowed air to be drawn in at that point. It would, however, have required the second O-ring to be also sealing inadequately. With the primer locked, the presence of the needle in its close-fitting bore will limit the rate of flow of air into the outlet gallery even if there were considerable leakage at the O-rings.

Air could, however, conceivably have entered the individual cylinder induction systems, via the priming pipes, in the region of the inlet ports. The bore diameter of the priming pipes and of the nozzles at the point where the fuel sprays into the ports would, however, have limited the amount of excess air able to enter the cylinders by this route, regardless of whether the primer was locked. Similarly, the bore diameter of the fuel passage in the exit union of the priming pump constituted a significant restriction.

Most light aircraft engines have their carburettor settings adjusted such that, with the mixture control set to the normal full-rich position, the mixture strength is considerably richer than optimum, even when the aircraft is operating at low altitudes. Mixture strength may be reduced manually (by means of the mixture control) to a value significantly leaner than optimum without any immediately noticeable effect on engine running. The mixture control is normally set at the fully rich position during low level operation.

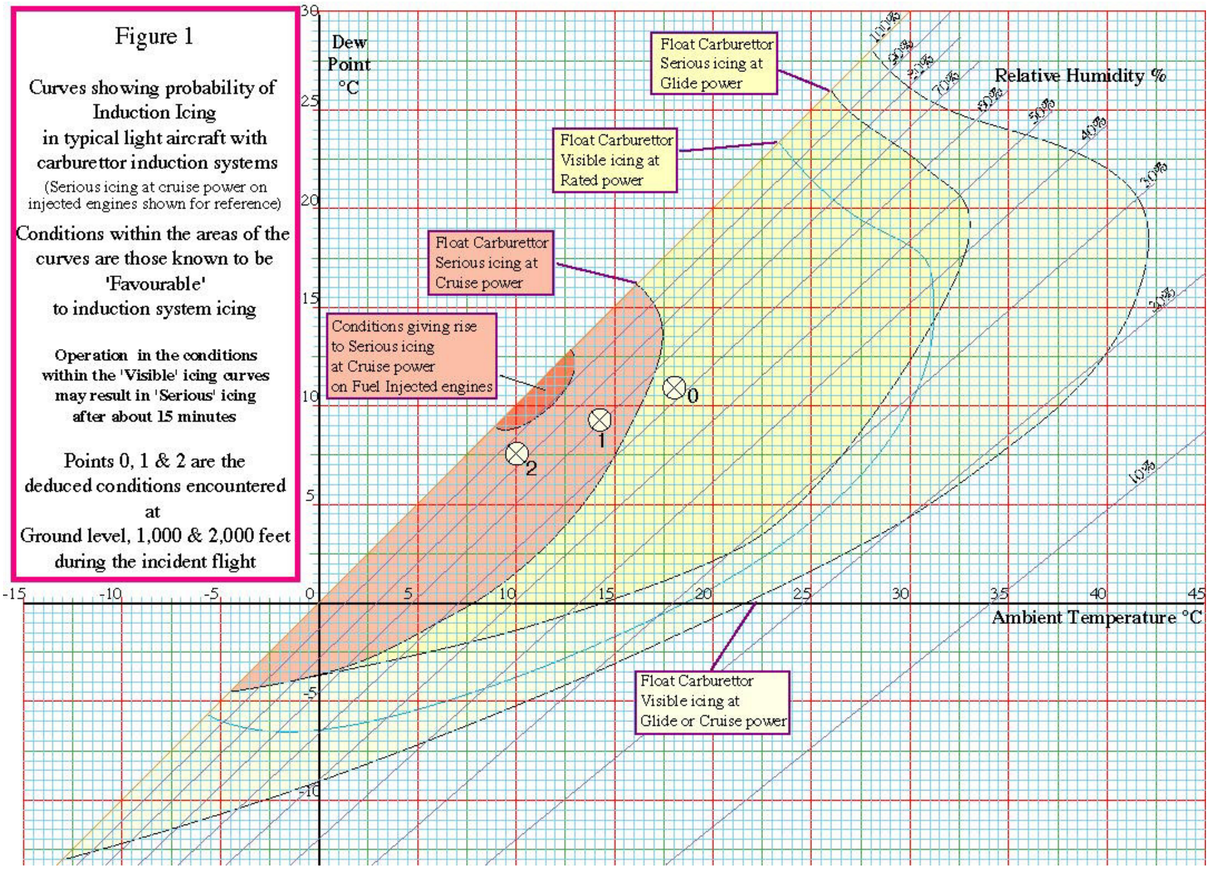
With a reasonable throttle opening (ie significantly above an idle power setting), the amount of air passing through the carburettor is many times more than the amount able to pass through the small bore pipes and nozzles of the priming system. The effect of any air leakage through the latter is thus unlikely to be sufficient to reduce the mixture strength to the extent required to cause a sudden loss of power, or a failure to regain power as the throttle is re-opened. Although loss of power is more likely at low throttle openings, advancing the throttle should return the mixture strength to a value which would enable the engine to operate normally.

