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The Certification of Rotorcraft in icing conditions: Technological & Economical challenges

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07.12.2016

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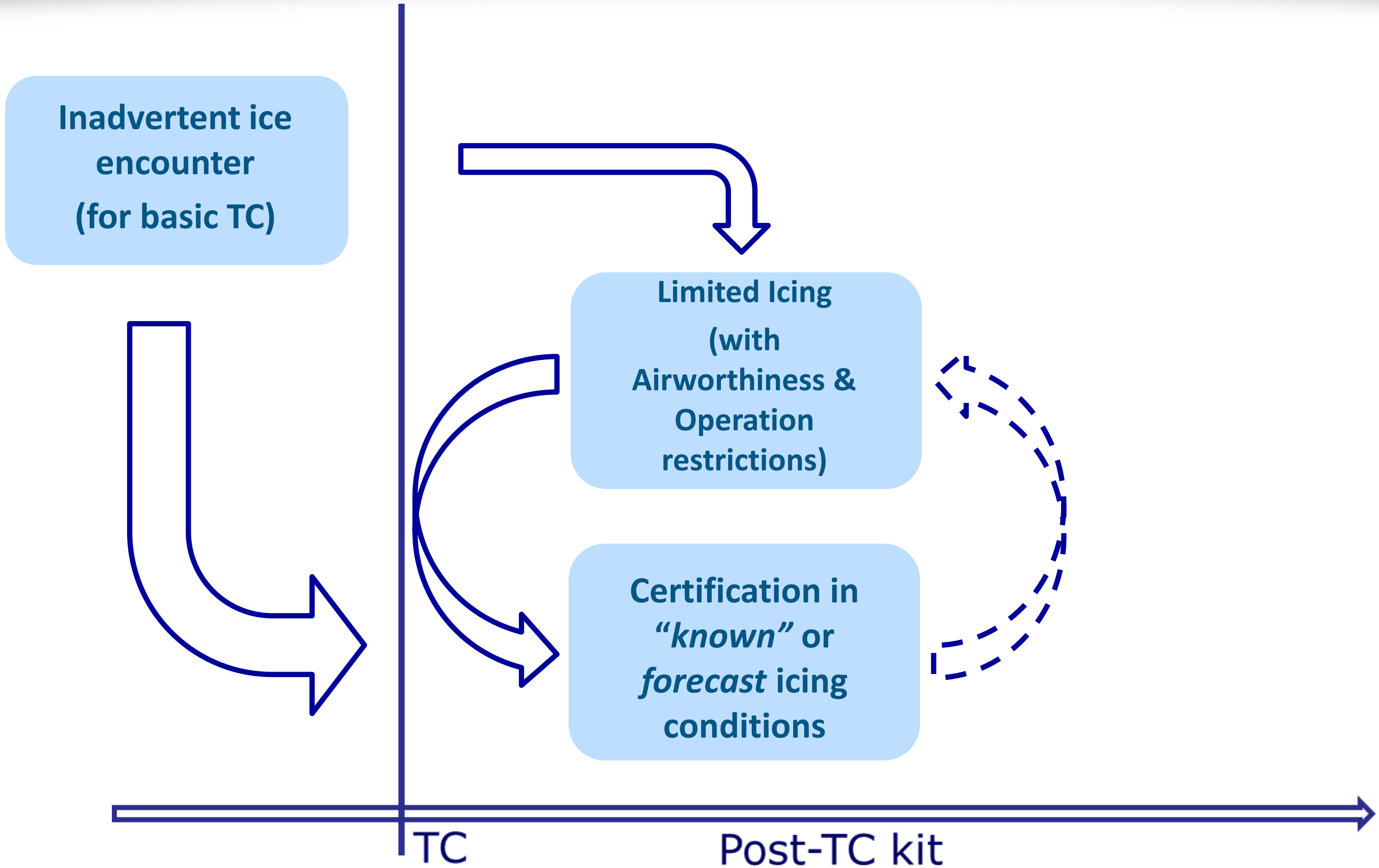
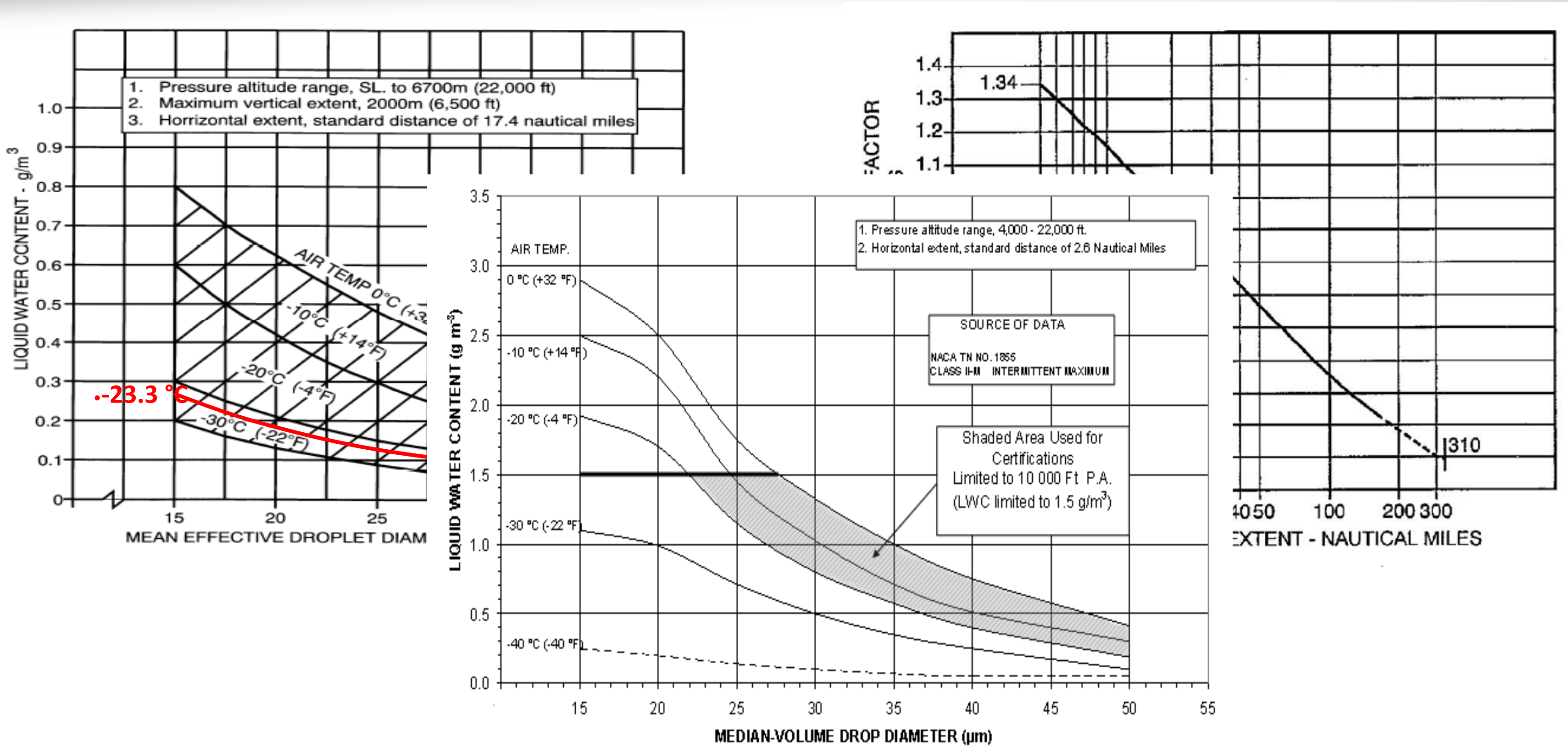
Rotorcraft flight penalties due to atmosphere icing

