The Icing Wind Tunnel of COPPE/UFRJ

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COPPE/UFRJ

Historical perspective

• 1st Workshop on Aviation Safety
June 1st and 2nd, 2010
COPPE/UFRJ

• 2nd Workshop on Aviation Safety
May 31st and June 1st, 2011
COPPE/UFRJ

• 3rd Workshop on Aviation Safety
May 31st and June 1st, 2012
COPPE/UFRJ

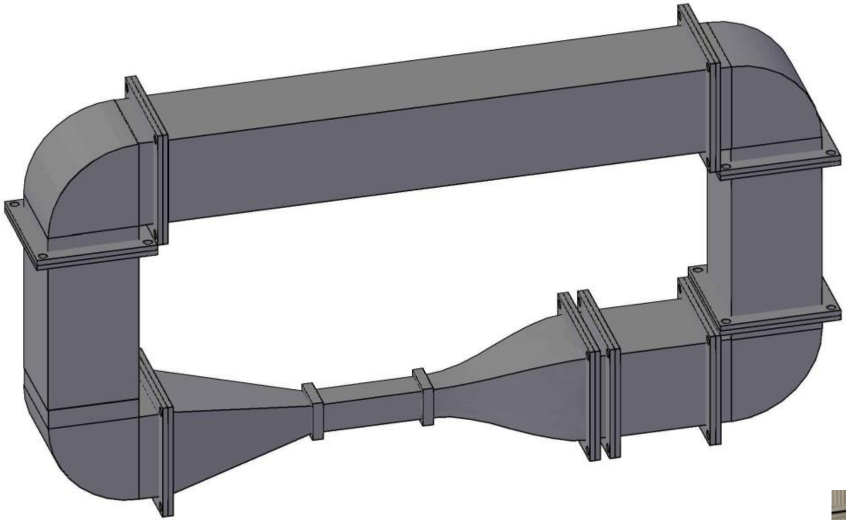
The Federal University of Rio de Janeiro gathered a group of scientists from academic institutions in Brazil, United States of America and France to establish an open scientific forum for discussing and exchanging information on aviation safety in general.

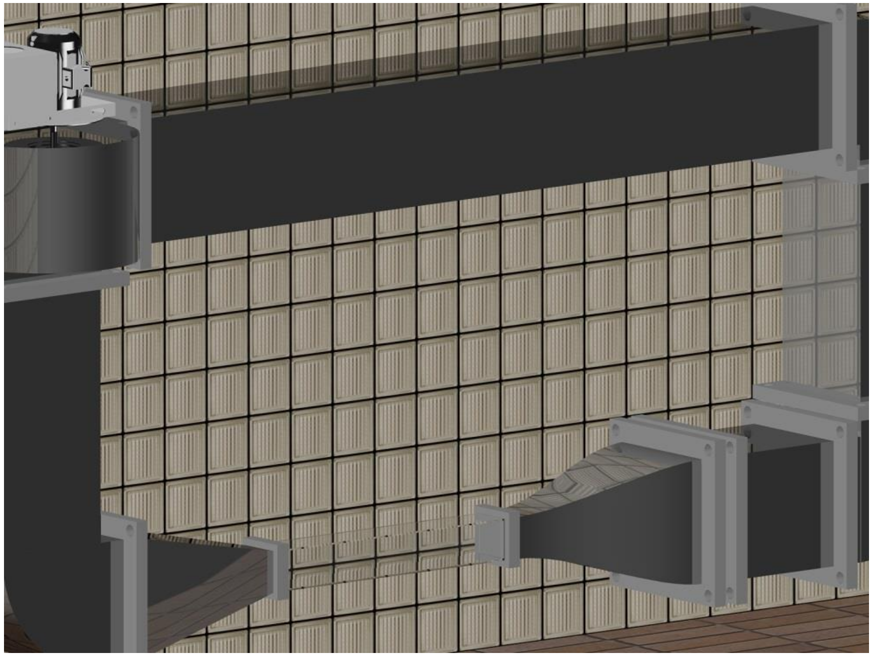
http://www.segurancaaerea.coppe.ufrj.br

2011/5/24 Bob Breidenthal <breident@aa.washington.edu>:
Dear Renato,

I enjoyed reading your paper. Very nice work.
I look forward to learning more about your new technology airspeed probes.
I think a good future step would be to build a small icing tunnel in Rio.
It would also complement Atila's two-phase flow work for Petrobras.
An icing tunnel need not be big to handle the pitot tube problem. A conventional rule for wind tunnels is that the flow blockage should be less than 7% of the cross sectional area of the test section. Since the pitot tube is so small, the tunnel could be, too.
As you undoubtedly know, Mike Ungs had called me some time back to discuss a possible icing experiment in the US, but apparently that project did not work out.
The icing tunnel would be useful for both conventional pitot tubes and your new technology probes. Balmy Rio could become the world center for airspeed probes in general, and icing performance in particular.
Best regards,
Bob

