DESIGN ISSUES OF A NEW WIND TUNNEL LABORATORY FOR ENVIRONMENTAL AND VEHICLE AERODYNAMICS

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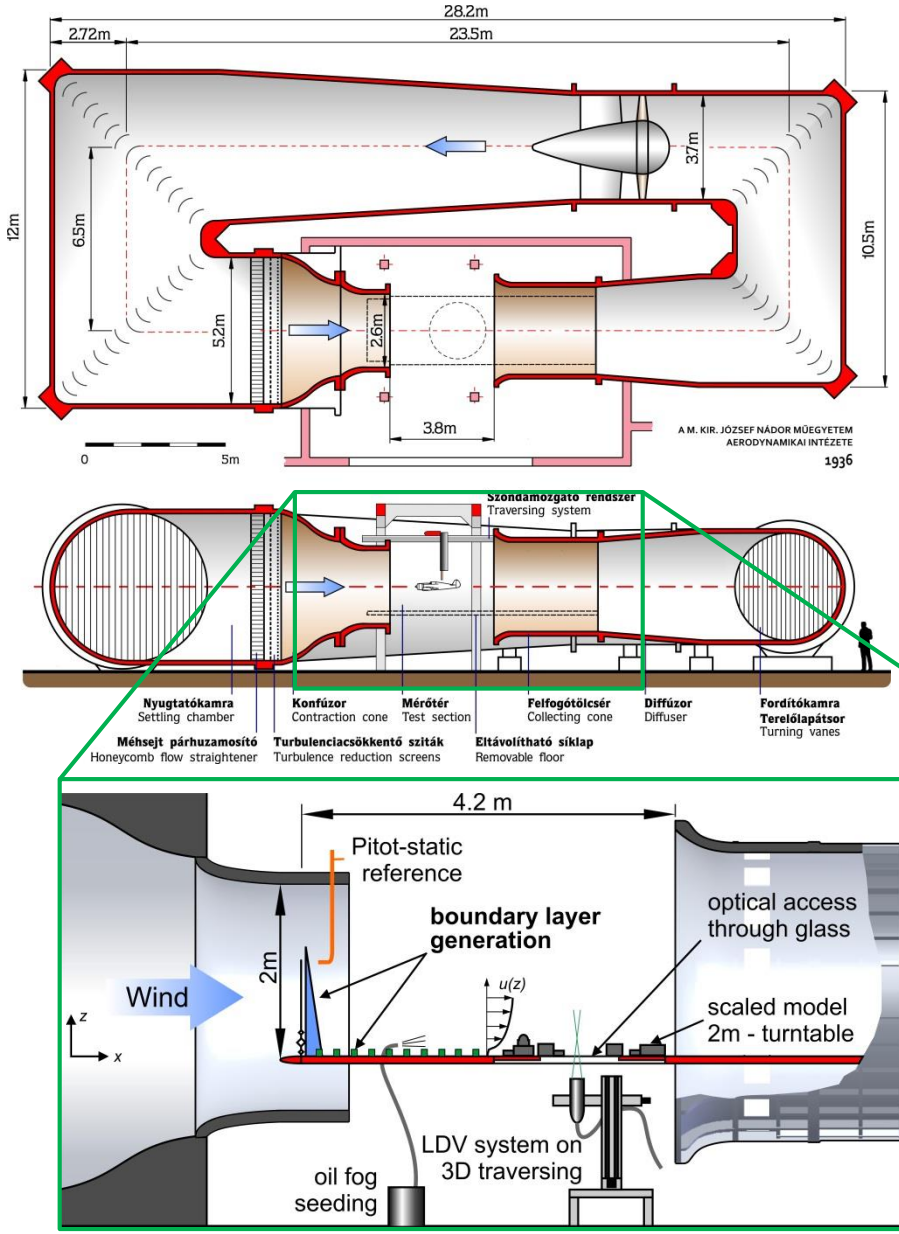
Fluid Mechanics

