Université de Liège

The University of Liège Wind Tunnel Facility

Technical description

1. WIND TUNNEL

1.1. Brief history and description of the wind tunnel

The wind tunnel of the University of Liège (ULg) was built on the Sart-Tilman site at the end of 1999. European and Walloon region funds supported the project.

In the past, ULg owned a wind tunnel on its Val-Benoit site. It was an open with return type wind tunnel. When the Faculty of Applied Sciences moved to the Sart-Tilman site, it was decided to take advantage of the space available and to build a new, bigger and better wind tunnel.

The new ULg wind tunnel is a closed loop subsonic tunnel (Mach < 0,15). Its modularity allows an open loop configuration. The wind tunnel was designed and built by the German company TLT.

The object of this document is to present the characteristics of the wind tunnel and its associated equipment.

1.2. Configurations

The ULg wind tunnel features two different test sections and two interchangeable nozzles. Each test section can operate in open or close configuration and is equipped with a rotating test table.

A schematic view of the wind tunnel can be found in Appendix A.

1.2.1. Aeronautic/Automobile test section (TS1)

This test section is used for models with a frontal area lower than $0.3m^2$. The walls of TS1 are made of glass to allow flow visualization via PIV technology (see 2.2.3).

1.2.1.1. General characteristics

Dimensions of TS1	2m x 1.5m x 5m (Width x Height x Length)
Speed Range	
Close loop	2 - 60m/s
Open loop	2- 40m/s
Test table	Diam 1.5m, rotation ±90°
Thermal stability	~1°C
Static pressure gradient (streamwise)	0.3% per meter
Mean angle divergence	< 0.2%
Speed non-uniformity	< 0.5%
Turbulence level	0.15%

1.2.1.2. Boundary layer suction

TS1 is equipped with a boundary layer suction device, which sucks the boundary layer in the vicinity of the wind tunnel floor and reintroduces it downstream of TS1. The objective is to keep the incoming airflow near the ground as uniform as possible. The main application of this set-up is automobile tests (ground effect).

1.2.2. Wind engineering test section (TS2)

This test section is used for civil engineering (e.g. complete scaled buildings) and wind engineering (dispersion of pollutants, air flow in urban environments). TS2 can be used with the standard nozzle containing TS1 or with the ‘atmospheric turbulence generation’ nozzle. TS2 is also used for applications requiring bigger test models (such as wind turbines). The frontal area can reach 0.45m².

1.2.2.1. General characteristics

Dimensions of TS2	2.5m x 1.8m x 2m (Width x Height x Length) plus 12m for atmospheric boundary layer generation
Speed Range	
Close loop	2 - 40m/s
Open loop	2- 30m/s
Test table	Diam 2.0m, rotation ±180°
Thermal stability	~1°C
Static pressure gradient (streamwise)	0.5% per meter
Mean angle divergence	< 0.2%
Speed non-uniformity	< 0.8%
Turbulence level	0.23%

1.2.2.2. Atmospheric boundary layer

The atmospheric boundary layer can be simulated by intelligently placing obstacles upstream of TS2 in the ‘atmoshperic boundary layer generation’ nozzle. A photograph of a particular wooden block setup can be found in Appendix B. A schematic view of the wind tunnel fitted with this nozzle can be found in Appendix C.

2. ASSOCIATED EQUIPMENT

The amount of associated equipment is continuously increasing. Each new piece of equipment is purchased specifically to match the needs of the wind tunnel and of the projects carried out in it.

2.1. Force measurement

The airflow over the model results in aerodynamic forces and moments. A force balance allows the measurement of the forces. The axis system commonly used in the wind tunnel is described in Appendix D.

2.1.1. Lift balance

The lift balance consists of a circular plate carried by a four-arm structure. The latter is fixed to a traction/compression force transducer to measure the vertical force (lift force). This balance measures only the lift force. The equipment sits below the ground wall of the tunnel, in the rotating test table. The whole system is outside the airflow. The maximal vertical force is 250kN. Photographs of the lift balance can be found in Annex E.

2.1.2. Aerodynamic balance pylon

The aerodynamic pylon consists of an instrumented beam with circular cross-section. The strain gauges are arranged in a Wheatstone bridge to measure the deformations in 2 orthogonal directions. Using the aerodynamic pylon with the lift balance allows the measurement of lift, drag and sideslip forces.

2.1.3. Instrumented Framework

The University has designed and built an instrumented framework structure. It is installed inside the airflow, in the vicinity of the tunnel walls. The structure is adaptable to the dimensions of the model. Its main purpose is to allow vertical and streamwise degrees of freedom. The model is guided in those directions via compressed air bushes, which ensure minimal friction contact. The model is also free to rotate around its rotation axis thanks to two ball bearings on both sides of the model. This setup allows two types of measurements:

- Static measurement of forces and couples acting on the model.
- Dynamic measurement of the movement of the model.

Photographs of the structure can be found in Appendix F.

2.1.3.1. Force sensors

Rigid rods are mounted on force transducers and linked to the moving and fixed parts of the framework structure (see Appendix F).

The characteristics of the force transducers are:

Force range	250N
Accuracy	±0.03%

This configuration allows the measurement of vertical and streamwise forces (lift and drag respectively).

2.1.3.2. Torque sensors

Pitch torque
The pitch torque is measured via two torque sensors. These sensors are fixed to the rotational axis of the model (see Appendix F)

Roll & Yaw torques
The roll and yaw torques are measured by the force sensors, by taking into account the moment arms.

2.1.3.3. Accelerometers

By replacing the rigid rods by calibrated springs, the support structure can be used to simulate the dynamic behavior of structures. It is possible to reproduce three degrees of freedom (DOF): pitch, plunge and streamwise movement. This dynamic set up is used for aeroelasticity applications. The spring-mounted structure is instrumented by accelerometers. The measured signal can be post-processed to obtain displacements and speeds of the structure in its 3 DOFs.

The characteristics of accelerometers are:

Model	PCB 3701D3FA20G
Acceleration range	20g
Frequency range	0 to 300Hz
Accelerometer dimensions	0.45x0.85x0.85 inches
Signal conditioning	PCB Piezotronics 3-channel signal conditioning - two units

2.1.4. Supporting interfaces

The model is fixed to the aerodynamic balance or framework structure via supporting interfaces. An example of supporting interface is presented in Appendix G. The supporting interface is adapted to each model and the associated required measurements. The workshops of the Aerospace & Mechanical Engineering Department are able to build several tailor-made solutions.

2.2. Flow measurements

The main wind tunnel flow data are available from Pitot tubes as well as the wind-tunnel's built-in instrumentation. The Pitot tubes measure the flow in the test sections while the built-in instrumentation measures the flow at the fan. The wind tunnel also disposes flow visualization equipment.

2.2.1. Pitot tube

The air speed in both test sections (TS1 & TS2) is measured via a Pitot tube (see Appendix H). The data is collected, processed and displayed by a KIMO CP300 system.