Wind tunnel design, September 2011





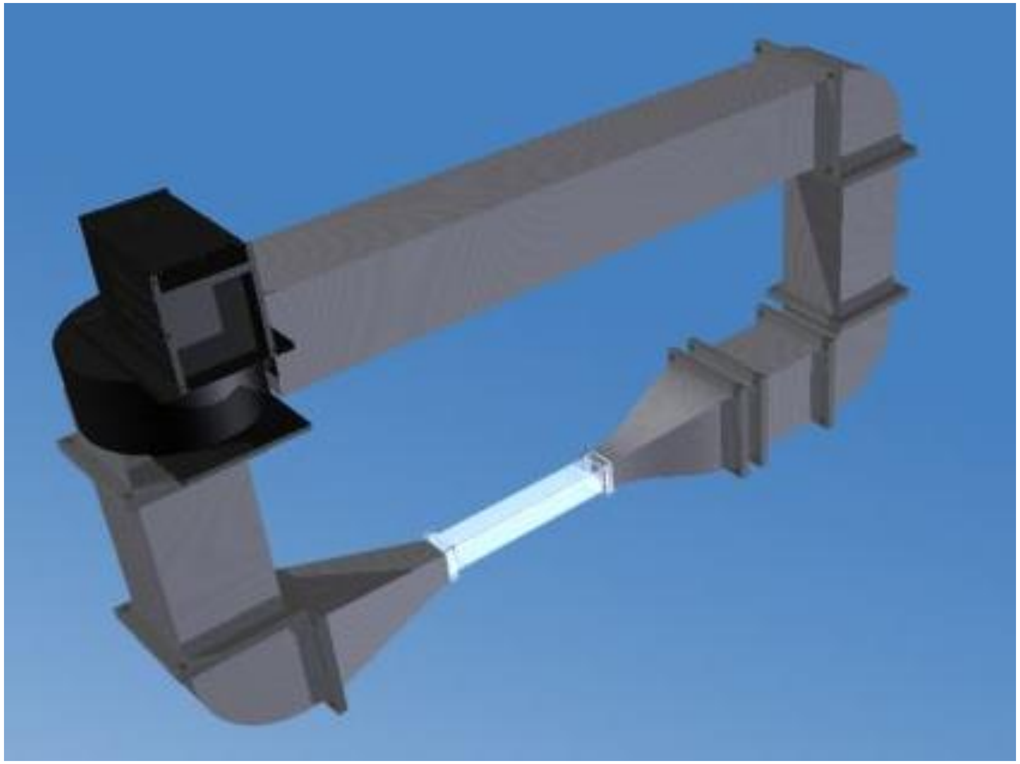
Icing Wind Tunnel: November 2012

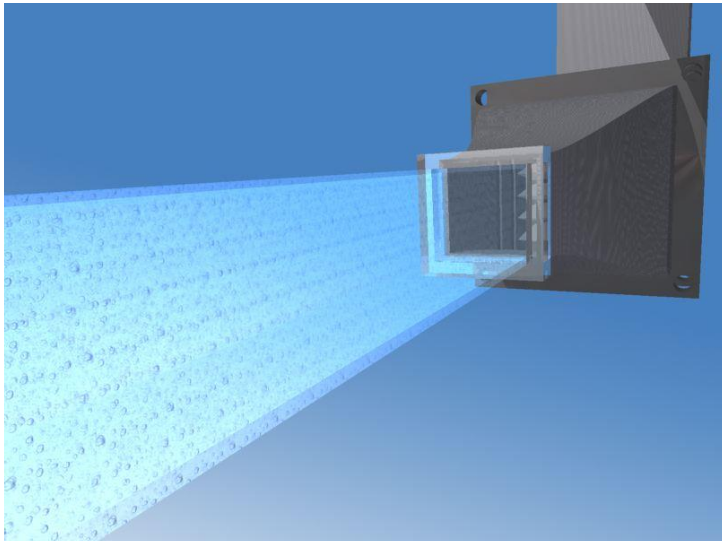
Icing Wind Tunnel: August 2013

Icing Wind Tunnel: 26 May 2014

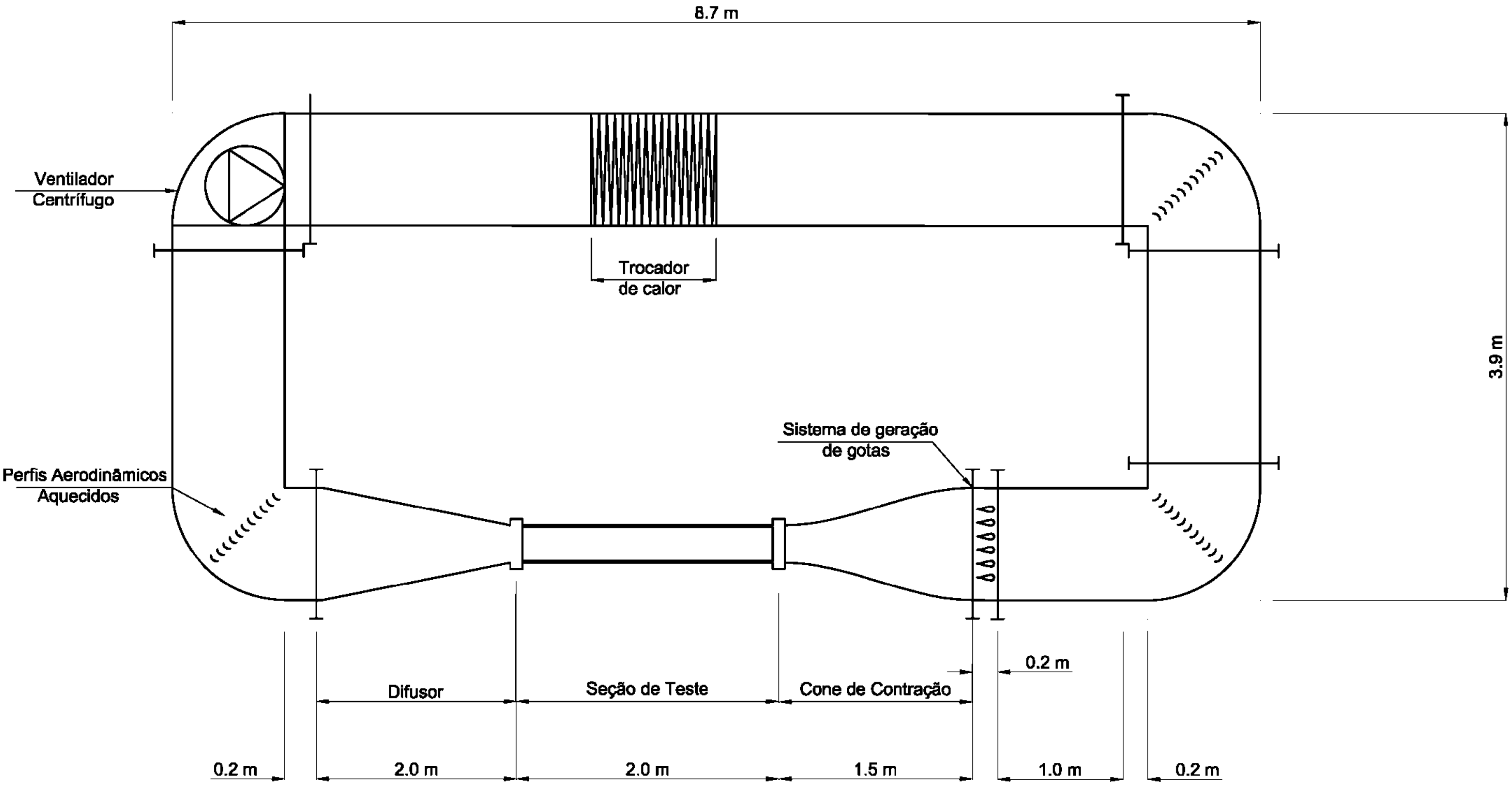
Icing Wind Tunnel: 28 May 2014

Wind tunnel design, September 2011





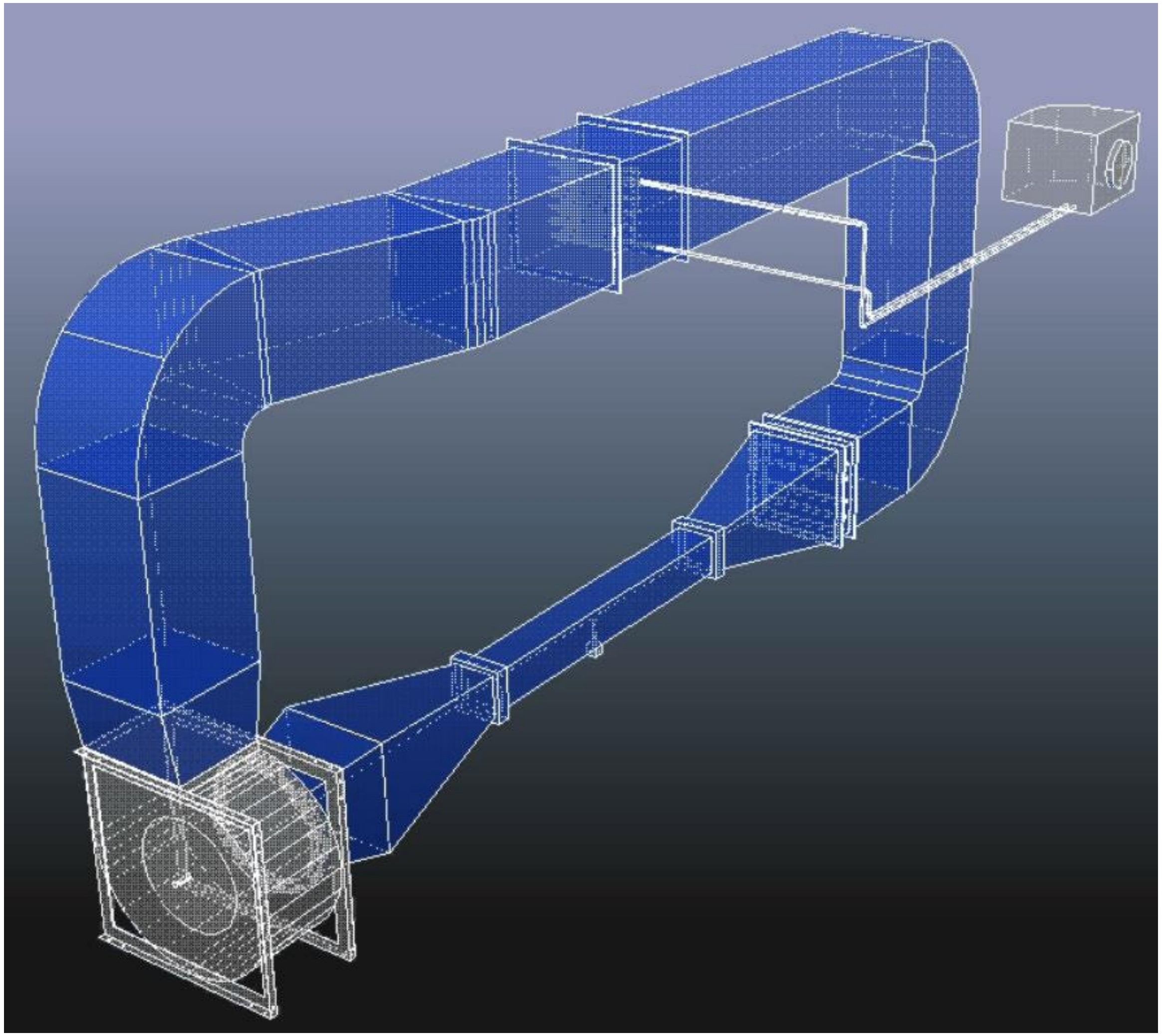
Wind tunnel design, September 2011



General characteristics of the project

- Closed and vertical circuit
- Dimensions: 7.5 m length x 3.5 m heigth
- Stainless steel piping
- Insulation: foam and fiber glass
- Velocity range: 0 to 58m/s
- Mach number: 0.2
- Temperature range: -20 ^{o}C to 25 ^{o}C

Design refinement, 2012



As built

- Closed and vertical circuit
- Dimensions: 8.7 m length x 3.9 m heigth
- Cross section: 0.8 x 0.8 m
- Stainless steel piping
- Insulation: fiber glass covered by a white PVC film
- Velocity range: 0 to 58m/s
- Mach number: 0.2
- Temperature range: -20 oC to 25 oC

As built

Propulsion system

- Limit load centrifugal fan, single suction
- Flow rate: 5.23 m^3/s
- Pressure: 2775 Pa
- Power supply: 22.32 kW
- Dimensions: 1,40 x 1,20
- Weight: 130 kg
