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SPECIAL STUDY

CARBURETOR ICE IN GENERAL AVIATION

NATIONAL TRANSPORTATION SAFETY BOARD
Washington, D. C. 20591
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Safety Center

Special Study

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Adopted: January 19, 1972

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16. Abstract

The carburetor ice to which reciprocating engine installations are susceptible was a probable cause or factor in [illegible] general aviation accidents over a recent [illegible]-year period. In these accidents there were [illegible] fatalities and [illegible] people injured out of a total of [illegible] persons aboard. Such losses as these can be reduced through the exercise of greater pilot awareness and vigilance. Included in this report are descriptions of conditions conducive to carburetor icing, modes of carburetor icing, and procedures for circumventing power loss due to carburetor ice. It is believed that reduction of carburetor icing accidents is attainable through further pilot education, and that the most effective means of accomplishing this would be for the Federal Aviation Administration to send a carburetor ice advisory to each of its registered pilots.

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CARBURETOR ICE IN GENERAL AVIATION

I. INTRODUCTION

It is realized and acknowledged that much of the material in this report will be familiar to most pilots. However, the National Transportation Safety Board believes that pilots in general can benefit from fresh exposure to this material, and that some carburetor icing accidents may be avoided through such exposure.

During the latest 5-year period for which complete data are available, there was a total of 360 general aviation accidents involving carburetor ice as a probable cause or factor. There were 40 fatalities and 160 persons were injured, 40 of them seriously, in these accidents. The number of persons exposed to death or injury in these accidents was 636; 47 aircraft were destroyed and 313 others substantially damaged.

"Carburetor ice," as used herein, means ice at any location in the induction system of aircraft equipped with reciprocating engines. The term is traditional. It is used in aircraft accident records, even though many reciprocating engine installations have fuel injection rather than carburetors [illegible]

Also, it should be [illegible] in evidence for very long after an accident [illegible]. Thus, there may have been a number of additional accidents for which carburetor icing actually was the cause or a factor, but which were not so identified because of the lack of evidence at the time of the accident investigation.

These losses resulting from carburetor icing can be reduced by greater awareness and vigilance by pilots. The Safety Board has long been concerned with carburetor icing as one of the "unnecessary" causal factors in general aviation accidents. Unlike mechanical failure over which the pilot has little in-flight control, carburetor icing can be avoided because the means to preclude it are readily available.

Since carburetor icing accidents can be attributed to the pilot in virtually all cases, improved pilot awareness, attention, and/or competence will reduce the incidence of accidents of this type. Toward that end, the Safety Board compiled this study. The report contains general background information on carburetor icing, proper means and procedures for its prevention, and a specific recommendation [illegible]

II. DISCUSSION

Awareness of carburetor icing conditions sometimes requires extra effort because of unique combinations of weather, engine installation, and engine operation. However, through familiarity with certain general information, modified or supplemented as necessary for the particular aircraft model being operated, the informed pilot should be able to avoid carburetor icing troubles.

It is important for pilots to know the three categories of carburetor ice, and the manner in which each is formed. These categories are impact ice, fuel ice, and throttle ice.

Impact Ice

Impact ice is formed by the impingement of moisture-laden air at temperatures between 15° F. and 32° F. onto the elements of the induction system which are at temperatures below approximately 32° F. Under these conditions ice builds up on such components as the air scoop, heat valve, carburetor screen, throttle, and carburetor metering elements. Pilots should be particularly alert to such icing when they are operating in snow, sleet, rain, or clouds. The ambient temperature at which impact ice can be expected to build up most rapidly is about 25° F., when the supercooled moisture is still in a semi-liquid state.

Susceptibility to impact ice is greatly reduced by an induction system that has been designed to eliminate free water by means of inertia separation.

