Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile

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TECHNICAL STUDY

Piston engine induction system icing - Summary

1- INTRODUCTION

The phenomenon of icing of the piston engine induction system is sometimes mentioned in safety investigation conclusions as either a proven or possible cause for a decrease in engine power. This is particularly the case when no other hypothesis is envisaged.

The nature of the phenomenon means that investigators rarely observe it or identify its physical evidence on the wreckage. To justify the use of this hypothesis, when engine data is not recorded and accidents are fatal, the estimated meteorological conditions at the time of the event are generally compared with a "Temperature/Dew Point" graph showing zones corresponding to different levels of icing probability/severity (see Figure 4). Several models of these graphs exist and are widely available.

The BEA's reflections on the legitimacy of this approach in the scope of a safety investigation prompted it to conduct this study. This work naturally led to the industry and the authorities being questioned about their knowledge of this phenomenon and how to take it into account.

The study focuses on three main areas:
- bibliographic research focusing on the information available from the various authorities, manufacturers and scientific sites;
- a test campaign on a powerplant equipped with a Lycoming engine;
- a measurement campaign on aircraft equipped with Rotax engines, supplemented by measurements on an engine of the same type installed on a test stand.

2- OVERVIEW OF ACCIDENTOLOGY

The BEA identified several articles presenting the proportion of cases of induction system icing on piston engines in overall accident statistics. The most recent sources show that the proportion of events associated with this phenomenon is generally between 1 and 2.5%. These events rarely result in serious bodily injury.

The BEA also analysed the cases in its database which met the following criteria:
- occurred between 2010 and 2020;
- involving an aeroplane, microlight or helicopter weighing less than 2,250 kg, equipped with a piston engine;
- was the subject of a completed BEA investigation.

Of the 941 cases meeting these criteria, carburettor icing was suspected in 13 cases (1.4%). In only one of these cases[1] was icing certain, based on the analysis of the data recorded by the onboard equipment.

[1] Accident to the Van's RV7 registered D-EIOI on 29 August 2018 at Bourg-Saint-Maurice.

3- BIBLIOGRAPHIC RESEARCH

3.1 Types of icing

“Carburettor” icing is the most frequently encountered icing phenomenon in the piston engine induction system. It consists of the formation of icing on the carburettor butterfly valve (or throttle valve) and in its direct environment.

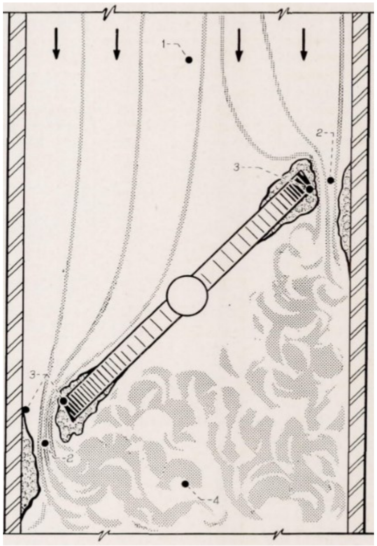

Figure 1: diagram illustrating carburettor icing
(source: Icing protection requirements for reciprocating-engine induction systems[2])

The other possible forms are **"impact" icing**, which occurs on the lips of air inlets, filters and all protruding parts, and **"fuel" icing**, which consists of water particles suspended in a fuel at negative temperature freezing on contact with the walls.

3.2 Types of carburettors

There are two carburettor families: **float-type carburettors** and **pressure carburettors**. In both case, the flow of the air-fuel mixture is regulated by the butterfly valve. The difference lies in where the mixing takes place, before or after this valve.

The piston engines that are currently installed on certified light aviation aircraft or microlights are essentially equipped with **float-type carburettors**. With these type of carburettors, the air and fuel is mixed at the venturi before the butterfly valve. According to the literature, this system encourages the formation of ice. Two phenomena contribute to a marked decrease in temperature at the same point: the vaporisation of the fuel and the vacuum created by the venturi.

[2] *Schematic diagram of throttle and throttle barrel showing air-flow pattern and throttling ice*, p. 3, NACA Technical Report, Willard D. Coles, Vern G. Rollin, Donald R. Mulholland, 1950.

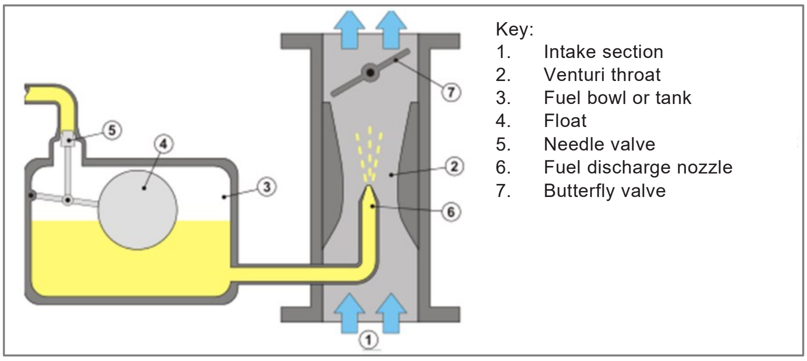

Figure 2: schematic diagram of a float-type carburettor
(source: Wiktionnaire, annotated by the BEA)

There are **two types of float-type carburettors**:

- the majority of four- and six-cylinder engines, such as those built by Lycoming Engines and Continental Aerospace Technologies, are fitted with **conventional carburettors**, generally Marvel-Schebler carburettors for the engines examined by the BEA during its investigations. They are positioned under the engine;
- engines built by Rotax are generally equipped with Bing **constant depression carburettors**. These carburettors are usually located on the top of the engine.

