CARBURETOR ICE

AN OLD ENEMY THAT STILL CLAIMS ITS VICTIMS

by KEN GARDNER / AOPA 132319

■■ The hazard of ice forming within the throat of a carburetor has been with us since the beginning of powered flight. Most experienced pilots know that and all student pilots are normally taught about it, but still carburetor ice continues to cause aircraft accidents.

While some such accidents are simply the result of carelessness, perhaps most are due to the lack of sufficient understanding. Many pilots refer to carburetor ice as being primarily a wintertime problem. Some believe it originates from water present in the fuel and that the addition of a can of alcohol to each tank of fuel will eliminate the problem. The term carburetor ice itself is to some degree misleading.

To begin with, there are two basic forms of carburetor icing—one of which the carburetor is not responsible for. We could better call these impact and mechanical icing. Impact icing occurs when visible moisture contacts a supercooled (below 32°F) surface. It is also possible to have supercooled moisture which can become ice upon contact with a surface at or below freezing.

We generally refer to this type of icing as structural or airframe icing. If such moisture is freezing to the exterior surface of the aircraft, it can also freeze to the carburetor airscoop, restricting the airflow, and within parts of the engine's air induction system.

Figure 1 illustrates ice formation within the interior of the induction system on a fuel-injected engine. Notice that structural ice is building on the leading surfaces of the upper and lower cowling. Ice has also begun forming on the inside of the induction air box in the first bend aft of the filter and in the second bend prior to entering the induction manifold runners. Formation of ice inside the air box and manifold could eventually restrict the amount of air reaching the cylinders, with a resultant loss in power.

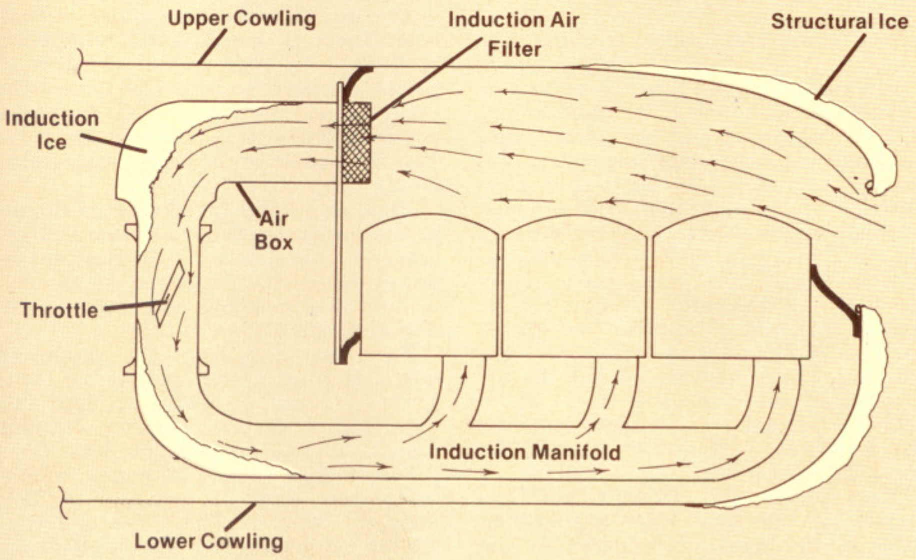

Figure 1

Such a phenomenon can hardly be defined as carburetor icing when this particular engine doesn't have a carburetor. More properly it is induction icing, caused by supercooled water contacting the cold metal of the air box and induction system.

This kind of icing should not come as a surprise to the pilot since he should be able to see structural icing on the airframe leading surfaces. The safety rule for this situation is quite simple: When you see ice forming on the exterior of the aircraft it can also form within parts of the induction system.

The first question is usually, "Why doesn't the air filter ice over?" While this is possible, it's not frequent. The filtering materials of the air filter are porous and normally it will be easier for moisture-laden air to pass through than solidify upon contact. Sudden contact with the cold, nonporous metal surfaces of the air box and induction system is a different situation, and ice could accumulate as illustrated in Figure 1.

