Potential Effects of de/anti-icing fluids on aircraft

EASA De-Icing Seminar

An Alenia Aermacchi and EADS joint venture

PROPELLING TOMORROW'S WORLD

Presentation summary

- **Historic Background**
- **Test campaigns on ATR**
- **Detrimental Effects**
- **ATR Materials (documentation and training)**
- **Conclusion**

Ground anti-icing fluids - Historic Background

1950's

Clean Aircraft concept appeared within ops rules

1970-1980

Development of Anti-icing fluid offering holdover time:

1980's

- **AEA published its recommendations and promote use of thickened fluids**
- **Working groups (Worldwide A/C manufacturers, operators, fluids manufacturer and research centres) started to establish more accurate fluids specifications addressing de/anti-icing performance and flow-off qualities**
- **Specifications ISO 11078 and SAE AMS1428 updates to address flow-off qualities through BLDT test**

1990's

- **Working group consensus on acceptable BLDT**
- **Hard competition between fluids manufacturers**
- **Type IV fluids offering longer Holdover time**

Ground anti-icing fluids - a kind of race

Needs from operators

- **Ensure safe dispatch under inclement weather**
- **Departure on time**
  - ➡ Efficient anti-icing fluids in term of anti-icing performance
  - ➡ Longer Holdover time for any weather conditions

Constraint from A/C manufacturer

- **Guaranty take-off performance with regulatory safety margins**
- **Necessity to evaluate fluids effects while fluids are continuously evolving (Type II then Type IV and Type III)**
- **Regularly update the applicable fluids specifications (compatibility with materials, BLDT, Fluid elimination, dry out,…)**
  - ➡ Fluid Qualification
  - ➡ Address incoming undesired effects at A/C level (Performance, Handling, residues)

➡ Reaction to new issues

Fortunately the SAE G12, TC and AEA do a great job

Complements foods – Another kind of race

Needs from media

- Propose great spectacle
- Increase audience to sell advertising slots

Needs from team managers

- Win to become popular
- Be attractive for medias
- Attract and pay best players

Constraint for the sportsmen

- Comply with the rules of the game
- Be efficient any time
- Improve his performance

The referees

- Establish the list of forbidden product
- Increase the number of controls
- Improve the means of control
- Regularly update the list above

➡ Reaction to new findings

Fortunately the WAMA and the USADA are here ☺

Ground anti-icing fluids – Test Campaign

Initial flight test on ATR

Type II fluids tested early 91

- Performance aspect mostly addressed as it was the main concern
- Test performed at approved dilution
- Few Type II fluids available at that time

Test results

- No measurable effect on A/C performance
- No loss of efficiency on the longitudinal and roll control

Type II fluids approved on ATR

- Any fluids approved for use as long they are compliant with SAE AMS1428 and ISO 11078

Type IV fluids approved in 1996

- No further test performed on ATR
- Compliance with SAE AMS 1428 was judged as providing sufficient confidence

Ground anti-icing fluids – Test Campaign

In Service Events

3 aborted take-offs with type II fluid during winter 1997/98

- High forces at rotation,
- First flight of the day,
- One step de-icing/anti-icing with 75/25 type II fluids
- All events occurred in Europe
- ➡ Loss of aerodynamic balancing of the elevator

1 aborted take-off with type IV fluid during winter 1998/99

- High forces at rotation
- First flight of the day
- Two step de-icing/anti-icing with 50/50 type I and type IV neat fluid (Kilfrost ABC-S)
- This event occurred in Europe (Copenhagen)
- ➡ Layer of Jelly green slush of 2 to 6 mm thick on the stabilizer upper surface

Ground anti-icing fluids – Test Campaign

Second batch of flight tests

1998 to 2000 in Toulouse and Kokkola (Finland)

Goal:

- To address in service events with type II fluids
- To answer airline demand for type IV fluids
- To test several anti-icing fluids at various dilution
- To check aircraft behavior at Take-off after fluid application
- Identify quiet areas prone to fluids accumulation
- Tentative to reduce stick forces at rotation (various devices)

Tested aircraft :

- ATR 42-500 fully instrumented (cameras, stick forces)
- Measurement of the stick forces during rotation
- Visualization of fluid elimination

Test Method

- Type II and type IV fluids tested at various dilution (1 step and 2 steps)
- Max forward CG

