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INDUCTION SYSTEM ICING ON PISTON ENGINES AS FITTED TO AEROPLANES, HELICOPTERS AND AIRSHIPS.

1 Introduction

1.1 Piston engine induction system icing, commonly, but not completely accurately, referred to as 'carburettor icing' may occur even on warm days, particularly if they are humid. IT CAN BE SO SEVERE THAT, UNLESS CORRECT ACTION IS TAKEN, THE ENGINE MAY STOP. Induction system icing is more likely at low power settings such as those used during descent, holding, on the approach to a landing or during auto-rotation on a helicopter.

1.2 Statistics continue to show an average of 10 occurrences, including seven accidents, per year which were probably caused by engine induction icing. After a forced landing or accident the ice may well have disappeared before an opportunity occurs to examine the engine, so that the cause cannot positively be identified.

1.3 Some aircraft and engine combinations are more prone to icing than others and this should be borne in mind when flying another aircraft type.

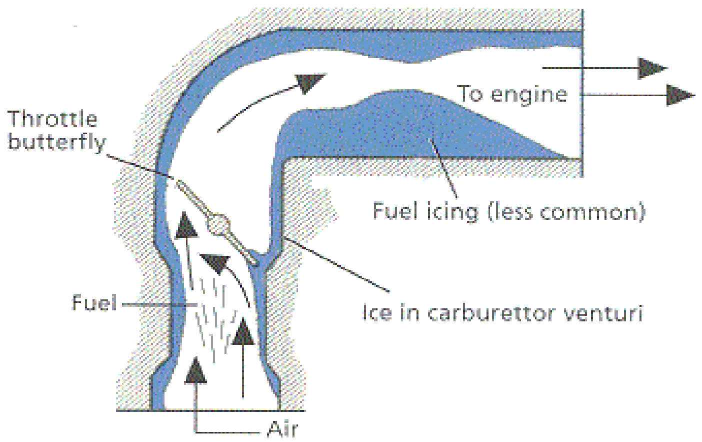
2 Induction System Icing

2.1 There are three main types of induction system icing:

a **Carburettor Icing:**

The most common type of induction system icing is carburettor icing which is caused by a combination of the sudden temperature drop due to fuel vaporisation and the reduction in pressure at the carburettor venturi. The temperature reduction may be as much as 20-30° C and results in moisture in the induction air forming ice. The ice gradually builds up, constricting the venturi, and by upsetting the fuel/air ratio causes a progressive decrease in engine power. Engines which have a conventional float-type carburettor are more prone to this type of icing than are those which have a pressure jet carburettor, ie: the Stromberg type of carburettor. Engines with a fuel injection system are not, of course, subject to carburettor icing;

BUILD-UP OF ICING IN INDUCTION SYSTEM



b Fuel Icing:

Fuel icing is the result of water, held in suspension in the fuel, precipitating and freezing in the induction piping, especially in the elbows formed by bends;

c Intake or Impact Ice:

Ice which builds up on air intakes, filters and carburettor heat or alternate air valves etc, is known as intake or impact ice (for consistency the term impact ice is used throughout this Circular). Impact ice can accumulate in snow, sleet or subzero-temperature cloud or in rain when the temperature of the rain or the aircraft is below 0° C, this type of icing affects fuel injection systems as well as carburettor systems.

2.2 Testing has shown that, because of the greater volatility and possible greater water content, carburettor and fuel icing is more likely to occur with MOGAS than with AVGAS.

2.3 Reduced power settings are more conducive to icing in the throttle area because there is a greater temperature drop at the carburettor venturi and the partially closed butterfly can more easily be restricted by the ice build-up.

