Optimization of ground icing protection for aircraft: Snow endurance tests, rheological analysis and thermography of anti-icing fluids

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Aircraft ground icing

The use of de-icing and anti-icing fluids

Aerospace Standards

The SAE G-12 committee creates, maintains, and updates documents for the Society of Automotive Engineers (SAE), which include detailed standards and recommended practices covering various de-icing and anti-icing techniques, specifications for the use of aircraft de-icing and anti-icing fluids, qualification and testing procedures, endurance testing, personnel training, and quality control.

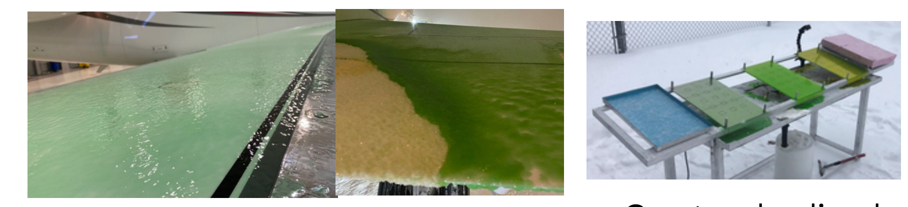
Endurance Time Testing Standard for Anti-Icing Fluids

SAE ARP5485

Failure Criteria for Snow Endurance Test: When **30%** of the plate surface is covered with white snow, the test is stopped, determining a failure time

Material specification standards — SAE AMS1428, SAE AMS1424

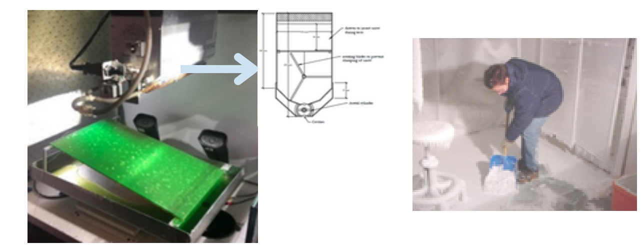
Outdoor Natural Snow Endurance Test



On an airplane wing

On standardized test plates

Indoor Artificial Snow Endurance Test



The production of artificial snow

Problematic

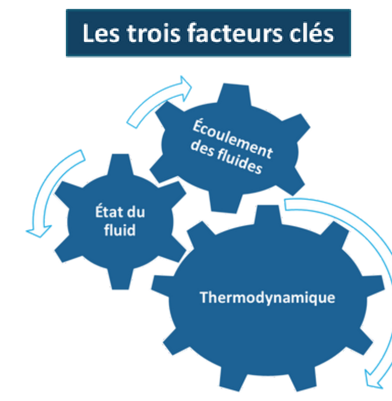
- Currently, the snow endurance time is determined outdoor under natural conditions
- Outdoor snow tests are expensive and require too much time and effort
- One of the most limiting factor is that they are only conducted during the winter session
- A sufficient correlation between indoor and outdoor snow tests has not been obtained yet

Objectives

The development of a reliable indoor artificial snow endurance test that correlates with and can replace outdoor natural snow endurance tests

Let's return to some fundamental principles to understand the behavior of aircraft anti-icing fluids during endurance tests

Les trois facteurs clés

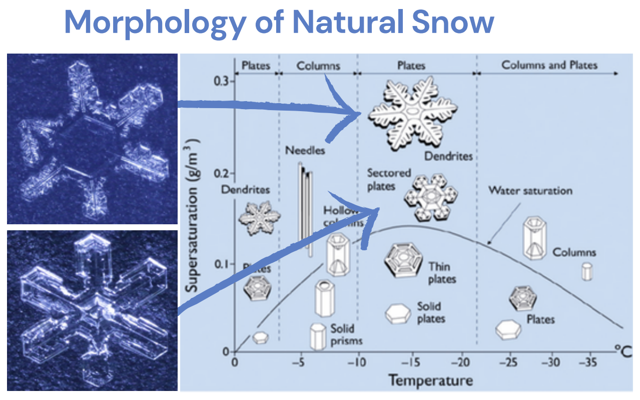


Methodology

- Analysis of the similarities between artificial snow and natural snow
- Improvement of the snow deposition system for artificial snow endurance tests
- Characterization of Anti-Icing Fluids → Rheology of Fluids and Behavior
- Thermography of Anti-Icing Fluids