Ground anti-icing fluids – Test Campaign

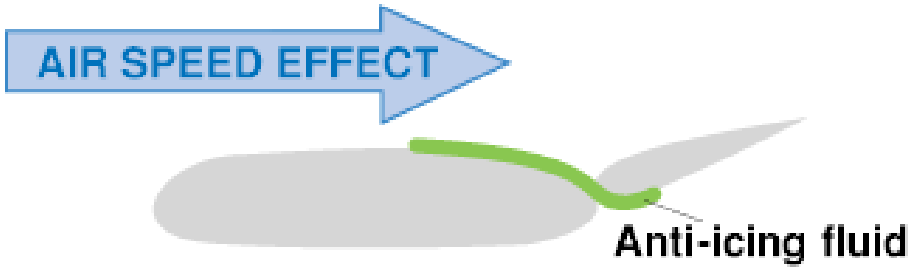
Second batch of flight tests

Test Results

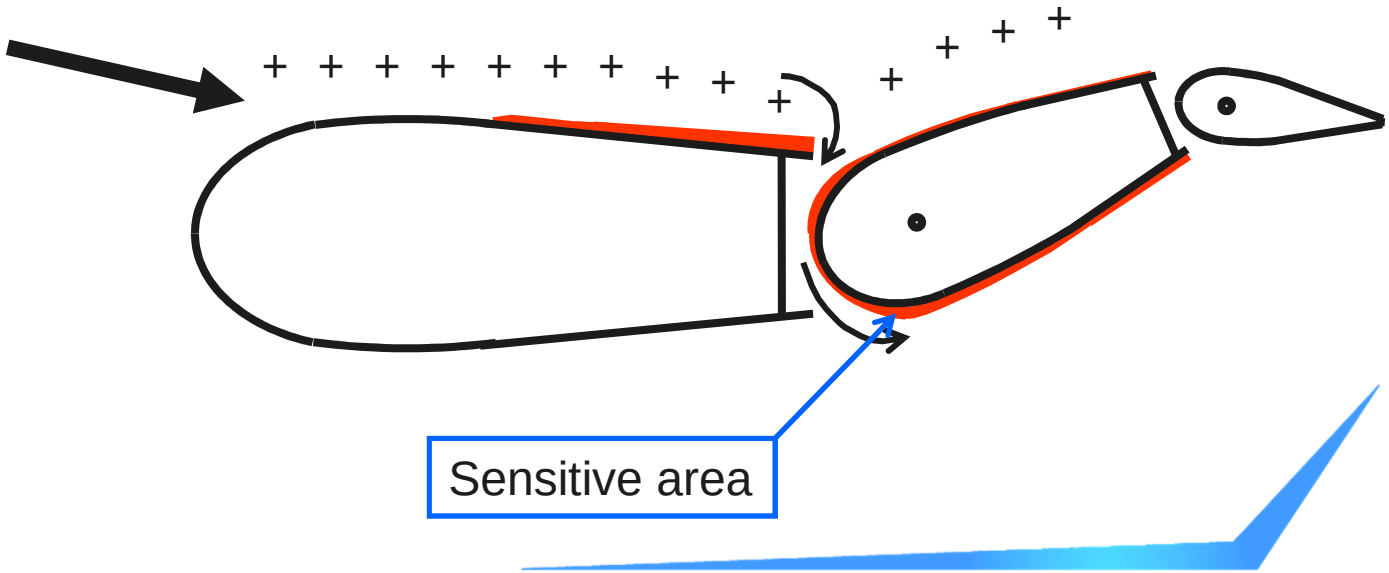
- **no noticeable effect on wing aerodynamics / performance and roll control**
- **only affects the horizontal stabilizer behavior**
- **Difficult to make a correlation between stick forces and fluid viscosity (kinetic viscosity)**
- **Type IV fluids provided lower stick forces than Type II fluids**
- **Stick forces increase are not predictable**
- **Stick force increase is due to contaminant accumulation on the lower surface of the elevator leading edge**
  - **Thickened fluids layer, or**
  - **Frozen drops (frozen precipitation or failed fluid)**