- Controlled by a frequency inverter

Icing system

Cooling and heating system:

- Temperature of the flow inside the test section: – 20 ^{o}C to + 25 ^{o}C
- Evaporator unit: maximum cooling load of 19.1 kW
- Pressure drop: 56 mmca
- Working fluid: R-404a
- Condenser: two units located on the roof, 10 kW each
- Two adjustable power sources 1kW AC each for heating the Pitot tube and heated test section glass
- One adjustable power source 7kW AC for anti-icing vanes located upstream of the fan inlet

Icing and heating system

Condenser units

Guiding vanes

Flow conditioning along the curves:

• Straighten and smooth the flow downstream of the corners

• Dowstream of the test section the guiding vanes are used as fins for heating the droplets and removing the water content

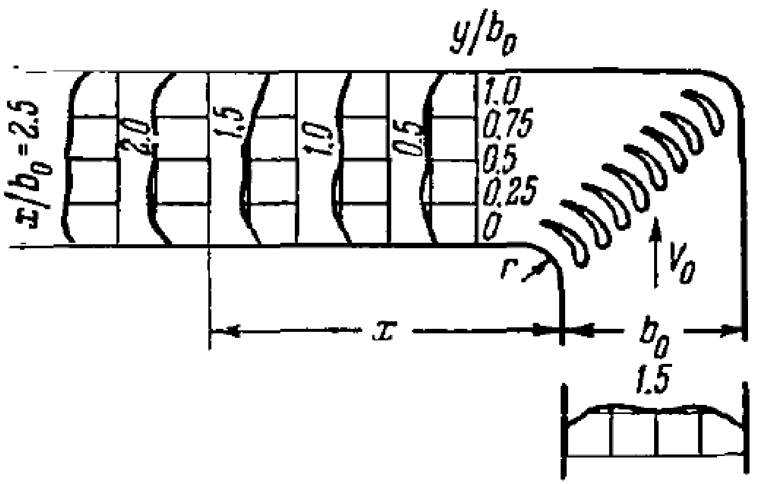


FIGURE 2.27. Velocity-head distribution downstream of a corner fitted with guide vanes. $\left(\frac{r}{b_0}=0.1;\ \frac{t}{b_0}=0.25\right)$.

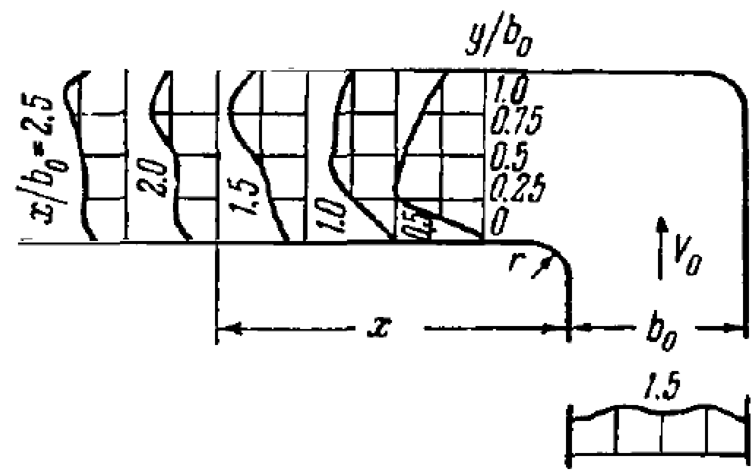


FIGURE 2.28. Velocity-head distribution downstream of a corner without guide vanes. $\frac{r}{b_0}=0.1$.

Figures from Gorlin and Slezinger, Wind tunnels and their instrumentation, 1964.

