Climatic Wind Tunnel **Vienna**

Quality in any weather

RAIL TEC ARSENAL

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Rail Tec Arsenal – **a success story**

Rail Tec Arsenal (RTA) is an internationally active independent research and testing institute for rail and road vehicles, aircraft and technical equipment exposed to extreme climatic conditions.

As a world-wide recognised centre of expertise for climatic tests, RTA operates **two modern climatic wind tunnels** (CWT) in Vienna with the aim of optimising thermal comfort in mass transport vehicles and improving the availability and safety of systems in industrially sensitive areas.

In 2013 the facility was expanded to include an icing rig for cloud simulation, a high-performance exhaust system and a kerosene tank for permanent aircraft fuel supply. In 2016 the icing rig was equipped with systems for simulating freezing rain and freezing drizzle [1]. In addition, an engine mass flow simulation fan system and a force jig were installed for measuring the lift and drag forces with and without ice over a large angle of attack range. The wide range of climatic simulations available and high-level expertise across all transport sectors now also enables RTA to provide the aviation industry with optimal conditions for product development and certification.

The **highly qualified RTA staff** also offers consulting services for the development of optimal testing scenarios. The technical challenges arising during test planning and testing are resolved in close cooperation with customers. The consistent implementation of customer requests and suggestions allows RTA to continuously improve and enhance its service portfolio.

The history of RTA

1961

The **two-chamber vehicle testing facility starts operation in Vienna** after three years of construction. Temperature range -40°C to +50°C at wind speeds of up to 120 kp/h.

1974

The temperature range is expanded to -50°C to +50°C and wind speeds increased to 250 kp/h in order to be able to test high-speed trains such as TGV and ICE.

2003

The new climatic wind tunnel starts operation in Wien-Floridsdorf after two years of construction. The facility can now test rail vehicles as well as busses, trucks and aircraft.

2013

Opening of the icing wind tunnel (IWT): a special icing rig for the simulation of clouds enables icing tests on aircraft components such as wing sections, engine inlets (with running engines), propellers or tail rotors [2].

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Climatic testing expertise – **for the aviation industry**

The **Vienna Climatic Wind Tunnel** operated by Rail Tec Arsenal offers the opportunity to analyse the effects of a variety of weather conditions on vehicles and components under realistic operating conditions. Any kind of weather can be reproduced at the push of a button – from extreme solar radiation to snow, rain, ice and clouds. In combination with wind, load and drive cycle simulation and running engines, it is possible to create extremely realistic test scenarios.

The facility is designed for climatic tests on rail vehicles, but also offers optimal testing conditions for the aviation industry. The availability of an Icing Wind Tunnel (IWT) significantly upgrades these technical capabilities.

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Available **Services**

Cold and hot start tests

The **RTA Climatic Wind Tunnel** permits cold and hot start tests on complete helicopters or small aircraft down to -45°C and up to +60°C and 98% relative humidity in order to test proper functioning of the electronic systems and engines. A modern high-performance exhaust system makes it possible to run the engines for extended periods at extreme environmental conditions to investigate e.g. condensation, ice droplet formation in the fuel tank, clogging of the fuel filter, overheating phenomena etc.

Climatic tests

Improving thermal comfort on-board aircraft is a **key to increasing the attractiveness of air travel**. The air-conditioning system plays a major role in this context. RTA has decades of experience in thermal comfort assessment for rail vehicles and was actively involved in preparing standards in this field.

Ground ice

In airport operation, ground ice requires time and cost-intensive de-icing procedures prior to take-off. RTA can **simulate this weather phenomenon** for the testing and development of de-icing systems.

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Structural tests at **high temperatures and solar radiation**

New materials are continuously developed to reduce the weight of aircraft, while also ensuring maximum stability. High thermal loads may, however, cause deformation and aging of these materials. RTA's CWT can produce high temperatures up to +60°C and solar radiation intensities of up to 1000 W/m² in order to analyse the effect of these conditions on the overall system. Although long-term tests are required for the detailed analysis of aging processes, CWT tests are an ideal method to rapidly identify arising problems like excessive thermal expansion of the material and critical temperatures in load-bearing structures for different materials and coatings.