Ground anti-icing fluids – Test Campaign

Fluid circulation



At Rotation



Ground anti-icing fluids – Detrimental effects

Known detrimental effects

- **Pitot probe, statics ports contaminated with fluids**
  - erroneous altitude and speed indications
- **Fluids entering within control surfaces (gaps, drain holes)**
  - Aerodynamic unbalance of the controls
  - Heavy control forces (roll and pitch)
- **Brake Carbon disks polluted with de/anti-icing fluids**
  - Braking performance degraded
  - Catalytic oxidation of brake disk with potential rupture
- **Landing gear, flight control actuators**
  - Damage to the seals (leaks)
  - Contamination of the connectors (malfunction)

Ground anti-icing fluids – Detrimental effects

How to handle these effects

- **Performance**
  - **Covered by AMS1428 but need to be checked by flight test**
- **Handling**
  - **Not covered by AMS 1428 then need to assessed by flight test**
- **Contamination**
  - **Need to be addressed within in ground de/anti-icing procedures (no spray areas)**
- **Material compatibility**
  - **Covered by AMS1428 but need to be assessed by design review**
- **Residues**
  - **Partially covered by AMS 1428 but need to be addressed by operational recommendations and maintenance program**

Ground anti-icing fluids – Detrimental effects

Fluid residues – ATR Findings

- **Anti-icing fluid trapped within gaps, quiet aerodynamic areas**
  - Glycol evaporate in dry conditions
  - Residues (gel, powder) may rehydrate in humid conditions then freeze.
  - Control surfaces, hinges or actuators may become jammed
- **Conditions prone to residue formation**
  - Preventive application of anti-icing fluid for overnight protection
  - Successive application of type II or IV anti-icing fluids in one step without cleaning
  - High temperature gradient on ground along the day

Ground anti-icing fluids – Detrimental effects

Fluid residues – ATR Findings

Ground anti-icing fluids – Detrimental effects

Fluid residues – ATR Findings

Ground anti-icing fluids – Detrimental effects

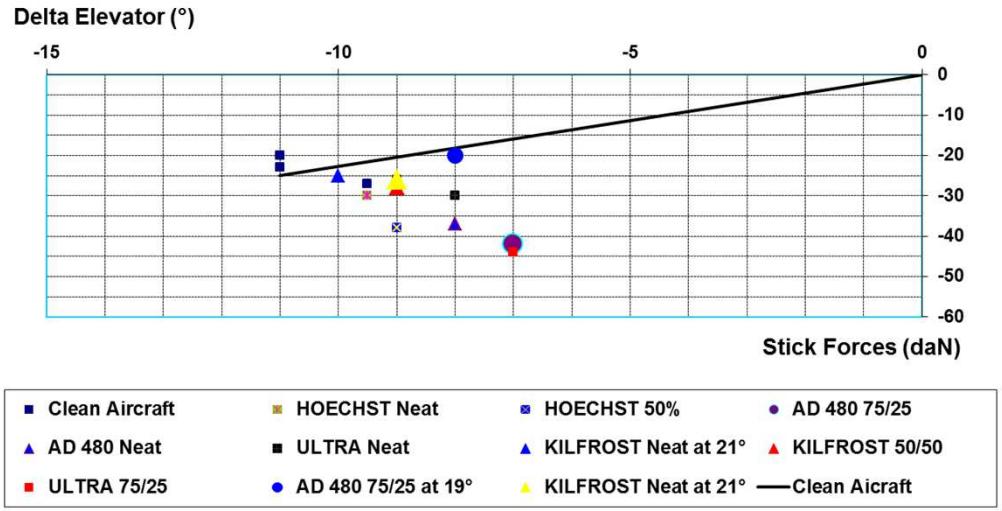
Fluid residues : ATR response

- **Recommendations**
  - Prefer two steps de/anti-icing procedure. First step will clean the aircraft from any contaminants
  - Perform periodic inspections of the critical surfaces to detect any residue formation.
  - Inspection interval recommended by ATR is 1 week but should be adapted according to operator experience and inspections feedback.