Analysis of Similarities Between Artificial Snow and Natural Snow

Morphology of Natural Snow

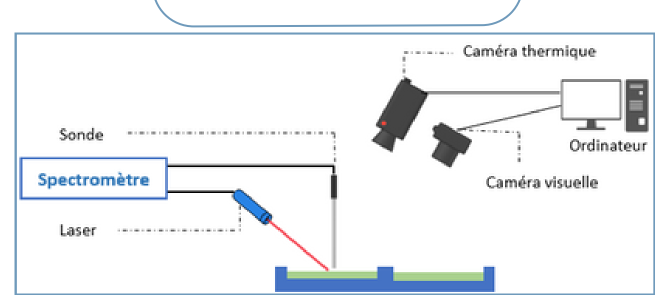


Nakaya Snow Crystal Morphology Diagram

Instruments that measure temperature, relative humidity, precipitation intensity, precipitation type, precipitation amount, atmospheric pressure, wind direction, wind speed, Liquid Water Content (LWC), and snow density

Improvement of the snow deposition system for artificial snow endurance tests

Small scale

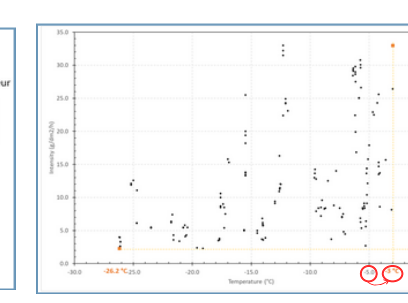


The elimination of flow effects and the study of the impact of snow intensity and temperature on the diffusion and concentration evolution of glycol

Medium scale

Improvement of snow distribution and uniformity, as well as the integration of an automated numerical method for failure detection reporting

Improvement and extension of the machine's limits



The operating temperature limits for the machine ranged from -5 °C to -25 °C

Our goal is to push the machine's limits to simulate a broader range of natural weather conditions

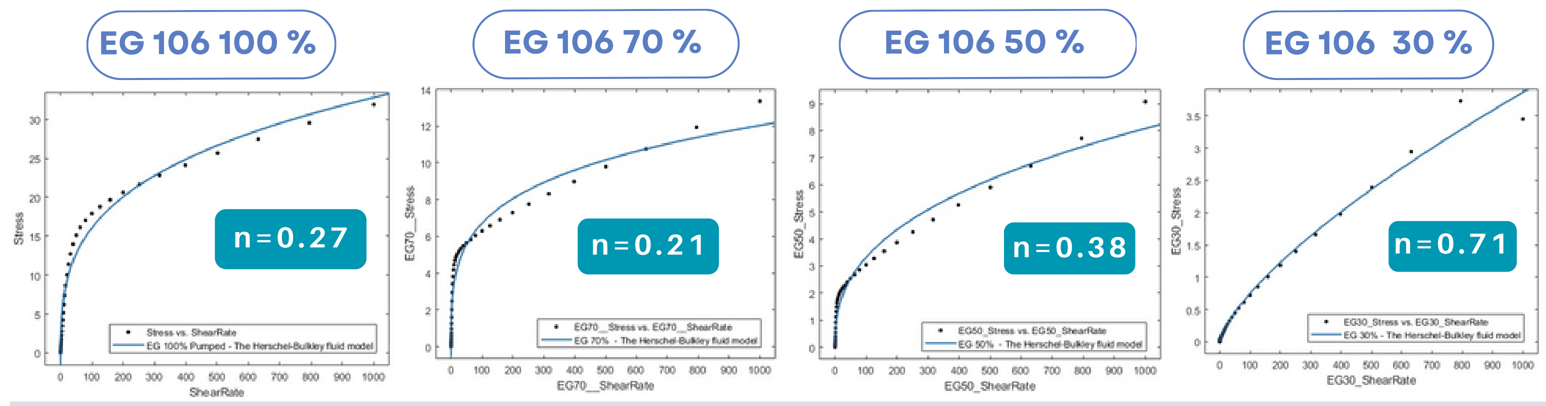
Characterization of Anti-Icing Fluids

Rheology of Fluids and Behavior

Mathematical Models for the Behavior of shear thinning Fluids

Numerous mathematical expressions have been proposed in the literature to model the characteristics of shear-thinning fluids. The following figures present the most suitable model for the studied fluids among five models