Obviously, the next question would be relative to remedial action. Installations such as depicted in Figure 1 will nearly always incorporate an induction heat source of some type. On some installations induction heat will occur automatically should the air filter become iced over. Small, spring-loaded doors on the air box will open should sufficient differential occur between ambient and manifold pressure in the upper deck (area of induction system between filter and throttle). Opening of these doors provides an alternate source of induction air, generally from a protected source such as inside the accessory section.

Some aircraft equipped with an automatic alternate air source also have a manual control. Where a manual control is provided, the pilot may employ alternate air at his discretion. Induction icing such as illustrated in Figure 1 is not common with fuel-injected engines. However, should such icing occur, use of alternate air can melt the accumulation and prevent any further formation. Application of alternate air may provide effects similar to use of carburetor heat.

continued

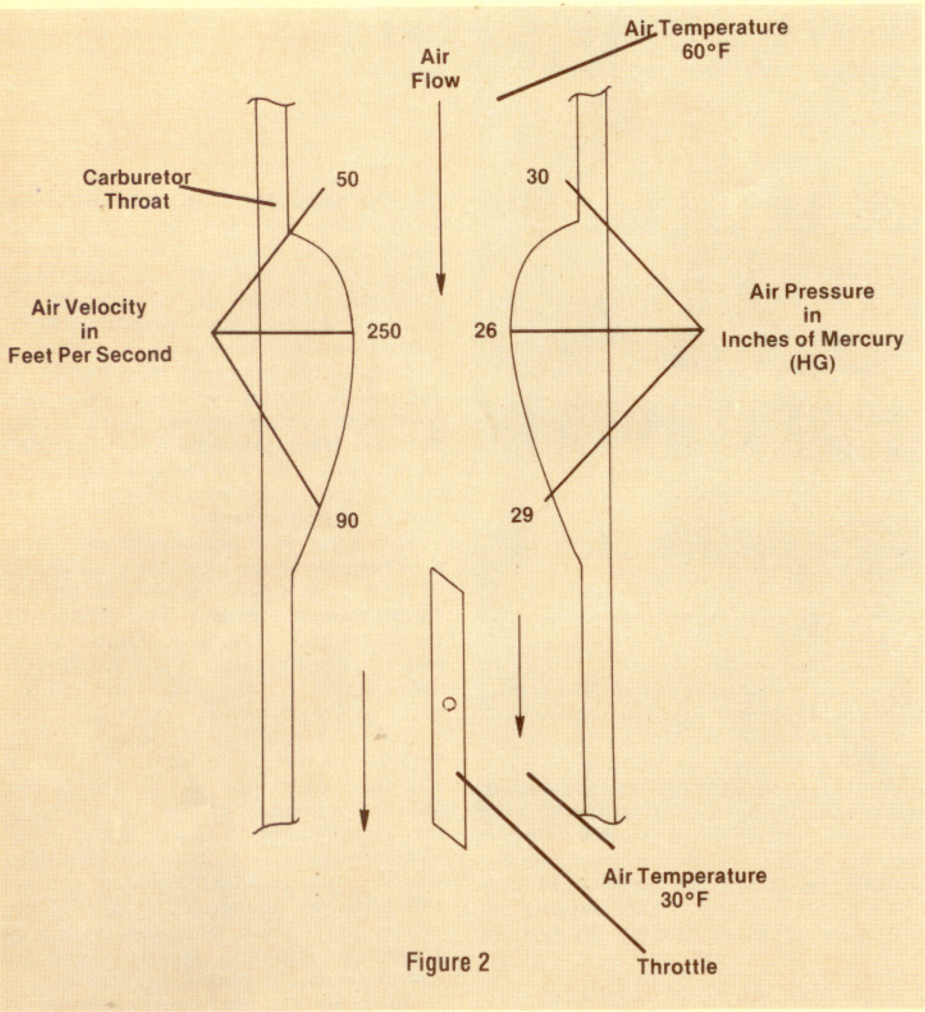

Figure 2

CARBURETOR ICE continued

If so, the mixture should be leaned as necessary to restore smooth engine operation and reduce power loss.