Ground anti-icing fluids – Detrimental effects

Handling Qualities– ATR Findings

- **Anti-icing fluids may temporally increase the stick forces during rotation**
  - **Anti-icing fluid circulating through the gap between the horizontal stab and the elevator change the balancing and the efficiency of the control surfaces (elevator and tab)**
- **Control surfaces contamination**
  - **When fluids are sprayed from aft of surfaces, they may penetrate inside the control surfaces through draining holes**



Ground anti-icing fluids – Detrimental effects

Handling Qualities : ATR response

- **Operational documentation updates**
  - Only use Thickened fluids when holdover time is required
  - Prefer two steps de/anti-icing procedure. First step will clean the aircraft from any contaminants
  - Dedicated procedures for take-off after de/anti-icing fluid application
- **De/anti-icing procedures update (AMM/JIC)**
  - Never spray fluids from aft the surfaces
  - Implement periodic inspection and cleaning if necessary

Ground anti-icing fluids – ATR Materials

ATR publications and training tools

- **Operational manual**
  - AFM (limitation section)
  - FCOM (section 2-02 and 2-03)
- **AMM JIC**
  - 12-31-12 PTN 10000
- **Service Letter (residues)**
  - ATR42-30-5013
  - ATR72-30-6006
- **Training material**
  - FCTM
  - Cold Weather Operation Brochure
- **Flight simulators specific modules**
  - Effect of de/anti-icing Type II and IV fluids at take off
  - Effect of elevator and horizontal stabilizer not totally de-iced

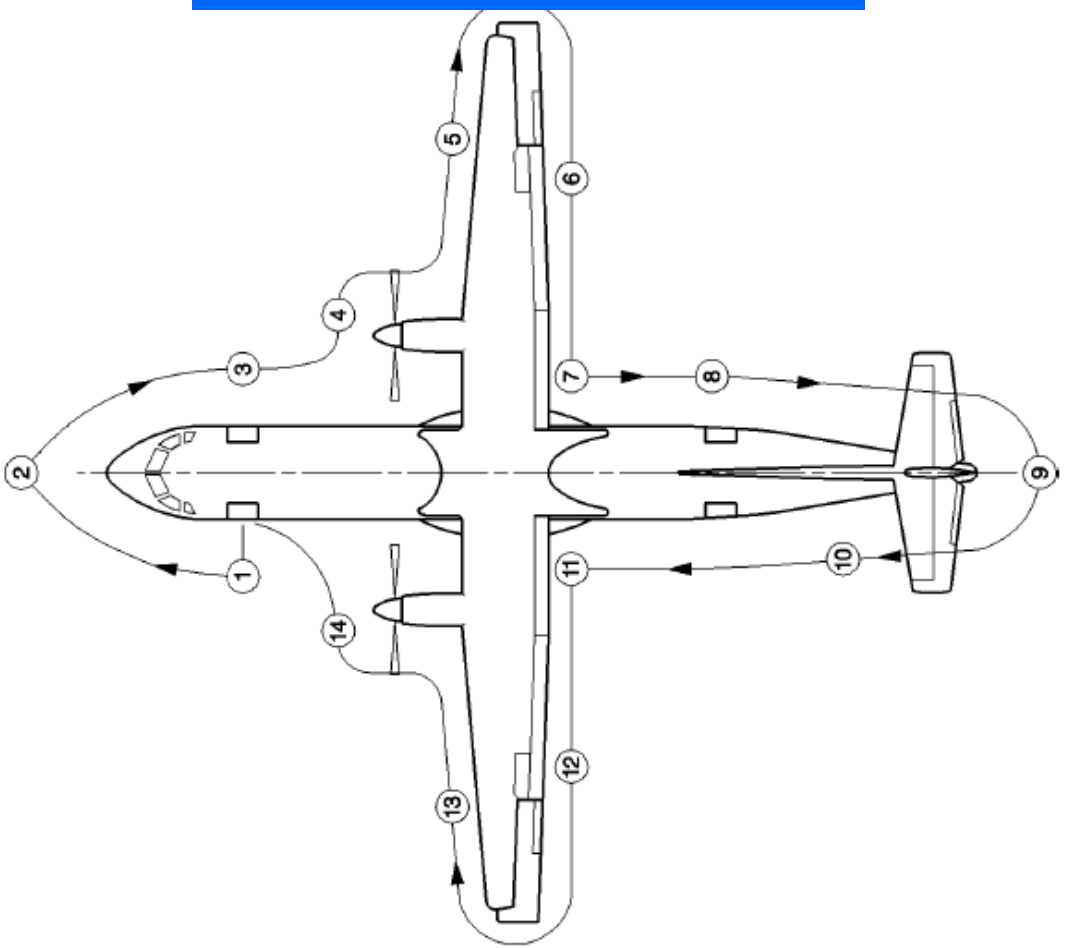
Ground anti-icing fluids – ATR Materials