- Ice accumulation on airframe increases rotorcraft drag/weight
  - Windshield ice accumulation could jeopardize the crew visibility
  - Icing can clog rotorcraft probe and impair the air data reading
  - Attention should be paid to ice shedding from unprotected area.
- Icing building-up on engine inlet may reduce engine power due to air pressure loss and in extreme case can cause engine surge-stall
- Ice shapes on the rotor blade may lead to:
  - loss of rotor aerodynamic efficiencies (increase of power/torque rise)
  - degradation of performance and handling qualities
  - Vibrations could make impossible to continue the flight

Rotorcraft icing certification strategy



The rotorcraft altitude limited icing atmosphere: continuous & intermittent maximum



- Based on FAA review of atmospheric icing data up to 10000 ft
- Minimum Temperature limited to -23 °C
- Engine induction to be certified according to CS 29 “full” Appendix C
- Conversion to distance-based envelope to compare ice encounters

Protected and unprotected surfaces: inadvertent icing

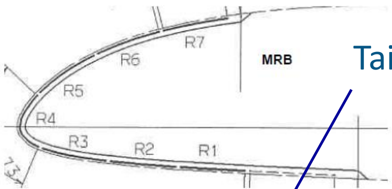
Engine air
Intake - protected

“Iced” pitot strut –
Pitot - protected

The basic certification: the inadvertent icing approval

- Although fly into “known” icing is not <u>planned</u>, protection against icing is requested anyway for:
  - Engine air induction and generally “essential systems” for IFR operation (air data system,..)
- Icing Wind tunnel tests with representative power-plant installation is the more suitable compliance methodology
  - Only continuous maximum icing and 30 minutes ice exposure (to cover the operational scenario “detect & leave”)
  - Most penalizing engine power is selected according to the air intake
- Possible extension to unlimited exposure is the more economical way to clinch clearance in view of rotorcraft certification into known icing
  - Alternating continuous/intermittent icing condition for 30 minutes or until “steady state stabilization”
  - Flight test in natural icing conditions is requested

Protected and unprotected surfaces: icing certification



Tail/Main Rotor blade – <u>protected or unprotected</u>

Vernier Accretion Meter - Icing rate

Engine air Intake - protected

Windshield (protected)

SLD detection probe

Horizontal Stabilizer - unprotected

Ice detector

“Iced” pitot strut – Pitot - protected

The certification in “known” icing conditions – Compliance Methodology

- Analytical tool and laboratory tests with simulated icing conditions maybe used to define the blade protection extension and the de-icing cycle (ON/OFF time)
  - Two driving design criteria: de-icing efficiency and blade structural integrity
- Flight tests in natural icing conditions is the primary means to show safe rotorcraft operation

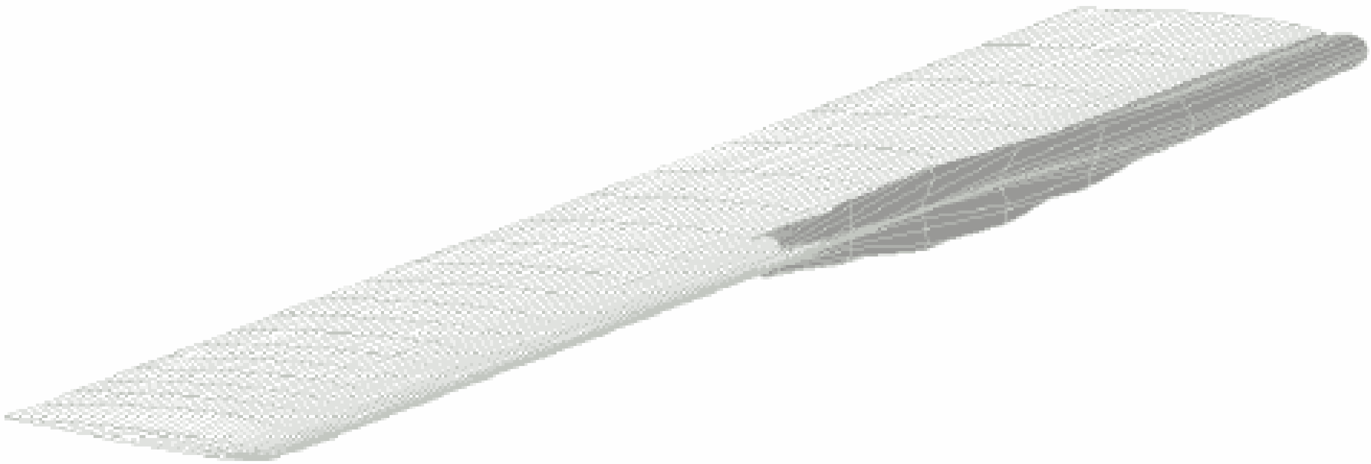
  - De icing efficiency criteria is the torque fall down when heating starts and blade temperature distribution