2.2.2. Pressure transducers

Models can be instrumented with pressure transducers to measure the pressure distribution around them. Two types of pressure measurements are available :

- A 64-channel sequential pressure measurement device (see Appendix I). This pressure transducer possess its own acquisition software.
- A 18-channel simultaneous pressure measurement device. These pressure transducers, working on the principle of the deformation of a piezoelectric membrane are connected to the NI data acquisition. The data processing is done through in-house developed software's. The main characteristics are :
  - Pressure range : 0-30 KPa
  - Operating model : Gauge pressure (Atmospheric relative)
  - Weight : 18g
  - Response time : 1 millisecond
  - sensing medium : non corrosive gas
  - Overload : 200 %
  - Operating temperature : - 40 to 120 °C
  - Shape : Cylindrical
  - Dimension : Diameter - 19 mm / height - 16 mm (without cap)

2.2.3. Particle Image Velocimetry (PIV)

The velocity distribution around the model can be measured in test section TS1 using the rapid particle image velocity equipment available. This rapid PIV system is a product of the DANTEC Dynamics company.

Capacities of the system are :

- 2D visualization of the flow field around any model;
- up to 1600 frames per second (depending of the visualization windows size);
- windows size up to 1612 pixels by 1200 pixels, corresponding to 15 by 15 cm;
- oil particles seeding (diameter 10μm).

The laser lies on a translation system which enable the positioning of the laser sheet in the zone on interest.

Photographs of the PIV system can be found in Appendix J.

2.2.4. Hot Wire Measurement

Local flow velocities in the test section can be measured using hot wire probes. The probes can be driven from outside the test section to measure velocities over a vertical plane. This instrumentation is also used to measure and validate the turbulence level in the atmospheric boundary layer. The available system is the *Stream Line CTA* of the DANTEC Dynamics company.

2.3. Miscellaneous

2.3.1. Data acquisition

A National Instruments NI PXI-1010 data acquisition and amplification module is available. It features 8 channels for voltage signal acquisition (such as conditioned accelerometer signals) and 32 channels for strain gauge signal acquisition.

2.3.2. 6-component force and moment balance for small loads

An ATI six-axis force force/torque sensor system can be used for measuring small loads (up to 12N lift, 8N drag). This instrument is ideal for small models at low airspeeds and has particular applications in biomechanics (e.g. aerodynamic load measurements on bat models).

2.3.3. Compressed air

Compressed air is available at up to 5bar and has several uses (e.g. for the pneumatic suspension of the Framework Structure).

2.3.4. Smoke Generator

A smoke generator is available for qualitative visualization of the flow around the model.

3. MODEL BUILDING

The wind tunnel possesses its own workshop. Moreover other workshops of the Aerospace & Mechanical Engineering Department participate in the building, adaptation and modification of models. The wind tunnel facility has close contacts with external companies for building models by rapid prototyping techniques.

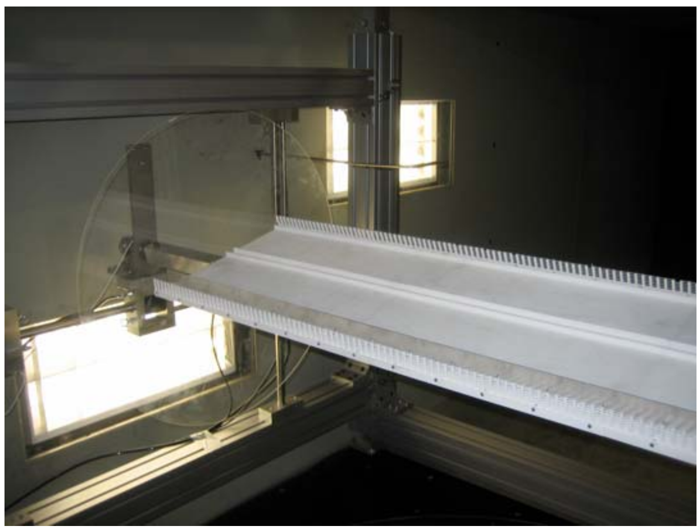
Clients may also provide their own models. In this case, the engineers of the wind tunnel can actively help the latter in the design and manufacture of such models (aerodynamic similarity considerations, integration of measurement equipment, etc).

Three examples are presented below:

- Building of aerodynamic aileron for race car

- Model of the deck of the viaduct of Millau

- Another model of the deck of a viaduct



- Model of a jet aircraft

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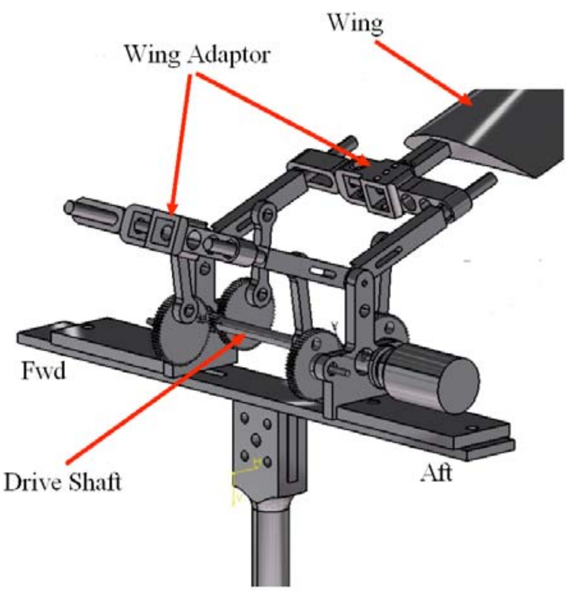
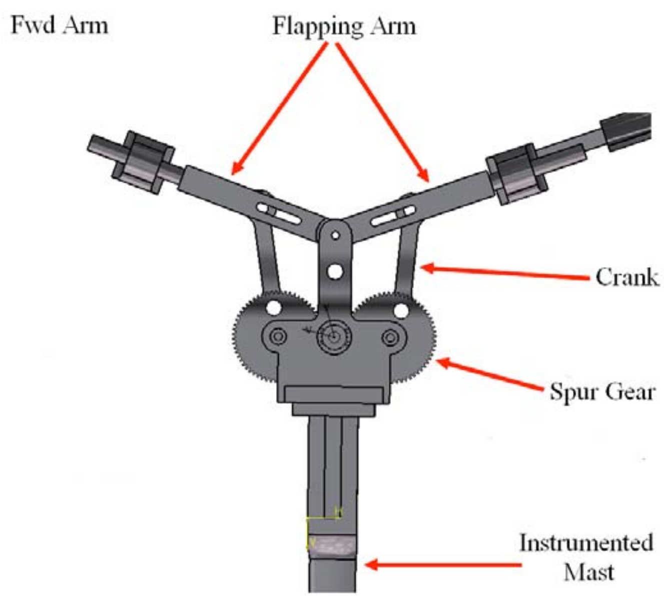
- Model of an air intake

- Model of a flapping and pitching wing





4. PERSONNEL

This is a list of the personnel working at the ULg Wind Tunnel facility.