Such induction icing is equally rare on supercharged engines since the compression process of the supercharger imparts a considerable rise in temperature to the air passing through the compressor. However, it is possible to encounter structural, or atmospheric icing, to the areas such as induction airscoop and air filter prior to the compressor. For that reason supercharged installations will usually be fitted with some type of alternate, or heated, air source.

The use of alternate air should be treated with the same respect as carburetor heat. With few exceptions alternate air bypasses the induction filter; therefore, unfiltered air is entering the induction system. Any heating of such air will have the effect of increasing the density altitude with the accompanying loss of power and need to lean the mixture.

The most common form of carburetor icing is the mechanical type and is limited to engines employing carburetors.

Practically all carburetors have venturis. A venturi is a specially shaped restriction in a tube that will produce changes in the velocity and pressure of the air flowing through it. The illustration in Figure 2 portrays the changes normally encountered when air is passed through a venturi. The figures at the left illustrate the effect the venturi has on air velocity. Notice the air is entering the carburetor throat at 50 feet per second (fps). Upon reaching the narrowest part of the venturi, the air velocity has increased to 250 fps.

Now notice the pressure readings shown on the right side. A four-inch drop in air pressure occurred in the same area where the velocity reached a maximum. The sudden restriction, immediately followed by a more gradual opening of the restriction, is the mechanics by which the venturi accomplishes a pressure drop. The purpose of this pressure drop will be explained later.

Also indicated in Figure 2 is a temperature change of the air passing through the venturi. Air entered the carburetor throat at 60°F, but its temperature after passing through the venturi dropped to approximately 30°F, or a net loss of 30°. A humidity of 70% or more is sufficient moisture saturation of the air passing through the venturi to cause icing. Both temperature and pressure drop in the venturi are relative to air velocity through the venturi. Thus, the greater the velocity, the greater the differential. This is an important factor, as you will soon see.

The effects of ice building in this throat area can change the contour of the venturi, thereby reducing its effectiveness, and can restrict air flow as well. Both conditions influence a power loss. Since most aircraft carburetors employ venturis, you can estimate a 30° lower than ambient temperature at the venturi during high- and cruise-power settings. It would be a simple matter then to subtract 30° from existing ambient temperature, so you would know whether or not the carburetor throat was in the icing temperature range.

For example, an ambient temperature of 90°F minus the 30° drop would indicate a carburetor temperature of approximately 60°F at cruise power or above. Ice would not form at 60°F, so it would seem that you need not be concerned about carburetor ice. However, this would be true with a pressure-injection type carburetor, but not for the more common float-type.

Essentially, there are two types of aircraft carburetors in common use. One is pressure injection, the other is float type. There is a substantial difference in their icing characteristics. Figure 3 shows a venturi and throttle valve as in Figure 2, except that a fuel discharge nozzle is present in the venturi bore. This is typical of float-type carburetor design.

Location of the fuel-discharge nozzle in the low-pressure area of the venturi causes fuel to flow from the float chamber to the discharge nozzle, the amount of fuel flow varying according to air flow through the venturi.

Fuel emerging from the discharge nozzle is quickly atomized by the high-speed (170 mph or better) air flow, and vaporization occurs. The vaporization process absorbs considerable heat from the immediate surrounding area, with a subsequent drop in temperature. The process is very similar to that of refrigeration. At cruise- and takeoff-power air flow velocities this vaporization process can subtract as much as 40° from surrounding temperatures. Together, the venturi action and the fuel vaporization process can reduce carburetor throat temperatures by as much as 70°F. On a 100°F day you could still find a temperature of 30°F in the carburetor throttle area.

Note how ice is forming in Figure 3 on the throttle valve and carburetor throat below the venturi. If this situation were allowed to continue, power loss would ultimately occur. Figure 3 does not depict any ice on the fuel-discharge nozzle or the upper area of the venturi. The intent here was to show only the effects of refrigeration-type icing from fuel vaporization. However, it is possible to accumulate ice on the discharge nozzle and upper venturi area, because these areas are also chilled by the venturi and vaporization actions.