Component tests **under snow conditions**

Safe functioning of components in different weather conditions is a key prerequisite for ensuring the reliability and availability of aircraft. RTA's CWT can simulate different forms of precipitation such as wet and dry snow, rain and freezing rain in order to be able to test and develop components under reproducible conditions.

Icing tests with **running engines**

Helicopter manufacturers are required to have their engine air intake systems certified. The system must ensure that the engine is supplied with a sufficient amount of fresh air for a period of at least 30 minutes when flying through different cloud types under icing conditions. RTA's facility features one of the largest IWT worldwide, which can simulate flights through different cloud types in a temperature range of -2°C to -30°C with engines running. This unique facility enables realistic simulation of actual flight conditions and has been used successfully in several certification tests together with clients and EASA representatives since 2014.

Icing tests on **wing components**

Aircraft wings are equipped with different anti- and de-icing systems. These systems must be tested for proper functioning, which is usually only sensible at full scale. RTA can test wing segments with a span of up to 3.0m under different icing conditions at speeds up to 80m/s. The IWT is equipped to measure and compare energy consumption and aerodynamic effects at different angles of attack with and without ice accretion.

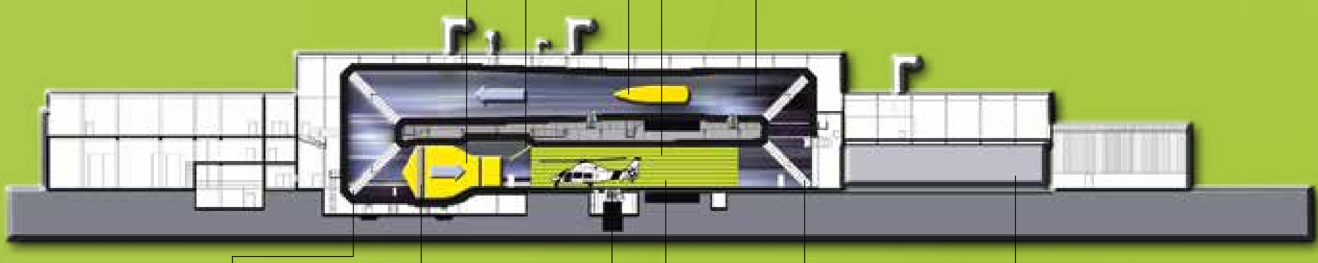
This is achieved by online measurement of the aerodynamic coefficients (lift force and stall angle) across a wide angle of attack range. State-of-the-art equipment such as high speed camera systems, pressure distribution measurements on the wing or high-precision 3D scans enable fast assessment and provide detailed information for efficient development. The service portfolio is complemented by validation of numerical simulations or 3D prints of the measured ice accretion for subsequent aerodynamic analysis. [3]

Icing tests with **engine mass flow simulation**

In addition to testing engine air intake systems under realistic conditions with engines running, the facility also provides the opportunity to realistically simulate engine mass flow using a continuously adjustable fan. This method requires less effort and enables efficient development of air intake systems. The systems can also be used for certification testing. [4]