Screens and honeycomb

Flow conditioning along the straight sections :

• The honeycomb straighten the flows by breaking up large vortices and also reduces the spread of longitudinal velocities.
• Screens are used to damp turbulence and to increase the uniformty of the velocity distribution
• Settling chamber for turbulence decay

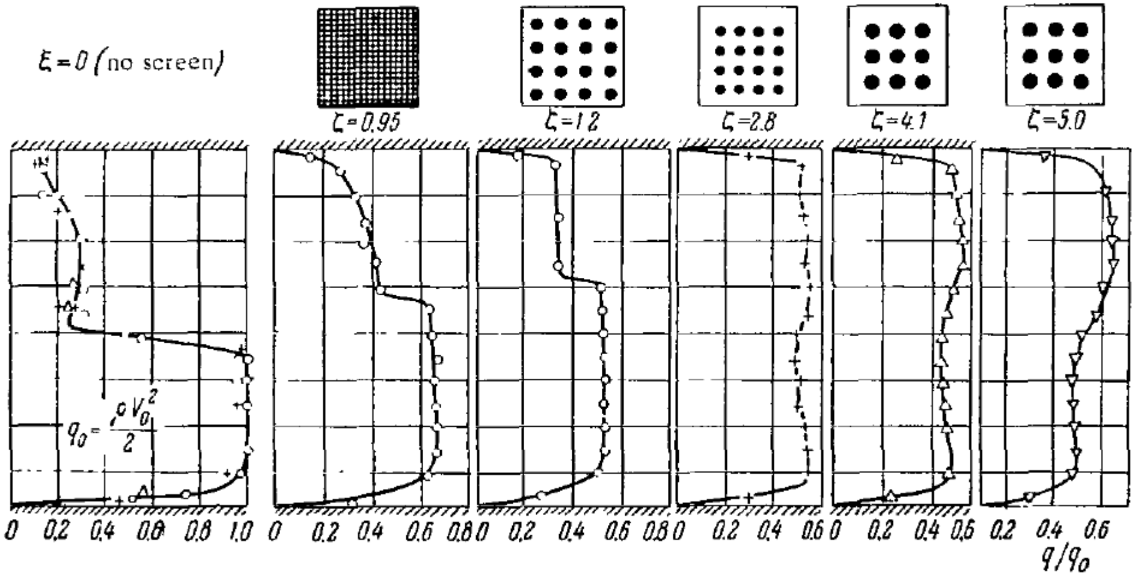
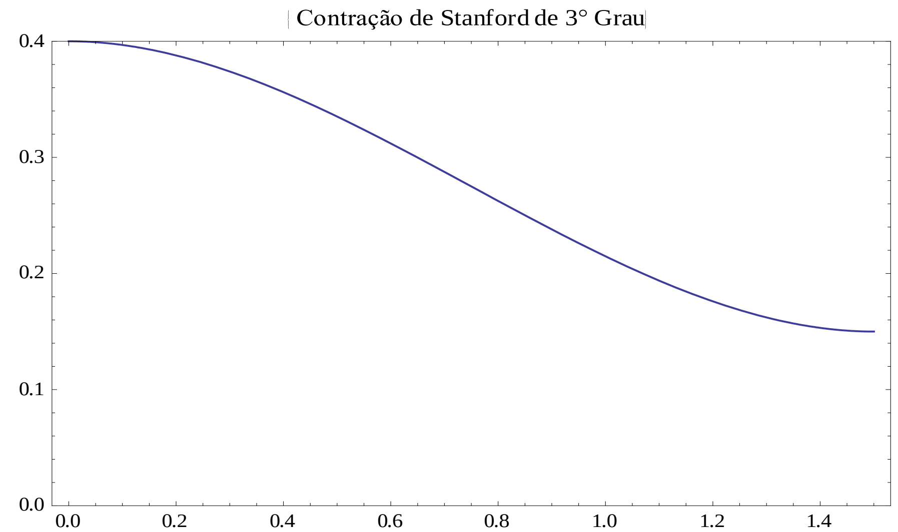


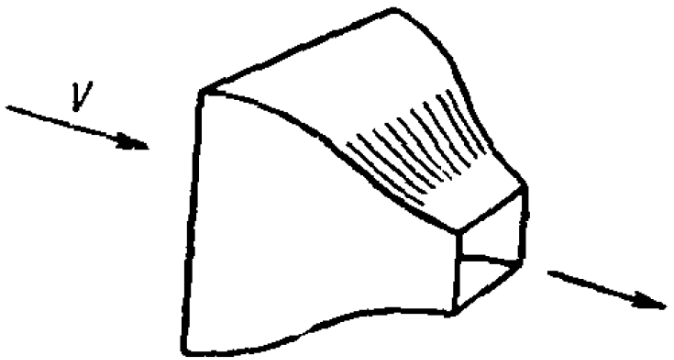
FIGURE 2.29. The smoothing effect of screens having different resistance coefficients.

Nozzle

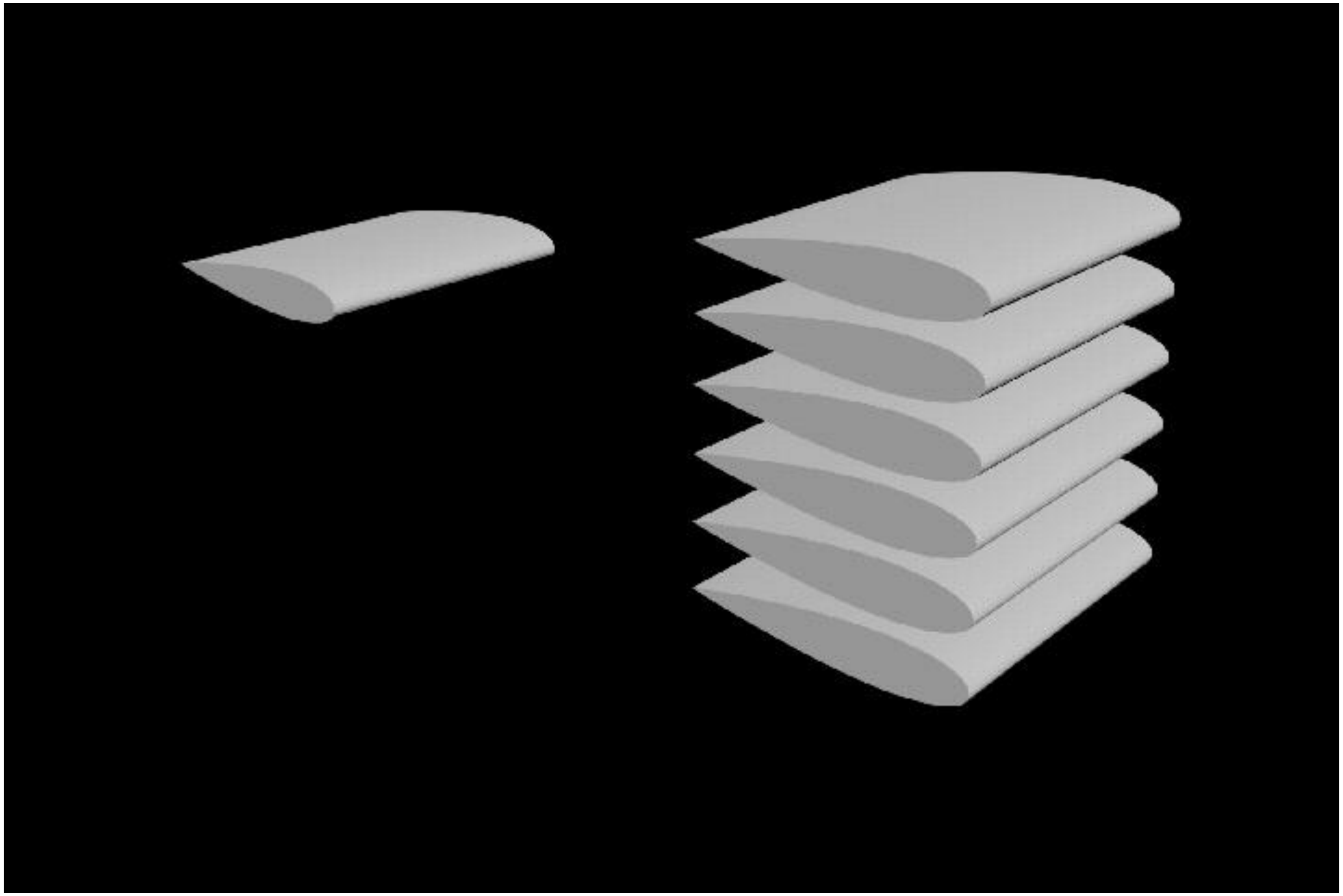
Conditioning the flow for the test section:

• The nozzle profile was designed to provide uniform velocity distribution at the outlet
• Nozzle length: 1.5 m
• Nozzle profile: 3rd degree polinomial curve
• Contraction ratio: 7





Spray bar system

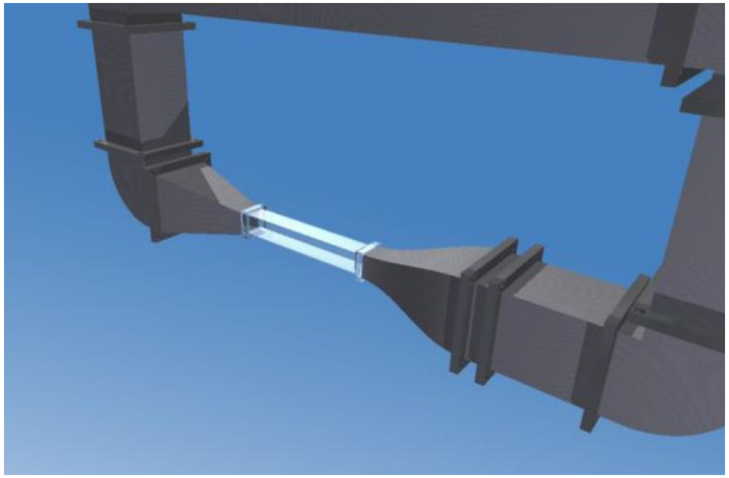


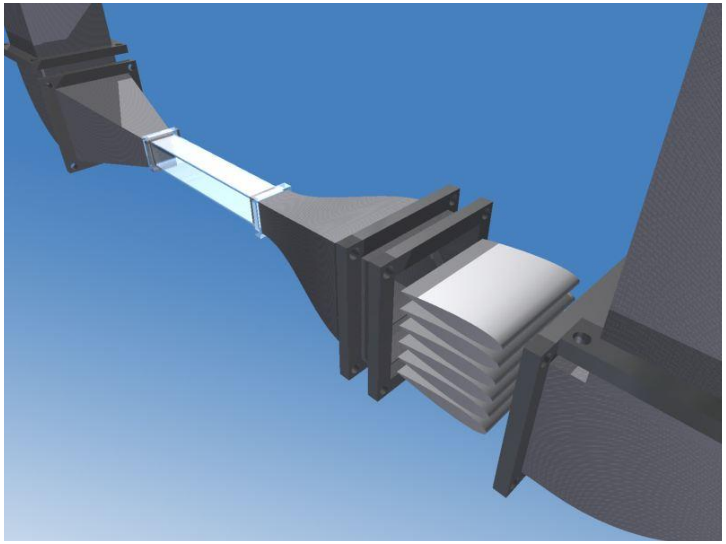
http://www.turbulencia.coppe.ufrj.br/tunel/motivacao.html

Spray bar system

Water atomization:

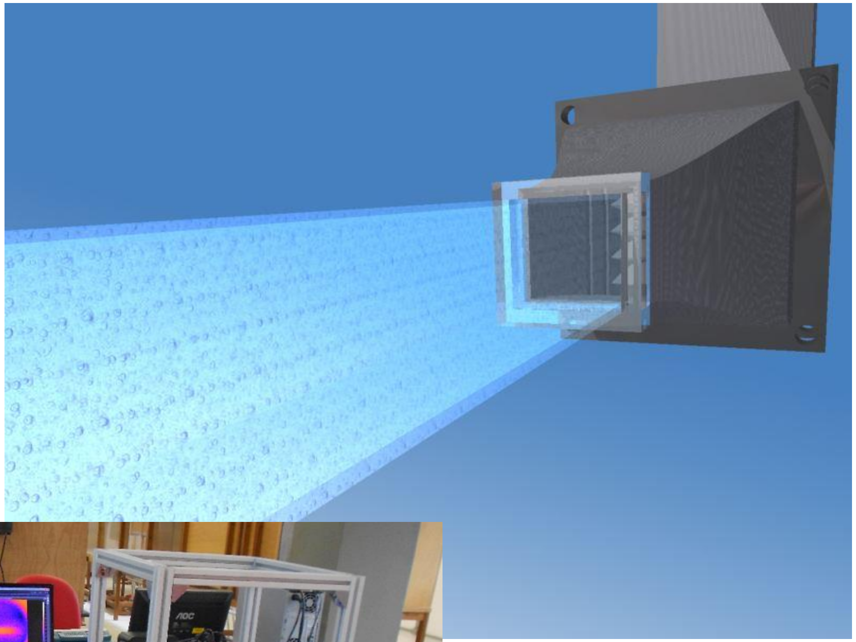
- Droplet size: 10 to 120 microns
- Liquid water content: 0,25 to 12,0 g/m3
- Six horizontal spray aerodynamic bars
- Twenty nozzles individually controlled by water and compressed air feeding lines
- Accurate water temperature control in order to avoid early ice formation