Overall recommendations and limitations

- **Select the fluid and the application methods according to the prevailing weather conditions and precipitations**
- **Approved for use on ATR :**
  - De-icing fluid type I (SAE AMS 1424)
  - Anti-icing fluids type II and IV (SAE AMS 1428)
  - Ask for the fluid valid certificate to the de-icing providers
  - List of approved SAE fluids available on University of Quebec at Chicoutimi web site (AMIL laboratory)
- **Not approved yet on ATR**
  - Anti-icing fluids type III as effect on aerodynamic not yet evaluated

Ground anti-icing fluids – ATR Materials

OPS: Walk around Inspection



Areas to be checked before each flight :

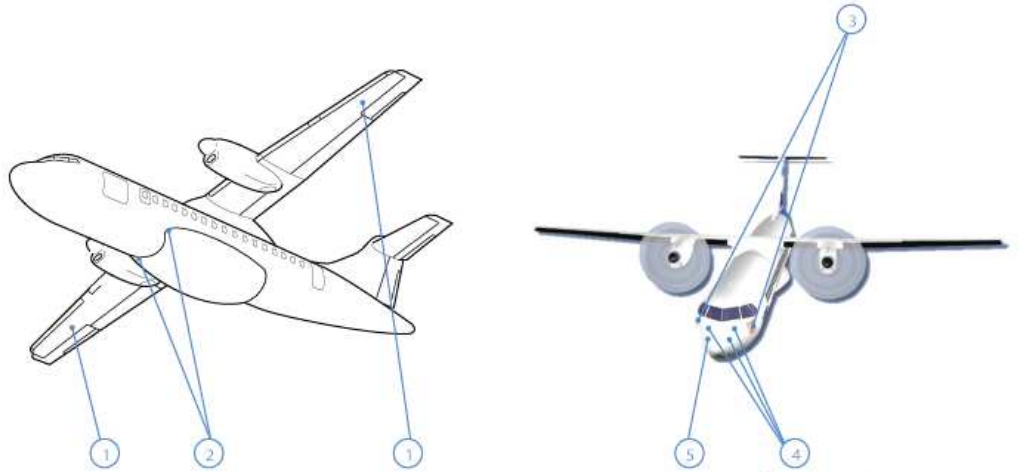
- **Engine inlets, cowling and draining**
  - **Pack inlets**
  - **Landing gear assemblies and doors**
  - **Angle of attack sensors, pitot and static vents (AOA free to move)**
  - **Fuel tank vents**
  - **Propellers**
  - **Fuselage**
  - **wings**
  - **Vertical and horizontal stabilizer**
  - **Control surfaces**

They must be clear of ice and snow and any other frozen contaminants and slush.

Ground anti-icing fluids – ATR Materials

AMM/JIC: Aircraft preparation

- **Blanking and Protective devices**



1 - Naca ports
2 - Air conditioning inlets of the main landing gear fairing
3 - Static ports
4 - Pitot probes
5 - Temperature sensors

- **Special precaution**
  - Shock absorber
  - Brakes
  - Engine air intake (for propeller de icing)

Ground anti-icing fluids – ATR Materials

AMM/JIC: Aircraft preparation

- **At parking area**
  - Engines not running
  - Doors closed
  - Aircraft facing into wind
  - Parking brake and wheel chocks

- **At holding point**
  - Engine 2 running in hotel mode
  - Bleed off
  - No use of de-icing/anti-icing gantry

Ground anti-icing fluids – ATR Materials

AMM/JIC: Aircraft de/anti-icing: snow removal

Snow shall be removed mechanically

- **To not damage these parts**
- **To not pollute the brakes**
- **To prevent fluid ingestion inside the engines**
- **To save de-icing fluids**

JIC 12-31-12 PTN 10000

```
A. SNOW REMOVAL.
   (1). BEFORE DE-ICING, SWEEP, OR BLOW OFF
        THE SNOW LAYER (PAY ATTENTION TO
        ANTENNAS, PROBES AND VORTEX GENE-
        RATORS)

     NOTE : -DO NOT WALK ON WING NO STEP
             AREAS.
            -TO AVOID SNOW ACCUMULATION IN
             THE VARIOUS HINGE POINTS, START
             FROM THESE CRITICAL AREAS AND
             WORK TOWARDS EXTERIOR.

   (2). REMOVE SNOW FROM ENGINE AIR INTAKES,
        PROPELLER BLADES, LANDING GEARS AND
        BRAKES.
```