3 Atmospheric Conditions

3.1 Carburettor icing is not confined to cold weather and will occur in warm weather if the humidity is high enough, especially when the throttle butterfly is only partially open as it is at low power settings. Flight tests have produced serious icing at descent-power with the ambient (not surface) temperature above 30° C, even with a relative humidity as low as 30%. At cruise power, icing can occur at 20° C with a relative humidity of 60% or more. Ice accretion is less on cold, dry winter days than on warm, humid summer days because the water vapour content of the air is lower. Thus, where high relative humidity and ambient temperatures of between -10° C and +25° C are common, as is the case in the UK and Europe, pilots must be constantly alert to the possibility of icing and should take the necessary steps to prevent it. If the appropriate preventive action has not been taken in time it is vital to be able to recognise the symptoms (see paragraph 4.2) so that corrective action can be taken before an irretrievable situation develops. Should the engine stop due to icing it may not re-start or, even if it does, the delay may result in a critical situation.

3.2 Carburettor or fuel icing may occur even in clear air and these are, therefore, the most insidious of the various types of icing because of the lack of visual clues.The risk of all forms of induction system icing is higher in cloud than in clear air but because of the visual clues the pilot is less likely to be taken unawares.

3.3 Specific warnings of induction system icing are not included in standard weather forecasts for aviation. Pilots must use their knowledge and experience to estimate the likelihood of its occurrence from the weather information available.When information on the dew-point is not available, pilots in the UK and Europe should always assume a high relative humidity, particularly when:

a The surface and low-level visibility is poor, especially in the early morning and later evening and particularly when near a large area of water;

b the ground is wet (even with dew) and the wind is light;

c just below the cloud base or between cloud banks or layers;

d in precipitation, especially if it is persistent;

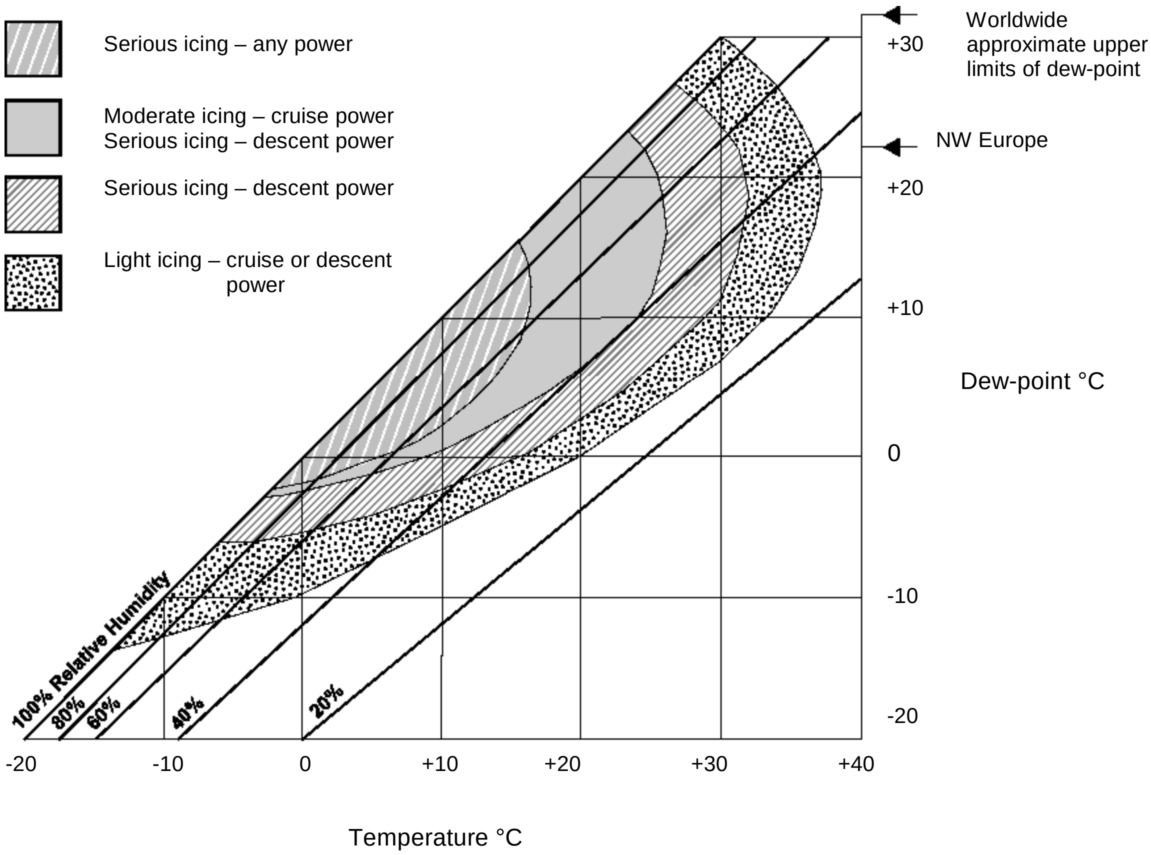
e in cloud or fog - these consist of water droplets and therefore the relative humidity should be assumed to be 100%; or

