THIRD EUROPEAN ROTORCRAFT AND POWERED LIFT AIRCRAFT FORUM

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OPERATIONS IN ICING CONDITIONS

by

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1. INTRODUCTION

The subject of the brief lecture,I have the pleasure to present you, has the great interest of allowing the lecturer to expose his own opinion without, for that, offending the truth, as in this field every person interested in helicopters is holding "his" own truth.
I believe that your questions or comments, at the end of this lecture, will confirm this.

In fact, what does "helicopter icing" means ?

For some people... nothing. "Icing conditions ? Do not know ! they say. There are countries where icing conditions are never met.

For others, not benefitting from such favourable weather conditions, it is a sleeping monster mentioned in flight manuals and which should not be approached.

So, prudently, it is avoided without saying anything

For still some others, this sleeping monster, laying across the road, is very inconvenient. These people hug, attempt, carry on... and come back full of pride declaring that icing is not a so vicious beast and it does not bite ! Therefore, for them it is not a monster.
And they are not quite wrong as that does not bite every time : the helicopters are so designed that periodically, the blades are shedding automatically a large part of the ice accumulated and if the engines are well-protected, it is possible to fly, without running into great trouble, for a limited time in some icing conditions.

Other flying crews, generally qualified and paid for this kind of work, are hunting the monster ; the beast reactions are so different and unpredictable that every crew returns from his hunting campaign with his own idea.

I will attempt to give you mine, which, in the present case, should not be considered as being an official opinion.

2. THE ICING CONDITIONS

For the physicist, icing conditions are the whole of atmospheric and aerodynamic phenomena causing the ice to form or deposit on some part of the aircraft.

Among the phenomena the most easily identified, we find :

- the temperature... but which one ? dry air ? damp air ? impact ? athermanous ? skin ? etc... And how can we measure it ?

- the local aerodynamic velocity, as vector, of course. But which one ? There are so many on a rotorcraft.

- the water droplet diameter. It is usual to consider the "mean effective diameter" which determines the areas and forms of catchment, but it is not easy to measure.

- the liquid water content, which, at a given velocity, represents the icing severity... but is determined with great difficulties and can not be predicted.

- the "liquid water/solid ice" mix which is the cause of the most severe icing conditions.

These various parameters are taken into consideration in the specifications defining the icing atmosphere, obviously in schematic form, which does not always correspond to the effects experienced in actual icing conditions.

3. FLIGHT IN ICING CONDITIONS

For the aircraft crew, the icing conditions are felt in a more direct form.

- the temperature is that read on the aircraft O.A.T. indicator. But, an instrument having been proved in icing atmosphere should be available and it should be properly located on the helicopter.

- the speed is that displayed by the aircraft pitot/static system.

- the droplet diameter is not discerned directly, but with some experience, the crews succeed in classifying the deposits from their shape and droplet size.

- the instantaneous water content is measured with difficulty and due to the present lack of accuracy, its determination has no great interest ; but the icing severity is well-perceived through the growing rate of the visible ice accumulation and the noise of the precipitations on the aircraft front parts.

Before entering into an aera of probable icing, the visual examination of the clouds is very useful, when it is possible;the cloud opacity, shape, type and vertical extensions give to a pilot the impression that "it is going to be tough" or, on the contrary " a piece of cake".

But, beware : even with a good experience, the crew may be in error and clouds are not so easy to assess. The airborne weather radar gives better results when well-adapted and properly used : first, in darkness, it replaces the human eyes when any visual assessment of the clouds is impossible, and, in day time, it allows the detection, within the clouds, of the areas where precipitations may be the most severe.

Therefore, the airborne weather radar is the most precious aid and the sole "remote icing detector" which can be installed easily on the helicopters capable of flying in icing conditions.
Such an installation is most advisable.

When steadily flying in icing conditions, the crew of a helicopter, not particularly protected, may meet some of the following phenomena :

a) In continuous and moderate icing (maximum deposit rate of 1mm/minute in cruising flight).

- high risks of engine flame-out or damage, hence of total power failure, particularly when going through positive temperature areas.

- a slight degradation in the aircraft performance due to the ice accreted on the airframe (higher weight) and lowering of rotor aerodynamic qualities.

- more or less extended periods during which the vibration level will be unpleasant, due to the blade partial self-shedding feature.

- periodic projection of ice lumps from one rotor into the other, with a risk of damage.

- high frequency vibrations caused by icing of the tail rotor.

- in some cases, pitch instability due to the ice accretion on the stabilizer.

- partial or total loss of visibility through the unprotected transparent panels.

- blocking of the various air inlets with more or less serious consequences.