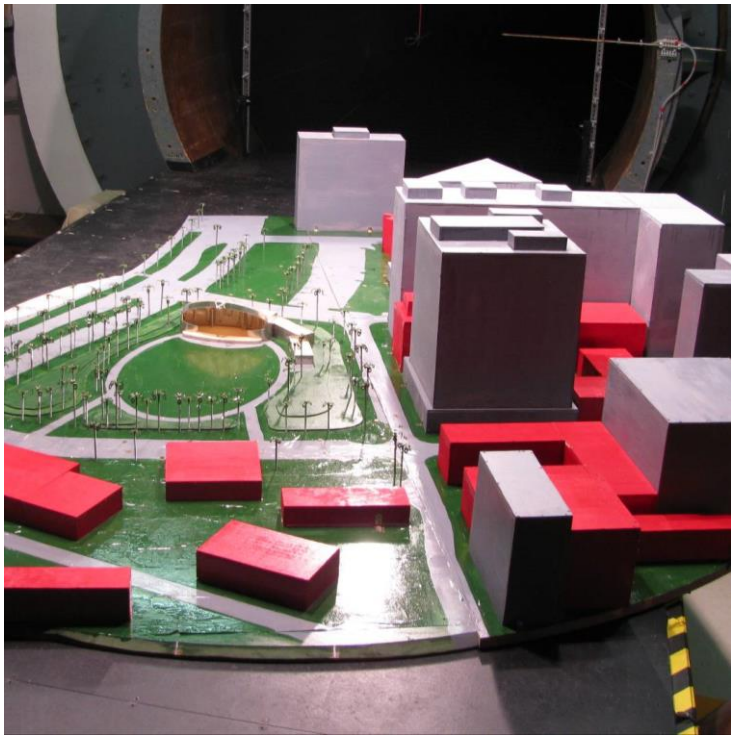
Theodore von Kármán
Wind Tunnel Laboratory

CONTENTS

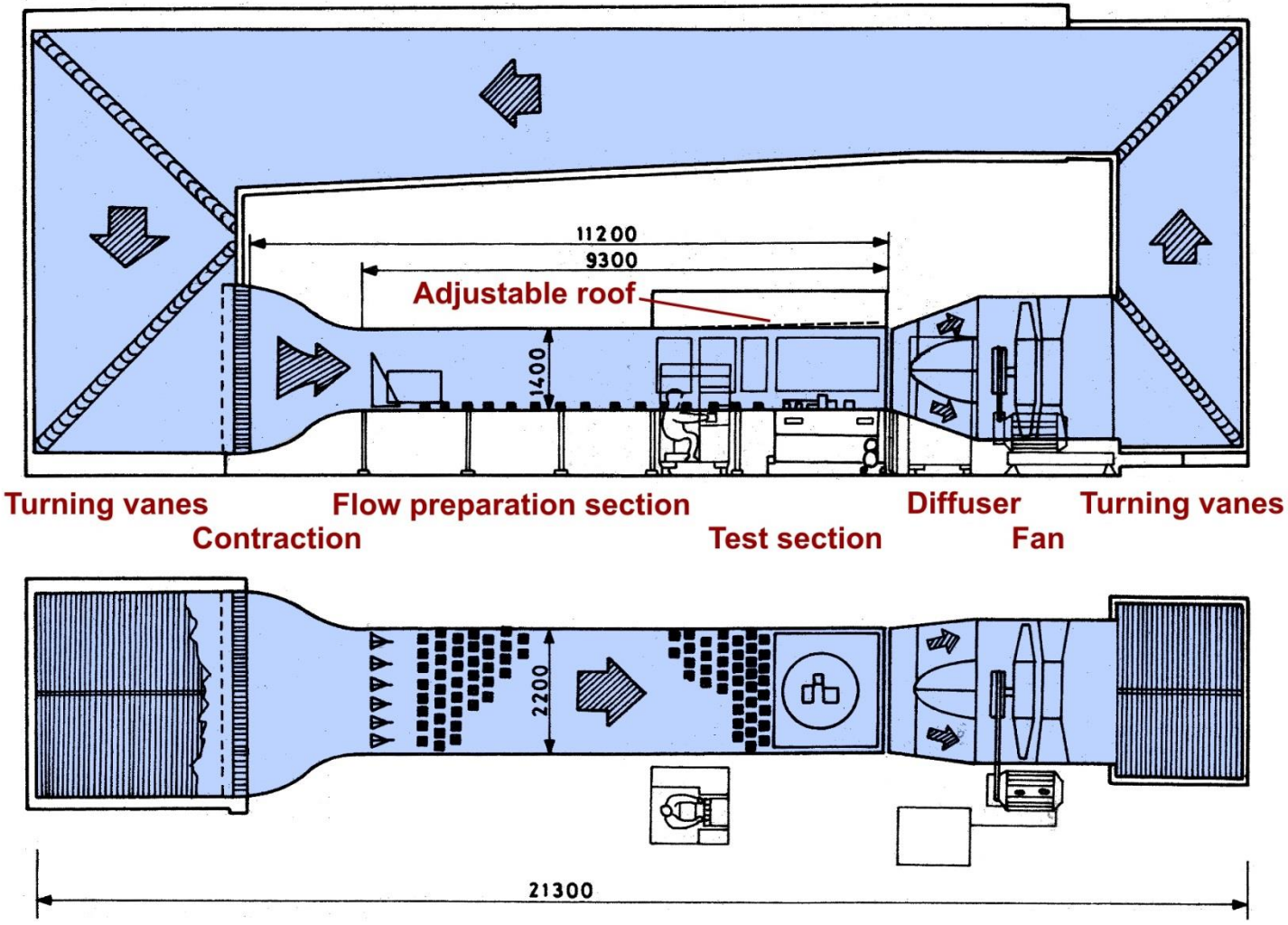
ENVIRONMENTAL AND BUILDING AERODYNAMICS AT THE THEODORE VON KÁRMÁN WT LAB