EG 106 100 % — EG 106 70 % — EG 106 50 % — EG 106 30 %

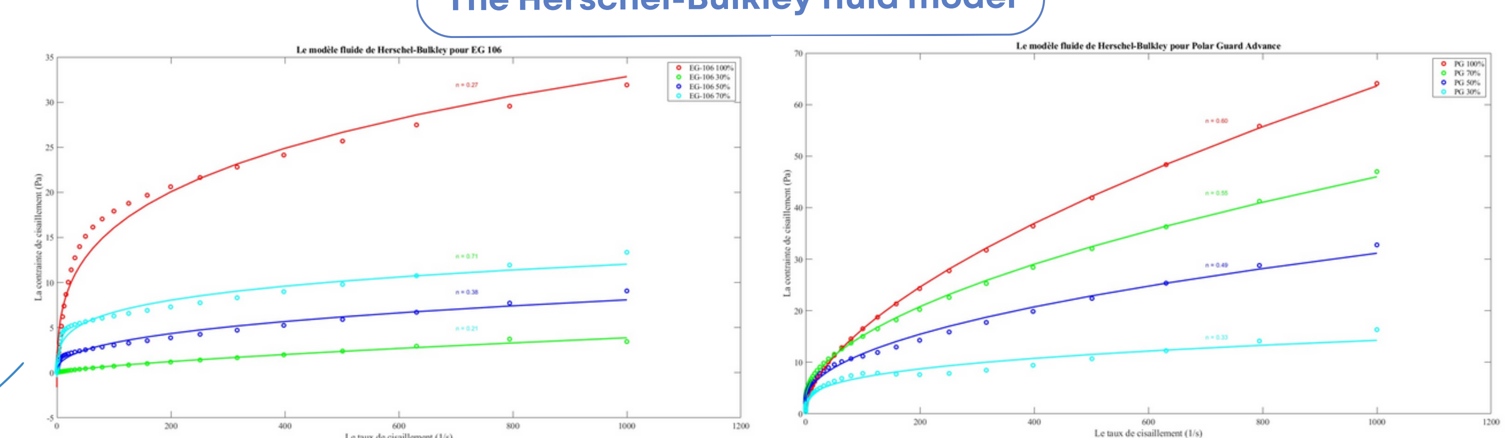


n < 1 The fluid exhibits shear-thinning properties

We are approaching a Newtonian behavior

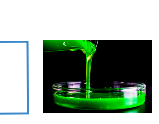
The value of n=1 indicates that the fluid exhibits Newtonian behavior

The Herschel-Bulkley fluid model



These fluids are non-Newtonian with pseudoplastic behavior, providing good adhesion and surface protection by forming a thick protective film at rest with sufficiently high viscosity, and easy flow during ground acceleration due to decreased viscosity

The anti-icing fluids studied in this research project



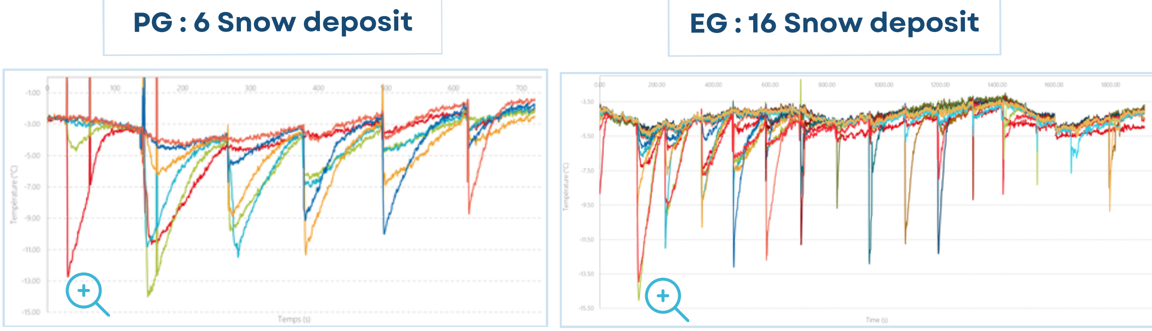
Type IV	Polar Guard Advance	Propylene Glycol 50 %	Type II	Safewing MP II FLIGHT	Propylene Glycol < 55 %
Type IV	EG-106	Ethylene glycol 50 %	Type III	AeroClear MAX	Ethylene glycol 50 %