Deterioration of a piston seal on a pump of the design used in G-MASS should not, therefore, have lead to a loss of engine power that could not be restored by simply re-opening the throttle. The symptoms of power loss observed during this incident are not, therefore, consistent with the deterioration of the priming pump seal.

Evaluation of meteorological data available

The cloud base, estimated from the aftercast, was 3,000 to 3,500 feet amsl and it would be reasonable to assume that the relative humidity reached 100% by 3,500 feet. This represents an average increase of approximately 10% in relative humidity for every 1,000 feet above sea level. Based on these premises, as the aircraft climbed to a height in the region of 1,900 feet, the relative humidity it experienced would have increased from 64% to 90%, approximately, whilst the ambient temperature dropped from +18°C to about +10°C.

On Figure 1, the deduced conditions at the surface, at 1,000 feet and at 2,000 feet in the locality where power loss occurred are plotted as points 0, 1 and 2 respectively on the generally accepted curves for the probability of induction icing related to air temperature and dewpoint or relative humidity.



From this it can be seen that the aircraft took off in conditions conducive to 'serious icing at glide power' or 'visible icing at rated power', and close to conditions of 'serious icing at cruise power'. As the flight progressed, the conditions encountered are estimated to have become steadily closer to the most critical combination for such icing, ie those which can cause severe icing even of injected engines at cruise power. (Injected units are lesssusceptible to induction ice build up than are carburettor equipped engines.) Thus any power reduction by the handling pilot of this aircraft, followed by prolonged operation at reduced power, once it had reached the higher levels of this flight, would have rendered it more than usually vulnerable to complete power loss from carburettor icing.

Information available to pilots for assessing the risk of induction icing

Considerable variation exists, between flying training providers, in the teaching of procedures and guidance for the operation of the carburettor heat control related to throttle setting and airspeed.

For much of the time in the period between spring and autumn, aircraft operating in the UK do so in conditions conducive to induction icing. On this occasion the after-cast data makes it clear that the likelihood of carburettor ice building up rapidly was much greater on the day in question than on a typical autumn day. In particular, the deduced conditions at the point where the engine power loss occurred were close to the severest which can be encountered in terms of conduciveness to ice build up in the induction system of a piston engine, yet other than being generally aware that carburettor icing conditions were present, a pilot would have had little information on the degree of icing risk.

Since the only data on which the likelihood of carburettor icing can be assessed is the temperature and humidity, a pilot is poorly placed to identify the occasions of high risk of icing. The wet bulb temperature figure can only be easily established from a METAR which only applies to the surface at one location and in turn is only issued in relation to major airports which are not normally frequented by carburettor equipped aircraft. Assessment of the humidity at cruise altitudes can only be roughly estimated from knowledge of the surface humidity and the local cloudbase.