In this type of icing conditions, except engine troubles and hazards of an autorotation landing which is very difficult when the rotors are loaded with ice, nothing happens quickly.

The parameter degradations are progressive, at least during the first 10-20 minutes. Afterwards, due to the accumulation effect, troubles may rise faster.

b) If icing is of the non steady type, going from medium to high severity, danger is increasing rapidly :

- The torque required to maintain level cruising flight increases rapidly in a very short time.
(for example, an increase of 50 % in less than one minute).

- The vibration level reaches sometimes an excessive one, making the reading of the instruments impossible.

If the icing conditions cease suddendly (for example, when flying out of a cloud), all these phenomena, hazardous for the aircraft and bearing anguish to the crew, decreases very rapidly (often in less than 20 seconds), but they may reappear as quickly when entering into the next cloud.

These conditions may be met quite often and correspond, from the weather aspect, to Cumulus Congestus, Alto-Cumulus bases and particularly Strato-Cumulus tops which are often met between 6000 and 15000 feet.

In this type of clouds, it may be necessary to descend after 2 or 3 minutes of icing, and the risk of engine flame-out or damage are very high.

A temporary loss of aircraft control has already been reported and often in these clouds to improve the climax, there are turbulences, radio interference, lightning, hail and so on.

The fixed wing aircraft, certified for flight in icing conditions, are capable of withstanding all this, at least in theory.
In fact, the airplane accident rate, imputable to icing and associated conditions, is very low.

4. QUALITIES REQUIRED FROM A HELICOPTER CAPABLE OF FLYING IN ICING CONDITIONS

You can note that, insidiously, in the midst of my reasoning, appears the reference to fixed wing aircraft. And it is there that difficulties come to light, since on airplanes the protection system technology is quite advanced and has progressed during these last 40 years.

The technology which may be used on helicopters begins only to reach the industrial level and it is mostly specific to helicopters !

How is it possible to make a rotorcraft capable of extended flying in icing conditions ? It is tempting to believe that this depends on the flight envelope contemplated, which could be limited as required.

- in altitude
- in temperature
- in maximum thickness of the cloud layer.
- in time
- with a requirement for clear air under the clouds
- in thickness of the ice deposit

... etc...

but, practically, the incertitude in weather predictions does not allow the avoidance of poorly defined icing conditions which could lead to disaster in a few minutes.

It is the reason for upholding, in France, the idea of having aircraft capable of flying in icing conditions without major limitations.

To prevent or fight the harmful phenomena described above :

a) it is necessary, therefore :

- to protect the engines against flame-out or important damage, since the autorotation in clouds down to the ground would be critical (at present, it is not even contemplated to authorize the flight of single-engined aircraft in icing atmosphere).

  The various systems retained for the engine protection go from the de-iced ram type air intake, which is efficient but energy consuming, to systems with plenum chambers and inertia separators, of lower aerodynamic efficiency, but the installation and adaptation of which are much easier.

b) to protect the rotors against any excessive ice accumulation so as to limit performance losses to acceptable values mainly from the security aspect, but also from the operational and commercial aspects.

- and also to limit the stresses imposed on the rotor head components and control rods.

- and finally, to reduce the size of the ice lumps shed symetrically from the blades, so as to limit the periodic unavoidable increase in the vibration level to acceptable values.

The cyclic de-icing systems, such as that retained for the SA 330 "PUMA" main rotor head, have to be carefully set so as to be capable of covering a wide range of temperatures and icing severities, by a frequent de-icing but without causing run back. The adaptation of heating and off times is the most delicate development test phase.

c) To adapt the airframe, together with some systems and equipment items, to the flight in icing conditions, but this may be made by direct analogy with the fixed wing aircraft, as for example, the stabilizer de-icing.

As regards the rotor heads, there has been a pleasant surprise which was confirmed all along the years : it is not necessary to provide them with a special protection. In France, the experience is based on rotor heads of various designs : ALOUETTE III, SUPER-FRELON, PUMA and tests run in cooperation with our British friends have shown that it was the same thing on the WESSEX, SCOUT, SEA-KING and LYNX helicopters.

5. THE AIRWORTHINESS REQUIREMENTS POINT OF VIEW

May be you have noted in the previous paragraph, many "it should...", "it is necessary to..." followed by a series of pious wishes.

But, what are the airworthiness requirements asking for and under which form ? Unfortunately for the certificating authority, the light is not shining brightly !

For example, the U.S. regulation FAR 29 paragraph 877 stipulates, without even a smile, that :

"The rotorcraft must be able to operate safely throughout the range of icing conditions for which certification is requested."

Thank you very much !

Then, we are falling back on the regulations relative to fixed wing aircraft and attempting to adapt them.