While you can expect carburetor throat temperatures of 60° to 70° below ambient for float-type carburetors operating at cruise power and above, the temperature drop for the pressure-injection carburetor is only about half this amount, due to location of the fuel-discharge nozzle.

The float carburetor utilizes a pressure differential to move fuel from the float chamber to the discharge nozzle. Therefore, the discharge nozzle must be located within the venturi. The more complex pressure-injection carburetor moves fuel to its discharge nozzle with pressure from an engine-driven fuel pump; consequently, the carburetor discharge nozzle may be located downstream from the venturi and the throttle valve where it won't contribute to throttle valve or throat icing.

For this reason, only the venturi temperature drop needs to be considered in this case.

Theoretically, the worst icing potential should be under takeoff conditions, and yet most experiences with carburetor ice have been at cruise power or glide-to-landing configurations. Carburetors can and have iced on takeoff; however, the duration of actual takeoff power is short and carburetor ice resulting from invisible moisture does not build as rapidly as visible or impact-type ice.

If substantial ice has formed from the mechanical process during takeoff, it will usually manifest itself somewhere in the climb. Humidity is the key factor in mechanical- or refrigeration-type icing; those damp days of spring, early summer, and fall are the most critical periods because cool, damp air contains more moisture per volume than warm, damp air. Of course, this is true only down to a point. Once air temperatures descend to 20°F the possibilities of mechanical icing from nonvisible moisture diminish rapidly.

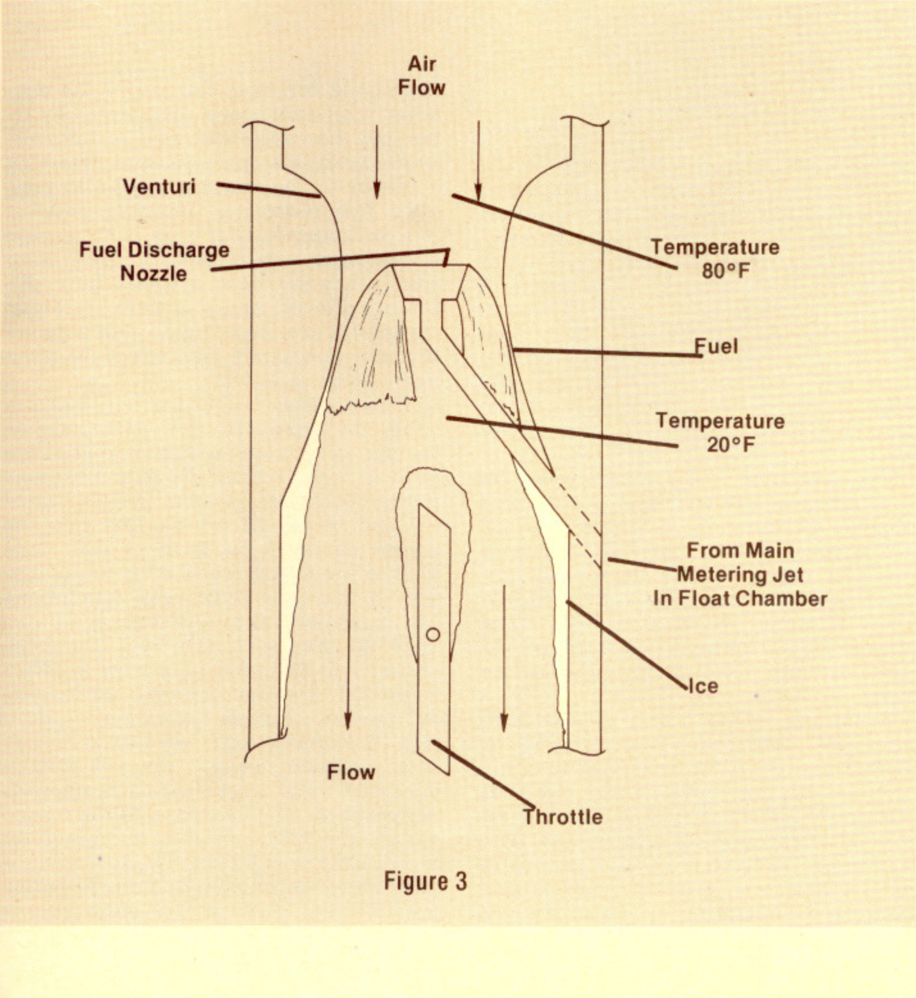

Figure 3

From what has been covered thus far it would appear that carburetor ice potential should decrease with lower power settings since venturi effects and discharge nozzle flow decrease with throttle reduction. This is true, except that reducing throttle opening to the near closed position increases airflow velocity around the edges of the throttle plate, which rapidly reduces the temperature of the throttle valve (much like the venturi process).