The flight test campaign in natural icing conditions

- Converted distance-based icing envelope is used to compare different ice encounters
  - CMI points are mainly used to verify the proper functionality in prolonged immersion for ice protection (runback, excessive inter-cycle accretion) and unprotected zones (ice accretion, shedding, drag)
  - IMI points are mainly used to verify whether the helicopter is overwhelmed by high LWC peaks leading to instantaneous and critical torque increase or vibration/unbalance
- Ice shedding behavior from unprotected areas (also from Kits)
- Demonstrate appropriate system failure modes in natural icing
- Substitute/complement flight tests in simulated icing conditions (HISS – Helicopter In-flight Spray System) may be used to test the most severe icing conditions difficult to find in nature, provided that the representativeness of natural ice conditions is substantiated

“Limited icing” approval: the proof of concept

- Rotorcraft with <u>unprotected</u> rotor-blades (so-called *cold blade*) may show capabilities to be <u>efficiently</u> operated within a <u>limited</u> set of atmospheric conditions - up to T_∞ =-6/-8 °C and LWC = 0.3-0.4 g/m^3
- Here below, ice accretion calculation along a blade at transonic tip conditions (M=0.8) in hover, T_∞=-8°C, LWC = 0.3 g/m^3



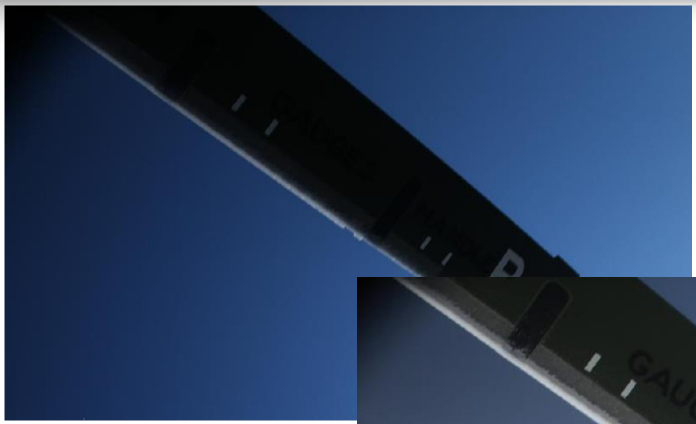
- The need for <u>additional</u> airworthiness and operational requirements

"Limited icing" approval: the Special Condition

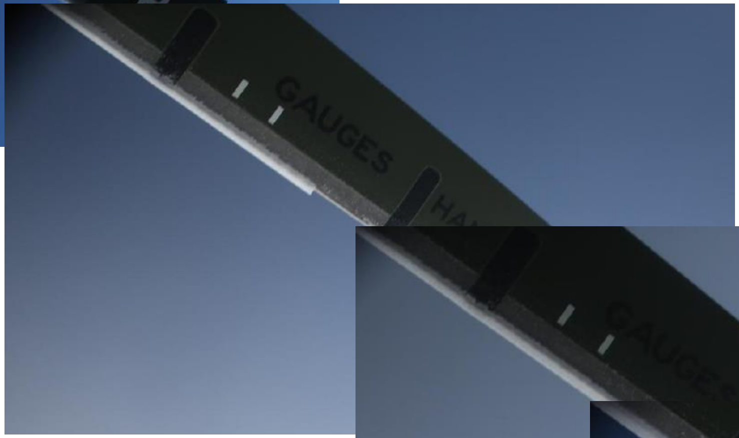
- A sub-set of icing conditions is requested to be demonstrated compared to "full" Appendix C

- Clearance is defined in terms of parameters readily available to the flight crew and may include a combination of:
  - Altitude, Airspeed, Outside Air Temperature & LWC (i.e. ice severity index)
  - Max ice accretion on unprotected area of the airframe (when correlated with ice accretion on any part of the airframe directly observable by the operating crew)
  - Any cockpit displayed parameter requiring the crew to leave icing condition (i.e., Power Index/First Limit Indicator)
- Procedures to leave icing conditions must be proved in the event some of the above parameters are exceeded
  - Operational conditions: existence of 500 ft de-icing layer (> freezing) above safety flight level to naturally de-ice the rotorcraft during descent (escape route)