3.3 Scientific articles

The first detailed and usable articles were written in the 1940s. At this time, the increase in air operations in complex meteorological conditions led the Air Transport Association of America to recognise the need to improve understanding of the causes, effects and solutions concerning piston engine induction system icing. The NACA (National Advisory Committee for Aeronautics) was asked to conduct a study programme. This work was conducted for the most part in a laboratory, in a wind tunnel for impact icing and on a few complete powerplants. It mainly concerned pressure carburettors associated with compressors.

This type of configuration is far removed from today's induction systems. The influence of the engine is not taken into account, and in particular the associated thermal environment.

Several of these publications propose graphs specifying icing zone limits. It can be seen that these limits vary according to the characteristics of the equipment tested.

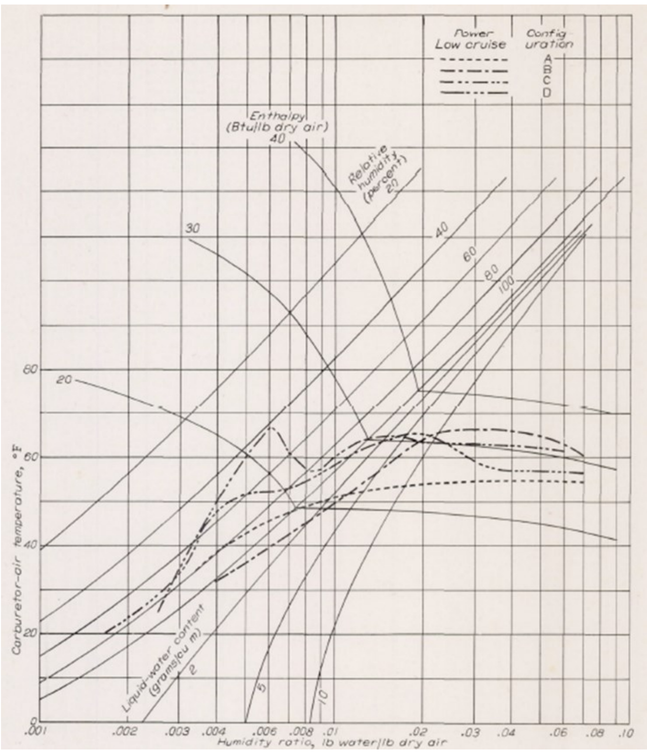

Figure 3: graphs defining the limit of the severe icing zone for four types of powerplant (source: Icing protection requirements for reciprocating-engine induction systems[3])

Following this study programme led by the NACA which gave rise to numerous publications, we observe that to this day, documents are regularly published with some of them mentioning the carrying out of tests. Contrary to the previous studies, the carburettors used during these tests are models used regularly in modern light aviation. However, very little accurate test data is provided. In particular, no data enabling the establishment of new graphs defining the icing zone limits was identified.

Among the notable results from the scientific articles identified, we note that:

- icing was mostly observed at relatively low temperatures and very high relative humidity;
- fuel type seems to be a key factor: the more volatile the fuel, the more prone to icing the induction system;
- the temperature of the carburettor body also seems to be a dominant factor in icing;
- one of the most recent studies (published in 2015) seems to indicate that the phenomenon is slow to start and to spread.

3.4 Graphs

Various graphs presenting the risk of icing are widely available within the community. In particular, the civil aviation authorities and safety investigation authorities EASA (Europe), FAA (USA), TC (Canada) and ATSB (Australia) have published their graphs.

[3] *Limiting serious-icing conditions for several different carburetor-engine configurations at simulated low-cruise power*, p. 13, op. cit.