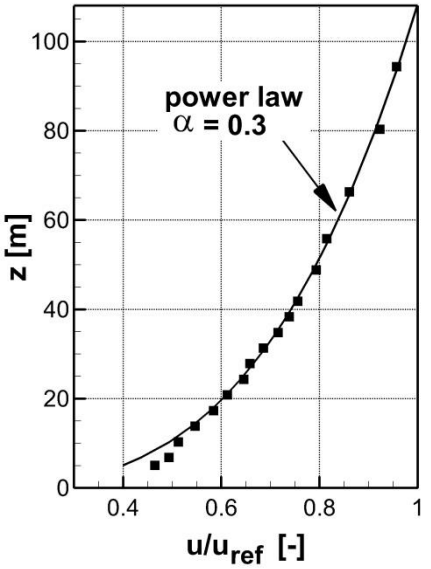


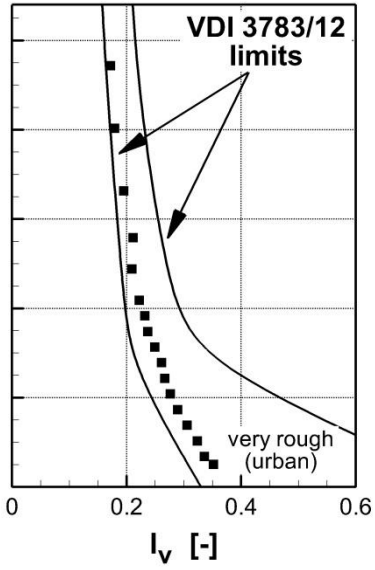
1. Large Göttingen-type wind tunnel
2. Boundary layer modelling using spikes, rods and roughness elements
3. Modell scale environmental : **1:350 -1000**
4. Modell scale building aerodynamics: **1:100 – 1:200** (turbulent length scale does not fit)