If sufficient moisture (70% or more) is present, ice will form upon contact with the cold throttle plate. This type of carburetor ice is often described as throttle-plate ice and can be quite hazardous. From the illustration in Figure 4 you can see that not much ice is needed to quickly bridge the gap between the throttle valve and throat walls.

Such a condition can freeze the throttle valve to the throat of the carburetor. When the unsuspecting pilot attempts to open the throttle for needed power, it doesn't budge. Application of force is more likely to break a part of the throttle linkage before it breaks the weldlike grip the ice has created.

It is this type of icing you were taught to prevent with the use of carburetor heat, and by gently gunning your engine during a glide to landing. Like the other forms of mechanical icing, throttle-plate icing is at its maximum potential during cool, damp days.

Fortunately both impact and mechanical forms of ice can be dealt with prior to their reaching cataclysmic effects. Structural icing of the aircraft should leave no doubt as to the possibilities of similar buildups with respect to the aircraft induction system. If you know your aircraft and its powerplant, then you should be able to handle the situation. If you don't, then you shouldn't be anywhere near known icing conditions. The potential for mechanical icing with carburetor-equipped aircraft is present with ambient temperatures from approximately 65°F to 20°F for pressure-type carburetors and approximately 100°F to 20°F for float-type carburetors.

So long as you remember that the temperature drop with pressure carburetors will seldom, if ever, exceed 30° while it can be as much as 70° for float types, have a reasonably accurate outside air temperature (OAT) gauge in your aircraft, and keep aware of the ambient humidity, you should never have

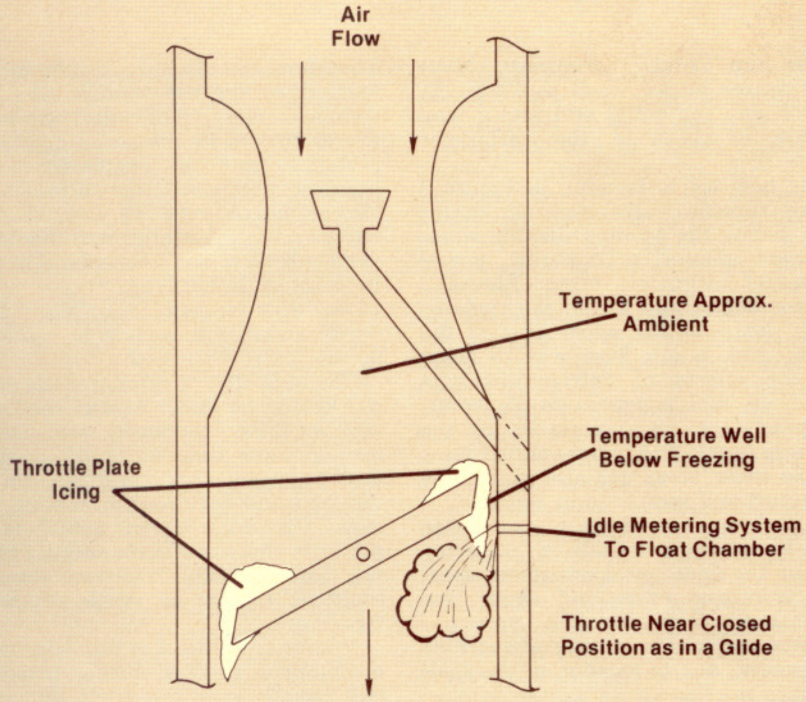

Figure 4

CARBURETOR ICE continued

a power failure from carburetor ice.