Ice shedding sequence on "cold blade" main rotor



Ice accretion starts…

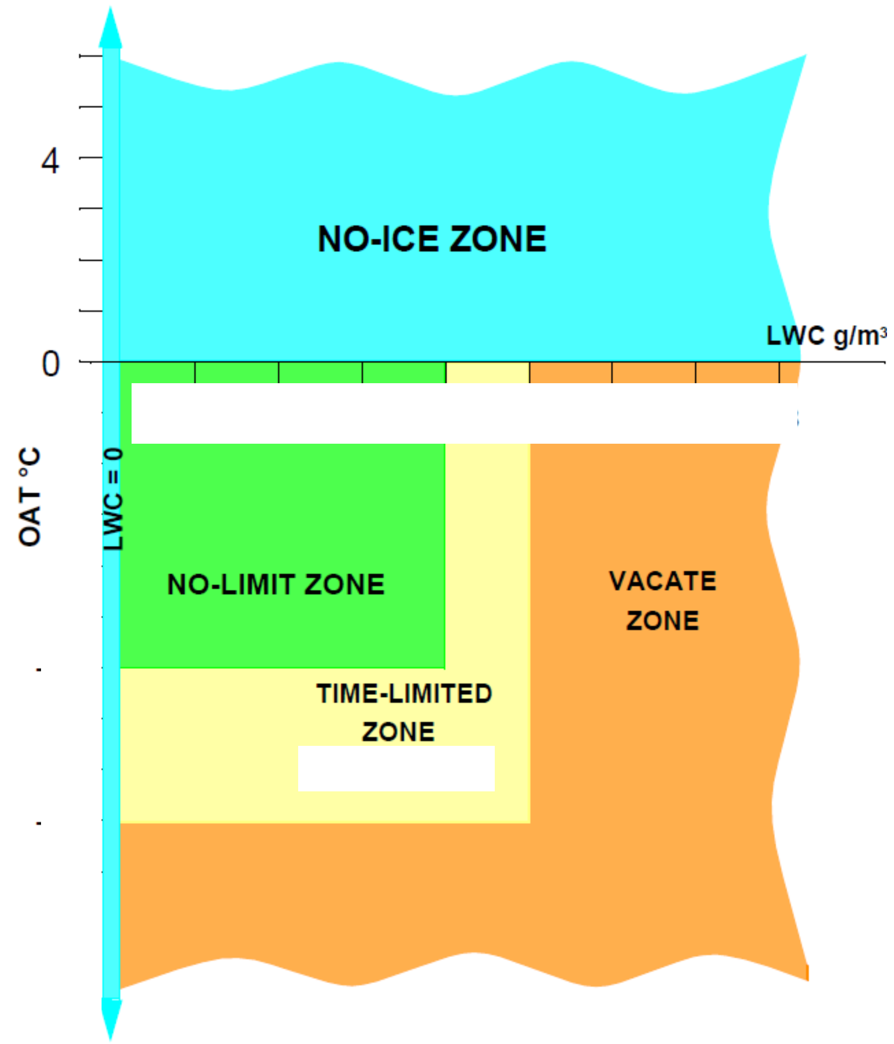


5 minutes later…

14 minutes later..

24 minutes later..