THE BOUNDARY-LAYER WIND TUNNEL



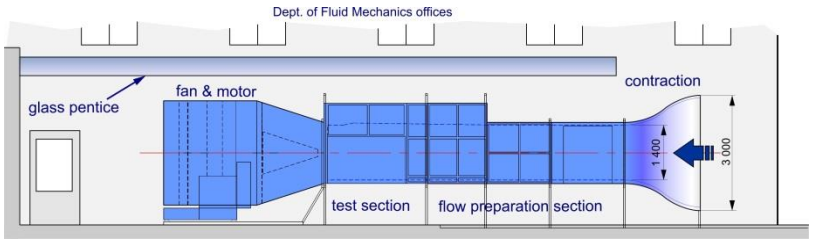


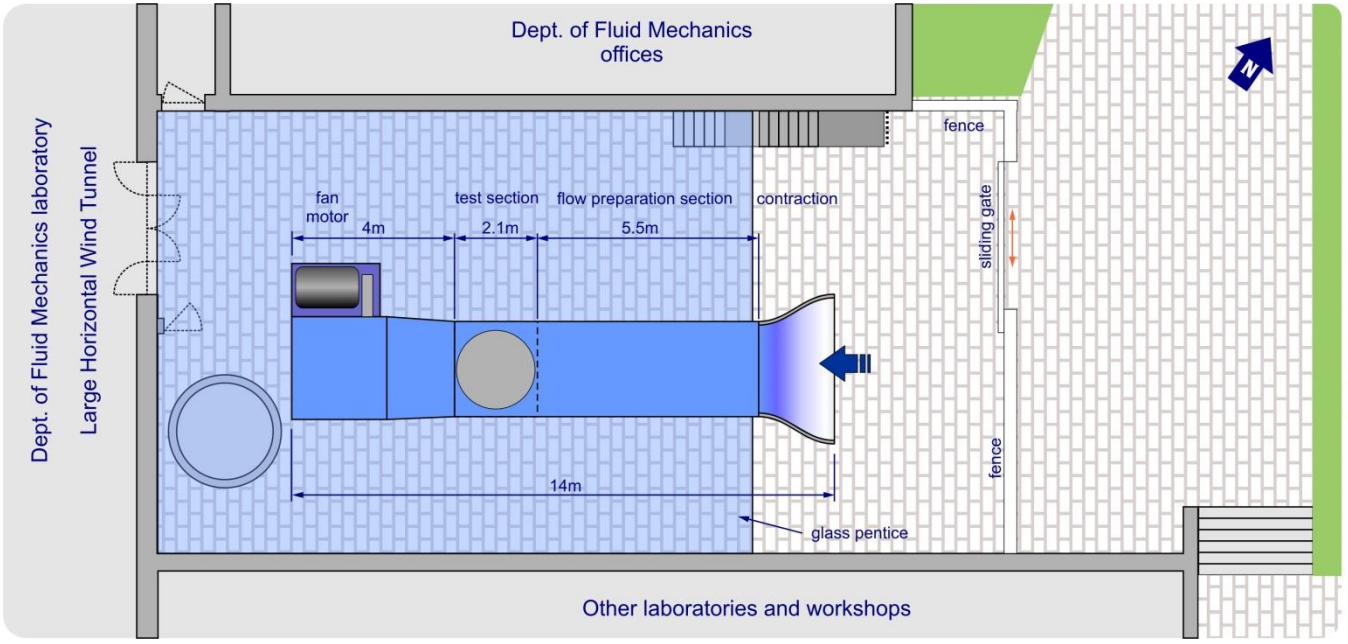


- WT of Building Research Institute (ÉTI), rebuilt 1984
- decommisioned and bought by our laboratory 2003

THE EXISTING BOUNDARY-LAYER TUNNEL

test section type	closed
preparation section length [m]	5.5
Test section [m]	2.2 x 1.4
max. wind speed [m/s]	19





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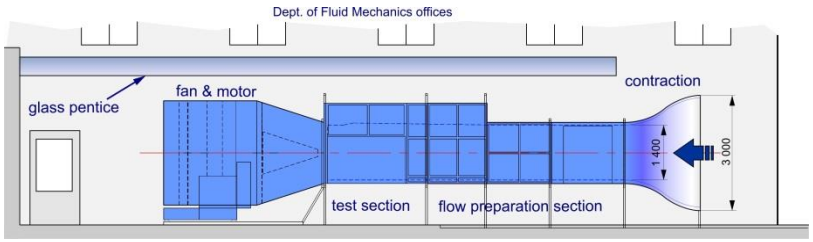


Problems

1. exposure to weather
2. dust generation during operation
3. no security of valuable instrumentation
4. extreme heat under the pentice during summer.
5. lack of curtains or disillumination for flow visualisation.
6. no laser protection of trespassers.
7. use of external air causes unsteady flow.