Ground anti-icing fluids – ATR Materials

AMM/JIC: Highlights

Remove first the contaminants within the gaps as they may:

- affect the aerodynamic compensation of the control surface, and or
- Jam the controls surfaces

Spray the fluid from the leading edge to the trailing edge

- To not damage the actuator connectors
- To not fill the control surfaces with fluids through the draining holes

JIC 12-31-12 PTN 10000

```
B. DE-ICING OR ANTI-ICING OF AIRFOIL AND
   CONTROL SURFACES
   - BEFORE STARTING OF DE-ICING/ANTI-ICING
     OF THE WHOLE SURFACE, START SPRAYING
     THE GAP BETWEEN FIXED AND MOVABLE
     SURFACES IN ORDER TO AVOID ACCUMULATION
     OF CONTAMINANT, THEN PROCEED FROM THE
     LEADING EDGE BACKWARD.

CAUTION : SPECIAL ATTENTION SHALL BE PAID TO
          THE GAPS BETWEEN
          - WINGS/AILERONS/TABS
          - HORIZONTAL STABILIZER/ELEVATORS/
            TABS
          - RUDDER/VERTICAL STABILIZER/TAB

WARNING : THESE GAPS MUST BE CLEAR OF ANY
          CONTAMINATION AND MUST BE
          CHECKED AFTER ANY DE-ICING OR
          ANTI-ICING PROCEDURE.
```

Ground anti-icing fluids – ATR Materials

AMM/JIC: Highlights

Horizontal stabilizer/elevator de-icing

- Spray the fluid from underneath with the elevator full up then from the above with the elevator full down to clean the elevator leading edge

JIC 12-31-12 PTN 10000

1. DE-ICING

   AN EFFICIENT CLEANING IS OBTAINED BY SPRAYNG SUCCESSIVELY FROM THE UNDERNEATH AND FROM THE ABOVE OF THE SURFACES.

Horizontal stabilizer/elevator anti-icing

- Spray an homogeneous layer of anti-icing fluid over the upper surface with the elevator in full down position
- It prevents excessive thicken fluid to enter the gap

JIC 12-31-12 PTN 10000

2. ANTI-ICING

   ONCE THESE PARTS ARE FREE FROM ANY CONTAMINANTS THE APPLICATION OF TYPE II OR TYPE IV ANTI-ICING FLUIDS SHALL BE PERFORMED WITH THE ELEVATOR TRAILING EDGE MAINTAINED IN THE FULL DOWN POSITION (CONTROL COLUM AT FULL FORWARD POSITION) THIS WILL ALLOWS THE EVACUATION OF EXCESS ANTI-ICE FLUID.

Ground anti-icing fluids – ATR Materials

AFM/FCOM: Aerodynamic effect

- **Fluid type II/IV operational procedure**

  Application of thickened fluids can sometimes generate high stick forces at rotation. These increased stick forces are temporary and disappear after take off. This effect is more pronounced when center of gravity is forward.

  - ➡ Anticipates the phenomena (pre-take off briefing)
  - ➡ Apply one of the two methods proposed by ATR

Ground anti-icing fluids – ATR Materials

AFM/FCOM: Aerodynamic effect

- **Method 1**

  For crew without specific training

  - Standard take-off procedure
  - TOR, TOD and ASD are increased by 20% on ATR 42 and 25% on ATR 72
  - In case of increased rotation forces, the pilot can consider to abort take off after V1