4.1. Current personnel

Dr Greg Dimitriadis	Head of the Wind Tunnel Laboratory
Mr Thomas Andrianne	PhD Researcher and Teaching Assistant
Mr Norizham Abdul Razak	PhD Researcher (starting March 2008)
Mr Emile Kagambage	Research Engineer (2-year appointment, starting in March 2008)
Mr José Ignacio Rothkegel	Research Engineer (2-year appointment, starting in January 2010)
Mr Chandra Shekhar Prasad	Research Engineer (2-year appointment, starting in October 2009)

4.2. Technical Staff

Technical staff is available from the Aerospace and Mechanical Engineering Department's technician pool. All technical work has to be applied for in advance.

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5. CONTACT INFORMATION

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gdimitriadis@ulg.ac.be

Acces map : http://www.ulg.ac.be/acces/plans/zoneb52.html

6. APPENDICES

A. General view of the wind tunnel

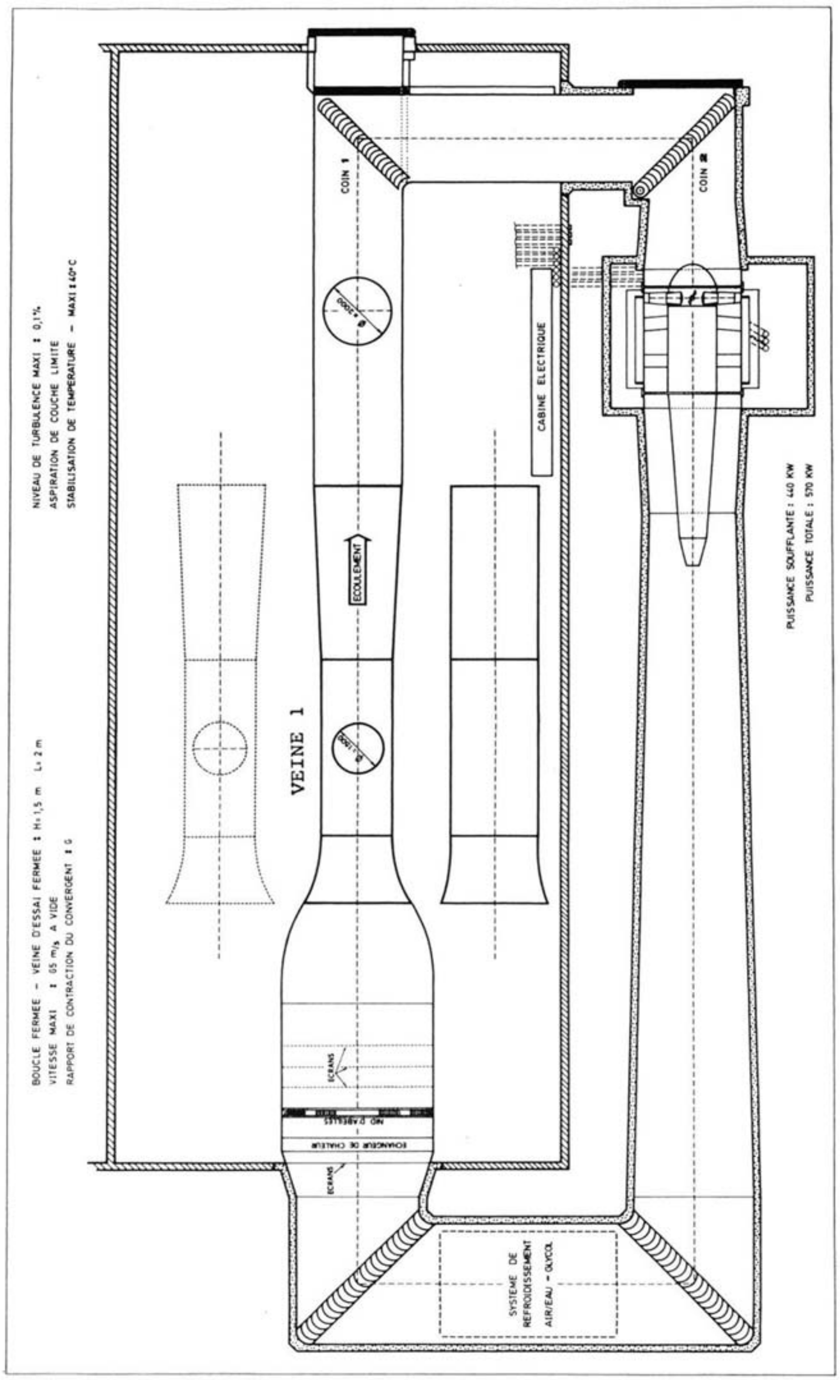
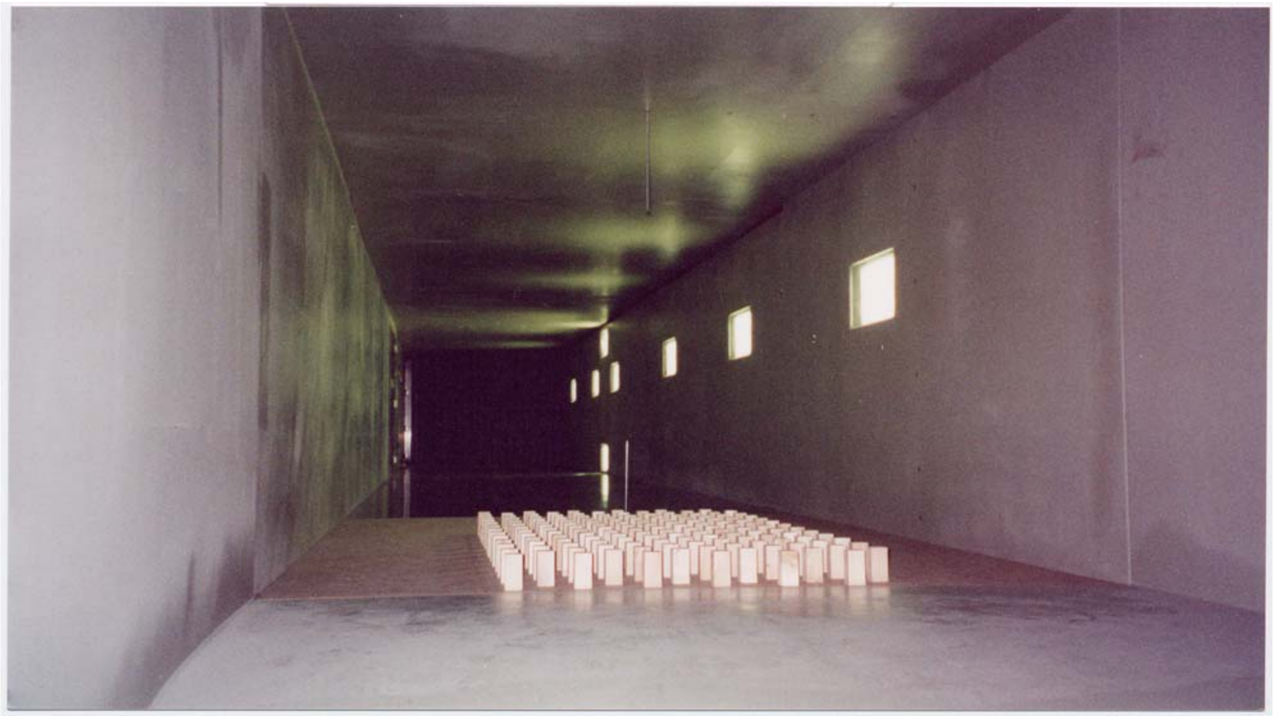