Fuel Ice

Fuel ice forms at and downstream from the point at which fuel is introduced, when and if any entrained moisture reaches a freezing temperature as a result of cooling of the mixture by fuel vaporization. This cooling process takes place in the aircraft induction system when the heat necessary for fuel vaporization is taken from the surrounding air, thus cooling the air. Then, since cooler air can hold less water vapor, the excess water is precipitated in the form of condensation. Further vaporization cooling freezes the condensate. When any structure, such as an adapter elbow, lies in the path of the water at time of freezing, ice accretion is initiated on that structure. If this condition continues and no anti-icing action is taken, the ice buildup will increase until the obstruction throttles the engine.

Visible moisture in the air is not necessary for fuel icing; only air of high humidity is required. This fact, coupled with the fact that fuel icing can occur at high ambient temperatures, makes this type of icing sometimes difficult for a pilot to believe unless he is fully aware of the fuel icing process. It can occur in no more than scattered clouds, or even in bright sunshine with no sign of rain.

The usual range of ambient temperatures at which fuel icing may be expected to occur is 40° F. to 80° F., although the upper limit may extend to as high as 100° F. A temperature of around 60° F. should be regarded as the most suspect. The minimum relative humidity generally necessary for fuel icing is 50 percent, with the icing hazard increasing as the humidity level increases.

Fuel ice is not a problem in systems designed to inject the fuel at any location beyond which the passage surfaces are maintained above freezing. Thus, injection of fuel directly into each cylinder obviously will preclude the possibility of such icing. In engines with centrifugal superchargers, the fuel is introduced at or downstream from the face of the impeller in a manner that will avoid splashback from the impeller blades so that fuel ice is not formed.

Throttle Ice

Throttle ice is formed at or near a partly closed throttle when water vapor in the induction air condenses and freezes, due to the expansion cooling and lower pressure as the air passes the restriction imposed by the throttle. This temperature drop normally does not exceed 5° F. When the ambient temperature is above 37° F., then, the pilot need not be concerned with throttle icing as long as only air passes the throttle, such as in a fuel injection installation with the fuel introduced downstream from the throttle.

When there is a fuel-air mixture at the throttle, however, any ice formation would be attributable to water vapor freezing from the cumulative effects of the fuel ice and throttle ice phenomena. Icing at the throttle then can occur at ambient temperatures much higher than 37° F. Throttle ice is not a problem in some fuel systems which are designed so that the throttle is located in a warmed region, such as between an engine-stage supercharger and the cylinders, or a constant supply of heat is provided to the throttle assembly and downstream surfaces in some other manner.

Carburetor Ice Formation and Prevention

Any one or combination of these ice-forming situations may cause loss of power by restriction of induction flow and interference with an appropriate fuel-air ratio. One reason it can be important to use carburetor heat as an anti-icer rather than a deicer lies in the "vicious circle" aspect, especially in fast-forming conditions and when the ice buildup might not be diagnosed at an early stage. An uncorrected carburetor ice condition can mean less power, and thus reduced carburetor heat which may result in the formation of more ice. It is certainly only prudent to guard against a buildup of carburetor ice before deicing capability is lost.

For a better conception of carburetor ice formation that might be expected in light-plane systems, the results of tests reported in Reference 1. of this report are summarized as follows:

Two typical light-plane installations were tested, one with a float-type carburetor, the other with a pressure-type carburetor. With the first, serious icing occurred up to carburetor air temperatures of 62°, 63°, and 93° F., and the lower limits of relative humidity of 80, 60, and 30 percent, for high-cruise, low-cruise, and glide-power conditions, respectively. With the pressure-type carburetor installation, the results were serious icing between carburetor air temperatures of 48° F. and 55° F. with relative humidity from 90 percent to 100 percent at low-cruise power, and up to approximately 75° F. with relative humidity greater than 32 percent at glide power. No serious icing occurred at the high-cruise power condition.

Carburetor air heaters in small aircraft are usually of the exhaust pipe cuff type. The exhaust-heated air is directed into the carburetor air duct as desired, so that with full carburetor heat the normal air duct is essentially closed off at the carburetor heat valve location.