Although much engine operation in the UK involves entering conditions conducive to carburettor icing, the particular conditions encountered during this flight, according to the after-cast, came close to the severest that can be encountered

Concerns related to the legal status of practice forced landings

The instructor remarked that the success of his ensuing landing was very much the result of regular practice in simulated forced landings which he had carried out. He pointed out, however, that the provisions of the existing Rule 5 seriously limited the opportunity for, and the realism of, such practice. It is a widely held view in the flying training community that the CAA will take firm action against those who break the rule, regardless of whether the transgressors are doing so in a reckless fashion or inadvertently breaking the rule as part of a responsibly planned and realistically carried out training exercise.

The rule is recognised to be a valuable safeguard against both nuisance and danger to third-parties. However, its perceived rigidity and lack of identification of the needs of training, by a considerable proportion of Flight Instructors, is seen as a factor increasing the risk to both aircraft occupants and third parties, by reducing opportunities for realistic training. In particular, at those airfields where engine failure after takeoff (EFATO) demonstration and practice cannot be carried out legally at a sufficiently low height to be a realistic training exercise it is felt that a greater risk of causing danger to the public exists from poor handling of genuine engine failures at takeoff.

The risk of a genuine failure resulting in an accident must, however, be balanced against the risk of one of the necessarily much greater number of practised failures going seriously wrong. The conditions under which Flight Instructors may give effective engine failure and forced landing training without transgressing the provisions of Rule 5 would, therefore, appear to depend on their having a clear understanding of the Authority's philosophy and preferred best practice for such training and of their being convinced of the soundness of both.

It is, therefore, recommended that the CAA publish a paper, for the information of Flight Instructors in particular, on engine failure and forced landing training, making clear their philosophy and promulgating what they believe to be acceptable best practice.

Conclusions

Taking all the available evidence into account, it is most probable that the power loss resulted from induction system icing. The subsequent safe landing was facilitated by the recent exposure of the Instructor to regular forced landing practice.

Safety Recommendations

For the past 12 months, the AAIB and CAA have been jointly engaged in a study to identify the key issues relating to the problem of carburettor icing. The ultimate objective is to make recommendations which encompass the findings of a large number of carburettor icing related accidents. When implemented, these will make available to the General Aviation community information to enable them to take all reasonable actions to avoid accidents due to carburettor icing, as far as is practically possible.

The study currently encompasses the areas of pilot training, the guidance and learning material available to pilots and the current procedures for the use of the carburettor heat control. Furthermore, research work is being sponsored by the CAA into methods of detecting or preventing the formation of carburettor icing and the value of fitting the latest types of carburettor ice detectors now commercially available.

Based on the findings of this investigation, the following aspects will fall within the compass of this ongoing study:-

a. The inclusion of information in the forecasts by the Meteorological Office, readily available to GA pilots, which will assist pilots to make a better assessment of the risk of Carburettor icing occurring on any day in the areas and at the time they intend to fly.

b. Improvement of the theoretical knowledge of known induction system behaviour required in the PPL training syllabus with emphasis on:-

1) the conditions favouring carburettor ice formation,

2) the effects and development of carburettor icing, and

3) the engine and induction system handling procedures most likely to reduce the hazard with the intention to replace the considerable variety of techniques currently taught with scientifically based procedures.

Related to this incident, but not only related to engine power loss or failure as a result of induction icing, is consideration of the likelihood of a pilot effecting a successful emergency forced landing. The instructor stated that, in his belief, his ability to make the forced landing successfully was, in large part, influenced by frequent practice and he expressed concern over his ability to give realistic instruction in the necessary procedures in a legal manner.

Safety Recommendation 2004-11

The Civil Aviation Authority should consider the safety implications of Rule 5 with respect to its effect on realistic training for engine failure after takeoff and en route engine power loss on single engined aircraft and publish a paper on the subject, for the information of Flight Instructors, making clear the Authority's philosophy and promulgating what they believe to be acceptable best practice.