FIGURE 1. - VEINE 1 - BOUCLE POUR ETUDES D'AERONEFS ET DE VEHICULES AUTOMOBILES

B. Atmospheric boundary layer creation



C. TS2

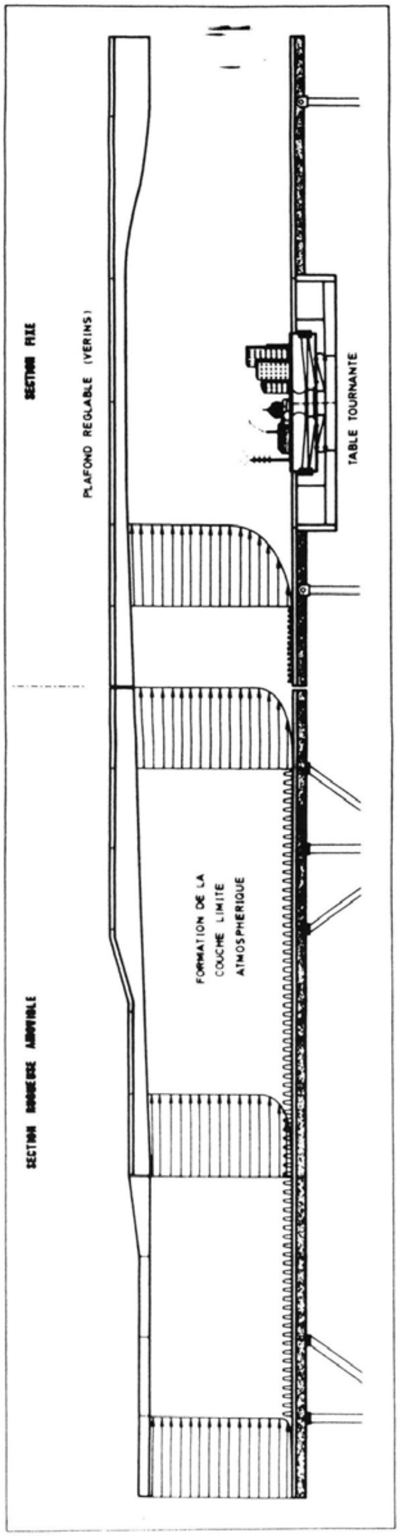