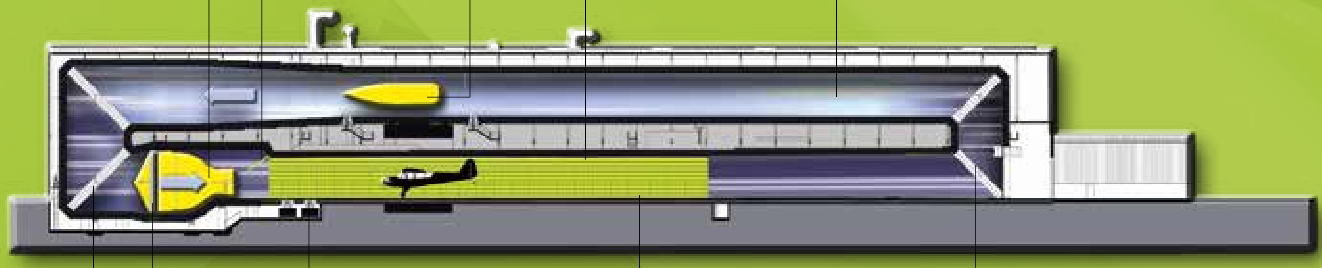
Icing tests on **rotating components**

Main and tail rotors of helicopters are especially prone to icing. Tests carried out in RTA's Icing Wind Tunnel help manufacturers to develop suitable anti- and de-icing systems and have them certified at high rotating speeds. Modern analysis methods such as stroboscope or high-speed cameras provide valuable support in certification and product development.



Climatic Wind Tunnel (CWT)

Description	small CWT	large CWT
CWT contraction nozzle dimensions width / height / area	3.5 m / 4.6 m / 16.1 m²	
Contraction ratio of nozzle	3.98	5.72
Test section width height cross sectional area	4.9 m to 5.1 m 5.9 m to 6.0 m 27.2 m² to 28.7 m²	4.9 m to 5.6 m 5.9 m to 6.2 m 27.2 m² to 32.2 m²
Distance between nozzle / spray bars and start of test section / test area	3.5 m / 11.45 m	
Test section length	33.8 m	100.0 m
Dimensions of lateral solar simulator length / height	30.0 m / 4.3 m	47.5 m / 4.3 m
Maximum wind speed restrictions at low temperatures -20 °C (no load inside CWT) large and small CWT combined -30 °C (1.1 MW load)	30 m/s 30 m/s -	80 m/s 55 m/s 40 m/s
Maximum temperature range	-45°C to +60°C	
Maximum temperature gradient in the temperature range -20 °C to +60 °C	10 K/h	
Relative humidity at temperatures > +10 °C	10% to 98%	
Solar intensity of lateral solar simulator at fixed 30° angle of incidence operating temperature > -10 °C	200 W/m² to 1,000 W/m²	
Solar intensity of front solar simulator **maximum wind speed:** at incidence angles < 45 ° up to 120 kp/h at incidence angles >= 45 ° up to 50 kp/h operating temperature > -10 °C	200 W/m² to 1,000 W/m²	
Mass flow simulation (fan system)	max. 12 kg/s at -30°C with differential pressure of 7 kPa	



Exhaust systems	max. 9 kg/s
Water supply for water brake system	max. 5.5 bar 700 l/min
Kerosene (JetA1) tank for permanent supply	4500 l / max. 550 l/h
General rain, snow and ground icing systems	stationary ceiling-mounted rain and icing system, mobile (snow) nozzles

Icing Wind Tunnel (IWT)

Description	**IWT cross section** 16.1 m²	**IWT cross section** 8.75 m²
CWT contraction nozzle dimensions width / heigh	3.5 m / 4.6 m	3.5 m / 2.5 m
Contraction ratio of nozzle	-	1.84
Distance between spray bars and start of test section	~ 11.5 m	
Test section length	3 m	3 m
Minimum wind speed **Maximum wind speed** Restrictions at low temperatures at -20°C and load of approx. 1.3 MW inside CWT at -30°C and load of approx. 1.3 MW inside CWT	20 m/s 20 m/s 20 m/s 20 m/s	20 m/s 80 m/s 60 m/s 40 m/s
Maximum temperature range for icing cloud simulation	-2°C to -30°C	
LWC at 20 µm MVD at min. wind speed LWC at 40 µm MVD at min. wind speed LWC at 20 µm MVD at max. wind speed LWC at 40 µm MVD at max. wind speed LWC FZDZ MVD < 40 µm LWC FZDZ MVD > 40 µm LWC FZRA MVD > 40 µm	0.25 – 1.20 g/m³ 0.42 – 2.40 g/m³ 0.13 – 0.60 g/m³ 0.21 – 1.20 g/m³	0.49 – 3.50 g/m³ 0.83 – 3.50 g/m³ 0.13 – 0.95 g/m³ 0.21 – 1.00 g/m³ 0.09 – 0.60 g/m³ 0.38 – 0.62 g/m³ 0.29 – 0.46 g/m³
Icing rig water treatment (temperature / conductance)	+2°C to +80°C / 0.06 µS/m	
Icing rig compressed air treatment	up to +80°C	