It should be realized that partial carburetor heat can be worse than none at all under certain conditions. For example, the fuel/air mixture temperature might be at 20° F., with no heat applied, which normally would not be so conducive to ice-forming as if the temperature were brought up to 30° F., by means of partial heat. Full heat, of course, could be expected to raise the temperature out of the icing range entirely. At least with the smaller engine installations when there is no carburetor air temperature or fuel-air mixture temperature instrumentation, the general rule should be to use full heat whenever any carburetor heat is applied. With the higher output engines and those employing superchargers, more discretionary use of full heat should be practiced because of the overheat and detonation hazard. Temperature instrumentation should be installed as a necessary reference to assist the pilot in modulating the appropriate amount of heat.

Excessive Use of Carburetor Heat

Notwithstanding the importance of using carburetor heat when necessary, the importance of guarding against undue overuse should be recognized. This is based on the lower powers and higher cylinder temperatures that generally result when carburetor heat raises induction air temperature. For example, the lower power can be critical in case a sudden go-around is required, and full carburetor heat at high-power levels and high-ambient temperatures can cause cylinder overheating and even detonation damage. It is noted that under high-power conditions carburetor heat is rarely required.

There are exceptions to the rule that carburetor heat application results in lower power. In extremely cold and dry weather, with no icing potential, the use of a little carburetor heat may actually increase power to a small extent because of improved fuel vaporization. This reversal of the usual, however, would not occur in most situations.

From the above, it can readily be seen that induction temperature instrumentation serves not only to assist the anti-icing effort, but also to protect the engine from overheat damage.

Appraisal of Carburetor Icing Potential

Cognizance of the prevailing humidity is basic to the important awareness of the possible carburetor icing hazard. Even though relative humidity is less than 50 percent at takeoff, one cannot be completely confident that he will not encounter a carburetor icing atmosphere some time during his flight. Whenever the pilot has reason to suspect high or marginal humidity, he should utilize the best means available to maintain cognizance of prevailing humidity levels.

When the aircraft is equipped with induction temperature instrumentation, humidity level awareness is somewhat less essential.

Operational Indicators of Carburetor Ice

Carburetor ice should be considered immediately as the possible cause of a power loss. With a fixed pitch propeller installation, a power loss obviously is indicated by an engine speed reduction. When there is a manifold pressure gage provided, a reduction in manifold pressure would show up along with the engine speed reduction. With a constant speed propeller installation, however, only the manifold pressure would be decreased.

Another way an iced carburetor condition might be first noted is through development of a slight nosedown attitude. Upon trim adjustment to level flight, an engine speed reduction might then be noted, again assuming a fixed pitch propeller.

Finally, an iced carburetor might cause engine roughness although in some cases roughness will not show up until the engine is close to complete stoppage.

Susceptibility to Icing

The susceptibility to carburetor ice varies greatly among the various aircraft models. For example, an engine installation employing a float-type carburetor and having the fuel introduced upstream from the throttle valve, would be the most susceptible to carburetor icing troubles. At the opposite end would be an installation with direct cylinder fuel injection, which would forestall the generally most troublesome fuel-type icing; however, the induction system with this might still be subject to impact icing and throttle icing.

It is theoretically possible to design an engine installation that would not be subject to carburetor icing. In practice, however, this ideal is not attained, for one or more reasons of a practical nature. Consequently, it is still incumbent upon all pilots to remain alert to the possibility of carburetor icing, and take preventive action as appropriate for the equipment and conditions.

Recognizing the fact that some installations require less carburetor ice concern than others, the procedural rules listed at the end of this section can only be generally applicable in guarding against carburetor ice troubles.

Prevention Procedures

To prevent accidents due to carburetor icing, there should be routine use of carburetor heat under certain operational conditions, plus awareness and appraisal at other times of possible icing conditions in the induction system, and the consequent need for carburetor heat as appropriate.

Carburetor icing troubles can be avoided by practicing the following procedures:

1. Periodically check carburetor heat systems and controls for proper condition and operation.

2. Start engine with carburetor heat control in the "cold" position, to avoid possible damage to the carburetor heat system.