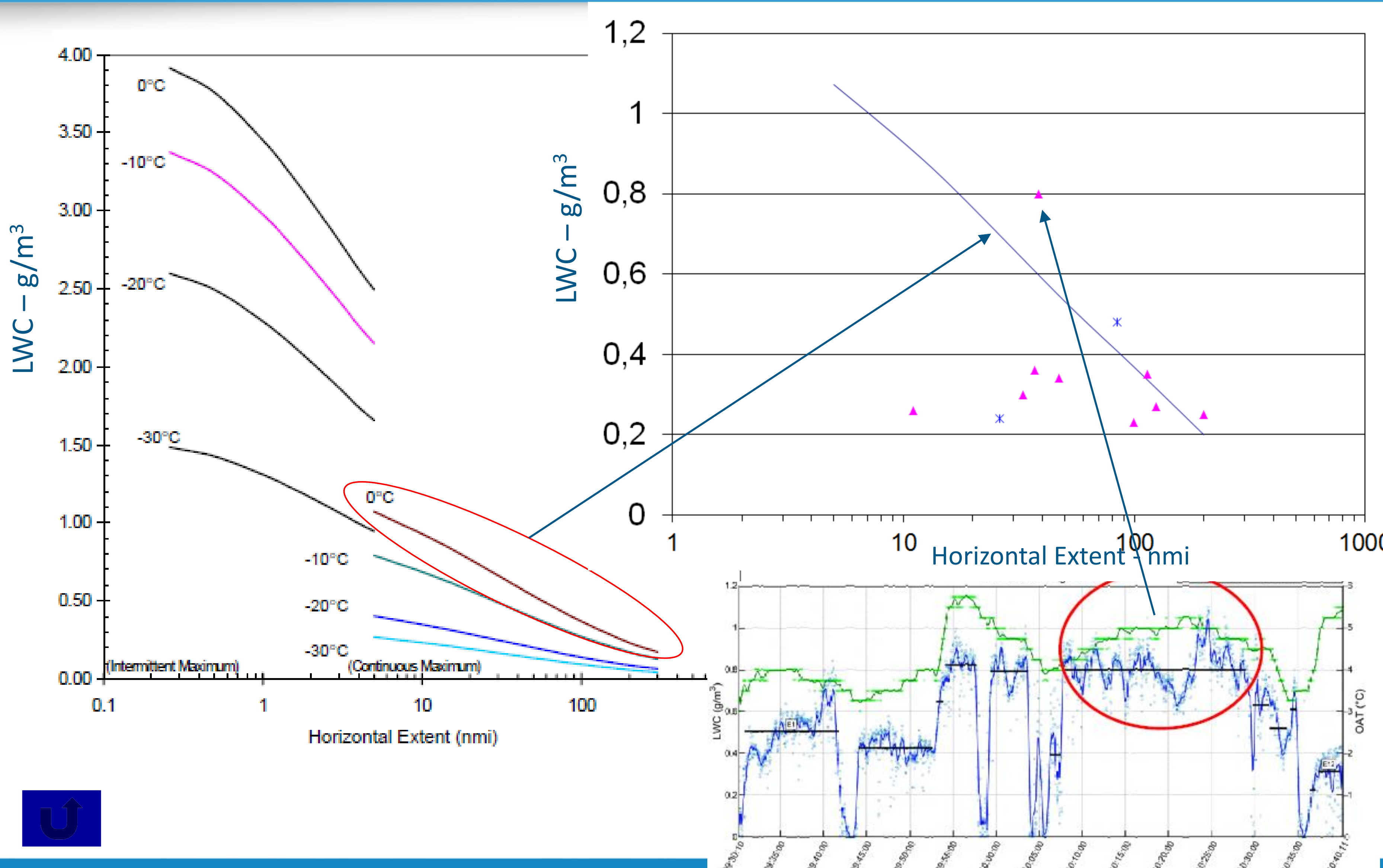
Limited icing approval:
the flight manual supplement “limitation”