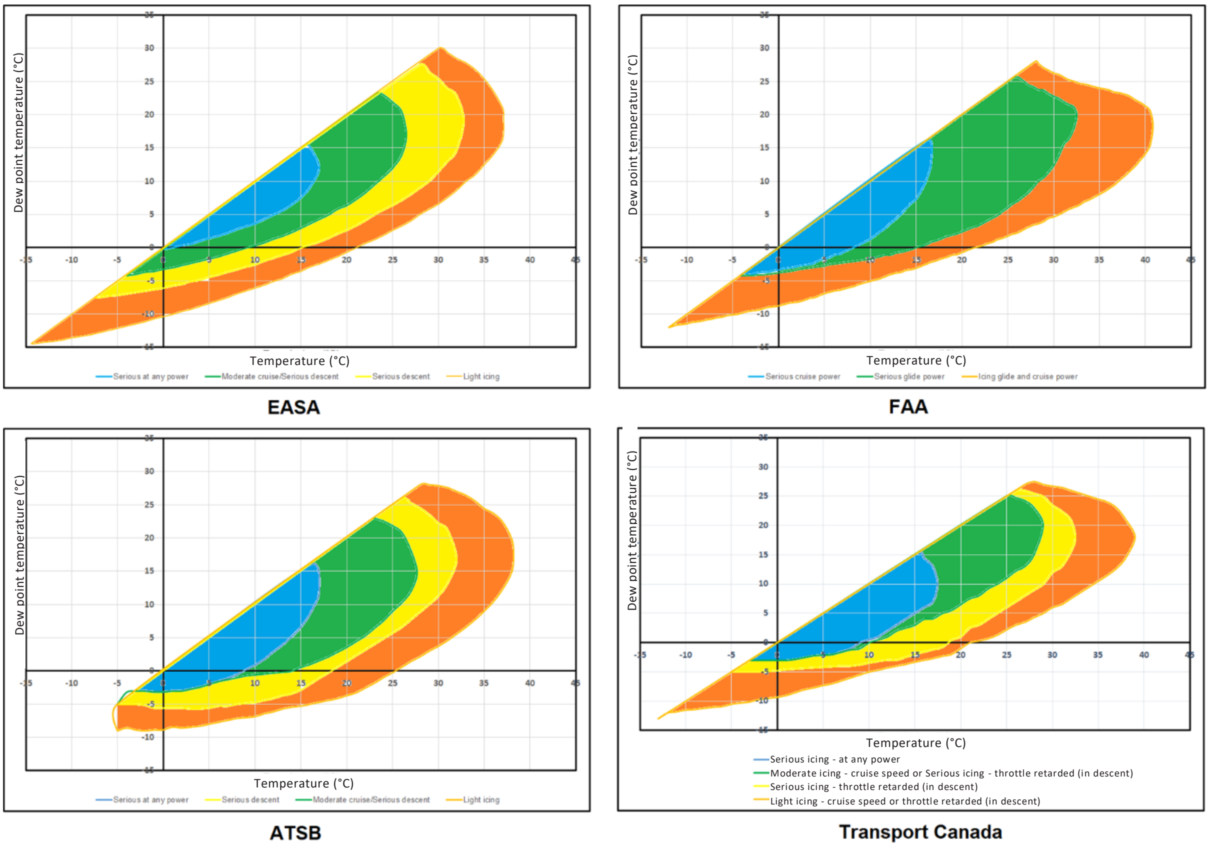

Figure 4: graphs proposed by the authorities

In these graphs, the criteria for determining the different risk zones are not defined objectively; they are limited to a qualitative statement, i.e. "severe" or "light". In addition, the data used to draw up these graphs is either unknown or very imprecise. Lastly, no mention is made of the scope of application of these graphs, especially with regard to the variability of existing powerplants.

A zone-by-zone comparison of these four graphs reveals a few differences, suggesting that different data was used in their construction.

The graphs taken from the scientific articles mentioned above have the advantage of defining the different icing zones represented:

- **icing not visible;**
- **icing visible** (ice visible without decreasing the air flow);
- **severe icing** (ice causing a decrease in air flow of at least 2% within at least 15 min).

Based on the data presented in these studies, the BEA reconstructed the charts resulting from these tests in the same format as the charts known today. The comparison of these charts shows very different icing zones between the studies, probably due to the type of carburettor, but also to the carburettor model for a given type.

The BEA also compared the charts constructed from the data in the scientific articles with the chart currently published by EASA. To do this, the BEA determined equivalences for the icing zones, which differ according to the data sources. In particular, this comparison work shows that the EASA chart is consistent with the results available from tests carried out with a float carburettor, but only for the upper part of the temperature envelope.

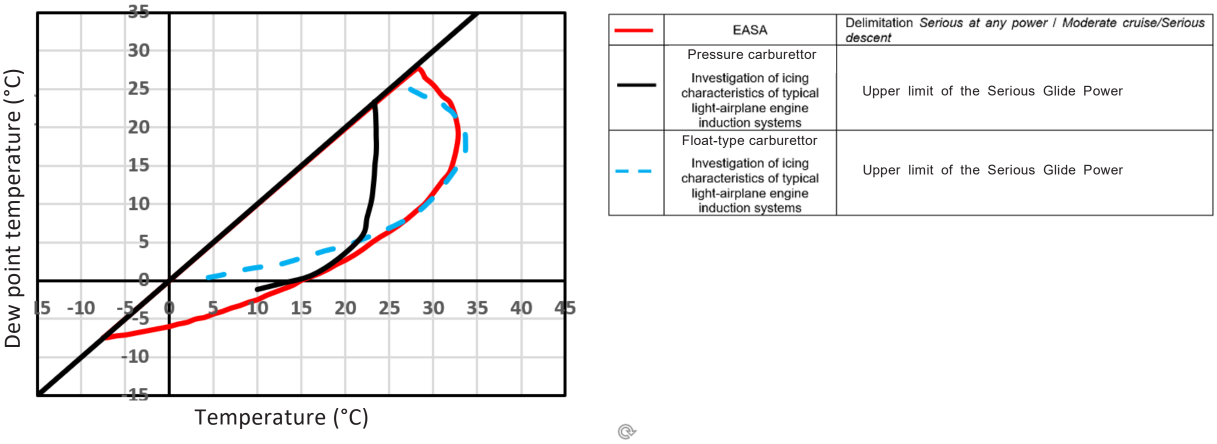

Figure 5: comparison of the graph proposed by EASA with that constructed based on the data from the two studies listed (source: BEA)

3.5 Certification requirements

The BEA reviewed the European and/or American requirements relating to the certification of light aircraft (CS 23 and PART 23), light helicopters (CS 27 and PART 27), gliders and powered gliders (CS 22), engines (CS E and PART 33) and, specifically in Europe, light sport aircraft (LSA CS), very light aircraft (VLA CS) and very light helicopters (VLR CS). Other documents were also consulted, either setting out standards or presenting certain Acceptable Means of Compliance (AMC) with regard to the icing phenomenon.

It emerged from this that these requirements and these AMC essentially focus on the carburettor heat system. In particular, different temperature increase criteria are set for a range of operating conditions. For example, for an engine fitted with a float carburettor, at 75% of maximum power and at sea level, a heat system is required which is designed to increase the temperature by 50°C. It should be noted that these requirements are set for particularly low outside temperatures (-1°C for EASA).

One FAA publication also specifies that it is the aircraft manufacturer's responsibility to integrate the engine and to ensure conformity to the icing protection requirements. We could thus expect aircraft manufacturers to be very knowledgeable about the performance in icing conditions of the propulsion systems installed on their aircraft.