But, in the end, the manufacturers are rather happy with this situation since all means of substantiation and interpretation are effective. What are there, compared with those available to the airplane manufacturers ?

The engineering justification documents

Required to describe and substantiate the technical choices, they cannot however be established easily to solve the thermal problems or set up by theory, the catchment areas as today the aerodynamic field model around the rotor is not properly known.

Laboratory tests of equipment

They are necessary for the qualification of equipment having to operate in a severe environment.

Particular care has to be taken for humidity, vibration, lightning, tests and so on.

De-icer laboratory development tests

From the thermal aspect, they can be only partial, as any really representative test requires the rotation of the blades !

Dry air tests may be useful in the development of protection systems, but often are more difficult to run than on fixed wing aircraft (for example, determination of airfoil skin temperatures).

These tests are necessary also to validate the non-protection of some aircraft areas (for example, in some cases, the lack of de-icing provisions for the stabilizer).

Artificial icing tests, which constitute a large part of the airplane protection substantiation are at present of little use for helicopters.

Hovering in front of a fixed spray rig similar to that of the National Research Council in OTTAWA, allows some development which afterwards may not be fully valid for flight in natural icing.

The ideal would be the forward flight in artifical icing provided a calm, homogeneous cloud having good micro-physic characteristics could be available, but this is not the case at present in spite of the existence of spraying aircraft such as the American "H.I.S.S.".

Natural icing tests constitute for fixed wing aircraft, the final trials where it is determined that all the tests previously conducted have been sufficient, that the aircraft behaves in a sound manner and that the crew work load, when flying in difficult icing conditions, does not jeopardize the safety.

At present, for helicopters, natural icing tests are run both for development and certification.

Its major inconvenients are :

- difficulties in measuring the icing conditions met, hence, an uneasy comparison with the "icing atmosphere" defined in the airworthiness requirements.
- difficulties in the organization of extended and intensive icing trials covering all the various icing conditions.

The chart given in the appendix summarizes and compares the possible substantiation means.

6. CONCLUSIONS

For the subject we are concerned with, today the helicopter is in a paradoxal and uncomfortable position. While the state of technics for aeronautical equipment, airborne or ground based, makes the "FULL I.F.R" capability (that is icing conditions included) almost automatic for multi-engined airplanes, the helicopters of equivalent complexity, size price and equipment may be grounded by the icing conditions, just like the airplanes forty years ago.

The aeronautical world is wondering, since the I.F.R. "except in icing conditions" capability is already developed.

Therefore, progress have to be made. And, even if the aircraft use is still poorly defined or if the protection systems of the first generations are rustic or inelegant, the aeronautical experience in this field must grow.

This experience of helicopter flight in icing atmosphere, accumulated in the various Western Countries, amounts to a few hundred hours only against several tens of thousands flown by thousands of airplanes.

The start of "de-iced" helicopter operations may be made with the "state of the art" still in the "debugging" period, provided a minimum security level is maintained.

This minimum security level should take into account the failure probabilities of the protection systems (hence, the importance of the failure analysis files) and the performance losses.

And, if a comparison with the fixed wing aircraft is to be made to evaluate the safety level achieved, let us take as reference some twin-engined aircraft of the same class and certified for flight in icing conditions : same weight, same carrying capacity, same flight altitudes, unpressurized cabin... etc.

It may be thought of, for example, the BEECHCRAFT 99 or the "QUEEN AIR", but a comparison with BOEING 747, the AIRBUS "A 300 B" or the FALCON 20 would be fully illogical.

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SUMMARY OF SUBSTANTIATION TYPES
NEEDED TO JUDGE THE ABILITY TO FLY IN ICING CONDITIONS

Type	Fixed wing aircraft	Rotary wing aircraft
- Analysis	Good prediction of ice catchment areas, size and weight of ice deposits. Failure cases analysis	No mathematical prediction. Just description and technological substantiation Failure cases analysis
- Laboratory tests	Thermal efficiency of the protection devices easy to measure.	Special attention to humidity, vibrations, lightning Thermal efficiency very difficult to measure
- Dry air tests	Flight with simulated ice on unprotected surfaces Skin temperature measurements	Flight with simulated ice on unprotected surfaces. Skin temperatures difficult to measure.
- Artificial icing tests	Mainly in icing tunnels. Essential to demonstrate the compliance with airworthiness requirements and the efficiency of the protection system.	Partially useful for development tests. Not usable, for the moment, as certification tests. (except some special points)
- Natural icing tests	Considered as global tests 1) To confirm that no new problem appears on complete aircraft 2) To gain experience in bad conditions before selling the first aircraft.	Essential to demonstrate the compliance with airworthiness requirements, and the efficiency of the protection system.