LWC: Liquid water content, **MVD:** Median volume diameter, **FZDZ:** Freezing Drizzle, **FZRA:** Freezing Rain


Continuous calibration for high reliability

Calibrations according to SAE ARP 5905 [5] have been carried out continuously since the Icing Wind Tunnel was opened in 2013. These calibrations serve to meet the requirements of the guideline as listed in the table below and to prove the long-term stability of the measured values.

	Measurement Instrumentation Maximum Uncertainty	**Tunnel Centerline Temporal Stability**	**Spatial Uniformity**	**Limit Value**
Aerodynamic Parameters				
Airspeed	± 1% [± 1%]	± 2% [± 2%]	± 2% [± 2%]	N/A
Static Air Temperature below -30°C	± 2°C [± 2°C]	N/A [± 2°C]	N/A [± 2°C]	N/A
Static Air Temperature between -30°C and +5°C	± 0.5°C [± 0.5°C]	± 0.5°C [± 0.5°C]	± 0.5°C [± 1°C]	N/A
Flow Angularity	± O/R° [± 0.25°]	N/A	± O/R° [± 0.2°]	N/A[2]) [± 0.3°]
Flow Turbulence				
(Air pressure-Off)	± 0.25% [± 0.25%]	± 2% [± 2%]	< 2% [< 2%]	2% [2%]
(Air pressure-On)	± 0.25% [± 0.25%]	± 2% [± 2%]	< 2% [< 2%]	5% [5%]
Pressure Altitude	N/A [± 50m]	N/A [± 50m]	N/A	N/A
Cloud Uniformity Parameters				
Liquid Water Content	± 10% [± 10%]	± 20% [± 20%]	± 20% [± 20%]	N/A
Median Volume Diameter	± 10% [± 10%]	± 10% [± 10%]	N/A	N/A
Relative Humidity	± 3%	N/A	N/A	N/A

Values achieved in the IWT, [ ] requirements according to SAE ARP 5905, **N/A:** not available, **O/R:** on request

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RTA is an accredited testing body according to EN 17025 and thus guarantees regular calibration of all physical parameters in accordance with recognised quality criteria. In addition, random measurements are carried out prior to each certification test to verify the calibration results.

The calibration curves for the median volumetric droplet diameter and liquid water content of the clouds to be simu-lated are shown in Figures 1 and 2 by way of example. **Fig. 1** shows a comparison of measured droplet sizes (MVDs) compared to the calibration curve. **Fig. 2** depicts the liquid water content values measured over the past three years compared to the calibration curve, with the maximum permissible deviation marked in grey.

RTA ensures continuous data acquisition and records the tests with photos and videos to document the proper functioning of the test facility. All measurement data and records are archived for at least 10 years for later retrieval and verification. All relevant calibration documents are available on request.

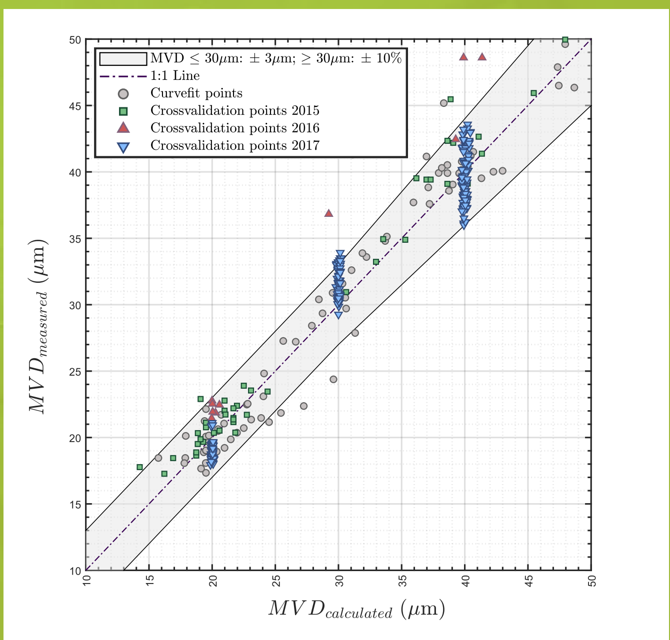

Fig. 1: Comparison between measured droplet sizes and theoretical values according to the calibration curve; maximum permissible deviation marked in grey.

