AC 20-113

DATE 10/22/81

ADVISORY CIRCULAR

DEPARTMENT OF TRANSPORTATION
Federal Aviation Administration
Washington, D.C.

Subject: PILOT PRECAUTIONS AND PROCEDURES TO BE TAKEN IN PREVENTING AIRCRAFT RECIPROCATING ENGINE INDUCTION SYSTEM AND FUEL SYSTEM ICING PROBLEMS

1. PURPOSE. This circular provides information pertaining to aircraft engine induction system icing and the use of fuel additives to reduce the hazards of aircraft operation that may result from the presence of water and ice in aviation gasoline and aircraft fuel systems.

2. CANCELLATION. This Advisory Circular cancels AC 60-9 and 20-92.

3. RELATED READING MATERIAL.

a. Advisory Circular AC 20-24A, 4/1/67, Qualification of Fuels, Lubricants, and Additives.

b. Advisory Circular AC 20-29B, 1/18/72, Use of Aircraft Fuel Anti-Icing Additives.

c. Advisory Circular 20-73, 4/21/71, Aircraft Ice Protection.

d. National Research Council of Canada, Mechanical Engineering report LR-536, Aircraft Carburetor Icing Studies, July 1970.

e. Investigation of Icing Characteristics of Typical Light Airplane Engine Induction Systems, NACA TN No. 1790, February 1949.

f. Icing - Protection Requirements for Reciprocating Engine Induction Systems, NACA Technical Report No. 982, June 1949.

g. Various Aircraft Owners Handbooks, provided by the manufacturers.

h. Carburetor Ice in General Aviation, NTSB Special Report AAS-72-1.

4. BACKGROUND/DISCUSSION. Reciprocating engine icing conditions are a constant source of concern in aircraft operations since they can result in loss of power and, if not eliminated, eventual engine malfunction or failure. The different types of icing conditions are characterized as air induction system icing and aircraft fuel system icing. Because of a substantial number of aircraft accidents attributed to incidents involving such icing, it is important for a pilot to know the kinds of ice formation encountered, and the manner in which each is formed.

5. INDUCTION SYSTEM ICING. Induction system icing may be characterized as Impact Ice, Throttle Ice, and Fuel Vaporization Ice. Any one, or a combination of the three kinds of induction icing, can cause a serious loss of power by restricting the flow of the fuel/air mixture to the engine and by interference with the proper fuel/air ratio. Because induction icing accidents can be prevented by the pilot in virtually all cases, improved pilot awareness, attention, and adherence to recommended procedures should reduce accidents of this type.

a. Impact Ice - Impact ice is formed by moisture-laden air at temperatures below freezing, striking and freezing on elements of the induction system which are at temperatures of 32° F. or below. Under these conditions, ice may build up on such components as the air scoops, heat or alternate air valves, intake screens, and protrusions in the carburetor. Pilots should be particularly alert for such icing when flying in snow, sleet, rain, or clouds, expecially when they see ice forming on the windshield or leading edge of the wings. The ambient temperature at which impact ice can be expected to build most rapidly is about 25° F., when the supercooled moisture in the air is still in a semiliquid state. This type of icing affects an engine with fuel injection, as well as carbureted engines. It is usually preferable to use carburetor heat or alternate air as an ice prevention means, rather than as a deicier, because fast forming ice which is not immediately recognized by the pilot may significantly lower the amount of heat available from the carburetor heating system. Additionally, to prevent power loss from impact ice, it may be necessary to turn to carburetor heat or alternate air before the selector valve is frozen fast by the accumulation of ice around it. When icing conditions are present, it is wise to guard against a serious buildup before deicing capability is lost. The use of partial heat for ice prevention without some instrumentation to gauge its effect may be worse than none at all under the circumstances. Impact icing is unlikely under extremely cold conditions, because the relative humidity is usually low in cold air and because such moisture as is present usually consists of ice crystals which pass through the air system harmlessly. The use of partial heat when the temperature is below 32° F. may, for example, raise the mixture temperature up to the danger range, whereas, full carburetor heat would bring it well above any danger of icing.

