System Interface Document BIWT

- Information and guidelines for customers -

Technische Universität Braunschweig
Institut für Strömungsmechanik
Braunschweig Icing Wind Tunnel (BIWT)
Hermann-Blenk-Straße 37
38108 Braunschweig

Scope

This document provides the system interfaces for the Icing Wind Tunnel (BIWT) of TU Braunschweig. Details of functional, mechanical and electrical interfaces are described in order to facilitate installation, testing and acquisition of test data from test articles at TU Braunschweig. For more information, specific requests or price quotation, please contact us directly.

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Acronyms

App. C Appendix C., EASA: CS-25, Amendment 18
App. O Appendix O., EASA: CS-25, Amendment 18
AC Alternating Current
DC Direct Current
IWC Icing Water Content
LWC Liquid Water Content
MMD Median Mass Diameter
MVD Median Volume Diameter

1 System Description

The BIWT is a small-scale facility that was built in 2014 to perform basic and applied research of icing at a university level. This wind tunnel provides a controlled testing environment for various applications, like fixed wings or wind turbines, but also automotive topics. Figure 1 illustrates the wind tunnel (marked in blue) and the accompanying systems, which consist of a refrigeration system on 2nd floor (No 4-7) used to cool down the BIWT and a cold room on top of the BIWT used for the generation of ice crystals (No. 8). All models are to be mounted in the test section of the tunnel, for which some more detailed photos are included at the end of this document. A quick cool-down time of under 30 minutes, allows to change conditions rapidly. The icing wind tunnel provides a test section of 50cm wide x 50cm high (20"x20") with the following capabilities:

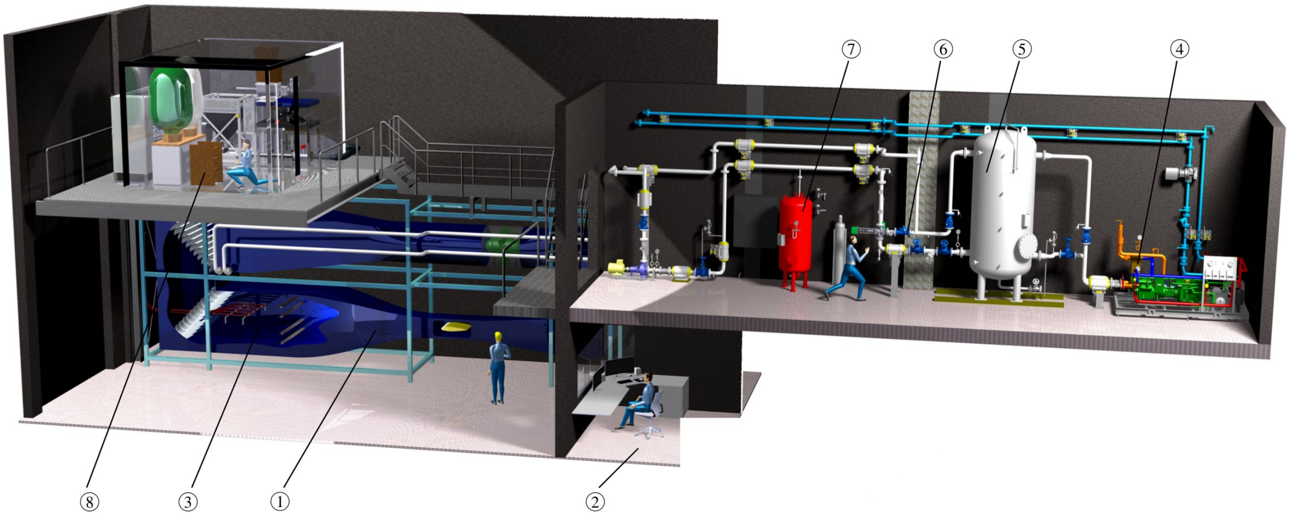

Figure 1: TU Braunschweig Icing Wind Tunnel, General Layout

- A spray system is available which allows for: 10µm to 60µm droplet size (MVD) and LWC between 0,1 g/m³ and 2 g/m³, LWC depending on MVD, see figures 2 and 3
- An extension of the system has been developed for bimodal droplet size distributions offering App.0 capabilities
- Ice particles with MMD of 80µm and IWC between 3 and 19 g/m³
- Air temperature between -20°C and +30°C (-4°F to +86°F)
- Sustained speed up to 40m/s (90 mph)