FIGURE 4. - VEINE 2 - ETABLISSEMENT DE LA COUCHE LIMITE

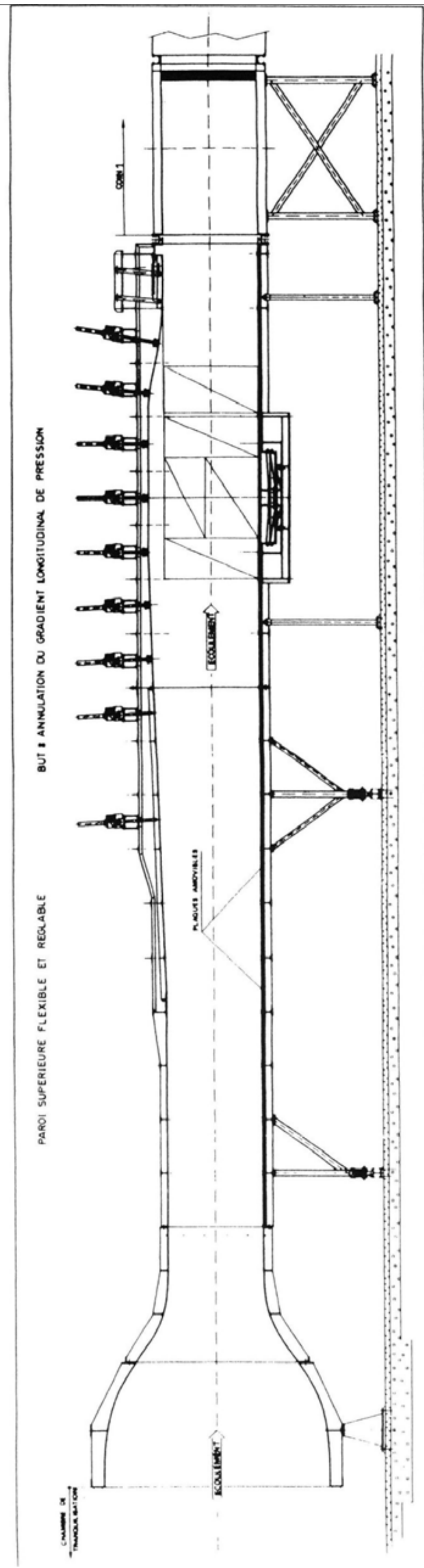
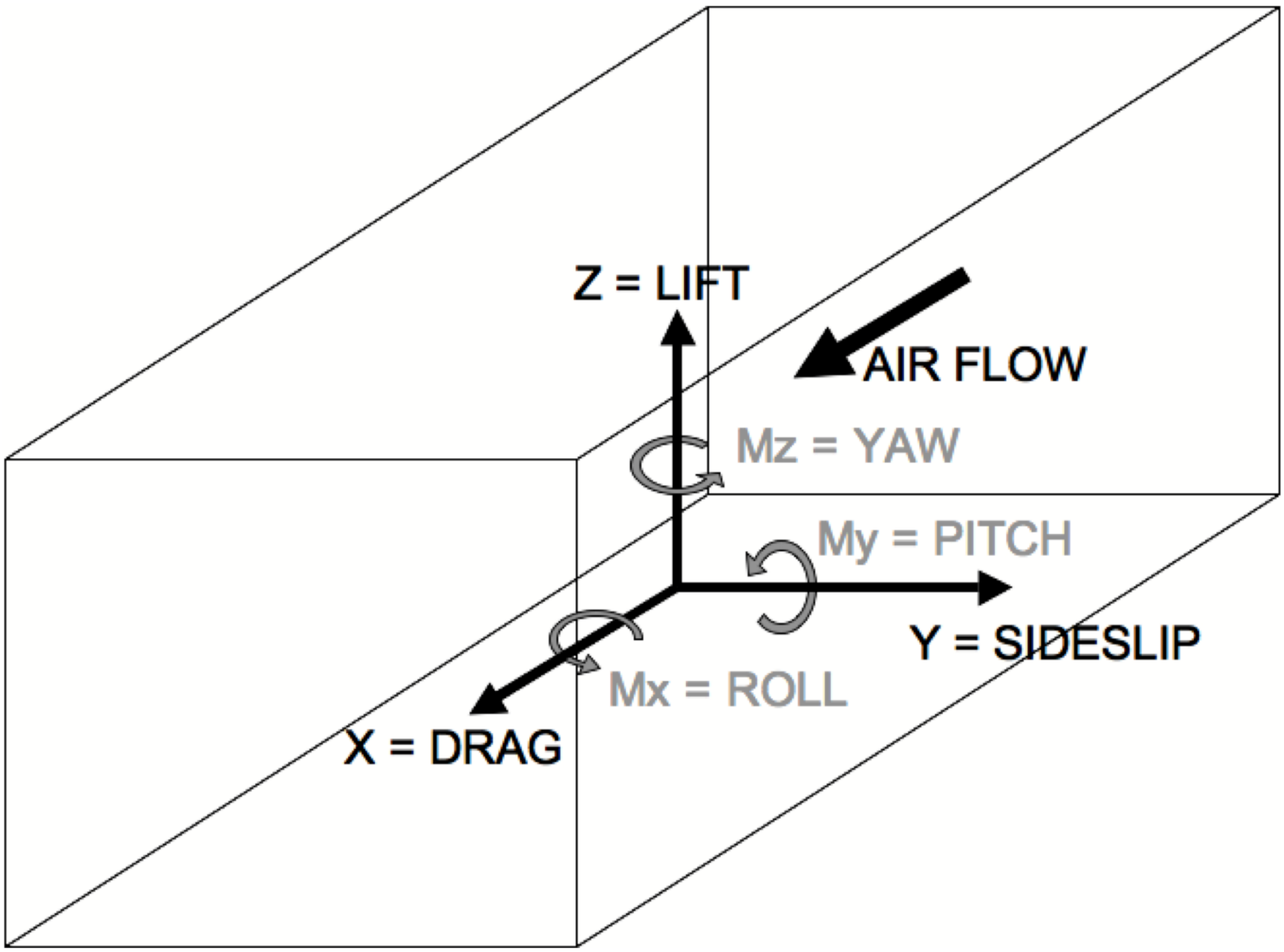
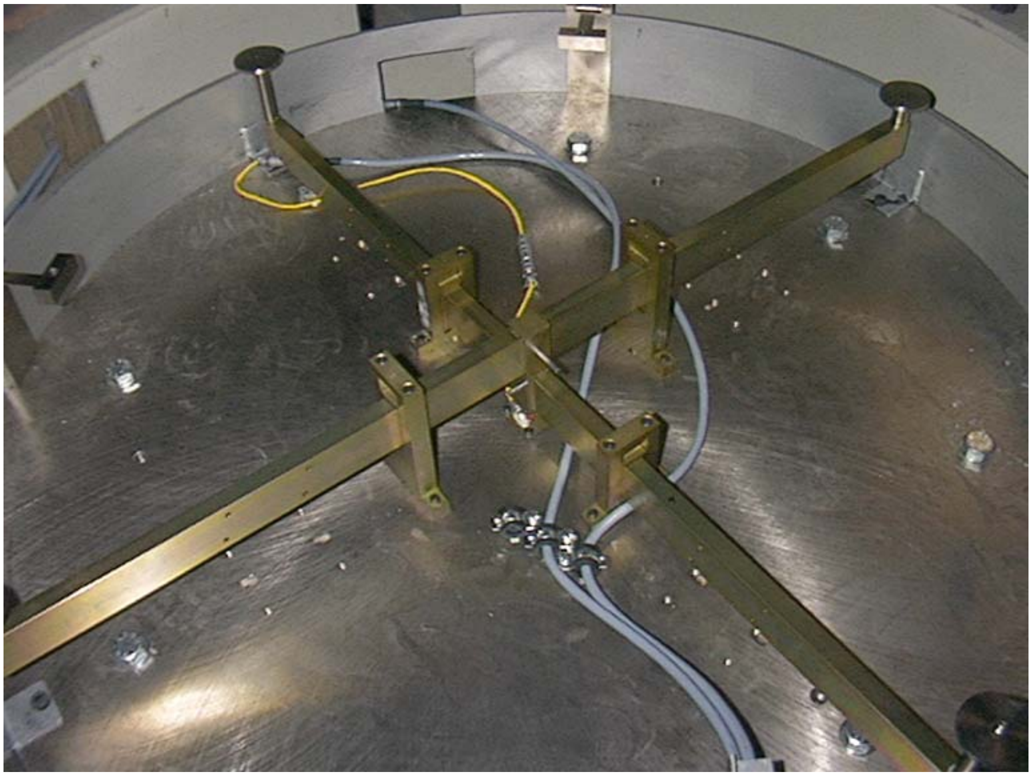