b. Throttle Ice - Throttle ice is usually formed at or near a partially closed throttle, typical of an off-idle or cruise power setting. This occurs when water vapor in the air condenses and freezes because of the cooling restriction caused by the carburetor venturi and the throttle butterfly valve. The rate of ice accretion within and immediately downstream from the carburetor venturi and throttle butterfly valve is a function of the amount of entrained moisture in the air. If this icing condition is allowed to continue, the ice may build up until it effectively throttles the engine. Visible moisture in the air is not necessary for this type icing, sometimes making it difficult for the pilot to believe unless he is fully aware of this icing effect. The effect of throttle icing is a progressive decline in the power delivered by the engine. With a fixed pitch propeller this is evidenced by a loss in engine RPM and a loss of altitude or airspeed unless the throttle is slowly advanced. With a constant speed propeller, there will normally be no change in RPM but the same decrease in airplane performance will occur. A decrease in manifold pressure or exhaust gas temperature will occur before any noticeable decrease in engine and airplane performance. If these indications are not noted by the pilot and no corrective action is taken, the decline in engine power will probably continue progressively until it becomes necessary to retrim to maintain altitude; and engine roughness will occur probably followed by backfiring. Beyond this stage, insufficient power may be available to maintain flight; and complete stoppage may occur, especially if the throttle is moved abruptly.

c. Fuel Vaporization Ice - This icing condition usually occurs in conjunction with throttle icing. It is most prevelant with conventional float type carburetors, and to a lesser degree with pressure carburetors when the air/fuel mixture reaches a freezing temperature as a result of the cooling of the mixture during the expansion process that takes place between the carburetor and engine manifold. This does not present a problem on systems which inject fuel at a location beyond which the passages are kept warm by engine heat. Thus the injection of fuel directly into each cylinder, or air heated by a supercharger, generally precludes such icing. Vaporization icing may occur at temperatures from 32° F. to as high as 100° F. with a relative humidity of 50 percent or above. Relative humidity relates the actual water vapor present to that which could be present. Therefore, temperature largely determines the maximum amount of water vapor air can hold. Since aviation weather reports normally include air temperature and dewpoint temperature, it is possible to relate the temperature - dewpoint spread to relative humidity. As the spread becomes less, relative humidity increases and becomes 100% when temperature and dewpoint are the same. In general, when the temperature-dewpoint spread reaches 20° F. or less, you have a relative humidity of 50% or higher and are in potential icing conditions.

6. FUEL SYSTEM ICING. Ice formation in the aircraft fuel system results from the presence of water in the fuel system. This water may be undissolved or dissolved. One condition of undissolved water is entrained water which consists of minute water particles suspended in the fuel. This may occur as a result of mechanical agitation of free water or conversion of dissolved water through temperature reduction. Entrained water will settle out in time under static conditions and may or may not be drained during normal servicing, depending on the rate at which it is converted to free water. In general, it is not likely that all entrained water can ever be separated from fuel under field conditions. The settling rate depends on a series of factors including temperature, quiescence and droplet size.

a. The droplet size will vary depending upon the mechanics of formation. Usually, the particles are so small as to be invisible to the naked eye, but in extreme cases, can cause slight haziness in the fuel. Water in solution cannot be removed except by deyhdration or by converting it through temperature reduction to entrained, then to free water.

b. Another condition of undissolved water is free water which may be introduced as a result of refueling or the settling of entrained water that collects at the bottom of a fuel tank. Free water is usually present in easily detectable quantities at the bottom of the tank, separated by a continuous interface from the fuel above. Free water can be drained from a fuel tank through the sump drains which are provided for that purpose. Free water frozen on the bottom of reservoirs, such as the fuel tanks and fuel filter, may render water drains useless and can later melt releasing the water into the system thereby causing engine malfunction or stoppage. If such a condition is detected, the aircraft may be placed in a warm hangar to reestablish proper draining of these reservoirs, and all sumps and drains should be activated and checked prior to any flying. Entrained water (i.e., water in solution with petroleum fuels) constitutes a relatively small part of the total potential water in a particular system, the quantity dissolved being dependent on fuel temperature and the existing pressure and the water solubility characteristics of the fuel. Entrained water will freeze in cold fuel and tend to stay in suspension longer since the specific gravity of ice is approximately the same as that of aviation gasoline.

c. Water in suspension may freeze and form ice crystals of sufficient size such that fuel screens, strainers, and filters may be blocked. Some of this water may be cooled further when the fuel enters carburetor air passages and causes carburetor metering component icing, when conditions are not otherwise conducive to this form of icing.

7. PREVENTION PROCEDURES.

a. Induction System Icing - To prevent accidents due to induction system icing, the pilot should regularly use heat under conditions known to be conducive to atmospheric icing and be alert at all times for indications of icing in the fuel system. The following precautions and procedures will tend to reduce the likelihood of induction system icing problems:

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

(2) Start the engine with the carburetor heat control in the COLD position to avoid possible damage to the system and a fire hazard because of a backfire while starting.

(3) As a preflight item, check the carburetor heat effectiveness by noting the power drop (when heat is applied) on runup.