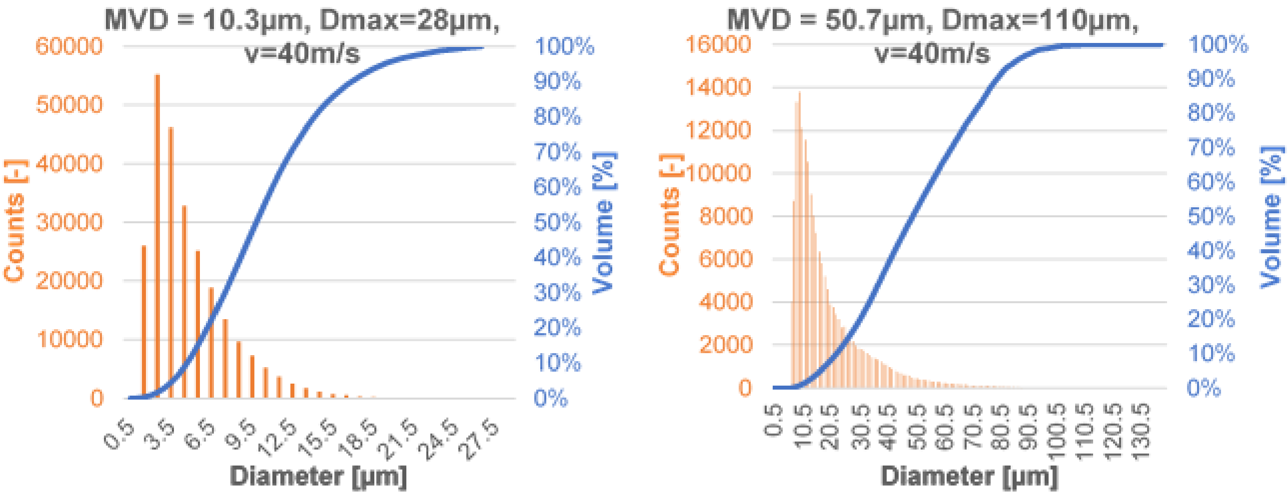

Figure 2: Exemplary droplet size distribution App. C

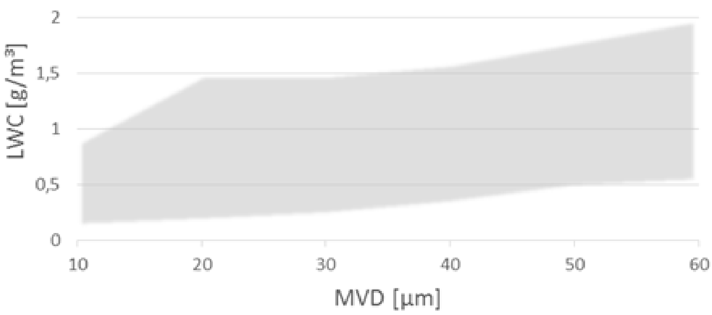

Figure 3: Calibrated droplet range App. C

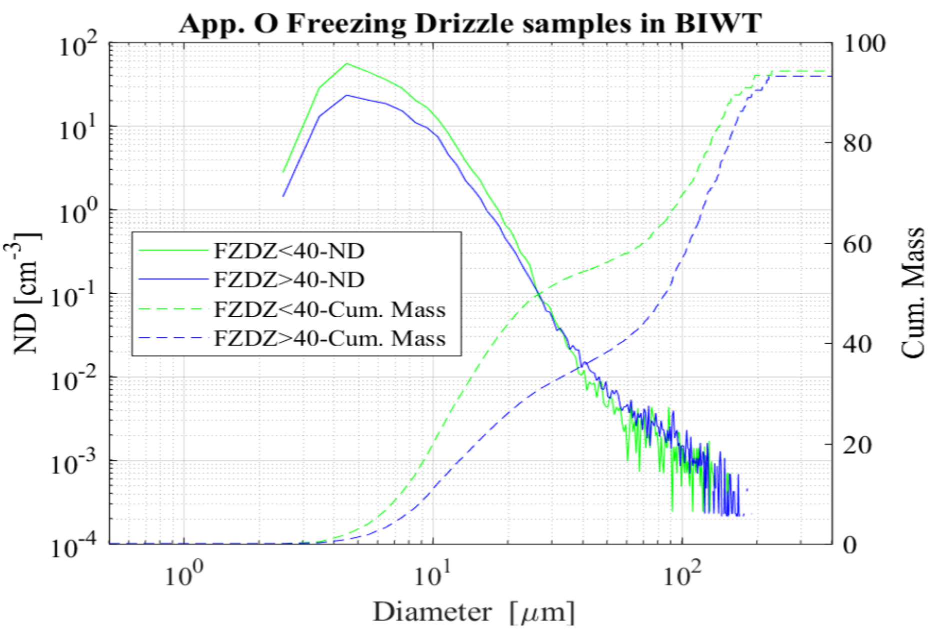

Figure 4: Exemplary droplet size distribution App. O

2 Mechanical Interface

Weight

The maximum mass allowed for models to be tested is 50 kg. Heavier models should be discussed with the TUBS team.

Dimensions

The overall dimensions of the test section are:
Length: 150 cm
Width: 50 cm
Height: 50 cm
To maintain a constant tunnel speed of 40m/s at all icing conditions, the model dimensions should not exceed the maximum blockage ratio of 35%. Blockage ratio is defined here as the ratio of the model cross-sectional area to the test section cross-sectional area. The model cross-sectional area includes the test specimen as well as all portions of the holding fixture located inside the test section. It should be noted that the model cross-sectional area changes as the Angle of Attack changes. Setups with a blockage ratio close to 35% might experience reduced tunnel speed in icing conditions. If ice accretes on several parts of the model, it would lead to limitations in running time of the experiments.

Access and mounting options

The test section can be equipped with two different sidewall frame systems providing full access to test section. The original sidewall frame consists of three easily removable glass windows, which provide quick access and good visibility to the model. An additional frame consists of solid inserts - where the wing models are typically mounted on -, and transparent inserts for optical access. Floor and ceiling of test section are also equipped either with glass (for optical access) or solid windows (for model fixation). Please note that floor and ceiling of the test section are not parallel to account for the thickening boundary layer. Models are therefore normally installed horizontally.
A transparent communication between model provider and TUBS project members is obligatory to clarify the mounting and access options.

Fixture to Facility

TUBS will provide guidance on fixture development to customers. A basic system of standardized side windows exists, for which TUBS can provide the corresponding drawings. There already exists a holder for standard canister probes from former test campaigns (see figure 5). If you have special requirements, the institute workshop might build the necessary fixtures. Please contact us directly for details.