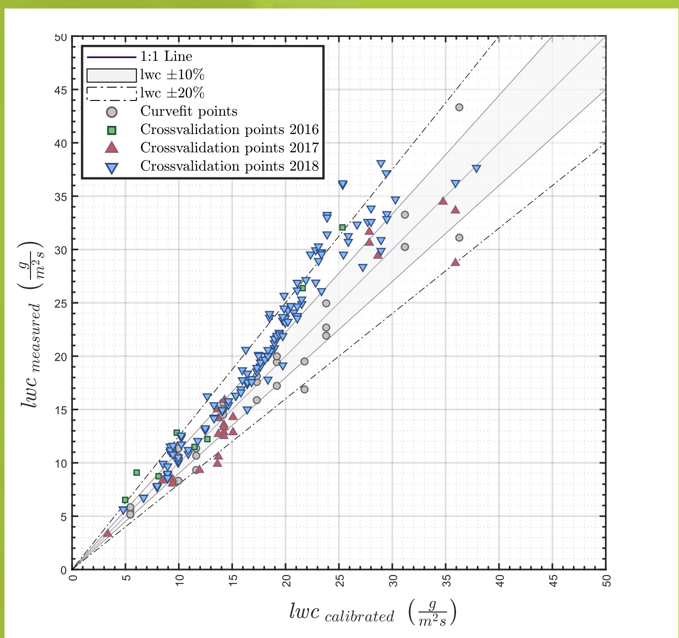

Fig. 2: Comparison between measured liquid water contents and theoretical values according to the calibration curve; maximum permissible deviation marked in grey.

Continuous **research developments**

RTA is involved in numerous research projects in the field of aviation and can therefore constantly optimize and expand its services. Inspired by industry needs, existing capabilities are constantly improved and new opportunities are created. The interaction of industrial requirements, a unique facility, enthusiasm at work and decades of experience in climatic simulation offer the best prerequisite for pioneering innovations.

RTA is open to all research projects that make a major contribution to the industry or help to extend and improve RTA's service portfolio.

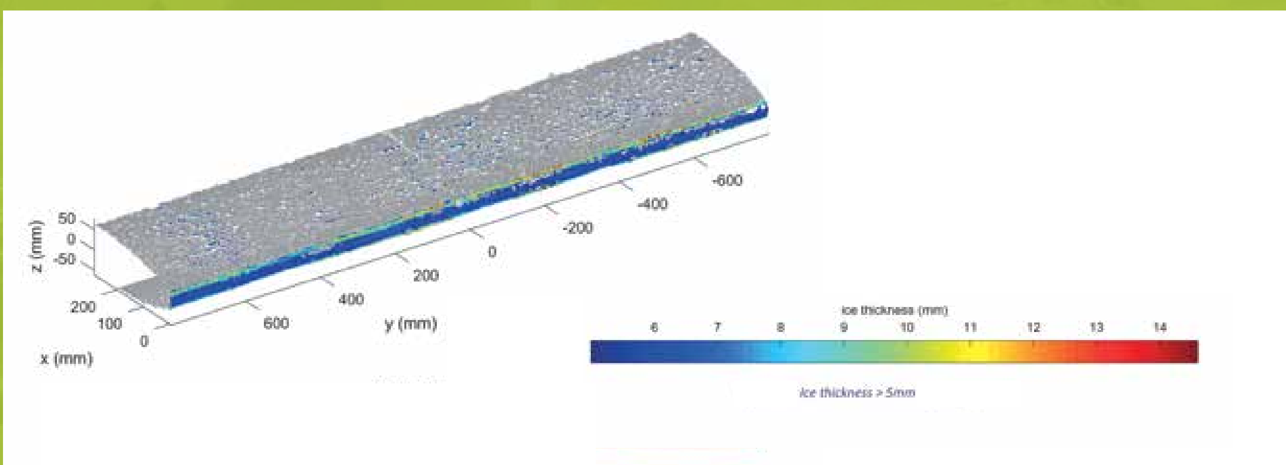

Fig. 3: 3D Scan of overall ice thickness of a freezing rain ice accretion (FZRA), ©AIIS