FIGURE 5. - VEINE 2 - PLAFOND FLEXIBLE REGLABLE PAR VERINS

D. Axis system



E. Balance

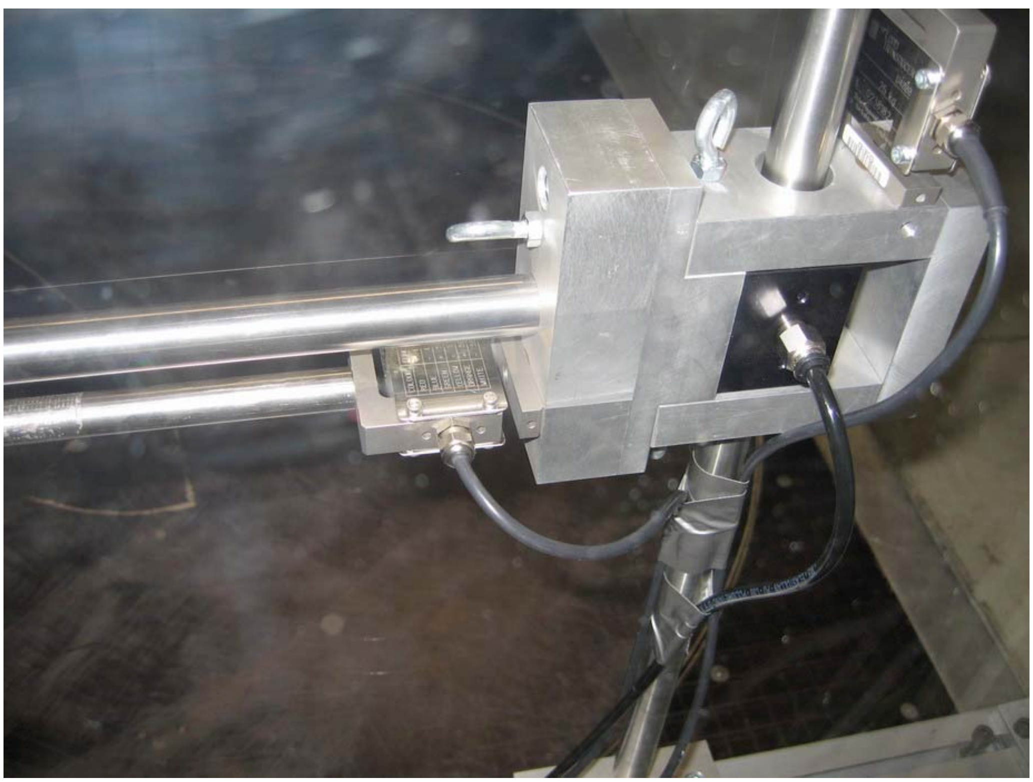


Lift Balance

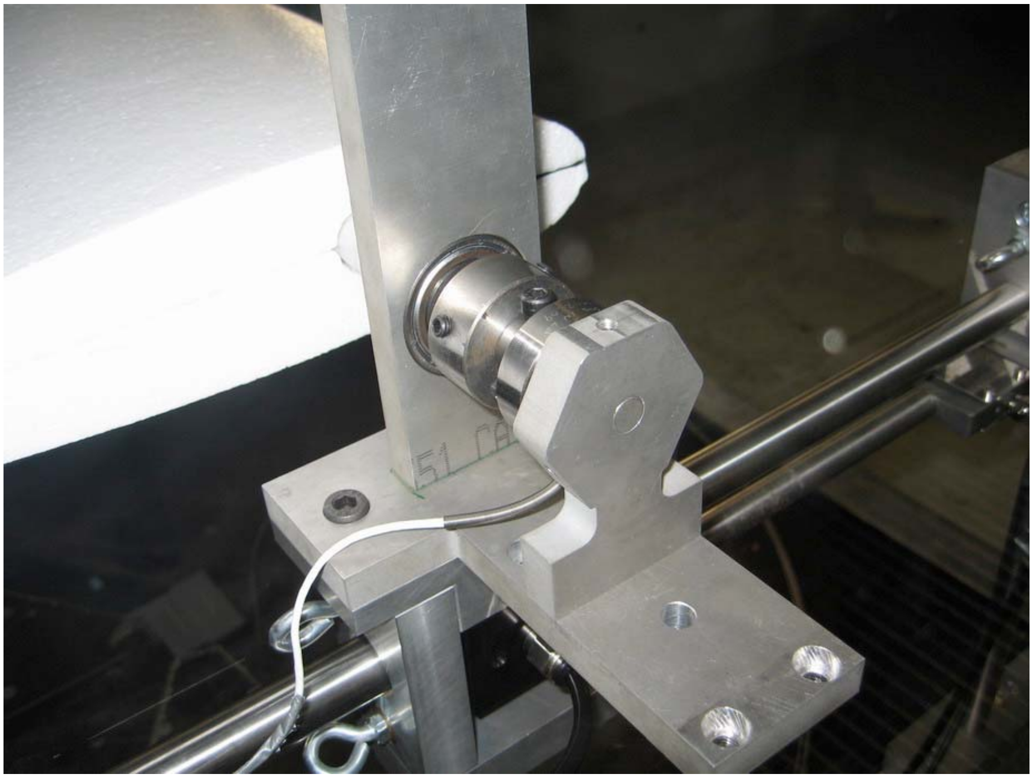
Drag and Sideslip Balance

F. Framework structure

Framework structure with wing model

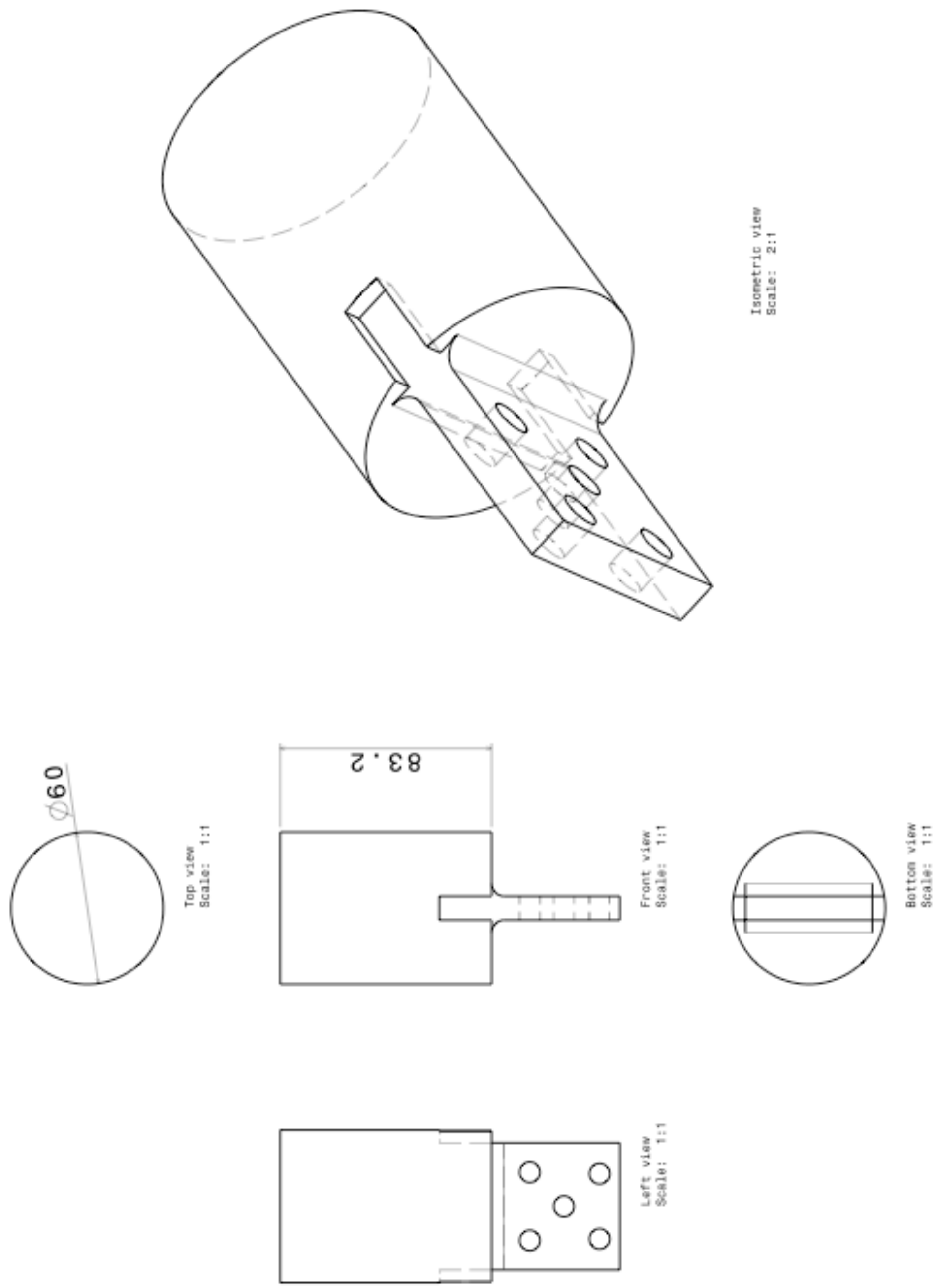