f in clear air where cloud or fog has just dispersed.

3.4 The chart below shows the wide range of ambient conditions conducive to the formation of induction system icing for a typical light aircraft piston engine. Particular note should be taken of the much greater risk of serious icing with descent power. The closer the temperature and dew-point readings, the greater the relative humidity.

CARBURETTOR ICING IN AIR FREE OF CLOUD, FOG OR PRECIPITATION

(risk and rate of icing will be greater when operating in cloud, fog and precipitation)



3.5 Impact icing occurs when flying through snow or sleet, or in cloud in which super-cooled water droplets are present. It can occur, but is less frequent, when flying through super-cooled rain or on an aircraft which has a surface temperature below 0° C when through rain which is above freezing temperature. The ambient temperature at which impact ice may be expected to build up most rapidly is about -4° C in conditions in which visible ice is forming on other parts of the aircraft.

4 Prevention, Recognition and Remedial Practices

4.1 Prevention

4.1.1 Whilst the following provides a general guide to assist pilots to avoid induction system icing, the Pilot's Operating Handbook or Flight Manual must be consulted for specific procedures applicable to a particular airframe and engine combination. The procedures are likely to vary between different models of the same aircraft type.

a In most combinations, carburettor icing is prevented by heating the intake air in an exhaust heat exchanger before it reaches the carburettor (design requirements typically demand a temperature rise of 50°C at 75% power). This is usually achieved by use of a manually operated carburettor heat control, marked HOT or COLD, which, in the HOT position, by-passes the normal intake filter and derives the induction air from a heated source. The HOT position should be selected in time to prevent the formation of ice, because if the selection is delayed the use of hot air might be too late to melt the ice before the engine stops. It should be noted that engines with carburettor heat selected to HOT will not produce full power due to the inlet charge heating effect reducing the intake charge density, producing a reduction in volumetric efficiency. This loss in power should not be confused with the effects of carburettor icing;

b several engine/airframe combinations heat parts of the intake or carburettor electrically. Use of these electrical systems is unlikely to cause more than a minimal reduction in power, so electrical heating should be applied in accordance with the manufacturer's instructions whenever the onset of carburettor icing is likely;

c engines with fuel injection normally have an alternate air intake, marked ON or OFF, located within the engine cowling and operated by a valve downstream of the normal intake. Although the air does not pass through a heat exchanger it derives some heat from the engine. Some engine installations have automatic alternate air selection activated by pressure-sensitive valves.

d other than on take-off, the HOT AIR position should be selected periodically when icing conditions are suspected or when flying in conditions of high humidity with the outside air temperature within the high probability ranges indicated on the chart at paragraph 3.4. Unless expressly permitted the continuous use of the HOT AIR position should be avoided, especially during hovering flight in a helicopter. It should be selected intermittently for long enough to pre-empt the loss of engine power (due to icing); this time period will vary dependent on the prevailing conditions.

e as a consequence of the increased susceptibility to carburettor icing at reduced power settings, for both air and electrical systems, the HOT position should be selected prior to descent, approach and landing.