3.6 Training and information material

The charts distributed by the authorities are an awareness-raising aid. They are inserted in safety promotion documents, directed at the widest possible audience, and especially pilots. As such, the diagrams can only be generic and universal in scope, particularly with regard to the specific features of different powerplants. In addition to the chart, by way of example, the most comprehensive document on this subject, "Piston Engine Icing", published by

EASA, provides pilots with information on how to prevent, detect and, if necessary, manage icing.

Various associations and federations publish awareness-raising material devoted to the phenomenon of piston engine induction system icing.
In their flight manuals, aircraft manufacturers point out the most common symptoms of icing: reduced power and vibrations. The information provided by manufacturers mainly concerns the use of the carburettor heat system. They emphasise that this is an on/off system and that the mixture must be adjusted when it is activated.

The two main manufacturers of piston engines for light aviation also provide information about piston engine induction system icing in their publications (Service Instruction).

Of the twenty or so flight manuals examined by the BEA:

- no manual refers to any of the awareness-raising material, particularly that produced by the authorities;
- no manual provides information indicating in precise detail, the sensitivity of an aircraft, particularly with regard to the specific features of its powerplant.

With regard to training aids, the reference manual in France for the PPL syllabus[4] devotes a chapter to piston engine induction system icing. Its content is very similar to that of the awareness document published by EASA, mentioned above. In the reference manual in France for the ATPL syllabus (published by Mermoz), the phenomenon is presented very briefly.

3.7 Safety investigations carried out by foreign investigation authorities

The BEA studied several dozen reports published since 2000 by various foreign authorities responsible for conducting safety investigations. The phenomenon of induction system icing is presented in these reports in a similar way: the hypothetical loss of power that resulted in or was a contributing factor to an accident or incident. This hypothesis is arrived at on the basis of the day's meteorological conditions on the ground, and by plotting these conditions in one of the charts mentioned above. The presentation made in these reports is therefore similar to that made by the BEA. Only one of the reports consulted includes an analysis that takes into account the specific characteristics of the powerplant.

4- POWERPLANT ICING TESTS

4.1 Partnership and objectives

This test campaign was carried out in partnership with DGA Essais propulseurs (DGA EP), which is an organisation of the French Defence Procurement Agency, attached to the Ministry of Defence. One of the DGA EP stands is a dedicated stand for testing small equipment
(e.g. probes, vanes, blade fragments, etc.) in icing conditions.

[4] *Manuel du pilote d'avion*, 19th edition, 2022, published by Cépaduès

These tests were carried out to:
- explore the icing envelope of the graph proposed by EASA in order to observe whether ice forms or not and the severity of any icing for the given powerplant;
- simulate the conditions described in investigation reports where induction system icing was mentioned;
- document the phenomenon by recording certain engine parameters when it occurs and by filming it.

The purpose of these tests was to gain a better understanding of the icing phenomenon that may occur on an induction system and to attempt to define dominant factors in the initiation of this phenomenon.

4.2 Feasibility study

A complete powerplant comprising the engine, propeller and aircraft cowlings was chosen as the specimen for these tests. The test setup corresponded to the powerplant of the Socata TB10, with the exception of the propeller. The latter was replaced with a specific propeller for tests on the engine stand which had the particularity of having four blades and a smaller diameter. The engine was a Lycoming O-360-A1AD fitted with a Marvel-Schebler MA4-5 carburettor positioned under the engine, close to the exhaust system.

Figure 6: TB10 powerplant (source: Aerobuzz)

Part of the feasibility study consisted in sizing the test stand section, as the section usually used on the test stand was designed for very small equipment and not a complete powerplant.

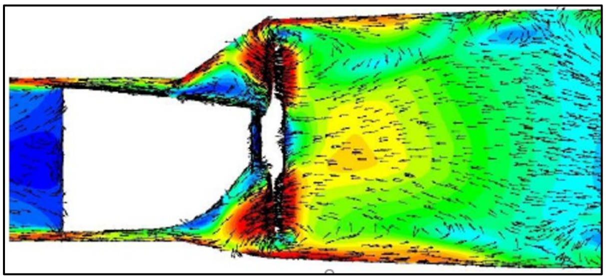

Figure 7: modelling of the speed field for one of the possible test stand section configurations (source : DGA EP)

To this end, the installation was modelled to enable theoretical simulations to be carried out, firstly in the free field to determine certain references, and then with respect to the three possible types of test stand section.

These theoretical simulations led to the conclusion that none of the configurations studied, by placing the powerplant inside the test stand section, would allow the specified tests to be carried out.

The setup that was finally chosen did not place the powerplant in the test stand section. It incorporated a 100 mm long aluminium alloy spacer between the propeller and the engine.

The positioning of the spacer allowed ducts to be installed in the space created to supply the engine's air scoops. A second duct was installed at the carburettor air intake, and others were positioned to extract the air introduced at the air scoops.

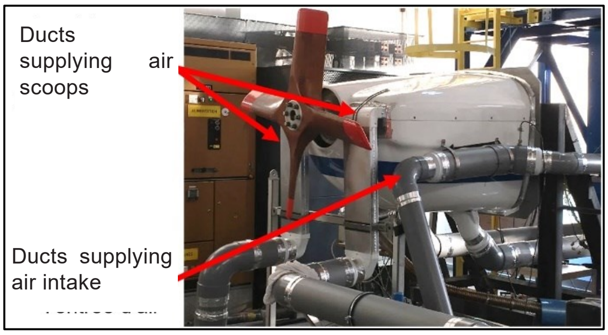

Figure 8: installation - 3/4 RH view looking forward (source: DGA EP)

The chosen setup thus allowed an airstream produced and controlled by the icing test bench to be directed through the powerplant.

4.3 Tests and results obtained

The powerplant was fitted with sensors to monitor the usual engine parameters (rpm[5], EGT[6], intake pressure, oil temperature), to determine the temperature at various other points in the engine and to visualise the interior of the carburettor at the venturi and butterfly valve.