Thermography of Anti-Icing Liquids

The fluids studied in this section are EG106 SAE Type IV and Polar Guard Advance Type IV. EG 106 is an ethylene glycol-based product, and PG is a propylene glycol-based product. For each test, 16.2 g of the product was placed on a small aluminum plate with a thickness of about 1.6 mm. The tests were conducted at -5 °C, and the cold chamber ventilation was set at 60. During this test, several snow deposits of the same quantity were applied to each product every 2 minutes

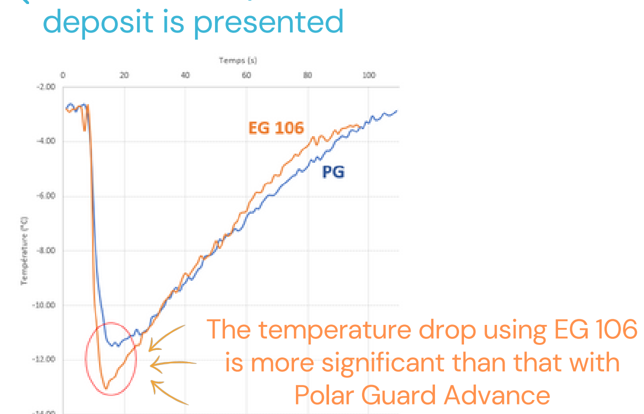
Each color represents a snow deposit

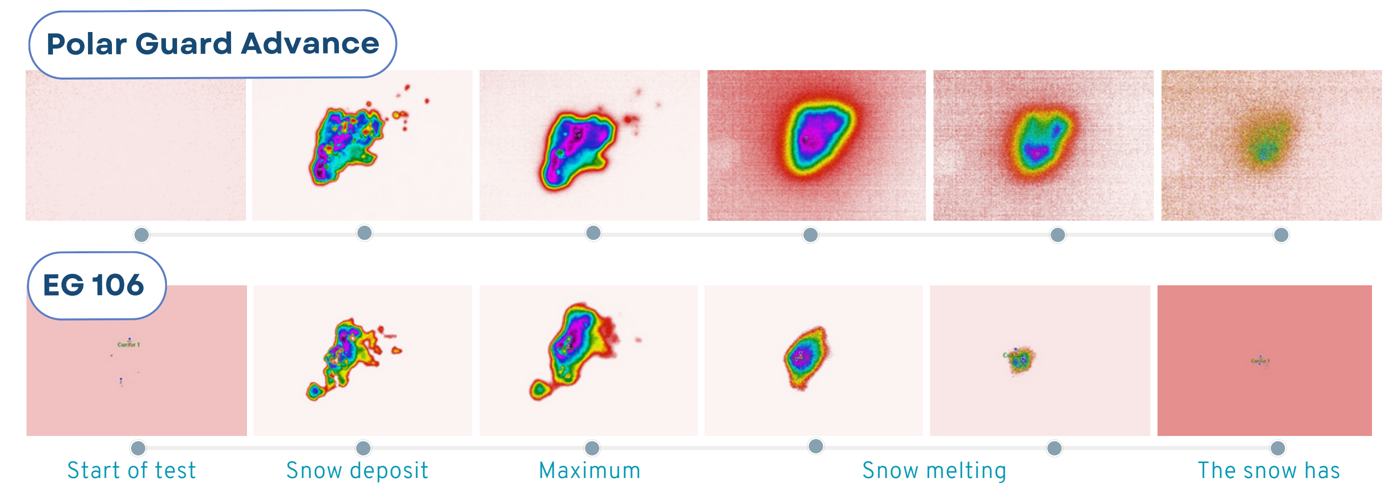
PG : 6 Snow deposit — **EG : 16 Snow deposit**



This highlights the degradation in performance of each fluid

To better visualize this phenomenon, a thermal analysis of the first snow deposit is presented





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Conclusion and Perspectives

- This research will provide new measurements and information on artificial snow, which should lead to the development of new correlated tests on artificial snow.
- The rheological characterization of aircraft anti-icing fluids still needs to be developed, with the industrial standard only requiring the measurement of viscosity, surface tension, and pH for these fluids.
- Studying the aerodynamic performance of fluids with different glycol concentrations at various temperatures will help us better characterize the endurance of the studied fluids.
- An improvement of the snow machine will be carried out during this project