(4) When the relative humidity is above 50 percent and the temperature is below 70° F., apply carburetor heat briefly immediately before takeoff, particularly with float type carburetors, to remove any ice which may have been accumulated during taxi and runup. Generally, the use of carburetor heat for taxiing is not recommended because of possible ingestion of foreign matter on some installations which have the unfiltered air admitted with the control in the HOT or ALTERNATE AIR positions.

(5) Conduct takeoff without carburetor heat, unless extreme intake icing conditions are present.

(6) Remain alert for indications of induction system icing during takeoff and climb-out, especially when the relative humidity is above 50 percent, or when visible moisture is present in the atmosphere.

(7) With instrumentation such as carburetor or mixture temperature gauges, partial heat should be used to keep the intake temperature in a safe range. Without such instrumentation, full heat should be used intermittently as considered necessary

(8) If induction system ice is suspected of causing a power loss, apply full heat or alternate air. Do not disturb the throttle until improvement is noted. Expect a further power loss momentarily and then a rise in power as the ice is melted.

(9) If the ice persists after a period with full heat, gradually advance the throttle to full power and climb at the maximum rate available to produce as much heat as possible. Leaning with the mixture control will generally increase the heat but should be used with caution as it may kill the engine under circumstances in which a restart is impossible.

(10) Avoid clouds as much as possible.

(11) As a last resort, and at the risk of catastrophic engine damage, a severely iced engine may sometimes be relieved by inducing backfiring with the mixture control. This is a critical procedure at best, should not be attempted with supercharged engines, and must be done with the carburetor heat control in the COLD position.

(12) Heat should be applied for a short time to warm the induction system before beginning a prolonged descent with the engine throttled and left on during the descent. Power lever advancement should be performed periodically during descent to assure that power recovery can be achieved. The pilot should be prepared to turn heat off after power is regained to resume level flight or initiate a go-around from an abandoned approach.

(13) The pilot should remember that induction system icing is possible, particularly with float type carburetors, with temperatures as high as 100° F. and the humidity as low as 50 percent. It is more likely, however, with temperatures below 70° F. and the relative humidity above 80 percent. The likelihood of icing increases as the temperature decreases (down to 32° F.) and as the relative humidity increases.

(14) General - When no carburetor air or mixture temperature instrumentation is available, the general practice with smaller engines should be to use full heat whenever carburetor heat is applied. With higher output engines, however, especially those with superchargers, discrimination in the use of heat

should be exercised because of the possible engine overheating and detonation hazard involved. In the case of pressurized aircraft, use of alternate or heated carburetor air may require depressurization of the passenger compartment. A pilot of an airplane equipped with a carburetor air or mixture temperature gauge should make it a practice to regulate his carburetor heat by reference to this indicator. In any airplane, the excessive use of heat during full power operations, such as takeoffs or emergency go-arounds, may result in serious reduction in the power developed, as well as the hazard of engine damage. It should be noted that carburetor heat is rarely needed for brief high power operations.

b. Fuel System Icing. The use of anti-icing additives for some piston-engine powered aircraft has been approved as a means of preventing problems with water and ice in aviation gasoline. Some laboratory and flight testing indicated that the use of hexylene glycol, certain methanol derivatives and ethylene glycol monomethyl ether (EGME) in small concentrations inhibit fuel system icing. These tests indicate that the use of EGME at a maximum 0.15% by volume concentration substantially inhibits fuel system icing under most operating conditions. The concentration of additives in the fuel is critical. Marked deterioration in additive effectiveness may result from too little or too much additive.

> CAUTION: It should be recognized that the anti-icing additive is in no way a substitute or replacement for carburetor heat. Strict adherence to operating instructions involving the use of carburetor heat should be adhered to at all times when operating under atmospheric conditions conducive to icing.

8. CONCLUSIONS.

a. The evidence is clear that carburetor icing and aviation gasoline fuel system icing problems are prevented with proper use of aircraft carburetor air heat and by good housekeeping to eliminate water from gasoline and the aircraft fuel system.

b. Fuel anti-icing additives have been found to have a beneficial effect on the prevention of fuel system icing when properly blended in the fuel systems of aircraft powered by reciprocating engines.

c. Fuel anti-icing additives are not effective in preventing or reducing carburetor ice under all operating conditions and are no substitute for the necessity of carburetor heat or following prescribed flight manual operating procedures.

d. The effects and recommendations described in this circular are general in nature and appropriate to most certificated airplanes. The pilot should refer to all available operating instructions and placards pertaining to his airplane to determine whether any special consideration or procedures apply to its operation.

M. C. Beard
Director of Airworthiness