REQUIREMENTS OF A NEW LABORATORY

1. Long boundary layer generation section ⇨ equilibrium boundary layer (BL)
   ⇨ larger BL thickness
   ⇨ larger model scale
2. (at least partial) weather protection ⇨ closed laboratory space

QUESTIONS

1. Refurbish the existing BLWT / extend the existing BLWT / fully new BLWT ?
2. use of external air (as today) / circulation of internal air / recirculating tunnel ?
3. How to fit the wind tunnel into the available space ?

BOUNDARY-LAYER WIND TUNNELS

Wind tunnel Owner	Built	Layout	Size [m^2]	Test section Type	W [m]	power [kW]	Top speed [m/s]	Comment / Specialities	Cost [€]
University of Adelaide	2011	closed circuit	31 × 19	closed/ open	3	6 × 135	33	2.75 × 2m high speed test section for aeronautical testing up to 50 m/s is located in the other leg.	3.65M
ETH Zürich / EMPA	2011	closed circuit	25 × 6.5	closed	1.9	110	28	Use of external air possible instead of recirculation. Test section blocks easily removable.	
Leibniz Institute for Agr. Eng. Potsdam	2012	open return	29 × 6.5	closed	3		20	Mainly used in agricultural research, odour dispersion	1.18M
TU Eindhoven	**	closed circuit	42 × 12**	closed	n/a	n/a	n/a	Facilitating building will be approx. 850 m^2	1.4M **

* flow preparation section + test section length added
** in design phase, estimated values based on [7]

Conclusion: closed circuit is the preferred type

WIND TUNNELS IN HUNGARY (1)

Wind tunnel (WT)		Built	Total length	Test section		Top speed	Application area	Comment / Specialties
Owner	Type	[year]	[m]	Type	Width [m]	[m/s]		
Budapest University of Technology and Economics	closed return	1936-38	28.2	open	2.6	60	aerodynamics of vehicles, buildings, pollutant dispersion	3D probe traversing system, modular floor, 2m-turntable
	closed return	1936-38	10.2	open	1.4	25	drag force measurement on smaller objects	
	open return, suction type	**1984**	**13.6**	**closed**	**2.2**	**19**	**building and environmetal aerodynamics**	**long flow preparation section, adjustable roof, located outside**
	open return, suction type	1941	6	closed	0.5	18	anemometer calibration, flow around bodies	3D traversing system installed
	open return, blower type	2013	5	open or closed	0.35	24	vehicle aerodynamics measurements	closed test section can be removed for open jet configuration
	open return, blower type	2013	5.2	open or closed	1	24	flow around 2D bluff bodies and airfoils	equipped with 3-component force balance
University of Miskolc	closed return	1982	13	closed	1.2	30	general fluid dynamics, boundary layer modelling	isolated wind tunnel, temperature adjustable between -10 to +50 °C
	open return/closed return	2009	8.6	closed	0.5	30	fundamental fluid dynamics research	at low speeds: closed return / high speeds: open return
	open return	2012	6.5	open	0.4	6	turbulence, turbulence generator research	3D traversing system installed

WIND TUNNELS IN HUNGARY (2)

Wind tunnel (WT)		Built	Total length	Test section		Top speed	Application area	Comment / Specialties
Owner	Type	[year]	[m]	Type	Width [m]	[m/s]		
National Agricultural Research and Innovation Center	open return, suction type	2004	13	closed	2	3	testing of agricultural spray application techniques	adjustable roof, 2.5m turntable
Szent István University	open return, suction type	2004	6	closed	0.5	19	calibration of anemometers	
	open return, suction type	2014	5.6	closed	1	25	calibration of anemometers	
Hungarian Meteorological Service	open return, suction type	2002	6.1	closed	0.652	50	calibration of anemometers	Theodor Friedrichs Co. Type 8420. Min. speed 0.15 m/s
University of Debrecen, Faculty of Science and Technology	closed return	1970	12.3	closed	0.8	14	soil erosion experiments	eqipped with a particle filter
University of Szeged, Faculty of Science and Informatics	open return blower	1980	12	closed	0.8	17	in-situ soil erosion experiments	WT without a bottom to be placed on the investigated soil surface
University of Nyíregyháza	open return or closed return	2012	9	closed	0.25	n/a	drying research	Not operational at the moment due to change of location