The best cure for carburetor ice is, of course, prevention. Know the symptoms of its presence. For aircraft equipped with fixed-pitch propellers, a gradual loss of rpm and airspeed will constitute the initial warning. If this goes unheeded, the second notice usually consists of engine roughness as the engine nears the stage where it will eventually cease firing. If you persist, the third stage may be the loudest quiet you ever heard.

The symptoms are a bit different for constant-speed propeller aircraft. The propeller governor maintains a constant engine speed despite the loss of power. The first signs will be decreasing airspeed, coupled with falling manifold pressure. Again, these symptoms come on gradually. The next two steps are the same as with fixed-pitch propeller aircraft.

When the first warning manifests itself, full carburetor heat should be applied and the mixture leaned to eliminate engine roughness from the side effects of carburetor heat. A gradual return of airspeed (and engine rpm with fixed-pitch propellers only) indicates that ice had been present. After several minutes of operation to clear the accumulated ice, you can verify the situation (constant-speed propellers) by returning the carburetor heat to full cold, re-enriching the mixture, and observing a return to the original manifold pressure. Just observing manifold pressure while carburetor heat is on is not always an accurate way to discover ice. Different carburetor heat systems have different effects on manifold pressure, depending on how much temperature rise and how much ram effect the alternate source negated.

Where considerable ice has accumulated, be prepared for some engine roughness immediately upon application of heat. This is generally due to extreme mixture changes caused by the heated air and pieces of ice passing into the engine. If one waits until engine roughness is already present prior to application of heat, the roughness that follows can be somewhat unnerving.

Once the accumulation has been cleared out the pilot may wish to select a partial amount of heat application to prevent further recurrence. However, Lycoming says *absolutely not* to this practice unless the aircraft is equipped with a certified carburetor air temperature (CAT) gauge. If there is no gauge, the policy of this manufacturer is full heat or full cold. The reasoning is good since, during flight through frozen precipitation such as dry snow, ice or ice fog with partial carburetor heat, there may be just enough heat to melt the airborne ice crystals, which otherwise would flow harmlessly through the carburetor, only to have them refreeze in the discharge-nozzle area. Where no CAT gauge is present, the use of full heat or none negates such possibilities.

There are several types of CAT gauge on the market, and some are designed to have their sensing probe installed directly into the critical area of the carburetor throat. This arrangement will facilitate the most accurate control since the reading is taken in the region of the carburetor throat where the ice forms.

Some instruments have range markings or a "desirable" indication. The desirable marking is a throat temperature safely above freezing to prevent ice, but low enough to negate much of the power loss associated with full heat. The pilot simply adjusts carburetor heat to maintain the gauge needle in the desired range. Such an instrument of good quality is well worth having aboard.

While application of carburetor heat is quite simple, its use must be accompanied with a reasonable degree of knowledge. To begin with, the system should always be checked during each preflight engine runup. A drop in rpm (both fixed pitch and constant-speed propellers) when applied to full heat indicates that heated air is entering the induction system. No drop is reason to abort and investigate.

While ground checking, keep in mind that most carburetor heat systems bypass the induction air filter. Consequently, operation of this system in dusty, dirty areas will introduce damaging grit into the engine.

Carburetor heat should not be used for takeoff or high power (above 75%); the increase in inducted air temperature from carburetor heat erodes the detonation margin designed into your engine.

When carburetor heat is to be applied for any length of time, such as in cruise flight, the mixture should be leaned enough to eliminate overrich engine roughness. This procedure will also restore much of the power loss caused by carburetor heat.

Some airwork procedures and glides to a landing usually dictate the use of carburetor heat. In such cases, apply heat prior to reducing power. Heat applied after power has been reduced is like throwing a log into the stove after the fire is out. During long glides with the heat on, the engine should be gently gunned periodically to clear the combustion chambers from the overrich effects caused by the heat and to generate sufficient carburetor heat to prevent throttle-plate icing.

An old friend once told me that he preferred his ice with his bourbon. For certain, keeping ice out of your carburetor will help keep you around whether you like bourbon or not. □