3. As preflight item, check carburetor heat availability by noting heat "on" power drop.

4. When the relative humidity is above 50 percent and the ambient temperature is below 60° F., use carburetor heat immediately before takeoff. In general, carburetor heat should not be used during taxi because of possible foreign matter entry when intake air is unfiltered in the "alternate" or carburetor heat "on" position.

5. Conduct takeoff without carburetor heat unless extreme carburetor icing conditions are present, when carburetor heat may be used if approved by aircraft manufacturer, and when conditions are such that there will still be ample power for takeoff without incurring engine overheat damage.

6. Remain alert after takeoff for indications of carburetor icing, especially when the relative humidity is above 50 percent, or when visible moisture is present.

7. With supplemental instrumentation, such as a carburetor air temperature gage, partial carburetor heat should be used as necessary to maintain safe temperatures to forestall icing. Without such instrumentation, use full heat but only intermittently if considered necessary.

8. If carburetor ice is suspected of causing a power loss, immediately apply full heat. Do not disturb throttle initially, since throttle movement may kill engine if heavy icing is present. Watch for further power loss to indicate effect of carburetor heat, then rise in power as ice melts.

9. In case carburetor ice persists after a period of full heat, gradually move throttle to full open position and climb aircraft at maximum rate available in order to obtain greatest amount of carburetor heat. If equipped with mixture control, adjust for leanest practicable mixture, (approach this remedy with caution - although carburetor ice generally serves to enrich mixture, the reverse can be true; if the engine is lost through excessive leaning, an airstart might be impossible with an iced induction system).

10. Avoid clouds as much as possible.

11. In severely iced conditions, and when equipped with mixture control, backfiring the engine can sometimes be effective in dislodging induction system ice. With carburetor heat control "off," lean engine while at full throttle (observe caution note in No. 9, above).

12. Consider that carburetor icing can occur with ambient temperature as high as 100° F. and humidity as low as 50 percent. Remain especially alert to carburetor icing possi ities with a combination of ambient temperature below 70 F. and relative humidity above 80 percent. However, the possibility of carburetor ice decreases in the range below 32° F. This is because of (a) lessened humidity as the temperature decreases, and (b) at around 15° F. any entrained moisture becomes ice crystals which pass through the induction system harmlessly. It should be remembered that if the intake air does contain these ice crystals, carburetor heat might actually cause carburetor icing by melting the crystals and raising the moisture-laden air to the carburetor icing temperature range.

13. Prior to closed-throttle operation, such as for a descent, apply full heat and leave on throughout throttled sequence. Periodically, open throttle during extended closed throttle operation so that enough engine heat will be produced to prevent icing. Be prepared to remove carburetor heat if go-around is initiated.

14. Return control to "cold" position immediately after landing. If carburetor heat should be further required, observe ground operation precaution in (4), above.

III. CONCLUSIONS AND FINDINGS

The National Transportation Safety Board, from its study of the carburetor ice problem area in general aviation, has concluded that:

1. Many accidents induced by carburetor ice continue to occur, despite the fact that the means of preventing carburetor ice are available to use at the pilot's discretion.

2. The incidence of carburetor icing can and should be reduced by further pilot education.

3. Distribution of an Advisory Circular on carburetor ice must be made to all pilots in order to reduce significantly carburetor ice involvement in aircraft accidents. This broad coverage is required because, even though only a very small percentage of all pilots can be expected to get into serious trouble with carburetor ice, there is no way of predicting which particular ones these will be.

IV. RECOMMENDATIONS

In view of these findings, the Safety Board recommends that:

1. The Federal Aviation Administration prepare an Advisory Circular on the prevention of carburetor icing in reciprocating engines used on general aviation aircraft.

2. The FAA mail this publication to all general aviation pilots, flight instructors, and flight schools.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD:

/s/ JOHN H. REED Chairman

/s/ OSCAR M. LAUREL Member

/s/ FRANCIS H. McADAMS Member

/s/ LOUIS M. THAYER Member

/s/ ISABEL A. BURGESS Member

January 19, 1972

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