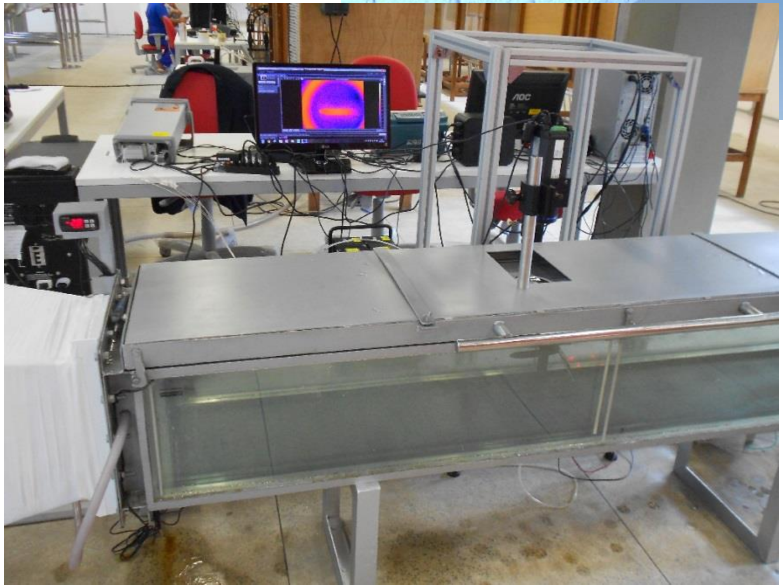




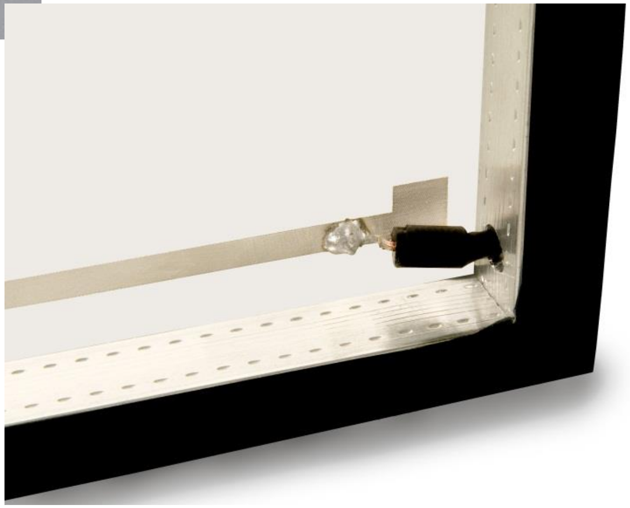
Test section

- Dimensions: 300 mm x 300 mm
- Length: 2m
- Velocity range: 0 a 58 m/s
- Wall heating for visual inspection of the flow
- Triple glass plates





Test section



Diffuser

• Gradual conversion of kinetic energy into pressure energy
• Prevent excessive friction due to high flow velocities along the whole length of the wind tunnel
• Divergence angle : 7°

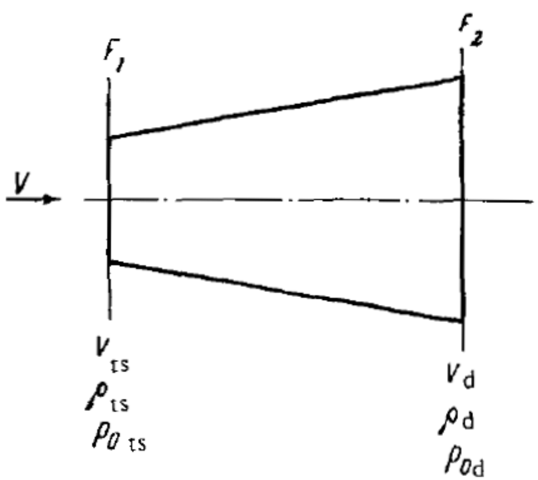
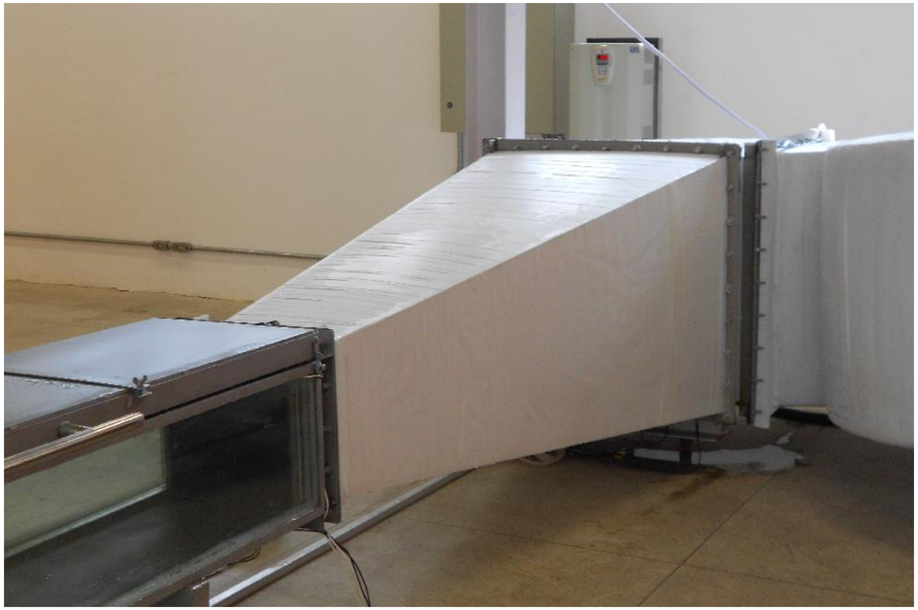
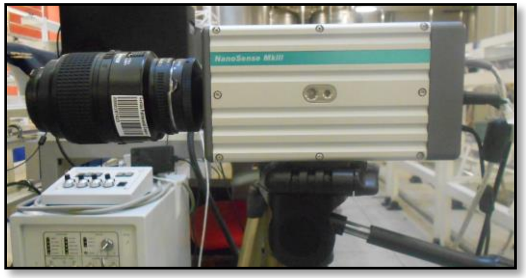
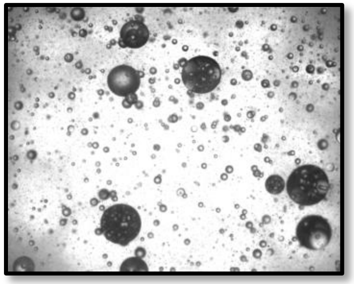


FIGURE 2. 20. A diffuser.

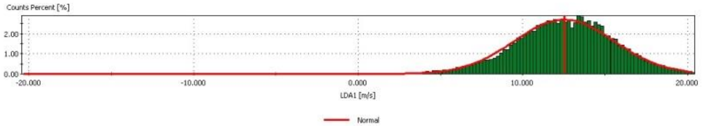


Instrumentation

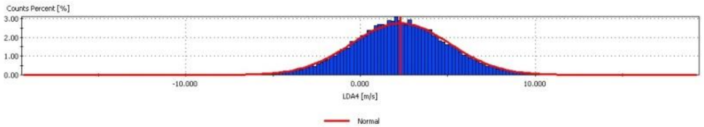




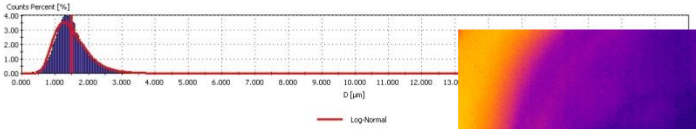
Flow measurement:
- LDA
- PIV
- HWA
- Pitot tubes

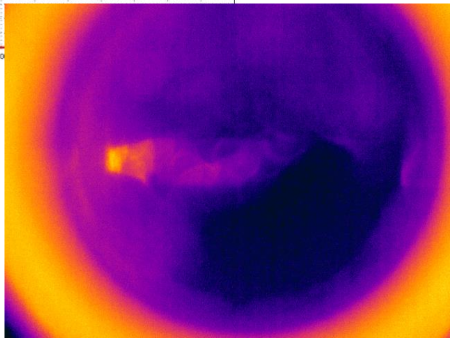


Temperature measurements:
- Infra-red camera
- Thermocouples
- Resistive thermometers



Droplet size distribution:
- PDA
- High speed camera





The instrumentation is fully operational.