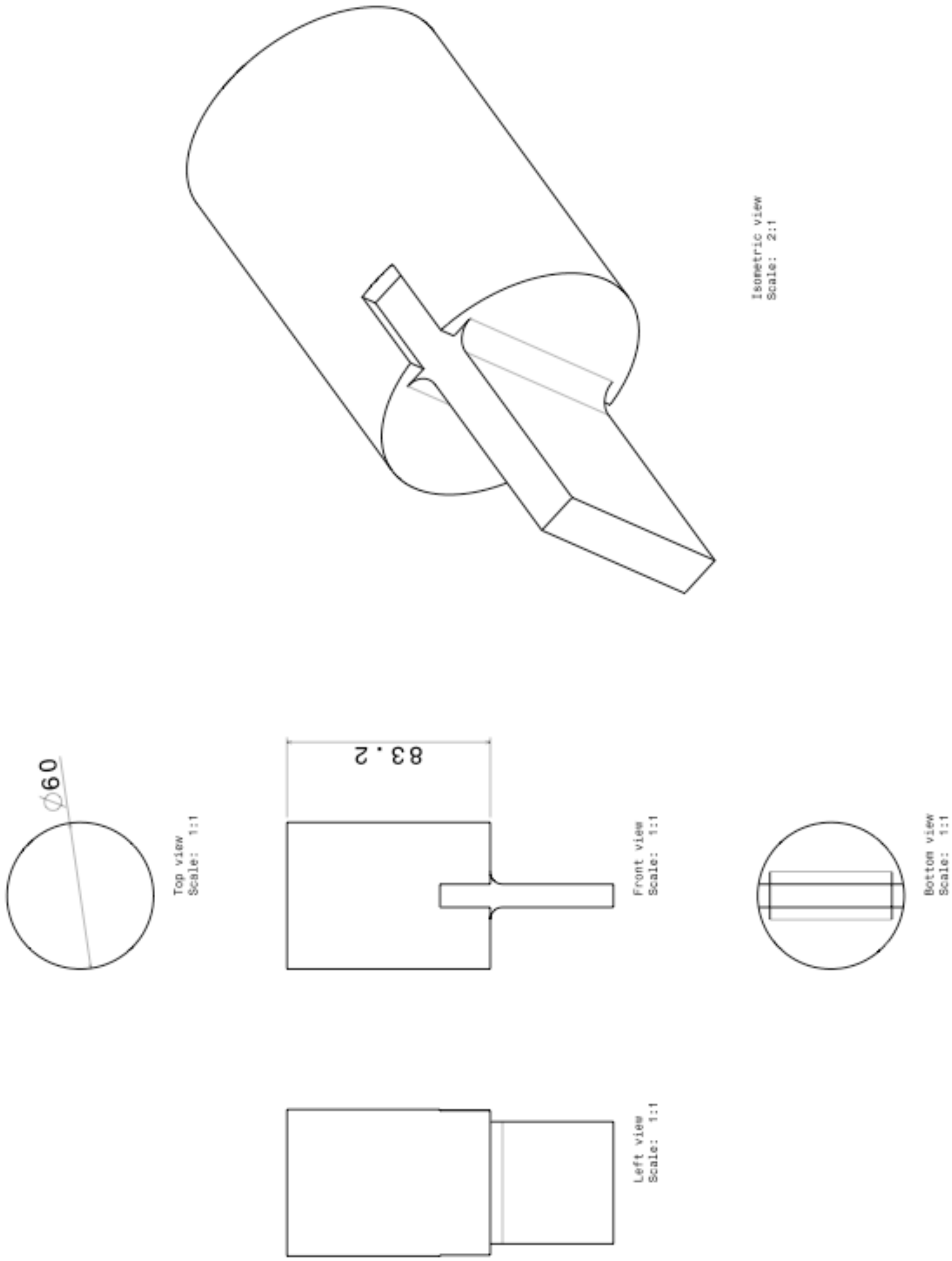
Force gauge



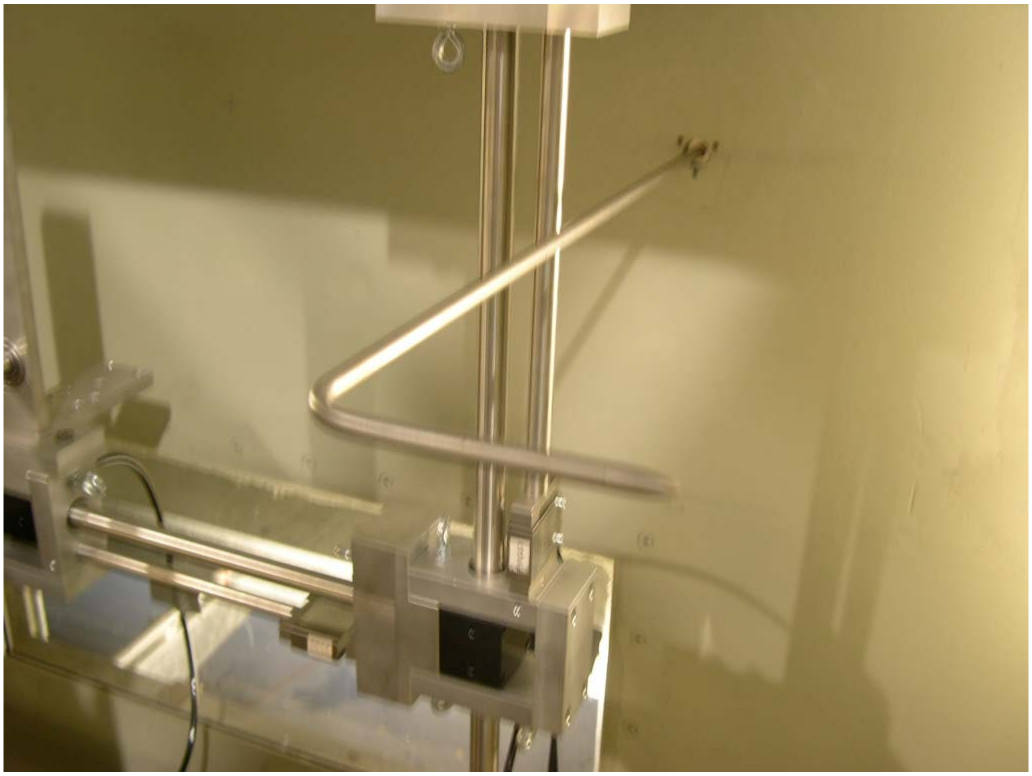
Torque sensor

G. Interfaces

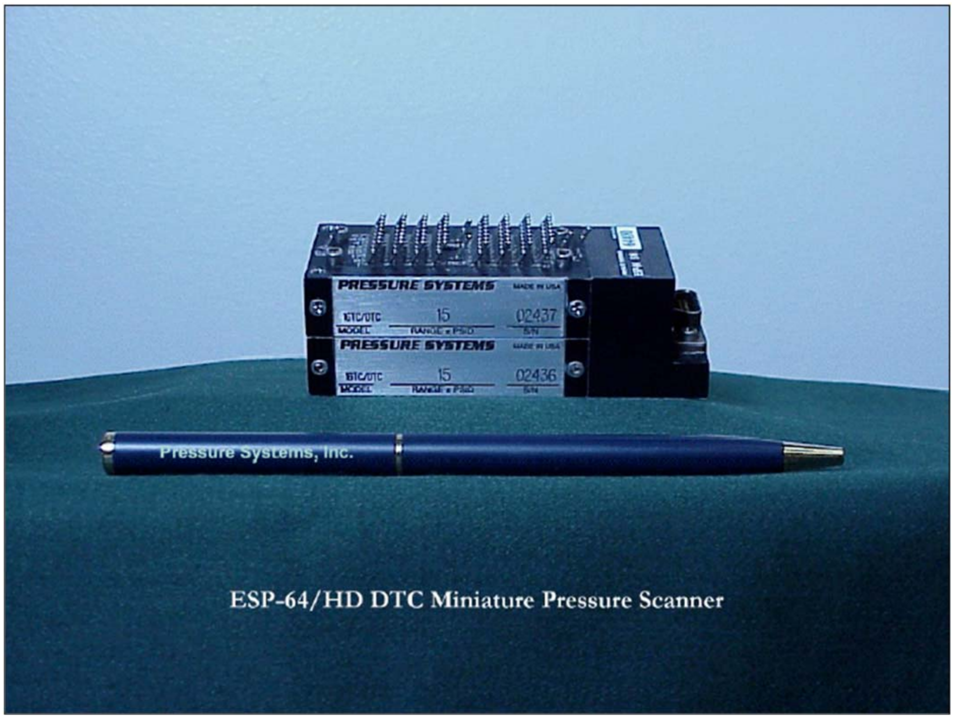


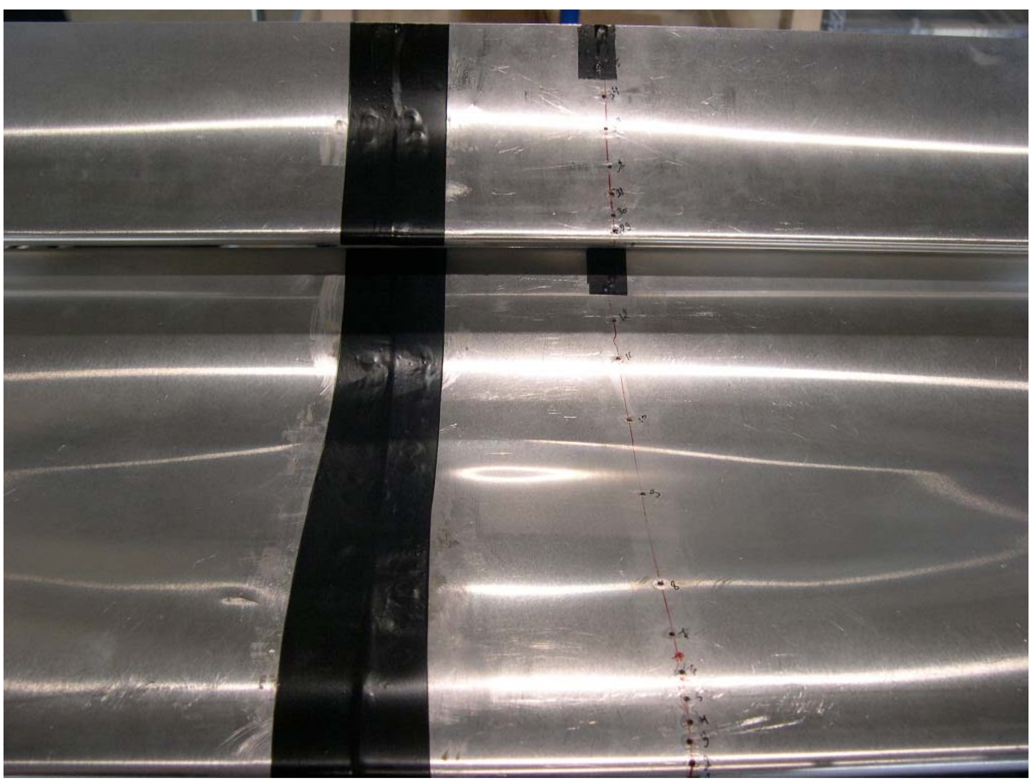

Isometric view
Scale: 2:1
Ø60
Top view
Scale: 1:1
83.2
Front view
Scale: 1:1
Bottom view