The BEA conducted two series of tests:

- the first left the powerplant in the configuration found on the aircraft;
- the second with thermal insulation positioned to isolate the carburettor from the exhaust system.

During these tests, the speed, temperature and humidity of the air injected into the powerplant were monitored.

In all, around one hundred test points were recorded.

[5] Revolutions Per Minute
[6] Exhaust Gas Temperature

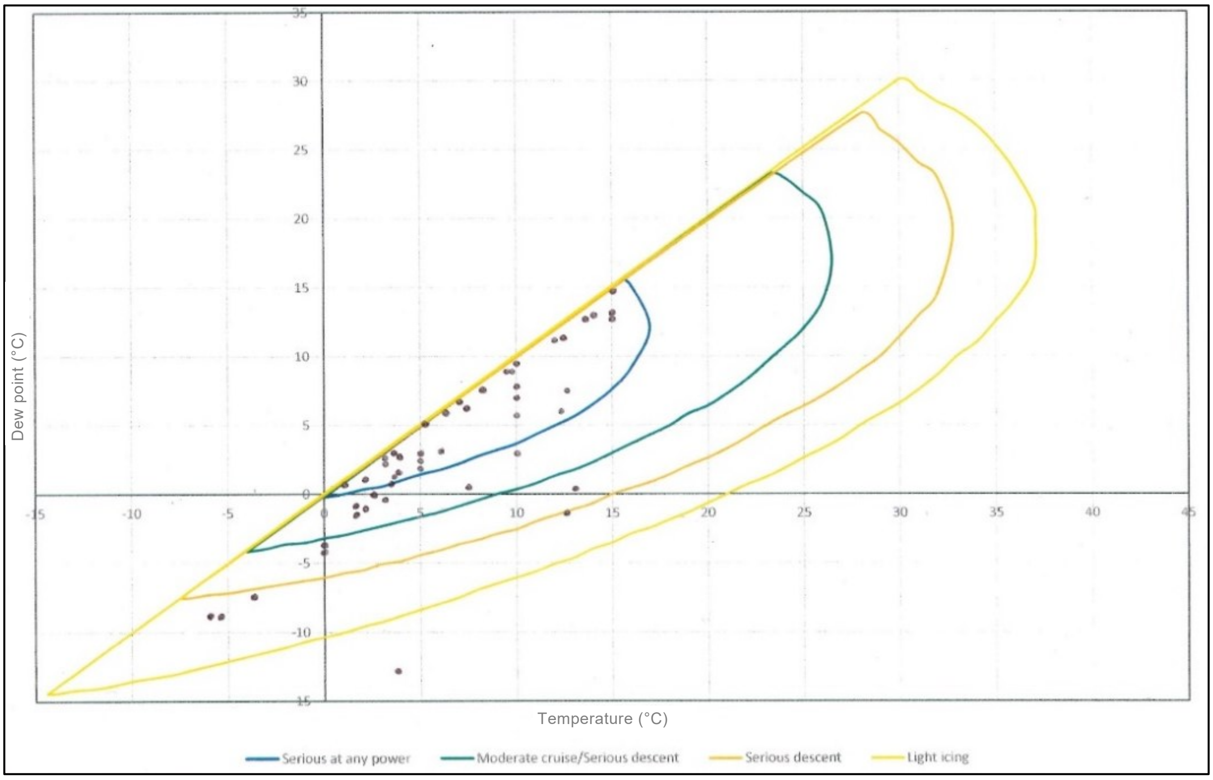

Figure 9: position of test points on graph proposed by EASA (source: BEA)

Carburetor icing was observed for three of these points:

- all three cases came from the second series of tests. This means that the creation of ice at the butterfly valve was only made possible after the carburettor had been thermally insulated from the exhaust muffler. This observation tends to show the importance of the temperature of the carburettor body;
- in all three cases, the incipient icing was located in the area where there is a severe icing risk, whatever the engine power, according to the EASA graph. The parameters associated with each of these three points (phase in which icing appeared) are presented in the following table:

	Air temperature (°C)	Relative humidity **(%)**	Dew point (°C)	Engine speed (rpm)	Airspeed (kt)	Surface temperature of carburettor (°C)	Temperature downstream of butterfly valve (°C)
Case No. 1	4	87	2	1,500	80	5.5	-2.5
Case No. 2	3.5 to 4	90 to 95	2 to 3.2	1,500	80	5°C	-2 to -5°C
Case No. 3	3.4 to 4.1	82 to 83	0.6 to 1.4	1,700	80	14.5 to 15.2	-1.7 to -0.3

Once the icing phenomenon had been detected, additional tests were carried out with respect to cases No. 1 and No. 2, in particular by readjusting the engine speed.

The following diagram shows the behaviour of the phenomenon during this test sequence for **case No. 1**.