WIND TUNNEL APPLICATION MATRIX

Boundary layer wind tunnel applications	open return		closed circuit
	external air	internal air	
building wind load measurements	++	-	++
aeroelastic testing	+	-	++
pollutant dispersion measurements	-	++	++
sand erosion / snow erosion / ‚dirty' measurements	++	-	+ *
laser based measurement techniques	-	+	++
vehicle areodynamics	+	-	++
use during winter (below 0 deg)	-	++	++
cold weather testing (during winter)	+	-	-

** with switchable external air supply or separator behind the test section*

Conclusion

- an open-return tunnel is limited in application (whether with external or with internal air)
- Closed circuit WT more flexible

SPACE AND DESIGN CONSTRAINTS

1. Budapest world heritage conservation area (buffer zone)
2. Access for users of neighbouring laboratories and workshops
3. Campus promenade (limits length)

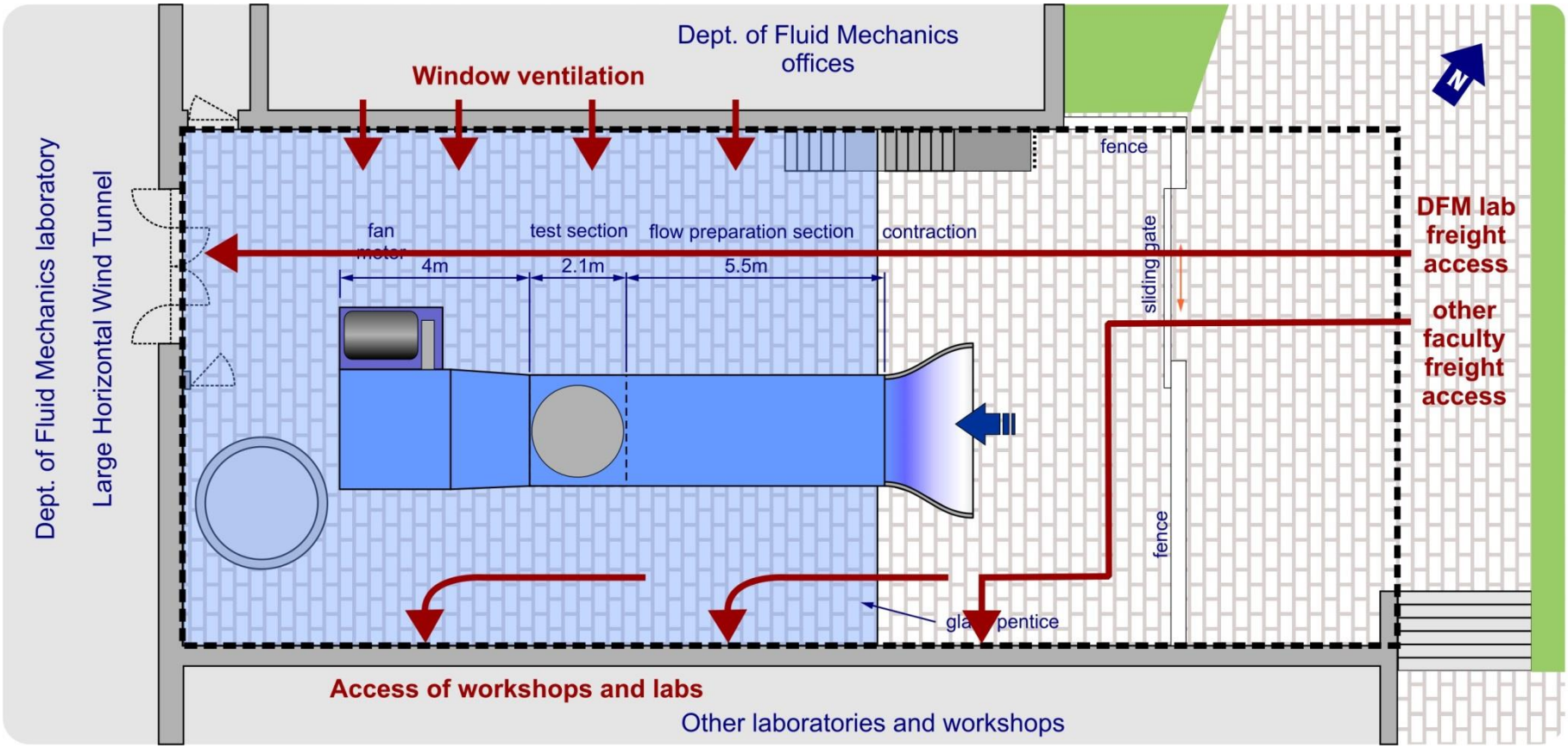
DESIGN VARIANTS

1. Budapest world heritage conservation area (buffer zone)
2. Access for users of neighbouring laboratories and workshops
3. Campus promenade (limits length)

Available space:

26.5 x 11 m

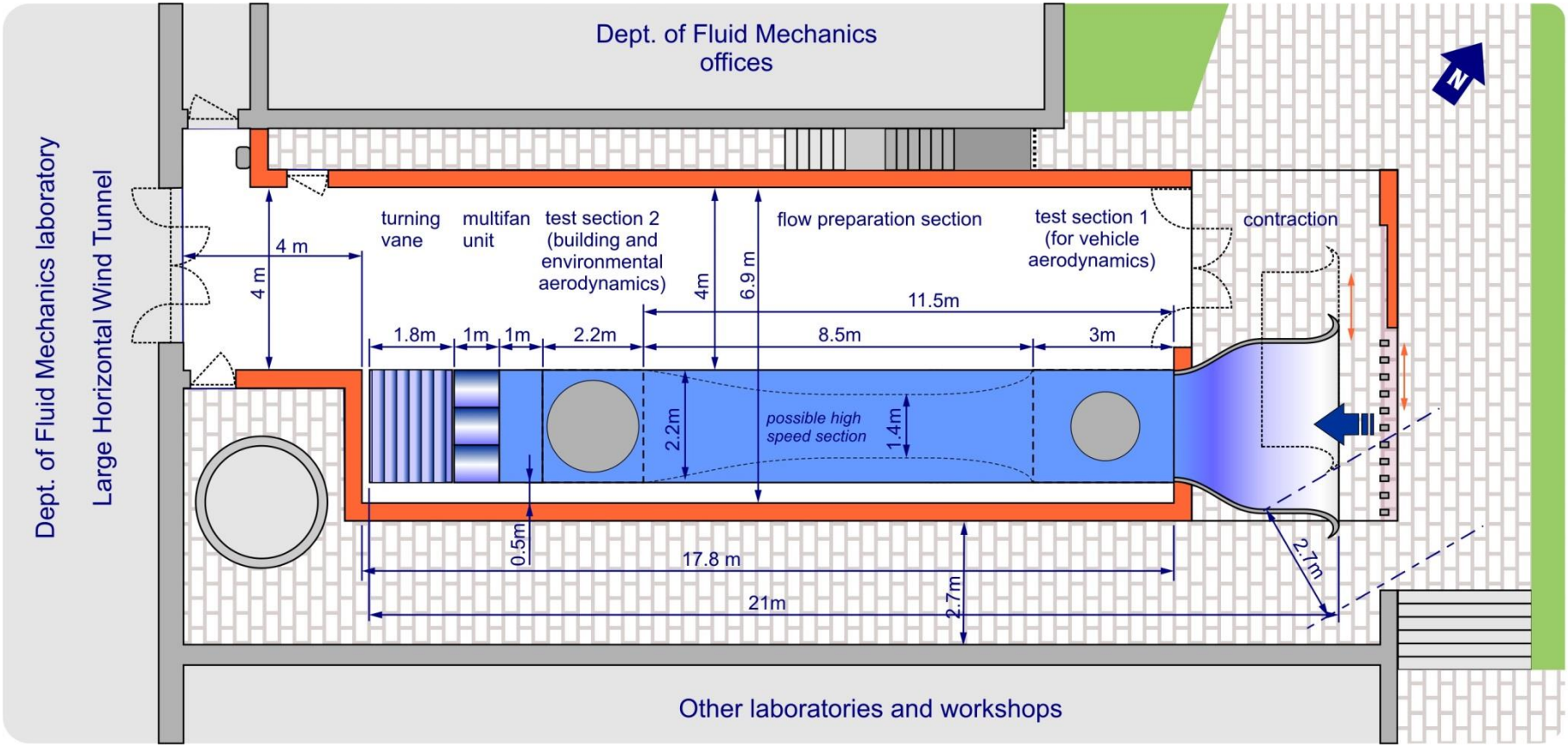
5 m height



DESIGN VARIANTS

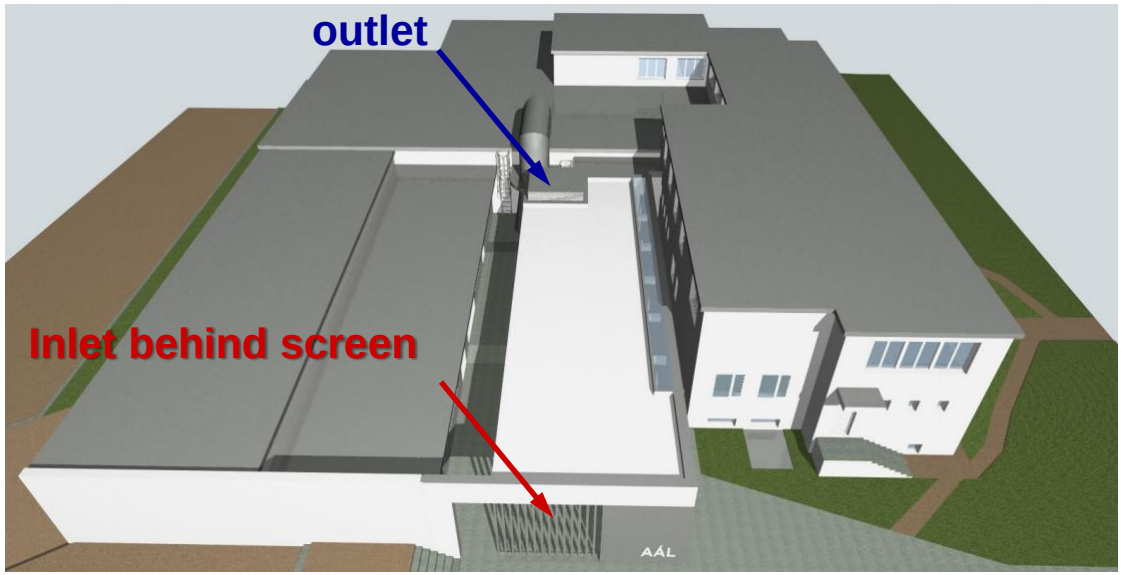
Version A – original design