4.2 **Recognition**

4.2.1 Should no preventative action have been taken, or was taken too late, or was insufficient, the onset of induction icing may be recognised in the following ways:

a With a fixed-pitch propeller, a slight drop in RPM is the first sign which may indicate the onset of icing in the induction system. If not rectified there will be a loss of airspeed and/or height. The loss of RPM may be gradual with no associated rough running. The usual reaction is to open the throttle slightly to restore the RPM and this action masks the early symptoms. As the icing increases there will be rough running, vibration and further RPM reduction; a loss of airspeed or height will result and ultimately THE ENGINE MAY STOP. Thus the main detection instrument is the RPM gauge used in conjunction with the Air Speed Indicator.

b where a constant-speed propeller is fitted, and in a helicopter, the loss of power would have to be large before the RPM reduced, hence the onset of induction system icing could be even more insidious. However, the effect of icing will be shown by a drop in manifold pressure and then by a reduction of airspeed or height. The primary detection instrument is, therefore, the manifold pressure gauge. Engine rough running may provide an additional indication.

c an exhaust gas temperature indicator will show a decrease in Exhaust Gas Temperature (EGT) with the onset of icing but engine rough running probably would have been detected already.

4.3 **Remedial Action**

4.3.1 When the presence of induction system icing is suspected the HOT or alternate air ON position must be selected immediately.

a The recommended practice with most engines is to use full heat whenever carburettor heat is applied. The control should be selected fully to the HOT position. Partial heating can induce induction system icing because it may melt ice particles which would otherwise pass into the engine without causing trouble, but not prevent the resultant mixture from freezing as it passes through the induction system. Alternatively partial heat may raise the temperature of the air into the critical range.

b with some engine installations the use of partial carburettor heat may be considered, particularly where an intake temperature gauge is fitted. An intermediate position between HOT and COLD should only be used if an intake temperature gauge is fitted and appropriate guidance is given in the Flight Manual.

Note: It should be remembered that the selection of the HOT position after ice has already formed may at first appear to make the situation worse because of the reduction in power due to the use of hot air and to an increase in rough running as the ice melts and passes through the engine. If this happens the temptation to return to the COLD position must be resisted in order that the hot air may have time to clear the ice. This may take 15 seconds or more and may seem a very long time in difficult circumstances.

5 Maintenance and Handling Procedures of HOT AIR Systems

5.1 **Maintenance**

5.1.1 The induction heating system and controls should periodically be checked for proper condition and operation. Particular attention should be paid to the condition of seals which may have deteriorated and are allowing the hot air to become mixed with cold air and thus reducing the effectiveness of the system.

5.2 **Start-Up**

5.2.1 The engine should be started up with the carburettor heat control in the COLD position or with the alternate air selector in the OFF position, as applicable.

5.3 **Ground Taxiing**

5.3.1 The use of hot or alternate air while taxiing is not normally recommended because in most engine installations this air is un-filtered, hence there is a risk of dust and foreign matter being ingested. However, if engine run down occurs this may indicate that induction system icing is present and the use of hot air will be the only way of preventing further problems.

5.4 **Pre Take-off Engine Run Up**

5.4.1 The RPM or manifold pressure setting should be noted before selecting HOT AIR. The pilot should check that there is the appropriate decrease in RPM and/or manifold pressure when the HOT position is selected (about 50-75 RPM and 3-5” manifold), and that the indications are regained but not increased when the COLD position is re-selected after 15 to 20 seconds. If RPM or manifold pressure have increased from the previous figure, ice was almost certainly present. The check should be repeated as required until no rise is apparent, and the pilot should be ready to carry out further checks before take-off.

5.5 **Immediately Prior to Take-off**

5.5.1 Induction icing can occur when taxiing at low power or when the engine is idling. If the weather conditions appear to be conducive to the formation of induction icing then the HOT position should be selected before take-off for sufficiently long to remove any accumulation which may have occurred. If the aircraft is kept at the holding point in conditions of high humidity it may be necessary to run up the engine to the take-off power setting more than once to clear any ice which may have formed. The take-off must not be commenced if the pilot has any suspicion that carburettor icing is present.