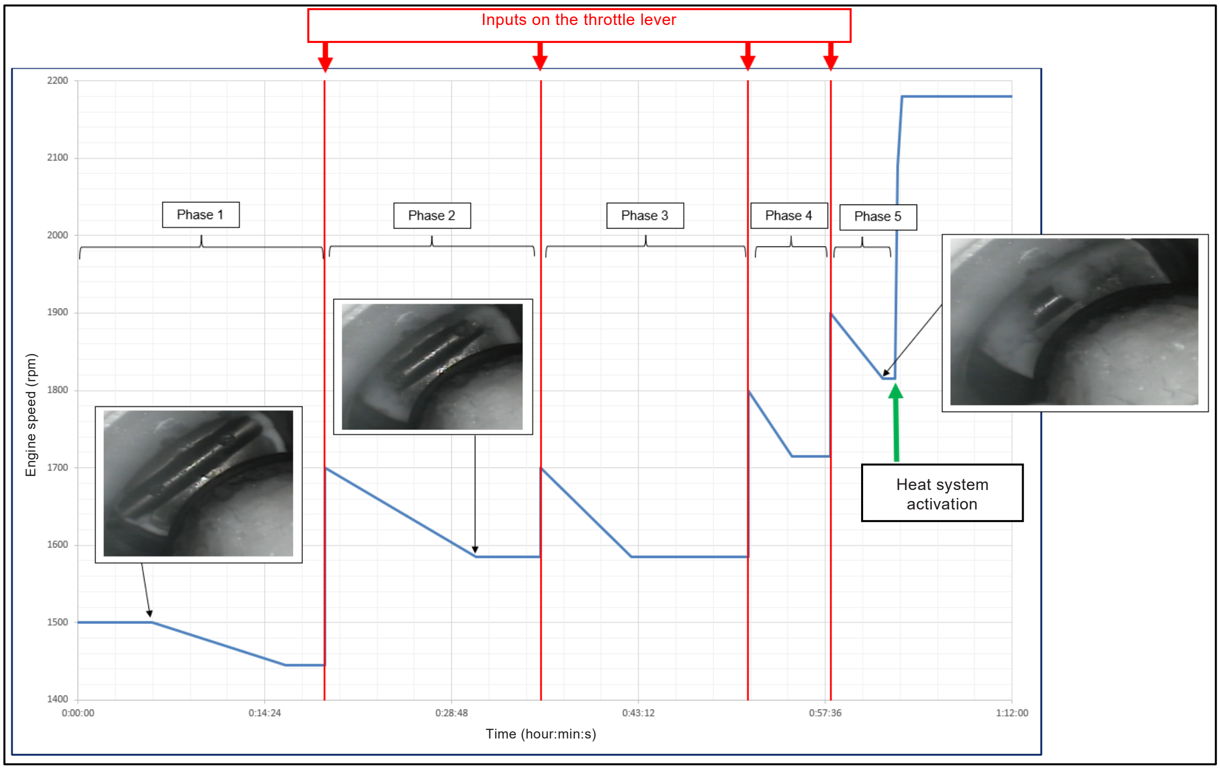

Figure 10: variation in engine speed during the 1st case of identified icing (source: BEA)

It can be seen that when the phenomenon has started, drops in engine speed of around 150 rpm are observed within a few minutes. When the heat system was activated, the ice build-up was destroyed almost instantaneously, accompanied by a very brief drop in engine speed, followed by an increase in speed. It should be noted that during this test sequence, the engine power was increased several times although the ice was present, without knowing the equivalent position of the throttle lever without icing. As a consequence, the post-icing engine speed was not known.

The tests carried out based on case No. 2 led to globally similar observations initially (reduction of 100 to 200 rpm after readjustment of engine speed). As in case No. 1, the ice build-up at the butterfly valve was associated with an unstable icing phenomenon, favoured by low and steady engine speeds. The initiation and growth of the icing required a significant operating time of the order of several minutes. However, the ice disappeared by itself after approximately ten minutes of operation at an engine speed of 2,000 rpm, without the activation of the heat system. Once the ice had disappeared, the engine speed increased by 150 rpm, without any action on the throttle lever.

Case 3 was detected a posteriori. The ice did not grow and eventually melted without any change in the conditions in which the phenomenon appeared, after approximately 9 min 30 s.

4.4 Identification of contributing parameters

In this part, the analysis focused on the parameters likely to affect:

- the **temperature of the external surface of the carburettor**;
- the **temperature just after the butterfly valve.**

The tests showed a correlation between the **speed at the air intake** and these temperatures:

- the temperature of the external surface of the carburettor evolved progressively in the same direction;
- the temperature downstream of the butterfly valve evolved in the same direction, with a similar profile to the speed curve.

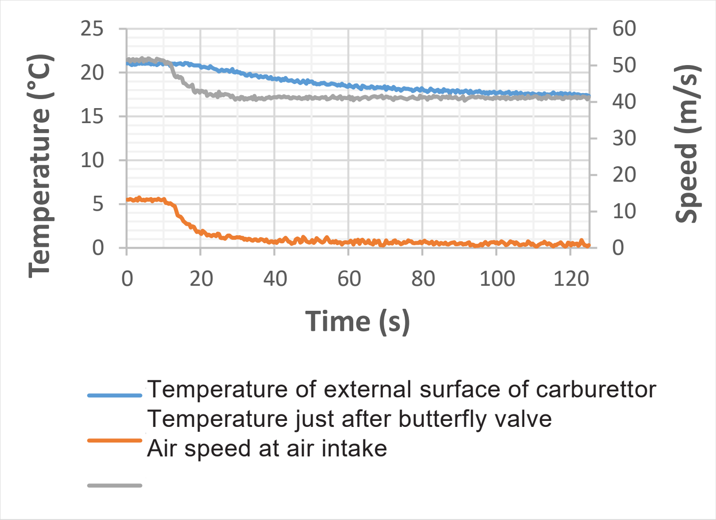

Figure 11: evolution of external surface temperature and temperature downstream of butterfly valve as a function of air speed at air intake (source: BEA)

The general trend shows that the temperature of the external surface and the temperature downstream of the butterfly valve increases when the **air temperature at the air intake increases**, and vice versa. The variation in temperature after the butterfly valve was particularly marked.

The test points did not result in an exact and precise definition of the influence of **relative humidity**.

The few points that could be used seem to suggest:

- a much less significant influence than temperature at the air intake;
- that the temperature of the external surface and the temperature downstream of the butterfly valve increase when the relative humidity increases, and vice versa.