Scale: 1:1
Left view
Scale: 1:1

H. Pitot tube

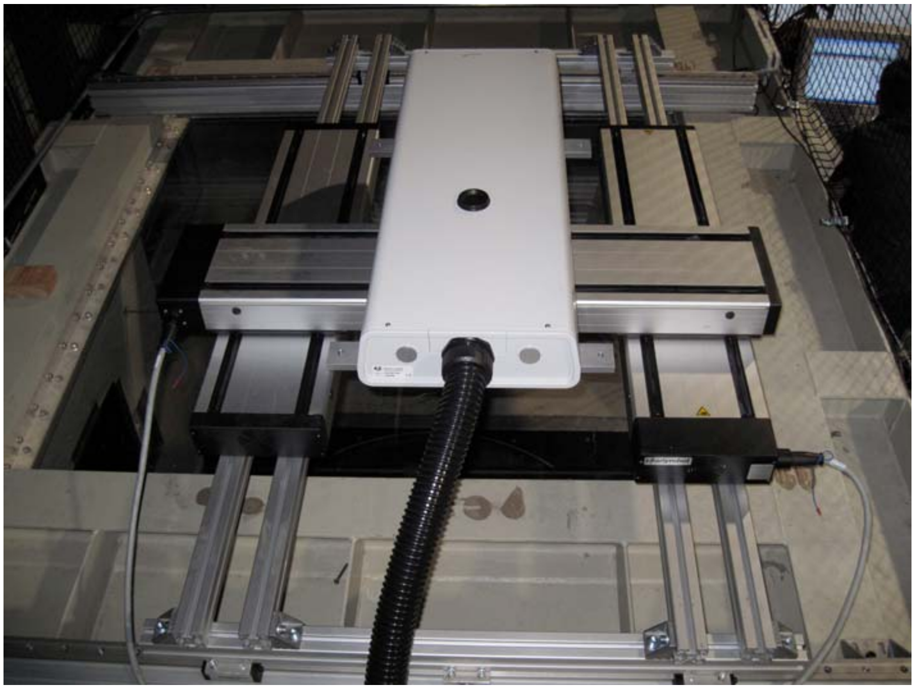


I. Sequential pressure transducers





J. PIV system



Laser on its translation system on the top of the test section

Laser on its translation system on the top of the test section

Laser power unit

High speed camera