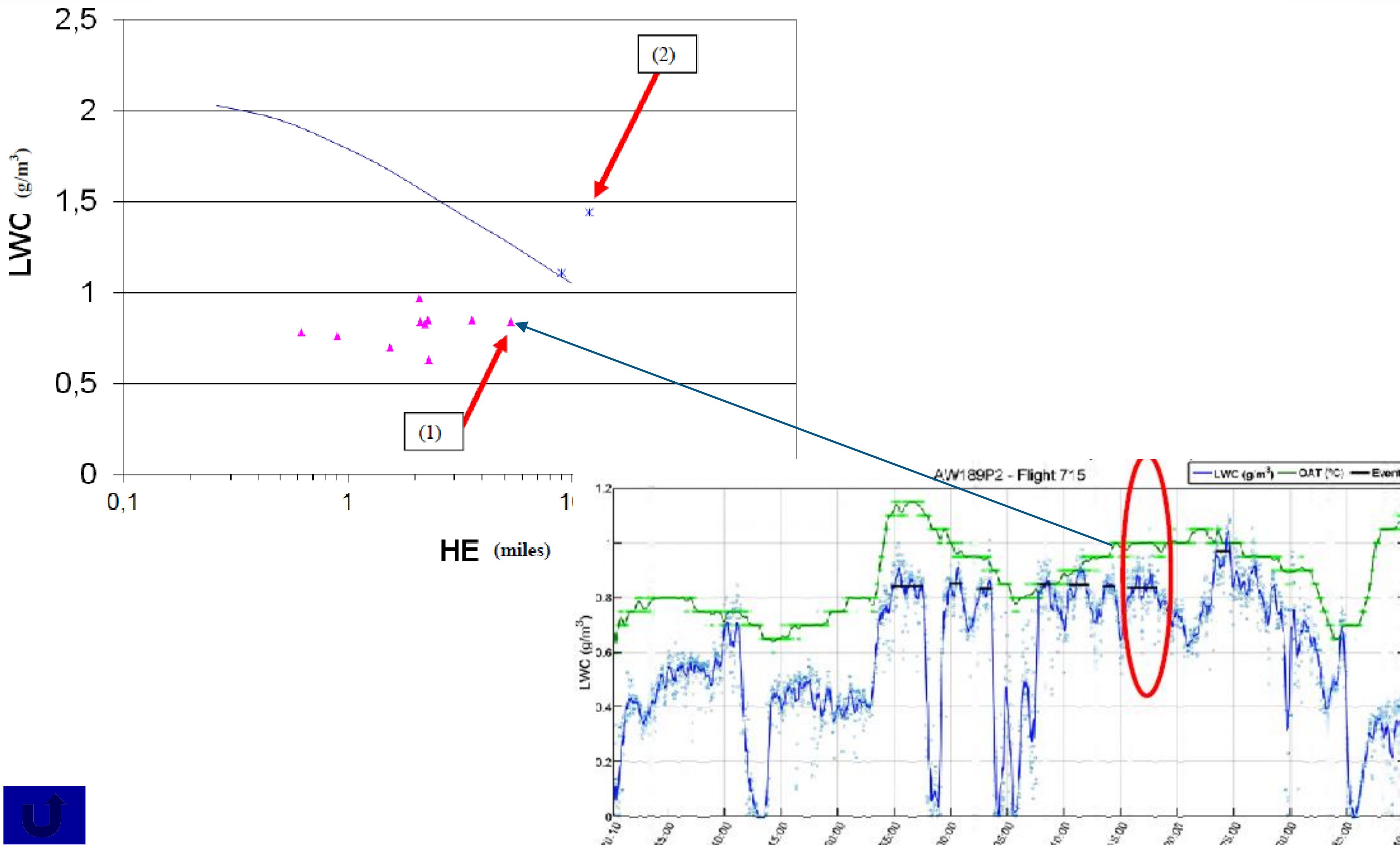
Conclusions

- The rotorcraft icing certification strategy has been presented
- Flight test in natural icing conditions is considered the primary means to demonstrate compliance
  - Flight campaigns may last over more than 150 hours (>50 hours in icing)
  - Very difficult and time-consuming to match the extremes of Appendix C envelope, especially under IMI
- HISS may complement the icing database with valuable results
- The "Limited Icing" approval may help the manufacturer in getting preliminary clearance to operate under specific restricted icing envelope and certain atmospheric condition
  - It deserves specific experience on helicopter behaviour in icing conditions (flight test pilots, operators,..)
  - This approval is not currently recognised by FAA

The flight trials in icing conditions: the distance-based envelope – MVD = 15 µm, CMI



The flight trials in icing conditions: the distance-based envelope – MVD = 15 µm, IMI



The use of HISS for rotorcraft icing certification

- Possibility to test the helicopter characteristics for the time required, without relying entirely on weather conditions
- Preliminary effectiveness of ice protection means could be performed and a “safer” assessment of system failure could be done
- Not all the rotorcraft parts could be analysed at the same time
- Not all the icing cloud parameters (MVD and LWC) can be always independently selected (i.e., difficult the creation of low LWC)
- Cloud uniformity and correct humidity saturation level (inside an actual cloud) is not easy to be re-created
- Comparisons between natural ice accretion and HISS is good for the shape but roughness is different in texture
- Effect of HISS rotor downwash, velocity and temperature limitations

Comparison between natural icing and HISS flight ice shapes

Natural icing

HISS flight

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Any Question ?