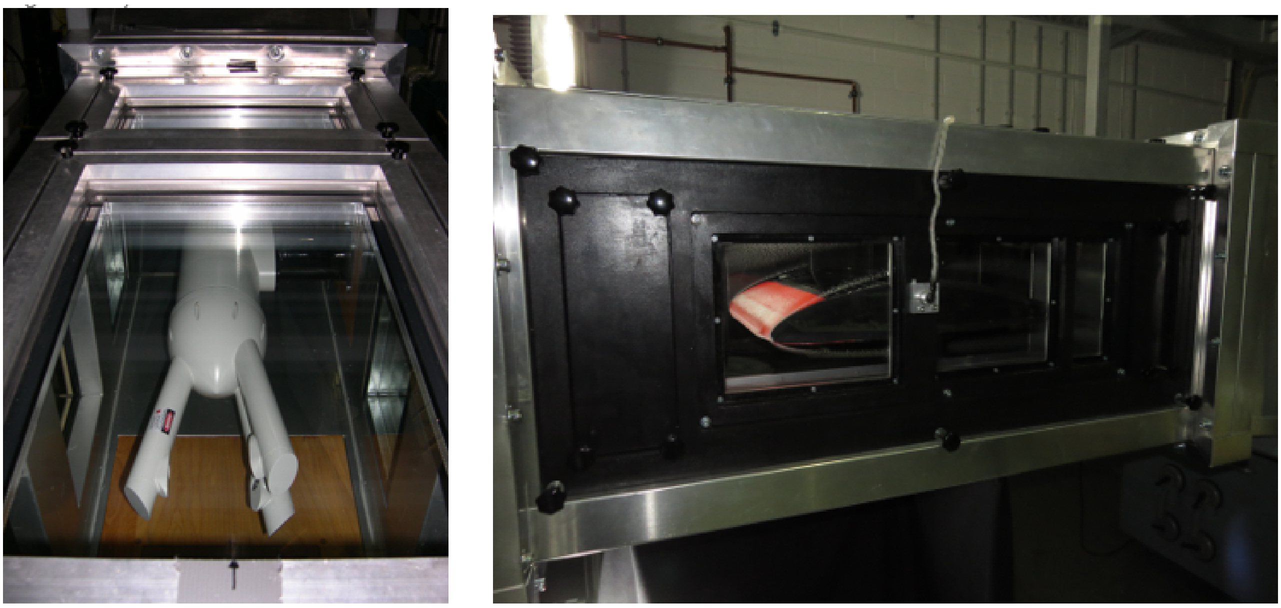

Figure 5: Examples of mounted probes and models

General Dimensions around Test Section

Distance from floor to test section: 950mm
Distance from test section to wall: 1200mm

Figure 6: Test section from different perspectives, left: from the room, right: from behind

3 Electrical Interface

The BIWT electric interface and power supplies are described in table 1 below. Existing mounting holes in the test section can be used for cable routing, additional holes may be added in side windows or top windows. The acrylic glass windows may also be modified to provide sensor and power pass-through ports. If support electronics is placed near the test section (which is recommended), cable length of 2-3m is sufficient. If connection to the control room is necessary, the cable length has to be at least 12m. All cabling inside the model needs to be properly insulated if voltages higher than 24VDC are used, e.g. for heaters. When cooling tunnel and model, condensed water will be present. Access to the inside of models is preferred to ease cleansing and drying. In order to minimize condensation, for example in optical setups, we can provide nitrogen to purge small volumes during testing.

Source	**Description**	**Characteristics**
120 V AC	Distribution Grid Output	120V AC, 1 phase, 50 Hz, 1.5kW max., 1 plug
240 V AC 1 phase	Distribution Grid Output	240 V AC, 1 phase, 50 Hz,16 amp, 8 independent circuits
400 V AC 3 phase	Distribution Grid Output	400V AC, 3 phase, 50 Hz, 16 amp 3 independent circuits
400 V AC 3 phase	Distribution Grid Output	400V AC, 3 phase, 50 Hz, 32 amp 3 independent circuits
400 V AC 3 phase	Distribution Grid Output	400V AC, 3 phase, 50 Hz, 64 amp 1 circuit
Laboratory power supplies	Programmable power supply (DC)	28V DC: Constant Current or Constant Voltage mode several units available: 28VDC at 5A, 30VDC at 30A, 60VDC at 15A and 150VDC at 4A

Table 1: Electrical capabilities of the BIWT

4 Data Aquisition and Monitoring

The BIWT uses a modular digital data acquisition system to record all data during the tests. The main parameters of the tunnel such as static temperature, speed, humidity, etc. are logged with every test. Additional data from customers can be included in the same time-stamped data sets. Also data from the control system, like triggering of the spray nozzles can be forwarded to a customer data acquisition system. Table 2 shows the input channels currently available for customers. The pressure scanner is shared with other wind tunnels at the institute, therefore, it needs to be booked well in advance.