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Open to **new challenges**

RTA defines new requirements together with customers in order to provide the basis and testing capabilities required for future standards. This enables efficient certification throughout the year, independent of the prevalent climatic conditions, as well as time and cost-efficient product development under reproducible conditions.

RTA is continuously expanding its expertise in the artificial production of all kinds of precipitation at different ambient temperatures in the Climatic Wind Tunnel. The ultimate aim is to offer a one-stop test facility for a wide range of relevant climatic conditions across all transport sectors, including aviation.

Snow, for example, a safety-relevant form of precipitation for all means of transport, cannot currently be produced artificially to a quality standard required for aircraft certification. RTA is therefore involved in the EU H2020 GENESIS research project to investigate and develop new testing capabilities for the simulation of snow conditions (snow generation close to natural snow properties), to define a common calibration methodology and to calibrate test facilities for the required scientific basis and test scenarios. In this project, RTA can draw on decades of experience in snow production and testing for other transport sectors.

The simulation of supercooled large droplets (SLD) is required by EASA CS 25 Appendix O and FAR Part 25 Appendix O. Over the past few years, icing wind tunnel operators have been faced with the challenge of developing the relevant simulation capabilities [6 and 7]. As part of a nationally funded research project, RTA has developed the first system [8] worldwide that is able to provide the required simulation conditions. It is planned to further expand and improve the system in order to be able to ultimately carry out certification tests on aircraft or helicopter parts.

List of relevant publications:

[1] “Development of SLD Capabilities in the RTA Icing Wind Tunnel,”
Hermann Ferschitz, Otto Bucek, Michael Wannemacher, Florian Knöbl,
Wolfgang Breitfuß, SAE International Journal of Aerospace.
September 2017, Vol. 10 Issue 1, page 12-21. 10p. (or ISSN: 1946-3855)

[2] „Neuer Vereisungs-Wind-Kanal für die Luftfahrt“,
Ingenieurspiegel March 2015, page 14

[3] “Aerodynamic assessment of complex 3D ice shape replications,”
Reinhard Puffing and Wolfgang Hassler FH Joanneum GmbH,
Thomas Neubauer and David Kozomara Austrian Institute for Icing Sciences,
Hermann Ferschitz Rail Tec Arsenal

[4] “Helicopter engine air intake Icing Wind tunnel certification tests”
K. Lammers, Stefan van ‘t Hoff, H. Ferschitz, M. Wannemacher,
presented at 44th European Rotorcraft Forum, Delft, The Netherlands,
19-20 September, 2018

[5] SAE International Aerospace Recommended Practice, “Calibration and
Acceptance of Icing Wind Tunnels,” SAE Standard ARP5905™,
Reaf. September 2015

[6] “Simulation of Water Droplet Cool Down and Freezing at the
RTA Icing Wind Tunnel Vienna “ Master Thesis, Andreas Rapf,
13 September 2017, Department Aviation at FH Joanneum Austria

[7] “Aerodynamic Comparison of Freezing Rain and Freezing Drizzle
Conditions at the RTA Icing Wind Tunnel,” Wolfgang Breitfuß,
Hermann Ferschitz, Michael Wannemacher, Florian Knöbl,
SAE International Conference on Icing of Aircraft, Engines, and
Structures, Minneapolis MN, USA June 17-21 2019

[8] “Device for producing water drops of a determined size”
patent no. AT 519015 B1 2018-03-15 (published 15.3.2018) and
EU patent no. 20544WO-WO_2018107191_A1 (published at 21.6.2018)

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