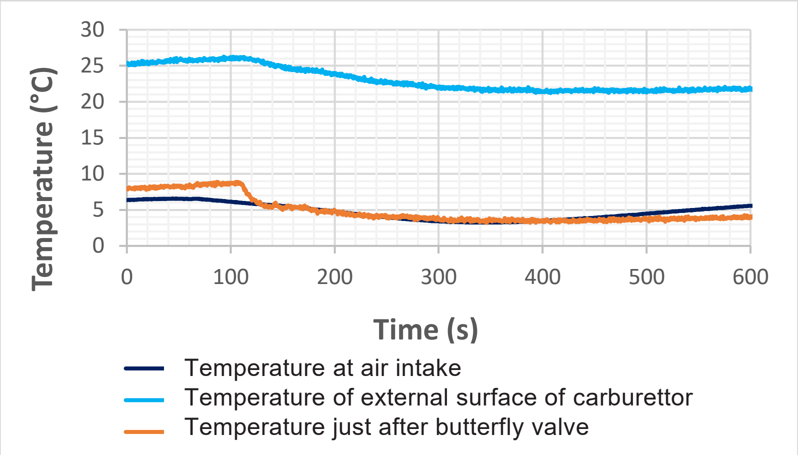

Figure 12: evolution of the temperature of the external surface and the temperature downstream of the butterfly valve according to the temperature at the air intake (source: BEA)

5- MEASUREMENTS ON POWERPLANTS EQUIPPED WITH A ROTAX ENGINE

5.1 Description of powerplants equipped with a Rotax (912 and 914 series) engine

The Rotax 912 and 914 series engines are both equipped with two carburettors. The parts common to these two engine series are: the technology of the engine unit, the ignition system, the cooling system, the lubrication system and the reduction gearbox. However, these two engine series differ in terms of their fuel system and the presence of a turbocharger on the 914 series.

The powerplants equipping these two engines are very different. These engines can be installed on conventional fixed-wing aircraft, in which case they are in the nose, under cowlings. In this configuration, there are two types of carburettor air supply.

Type 1: air filter (912 series)	Type 2: airbox (912 and 914 series)
Each carburettor is equipped with an air filter. The air that is sucked in by the engine is the air present under the cowlings. It is a mix of outside air (the position and size of the air intakes is different according to the aircraft) and the air heated in the engine environment.	The carburettors are connected to a shared airbox which is in turn connected via a flexible hose to an air intake. The air that is sucked in by the engine is the outside air. The air heat system introduces air heated around the exhaust muffler into the airbox.

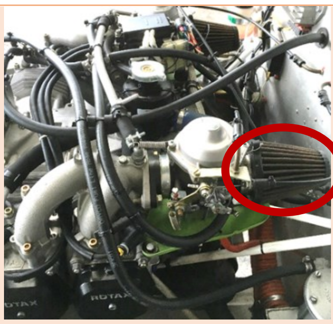

Figure 13: Tecnam P92 powerplant (source: BEA)

Figure 14: TecnamP2008 powerplant (source: BEA)

5.2 **Objective of measurements**

The objective of these measurements was to gain better understanding of the operating conditions of the carburettors equipping Rotax 912 and 914 engines on production aircraft, to enable the BEA to be more critical about the propensity of such powerplants to be influenced by the icing phenomenon.

To this end, a measurement campaign was carried out in flight on aircraft in service equipped with Rotax engines, and on the ground on an engine installed on a test stand.

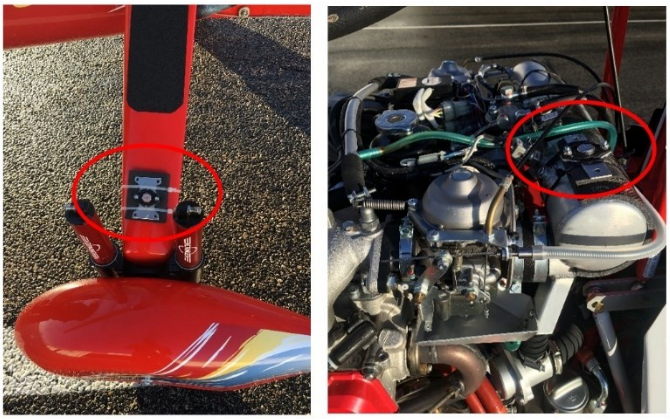

Figure 15: position of sensors (source: BEA)

For engines with carburettors equipped with filters (“type 1”), the temperature and relative humidity in the immediate vicinity of the carburettors was measured whereas for the engines with carburettors associated with an airbox (“type 2”), the temperature inside the box was measured. (The relative humidity could not be measured inside the box.)

In both cases, these measurements as close to the carburetors as possible were supplemented by other measurements made outside the aircraft. Indeed, to date, the post-accident analysis of the possibility of icing is essentially based on outside conditions, with these often being based on those on the ground provided by Météo-France. The aim of these measurements was to assess the differences between these outside conditions and those closer to the carburetors.

Additional measurements were made on a Rotax 914 engine belonging to the BEA, at the *Ecole Nationale de l'Aviation Civile*[7] (ENAC) Castelnaudary test stand, in the atmospheric conditions of the day. The carburettors are associated with an airbox ("type 2") and the engine is coupled with a three-blade propeller. The main objective of the tests conducted on this 914 engine was to better comprehend the consequences of adding a turbocharger to an engine of this type (associated increase in temperature).

5.3 Tests and results obtained

First series of measurements

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Magny M16 (gyroplane)

- Rotax 914
- Unducted powerplant
- Carburettors with airbox (type 2)

Figure 16: Magny M16 (source: Vaucluse ULM)

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- On the ground, once the engine start-up had been completed, the temperature in the immediate vicinity of the engine was initially higher than that measured away from the engine. From the start of taxiing and then in flight, the temperature in the immediate vicinity of the engine gradually decreased until it was similar to that measured away from the engine (relative humidity evolved inversely). We can assume that the time required for the temperatures to balance varies according to external conditions.

