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Carburetor Ice Flight Testing: Use of an Anti-Icing Fuel Additive

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Abstract

THE effectiveness of an anticarburetor-icing fuel additive was tested in-flight in a light twin-engine airplane. Fuel containing 0.15% ethylene glycol monomethyl ether was used in one engine while the other used stock aviation gasoline. The results show that the additive was very effective in preventing carburetor ice during cruise. Both the maximum severity of the icing and the range of environmental conditions conducive to its formation were reduced.

During descents, the results are inconclusive. While the average rate of carburetor ice formation was reduced with the additive, it did not appear to be effective under certain conditions of temperature and dew point.

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Carburetor ice has historically been a major cause of light airplane engine stoppages. Caused by the cooling of moist air within the carburetor, ice formation disrupts the flow of fuel and air to the engine. This cooling is a result of the expansion of the air as it passes through the carburetor venturi and around the throttle butterfly and is augmented by vaporization cooling as the fuel is added to the airstream. The static temperature drop can reach 70°F.

During the period 1969-1975, the National Transportation Safety Board (NTSB) files show a total of 468 accidents where the probable cause was cited as "engine failure—carburetor/induction system icing." These accidents caused 44 fatalities, 202 serious injuries, and destroyed 75 aircraft. Surprisingly, 62% of these accidents occurred during climb and cruise. Only 26% happened during the supposedly carburetor-ice prone phases of flight: descent and landing.

In addition to these accidents where carburetor ice has been cited, there are approximately 180 accidents per year caused by engine stoppages where the specific cause of the stoppage was not determined. It has been suggested that many of these accidents might actually be caused by carburetor ice. A review of one year's "undetermined engine failure" accidents to Cessna 150 aircraft showed that 43% exhibited all of the symptoms of carburetor ice—the power loss followed a carburetor ice pattern, weather conditions were conducive, and the pilot failed to use carburetor heat. In 29% of the accidents, only two of these factors were present, so carburetor ice can only be considered probable. Based on these observations, we conclude that approximately one-half of the Cessna 150 carburetor ice accidents are not identified as such by the NTSB. By extension to other types, carburetor ice statistics should be scaled up by a factor of about two.

While the problem remains a serious one, preventive measures have changed little since the NACA work of the 1940's.[1,2] The conventional approach to protect engines from carburetor ice is an exhaust heat-exchanger to preheat the incoming air during conditions conducive to ice formation. Current FAA requirements are the addition of 22 BTU/lb_{air} during cruise.[3] This compares with the NACA recommendation of 34 to 42 BTU/lb_{air}.[2]

In the late 1960's Gardner and Moon conducted dynamometer tests with a variety of fuel additives in an attempt to find a solution for carburetor ice.[4] These tests were all performed using an automotive engine equipped with a typical updraft aviation carburetor. The incoming air was nearly saturated with moisture at a temperature of 40° F. The two most promising fuel additives were hexylene glycol and ethylene glycol monomethyl ether (EGME). While hexylene glycol reduced the formation of carburetor ice more at its optimum concentration, EGME was much less sensitive to reduced additive concentrations. Accordingly, Gardner and Moon recommended that EGME be added to aviation gasoline in the proportion of 0.15% by volume. Gardner and Moon also evaluated Teflon® coated throttles, but found this approach to be less effective than the glycol-based additives; however, the coatings did have a synergistic effect with EGME.

In an effort to validate the effectiveness of EGME in flight, a Piper PA-23 was chosen as a test vehicle. The test airplane was equipped with two newly remanufactured AVCO-Lycoming 0-320-A3B engines. Each engine was operated with aviation gasoline except that after initial testing, 0.15% by volume of EGME was added to one fuel tank using Prist® aerosol spray cans. Periodically, both engines were operated with stock aviation gasoline to confirm that they were equally susceptible to carburetor icing.

Two flight profiles were used to obtain carburetor ice. A normal profile was used for steady-state icing at cruise and higher power settings. A descent profile was used to obtain carburetor ice data during landing approaches at reduced power. Early in the test, descent power icing was attempted using one engine at normal power and one at reduced power. However, the differences between the icing rates made interpretation difficult. The descent profile was felt to be necessary to have identical conditions for the two engines.

In the normal profile, once the altitude and geographical location had been chosen, based on weather reports, the airplane was flown to the test area and the desired flight conditions (power and mixture settings) established. The airplane was flown in these conditions until a power loss rate could be measured or the absence of ice confirmed before changing the test conditions.

In order to obtain data with near idle power, the descent profile consisting of a normal landing from 3000 ft was used. Carburetor heat was not used during this profile. Following the landing, the airplane was taxied to the parking area and a carburetor ice check made to determine the amount of ice.

