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Dear Aviators

Being well and truly deep into the winter months of July and August, this issue of Tech Talk 22 covers the topic of "Weathering Induction icing."

This issue was prompted by a question that was asked of Rob Midgley, Technology Manager, Shell Aviation Fuels. The question was whether there is a fuel additive available that will prevent carburettor icing. The simple answer Rob could have given was no, but that would make for a very short technical article wouldn't it?

There are approved additives to prevent ice forming in fuel tanks; there are no additives that prevent induction, or carburettor, icing. So Rob thought that with summer coming it may be a good time to talk about induction icing: what causes it, how to recognise the symptoms and how to deal with it effectively. What does Rod mean, with summer coming, surely that's a misprint? Well no, venturi icing is actually just as much a summer phenomenon as a winter one, as Rob will discuss later.

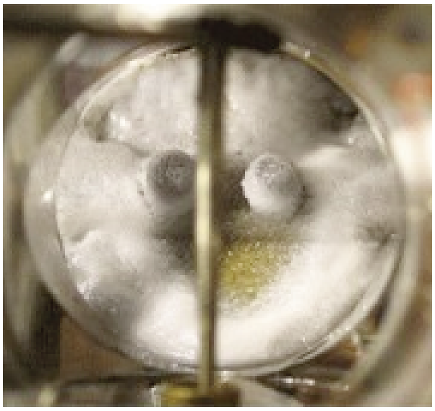
Happy Flying

Craig Rudolph
Regional Account Manager - Oceania
Aviation Lubricants and Specialities
Mob: +61 0401677301 Fax: +61 2 9317 4673
Email: craig.rudolph@shell.com

AeroShell TECH TALK

Weathering Induction Icing

Even in summer, it is possible for pilots to experience a loss of power due to two different forms of icing that may affect their engine.



Complete icing of a Bing 64 carburettor throttle butterfly that resulted in engine failure. This icing occurred with an outside air temperature of 8°C and relative humidity of 85 per cent - conditions easily achievable at moderate altitude in any season. Photo: Maxwell Ansboro

The obvious problem with induction icing is that it restricts the supply of air to the engine and therefore limits the amount of power that the engine can produce. It typically takes one of two forms: impact ice and throttle venturi ice and whilst carburettor engines are prone to both types, injected engines are not immune from icing either.

AIRBORNE MOISTURE

Let' s take impact icing first. Impact icing is easy to understand and is commonly associated with those conditions that also lead to airframe icing: airborne moisture impacts upon an airframe which is at or below freezing point and results in the build-up of ice, not just on the wings, but also potentially in the engine inlet air ducting. However, induction icing is not just a concern when airframe icing is obvious; impact icing may still cause problems in conditions where you may have discounted it. Flying in wet conditions with rain streaming off the canopy you might think you' re safe from impact icing, especially flying a fuel injected aircraft, but you may not be. Combine these conditions with temperatures just above freezing then even fuel injected aircraft have documented loss of power due to icing. Investigation of incidents such as these has shown that it is possible for cold, but liquid, water to form ice on the air filter restricting its flow and causing power loss. These cases are not isolated or even uncommon and use of alternate air or carburettor heating should always be a consideration when faced with a loss of power even when airframe icing is not present.

This brings me onto the more troublesome form of induction icing: the venturi icing common with carburettor-supplied engines. In a carburettor there is a narrowing of the induction system, known as a venturi, which in turn causes an increase in the speed of the airflow, in much the same way the flow of a river increases through a narrow channel. Remember Bernoulli' s equation from when you were studying how wings work? Well, it applies just as well in carburettor engines: an increase in the speed of the air results in a decrease in static pressure in the venturi. This allows fuel to be drawn from the float chamber and into the air stream, but the venturi shape has another secondary effect thanks to another law: Guy Lussac' s Law. This states that for a fixed volume of gas the temperature of the gas is proportional to its pressure. So by having a venturi, Bernoulli predicts the reduction in pressure – achieving the objective of the exercise to draw fuel from the float chamber – but at the same time Guy Lussac' s Law demands that the air temperature is also reduced. One can see the start of the icing problem, but it does not stop there.

In a venturi we are intentionally evaporating fuel in the air to form a combustible vapour for the engine. This means that the liquid fuel starts to form a gas as soon as it is exposed to the induction airflow. Those parts of the fuel that are most volatile – meaning most easily able to form a vapour – will transition from liquid to gas very quickly in the venturi. In forming a vapour they require energy; the fuel gets this from the surrounding air. How much energy the fuel needs is dependent upon how much light, volatile material there is in the fuel and the latent heat of vaporisation of the fuel itself – something I will come back to later. The key point for now is that evaporating fuel extracts energy from the air resulting in the temperature of the air in the venturi dropping yet further.