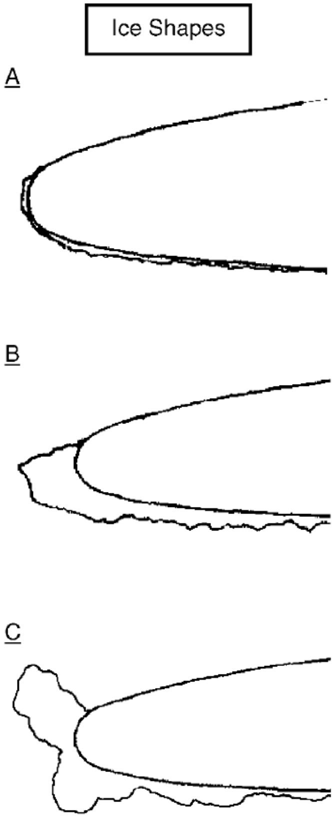
Wind tunnel capabilities

• Able to reproduce extreme weather conditions under controlled laboratory environment

• Simulation of natural icing cloud conditions encountered during flight by injecting water droplets into the airstream via a spray bar system

• Simulation of ice accretion on aeronautical sensors and mechanical structures

• Allow the investigation, modelling and development of new sensors and materials to increase the current knowledge about ice accretion, de-icing and icing prevention mechanisms



New research topics

• Investigation and development of new instruments for air velocity and cloud particle droplet size measurements that can be used to aeronautical and weather applications

• Evaluation and development of new systems for anti-icing and de-icing of aeronautical structures

• Fundamental studies of the ice accretion mechanisms on aeronautical structures: first principles

• Generation of experimental dabase for validation for mathematical models and numerical codes developed for the prediction of icing conditions

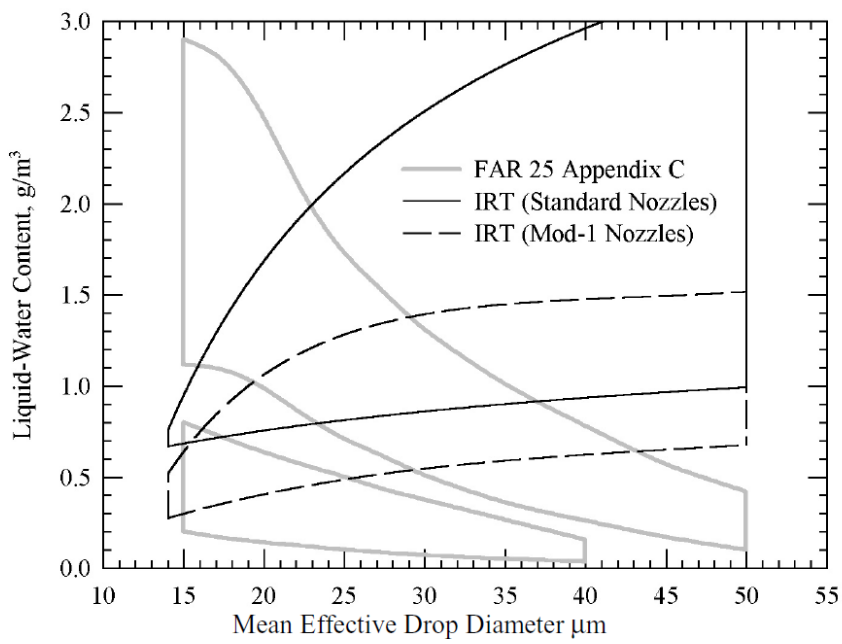
References

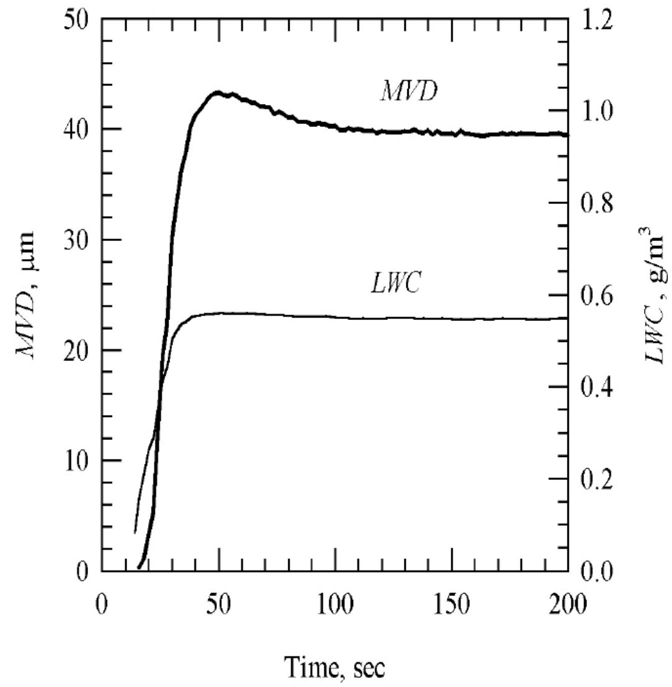
Spray bar system:

DOT/FAA/AR-01/28

Office of Aviation Research
Washington, D.C. 20591

Capabilities and Prospects for Improvement in Aircraft Icing Simulation Methods: Contributions to the 11C Working Group