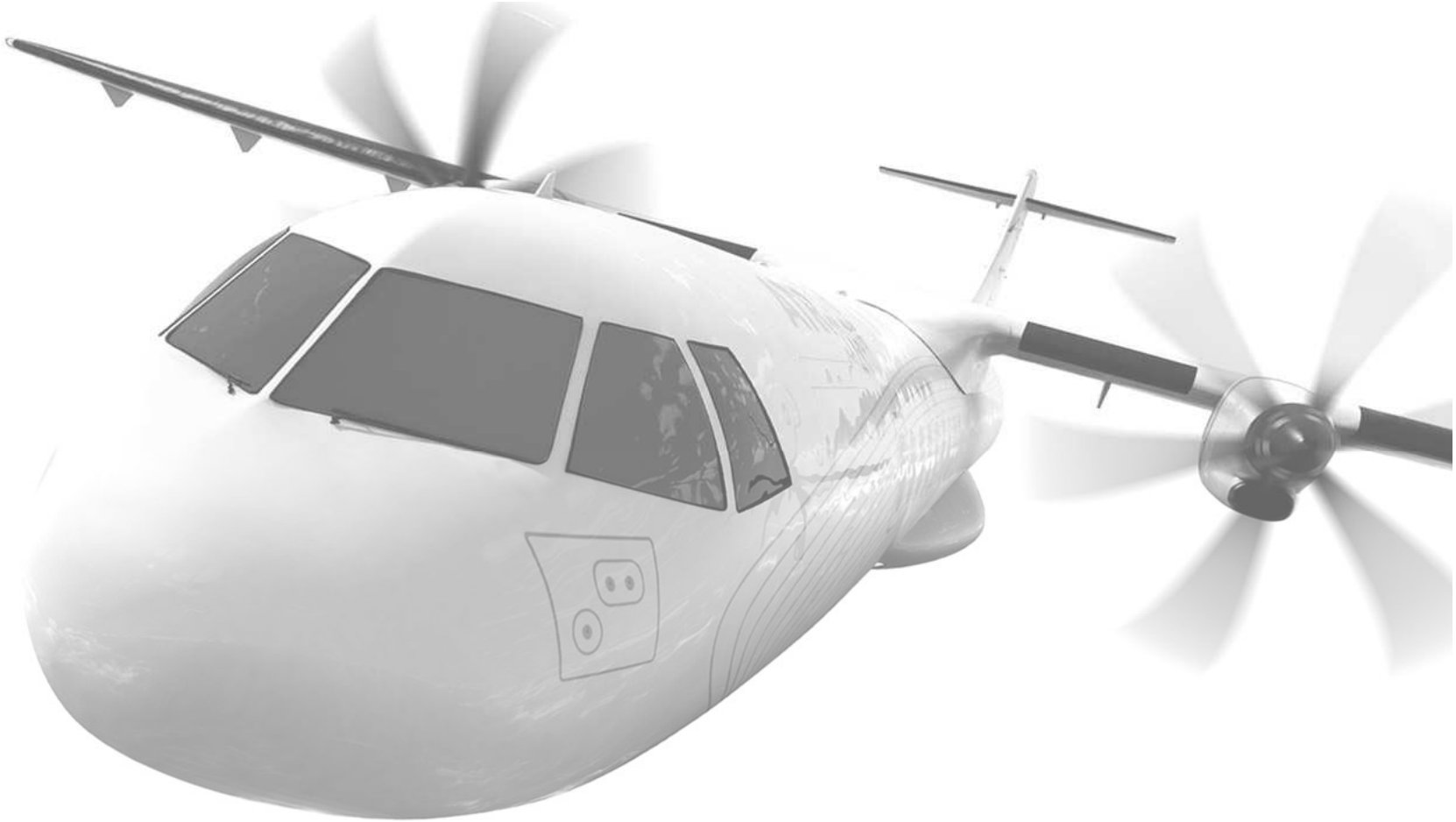
- **Method 2**

  For crew who has received specific training

  - Specific take off briefing
  - TOD increased by 70m
  - Captain is PF
  - In case of increased rotation forces, Captain requests First Officer assistance
  - Captain orders « Pull »
  - First Officer pulls its control column until 5° of pitch

Ground anti-icing fluids – Conclusion

- **All thickened fluids available on the market shall comply with the AMS 1428**
- **The AMS 1428 is regularly updated to address issues related to anti-icing fluid treatment**
- **Aircraft manufacturers did a lot of concessions to accept potential fluid effects on aircraft performance (clean wing concept ???)**
- **Small airports only have thickened fluids available while type I fluids would be sufficient to ensure the dispatch.**
- **All the detrimental effects of thickened fluids cannot be anticipated for a given aircraft**
- **Fortunately the AEA, SAE G12, AMIL laboratory do a great job dedicated to training, specification update and fluids qualification .**



Thank You for your attention