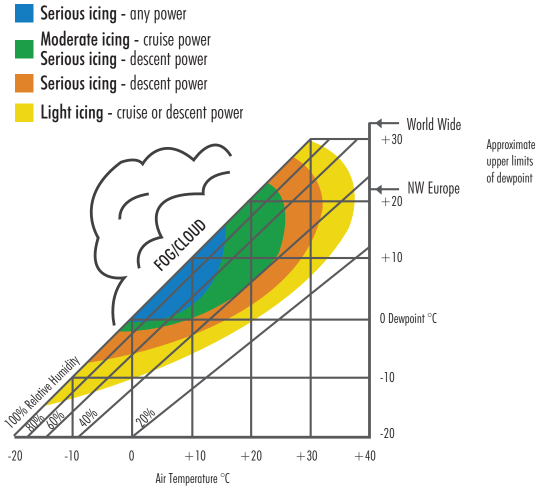
CONTRIBUTORY FACTORS

When summer flying, do you consider the chance of induction icing? Photo: www.aviationpictures.com

The combination of these two factors can cause moisture in the inlet air to freeze and adhere to the carburettor venturi, restricting its size and therefore compromising the available power. The significance of the cooling effects in the venturi is that icing can happen at outside air temperatures considerably above freezing. It is critical to notice that it is water vapour from the incoming air that causes the icing and not water in the fuel. In fact, the icing happens predominantly in areas of the carburettor that the fuel never even touches. The cooling effects are most intense around where the fuel is introduced, but the fuel itself is rapidly being taken downstream and so doesn' t touch the walls of the venturi at the point where the cooling effect is at its greatest. This takes us back to the original question of whether there is a fuel additive that can prevent induction or carburettor icing; we can start to see why an anti-freeze in the fuel can have little or no effect.

For a given fuel, the factors that affect formation of venturi ice are the pressure, air temperature and moisture content of the air. As we saw earlier, the lower the pressure, then the lower the temperature of the air. This explains why the venturi effect

is greatest at partial throttle settings and this is why your flying instructor always told you that carburettor heat is recommended when at partial power.



Technical chart: From the UK CAA's Safety Sense leaflet 14, Piston Engine Icing

The chart (above) goes some way to showing this graphically. What is interesting from this chart is that the most intense icing is encountered at outside air temperatures between approximately 0˚C and 15˚C. Remember that temperature reduces with altitude at the rate of about 2˚C per 1,000 feet, so a summer evening flight at the bottom of the clouds (where the humidity is, by definition, high) could well have you inadvertently operating in the very worst icing conditions even at cruise power. Ask yourself: how often do you take notice of the dew point when air traffic control tells you what it is? What you should be doing is mentally asking yourself whether you will be operating within 10˚C of the dew point during your flight. Make sure you are conscious of induction icing if you are, even in summer.

Fuel choice also makes a difference. Remember how it is the most volatile parts of the fuel that take energy from the air in the venturi itself? Well, different fuel compositions will be worse than others – those that will extract a lot of heat from the air in the process of changing the fuel from a liquid into a vapour. Fuels with a higher proportion of low boiling point material in them tend to promote venturi icing – so motor gasoline (Mogas) is worse than aviation gasoline (Avgas) – as do fuel types that have a high latent heat of evaporation. Alcohols come into this second category and so whilst you might instinctively think that alcohol might act as an anti-freeze and prevent induction icing, the opposite is in fact true.

These factors are central considerations in specifying Avgas where alcohols are not permitted and the volatility is carefully controlled. With other fuels, such as Mogas, they are far less carefully specified in this regard as induction icing is far less of a concern with ground vehicles. I should also point out, as I did in a previous Technical Talk, that most of the world's Mogas will soon contain alcohol as there are mandates compelling the use of biofuel components in ground fuels. The safety issues surrounding using alcohol as a fuel component in aircraft are much more extensive than just induction icing concerns and these issues are recognised by the approval authorities. Mogas containing alcohol is specifically not approved in any aircraft even under the existing Mogas Supplementary Type Certificates, therefore using fuels that contain alcohol is not just dangerous and illegal, but it technically renders the aircraft un-airworthy. Be sure you are aware of it.

LOOK FOR THE SIGNS

So back to induction icing, how do you spot it?

The most typical signs are a gradual loss of power, meaning a reduction in engine speed in fixed pitch propeller aircraft, or a reduction in manifold pressure in aircraft fitted with constant speed propellers. If spotted early, alternative air or carburettor heating will deal with the issue before the compromise in power becomes a problem.

However, it is far more common for pilots to notice a small change in engine speed or manifold pressure and to simply increase the power to recover the original settings. If done repeatedly, adjusting for the small losses of power time and again, it is possible to have the power lever at its maximum before realising there is a problem and starting to deal with the underlying cause.

There are two significant things about the application of carburettor heat – first of all it will not melt induction ice instantaneously and secondly, its use will result in a reduction in power of up to 15 per cent. The combination of these two facts can be frightening for a pilot who may already be finding maintaining altitude difficult. If you have been late in recognising the symptoms then a further reduction in power can be alarming; however, a wise pilot keeps the carburettor heat selected for at least a minute as it takes at least this length of time to clear heavy ice deposits.

The power reduction when selecting carburettor heat is due to the incoming warm air causing both a richer mixture and also the increase in induction temperature reducing the cycle efficiency of the engine. Incidentally, this is why carburettor heat should always be deselected before going to high power – the reduction in power is otherwise significant and the additional induction heat will also take the engine closer to its detonation boundary.

At cruise power settings things are slightly different. If conditions are such that icing is likely in the cruise, it is possible to leave the carburettor heat on constantly, but it should be realised that for most engines this means bypassing the air filter so use of unnecessary carburettor heat should be minimised in dusty conditions, something you should especially be aware of while taxiing.

Hopefully this has given some insights into how induction icing occurs and explains why your old instructor drilled into you about using carburettor heat as part of the "E" in your 15-minute FREDA checks (remember them, Fuel, Radio, Engine, Direction Indicator and Altimeter) and also why selecting it during descent is sensible. Next time you do, no doubt you'll mutter to yourself that all you're doing is trying to combat Guy Lussac's law.

Happy flying.

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