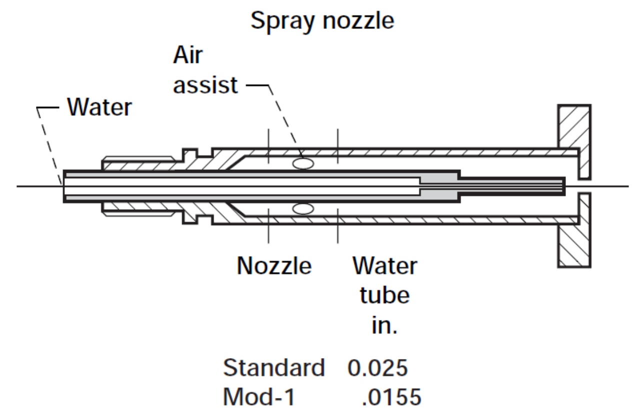


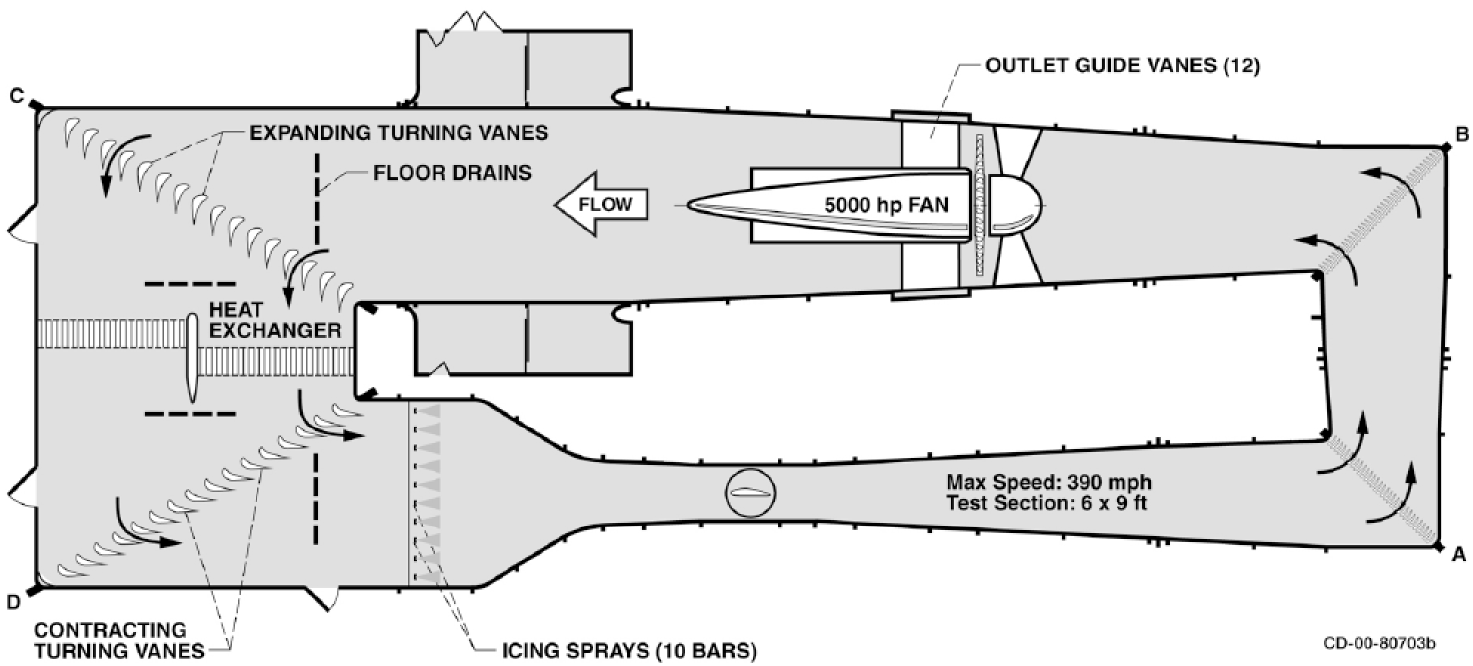
References

NASA/TM—1999-208891

AIAA–98–0143

New Icing Cloud Simulation System at the
NASA Glenn Research Center
Icing Research Tunnel





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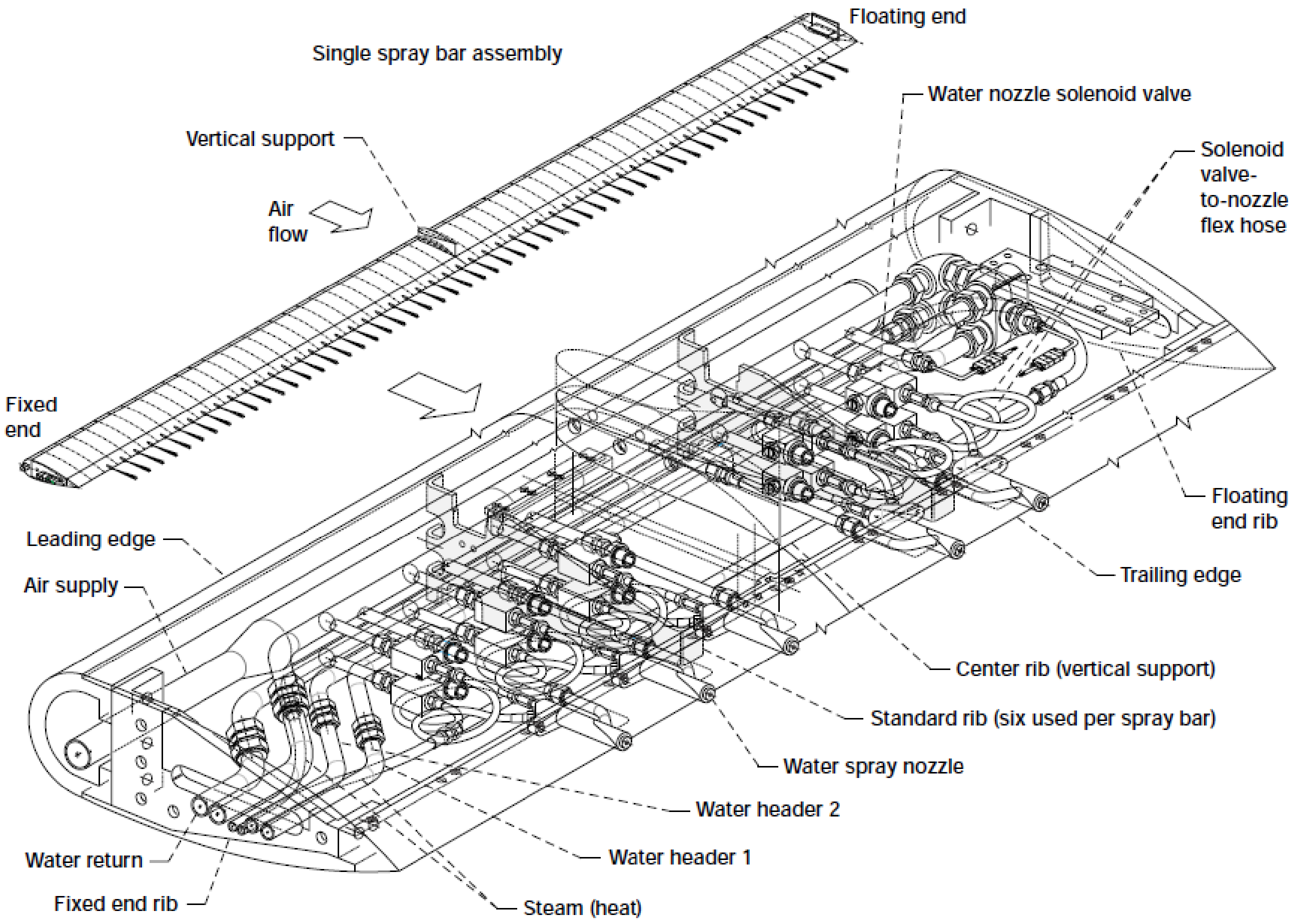

Figure 2.—New spray bar system cutaway showing internal components and plumbing.

Final remarks

• This is the first icing wind tunnel constructed in Latin America. This project was entirely developed at Coppe/UFRJ by a team of undergraduate and graduate students and constructed by a local company. Research conducted here will contribute to increase knowledge on icing related problems.

• This project will allow the development of new optical sensors and new surface finishings based on nanotechnology.

• The wind tunnel measurements will provide experimental validation for the mathematical modelling and numerical simulations of icing related problems.

Acknowledgements

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