The accumulation of carburetor ice was monitored by noting the manifold pressure drop and the variations in exhaust gas temperature (from cylinder to cylinder) as functions of time. Once a power loss had been detected, carburetor ice was verified by applying full heat for a sufficient time to melt the ice. The amount of ice was measured by comparing the manifold pressure regained with the manifold pressure just prior to the application of heat. The observed carburetor

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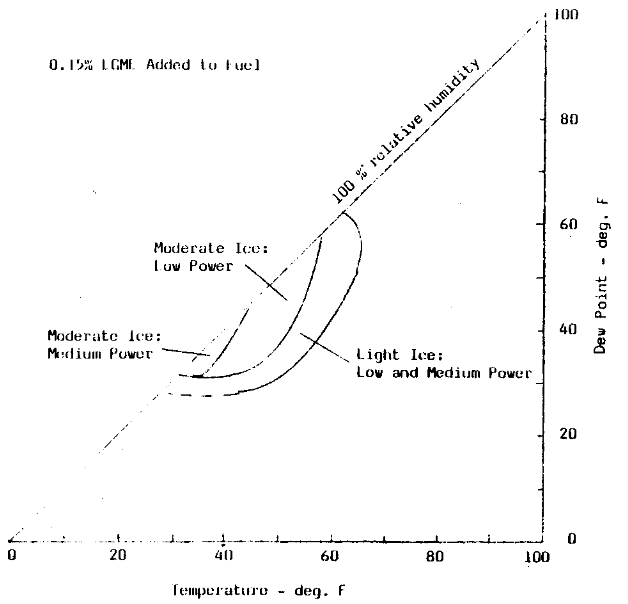

Fig. 1 Summary of flight test results; cruise power: EGME added.

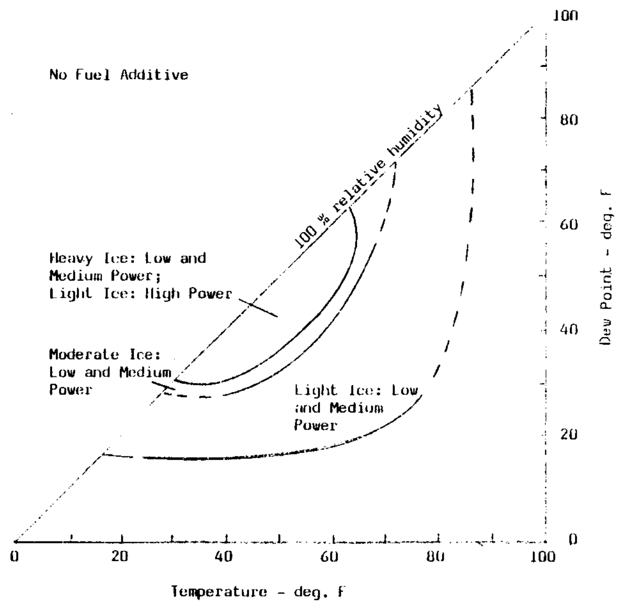

Fig. 2 Summary of flight test results; cruise power: stock fuel.

ice rates were classed as trace, light, moderate, heavy, and severe.

The results (shown in Fig. 1 and 2) show that the rate of icing is much less with EGME added to the fuel. Both the maximum rate of icing and the extent of temperatures and dew points conducive to its formation are reduced. In cruise conditions, the use of EGME appears to completely eliminate icing severe enough to cause engine stoppage. According to the distribution of accidents discussed earlier, this would amount to about 62% of carburetor ice accidents.

The effectiveness of EGME is less at the lower power settings. At 75% power, the EGME protected engine iced at an average rate of 2% when compared to the unprotected engine. As the throttle was closed, this rate increased relative to the unprotected engine. As a result, the effectiveness of the additive at idle or near idle power is not clear. In particular, there is some evidence that the presence of EGME in the fuel may increase the tendency to carburetor ice at certain flight conditions (temperatures near 60°F/dew points near 60°F and temperatures of 20 to 40°F/dew points near 15°F). Nevertheless, on the whole, the addition of EGME does seem to have an overall beneficial effect on the prevention of ice during descent, but not nearly as great as during cruise.

The carburetor air temperature gages did not appear to be particularly helpful in detecting favorable conditions for ice within the carburetors. For the most part, the temperatures were in the range of 25 to 40°F and seemed to be more a function of throttle position than of outside conditions. Several times carburetor ice formed with an indicated carburetor temperature well outside of the yellow icing band of 14 to 41°F (−10 to +5°C).

Most of the carburetor ice data was collected while flying within fairly localized portions of the atmosphere. Nevertheless, we did note that there were temperature, dew point, and icing rate variations on a fairly small scale (of the order of a mile). Based on subjective observations, we do not feel that the average visual flight rules (VFR), pilot on a cross-country trip would remain very long in conditions conducive to carburetor ice. These conditions are more common than are commonly believed by pilots; however, few of them are exposed for any significant time during any single exposure. Thus, they may well miss detecting the loss in engine power.

The EGME in this study was added during aircraft refueling using an aerosol can designed for turbine pumping rates. Its addition required the use of a stopwatch and a pocket calculator. In spite of the extra care, one tankful was found to have a serious over-concentration (0.25%). Since it seems reasonable to predict that most general aviation pilots and line crews would not be as careful with the use of the aerosol spray cans, we do not recommend such cans be used for general aviation piston-powered airplanes.

Three aspects remain unresolved in the flight testing of EGME as an anti-icing fuel additive. The overall descent data is incomplete and requires additional data to confirm its effectiveness and check the possible enhancement of ice formation under certain environmental conditions.

A second remaining aspect of EGME use in light airplanes is its effectiveness at reduced concentrations. All of the tests reported here were conducted at a nominal concentration of 0.15%. The FAA has reported that the concentration in turbine fuel can be reduced by a factor of three between addition and delivery to the aircraft tank because of leeching by free water.[5] This loss of concentration in aviation gasoline should be measured and the effectiveness of the resulting reduced concentration should be evaluated in a similiar fashion as the tests reported here.

The last item remaining before EGME can be considered as a useful anti-icing technique is to determine if there are any serious effects resulting from its long term use in aircraft fuel systems and engines.

Acknowledgments

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