Equipment	Description	Characteristics
General Data Aquisition	Modular Data Acquisition	• 51 channels for RTD temperature sensors (-30°C to +70°C) ,16 bit, 250kS/s • 32 analog inputs, 0-10V, 16bit, 250kS/s • 16 digital inputs/outputs, 30VDC
Pressure Systems PSI	Ethernet Pressure Scanner	• 300 to 1000 samples/channel/second depending on number of channels • up to 200 channels available • ± 0.05% full scale long term accuracy • 0 - 5 psi pressure range • Temperature compensated pressure sensors

Table 2: Sensor capabilities of the BIWT

Various pressure probes (Pitot, Prandtl, Multi-hole, etc.) are available, as well as various traverse systems (mechanical and electrical). A host of cameras and video cameras are available during the tests. Special equipment like high-speed-camera is available, but has to be booked well in advance, too.

Boundary conditions

Table 3 summarizes the test conditions that can be tested in the BIWT. The cloud parameters are obtained from our previous calibration tests.

Parameter	Range
Velocity	Wind speeds range from 0-40 m/s (0-90 mph)
Temperature (static)	-20°C to 30°C (-4°F to 86°F), Microprocessor controlled within ± 1°C
MVD (droplets)	10-60 µm + App. O
LWC (droplets)	0.1 - 2.0 g/m³
MMD (ice crystals)	≈ 80 µm
IWC (ice crystals)	3-19 g/m³
Relative humidity	100% (not controlled during tests)
Static pressure	≈ surrounding (not controlled during tests)

Table 3: Boundary conditions of the IWT

5 Cold Room

An additional cold room is available. It is primarily used for the snow generation system, but is open for customer usage as well. It is capable of temperatures as low as -18°C / 0°F. It is located close to the BIWT, making it possible to transfer materials and collect ice shapes directly from the tunnel with only short exposure to temperatures above freezing. If not needed for snow production, a special freezer with temperatures as low as -50°C / -58°F can be used for storage of frozen probes.

6 Testing Procedure

In order to plan measurements ahead, it is vital to know how the testing at our facility is conducted. Naturally, this depends on many aspects, however a few guidelines can be given here. Working hours at the BIWT are from 8.00 o'clock to 17.00 o'clock, with extension possible, if testing demands. Cooling down the tunnel for the first time a day takes up to 45 minutes, depending on requested tunnel temperature. It is preferred to begin with measurements at higher temperatures and cool down during the course of the day. For every test point we take some 5 minutes to establish constant temperature and velocity, especially after changing the settings. If needed, a quick opening of the test section and de-icing of the model or probe after a test can be done in 5-10 minutes, depending on the severity of accretion. A de-icing of the tunnel is needed at least once a day, taking around 30 minutes. Preferably this is done over the lunch break to minimize downtime.

The amount of tests per day strongly depends on the boundary conditions. Doing short (1-2 minutes) measurements at constant tunnel speed and temperature with only the spray settings changing, more than 20 tests per day are possible. Doing long-term tests (30 minutes) or tests with very high LWC at different tunnel temperatures might cut that to only 5 or 6 tests per day. For doing tests with injection of ice crystals the number of tests per day is generally lower, as working with the ice crystal injection system is more time-consuming than with the spray system. A discussion of the test points prior to the test campaign is highly recommended.