5.6 **Take-off**

5.6.1 When the throttle is fully open for take-off the pilot should check that the manifold pressure and/or RPM are correct for the aircraft type. The static RPM with a fixed-pitch propeller will be less than the maximum RPM approved for the engine but the relevant value should be known for each aircraft. Carburettor heat must not be selected to HOT nor alternate heat to ON during take-off unless specifically authorised in the Flight Manual or Pilot's Operating Handbook.

5.7 **Climb (including hovering flight in a helicopter)**

5.7.1 The pilot should be alert for symptoms of induction icing, especially when visible moisture is present or when the dew-point and ambient temperatures are close, indicating high relative humidity.

5.8 **Cruise**

5.8.1 The pilot should monitor the RPM, manifold pressure, induction or carburettor air temperature gauge, or EGT for a slow decline which would indicate the onset of induction system icing. The pilot should periodically select the HOT AIR position for long enough, as in paragraph 5.4 above, to check for the presence of induction icing. The pilot should maintain the HOT selection and remember that it may take 15 seconds or more to clear the ice and the engine may run roughly as the ice melts. If the icing is so severe that the engine stops, the HOT selection should be maintained as the residual heat may still be sufficient to melt the ice and enable power to be restored. If impact icing is encountered HOT or alternate air ON should be selected in case the selector valve becomes immovable due to packed ice. Clouds should be avoided as much as possible.

5.9 **Descent and Auto-rotation Flight in a Helicopter**

5.9.1 As reduced throttle openings are much more conducive to the formation of carburettor icing, the HOT position should be selected before the throttle is closed for the descent or an auto-rotation, i.e. before the exhaust temperature starts to fall. The HOT selection should be maintained during prolonged periods of flight at reduced throttle settings, e.g. during long descents at low power, and engine power should be increased with HOT AIR still selected to cruise settings at intervals of approximately 500 ft so as to increase exhaust temperatures in order to melt any ice which has formed.

5.10 **Downwind**

5.10.1 The pilot should either select HOT AIR during the pre-landing checks or include a check of the carburettor heat in the pre-landing checks and observe the reduction and subsequent increase in manifold pressure and/or RPM.

5.11 **Base Leg and Finals**

5.11.1 Unless stated to the contrary in the Pilot's Operating Handbook or Flight Manual the HOT position should be selected on base leg before the power is reduced for the approach. On some engine installations, to ensure better engine response and to permit a go-around to be initiated without delay, it is recommended that the carburettor heat should be selected to COLD at about 200/300 ft on finals.

5.12 **Go-Around or Touch and Go**

5.12.1 If the carburettor heat has not been selected to COLD on finals this should be done concurrently with the application of go-around power, or as shortly thereafter as is possible.

5.13 **After Landing**

5.13.1 The pilot should ensure that the carburettor heat has been selected to COLD or the alternate air to OFF before taxiing.

6 Main Points

6.1 It is better to prevent ice building up than to attempt to melt it.

6.2 Induction system icing forms insidiously.

6.3 Icing can occur in warm and humid conditions, and is a possibility at any time of the year in the UK and Northern Europe.

6.4 The pilot should be aware of the possibility of the formation of induction system icing and be prepared to take appropriate preventive measures in time.

6.5 Carburettor icing is more likely to occur at low power settings.

6.6 When flying in conditions conducive to the formation of carburettor icing the HOT position should be selected periodically and certainly at the first indication of a reduction in RPM, manifold pressure, airspeed or height.

6.7 Some aircraft/engine combinations are more susceptible than others.

6.8 Use of MOGAS increases the possibility of carburettor icing.

6.9 Unless the Flight Manual or Pilot's Operating Handbook authorises a different procedure the HOT/ALTERNATE air control should be selected fully ON or OFF.

6.10 If ice has been allowed to form it will take some time to melt and the engine may run roughly while this is happening - PERSIST!