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Magny M24 (gyroplane)

- Rotax 914
- Ducted powerplant
- Carburettors with airbox (type 2)

Figure 17: Magny M24 (source: Vaucluse ULM)

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- The temperature in the upper part of the engine compartment was initially similar to that outside. From the start of taxiing and then in flight, it gradually increased. This trend was therefore the inverse of that observed on the M16.
- Symptoms of icing were only observed on the ground after the first start-up. The symptoms were then no longer identified.
- The relative humidity in the upper part of the engine compartment was initially similar to that outside. From the start of taxiing and then in flight, it then gradually decreased.

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[7] National School of Civil Aviation

Aeroprakt A22 (fixed-wing microlight)

- The Rotax 912is equipped with an injection system

<u>Note</u>: the use of an injection system avoids the problem of icing. However, the conditions in the immediate vicinity of the engine are identical to those of a similar engine with carburettors.

Figure 18: Aeroprakt A22 (source: Vaucluse ULM)

- The temperature in the engine compartment was always at least 5°C higher than the outside temperature. This difference increased very markedly at shutdown.
- Conversely, the relative humidity under the engine cowling was always around 10% lower than at the struts.

In addition to the initial results obtained, this series enabled the measurement system to be adjusted.

Second series of measurements

The second series of measurements was taken on the following aircraft.

This series of measurements differed from the first in terms of better instrumentation of the test conditions, notably with the addition of thermocouples.

It was observed on **aircraft with a type 1 carburettor (air filter)**:

Tecnam P92 Echo Light

- Type 1 carburettor (air filter)

Figure 19: Tecnam P92 Echo Light *(source: https://www.ekeraviation.com)*

- The air taken in by the carburettors had very different characteristics to the outside air: it was warmer and drier (10 to 14°C higher in temperature and 40 to 50% lower in relative humidity).
- Icing only seemed to be possible in extreme atmospheric conditions.
- The data measured on the Tecnam P92 and the Aeroprakt A-22L, as well as its relative evolution, differed in most phases of flight, even though these two aircraft are equipped with the same Rotax 912 UL engine. This finding highlighted the influence of the specific features of each powerplant on the carburettor’s environment.

Aeroprakt A-22L

- Type 1 carburettor (air filter)

Figure 20: Aeroprakt A-22L (source: BEA)

- The phase that seemed most conducive to icing was the one on the ground, before take-off. This finding was in line with the experience of operators of aircraft equipped with a Rotax engine who reported phenomena associated with icing on the ground prior to take-off.
- However, the recorded data suggested that the temperature and relative humidity parameters were not conducive to icing during the descent phase. In particular, a relative humidity under the engine cowlings that was much lower than the outside relative humidity and a temperature of the external surface of the carburettors much higher than the temperature measured after the butterfly valve was observed.

It was observed on **aircraft with a type 2 carburettor (airbox)**:

Tecnam P2002 JF

- Type 2 carburettor (airbox)

Figure 21: Tecnam P2002 JF (source: BEA)

Tecnam P2008 JC

- Type 2 carburettor (airbox)

Figure 22: Tecnam P2008 JC (source: http://tagazous.free.fr)

- The air in the airbox was higher in temperature than the outside air temperature, slightly lower than the temperature prevailing in the engine compartment.
- The temperature changes were similar to those observed on type 1 powerplants. In these conditions, the analysis was similar to that proposed for type 1 powerplants.
- As for aircraft with a type 1 powerplant, large differences between the Tecnam 2002 and Tecnam 2008 were observed, in particular when activating the heat system.

6- CONCLUSIONS

1.1 Findings

The preliminary findings and the analysis of the literature carried out during the course of the study indicate:

- the most recent sources show that the percentage of occurrences associated with piston engine induction system icing is generally between 1 and 2.5%, and these occurrences rarely result in serious bodily injury;

- in most cases, to justify putting forward this hypothesis, the investigation authorities compare the estimated meteorological conditions at the time of the occurrence with a "Temperature/Dew Point" diagram showing zones corresponding to different levels of icing probability/severity;

- the diagrams published by the authorities are difficult to interpret, as the data used to produce them is very imprecise and even unknown. Their scope does not take into account the variability of existing powerplants;

- the certification requirements are essentially limited to certain characteristics of the carburettor heat system;

- aircraft manufacturers' documentation does not reflect in-depth knowledge of each type of aircraft. In general, aeronautical documentation (training manuals, flight manuals, safety promotion material) is limited to describing the most common symptoms of carburettor icing and the expected use of the carburettor heat system.

1.2 Lessons learned

The various tests carried out by the BEA in the course of this study, both on test stands and in flight, on different types of aircraft and engines, have made it possible to document in a methodical and detailed way, the behaviour of these powerplants with regard to carburettor icing (one of the three icing phenomena of the piston engine induction system).

The main lessons learned from this study are:

- the occurrence of carburettor icing is observed only in very rare cases, corresponding to extreme atmospheric conditions;
- the charts available are difficult to use as they stand, to hypothesise on carburettor icing;
- in practice, for recent powerplants, the risk of icing is generally much lower than shown in the charts usually used by the aviation community;
- the way in which the engine is installed on the aircraft has a major influence on the likelihood of the phenomenon occurring, as it acts on the temperature and humidity of the airflow in the carburettor and the temperature of the carburettor body.

During an investigation, simply comparing the meteorological data with the charts proposed by the aviation authorities is not enough to validate the hypothesis of carburettor icing.