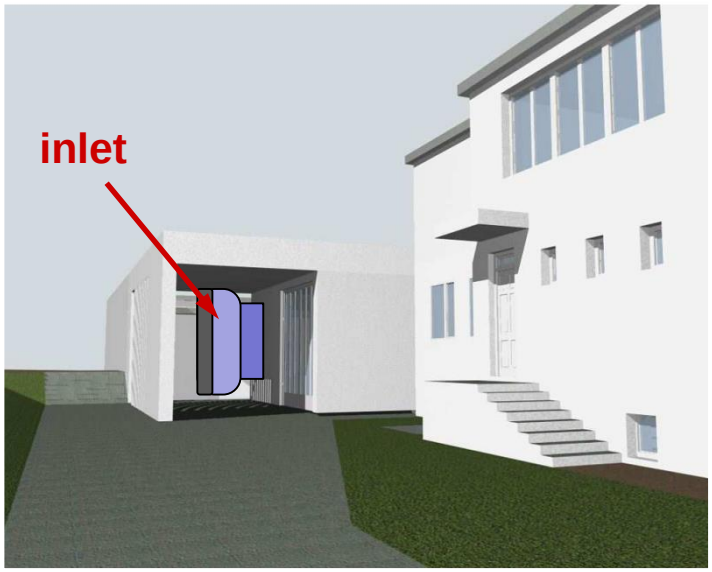
- Wind tunnel using external air but placed inside a closed laboratory
- Multiple fans to save length
- Optional forward test section

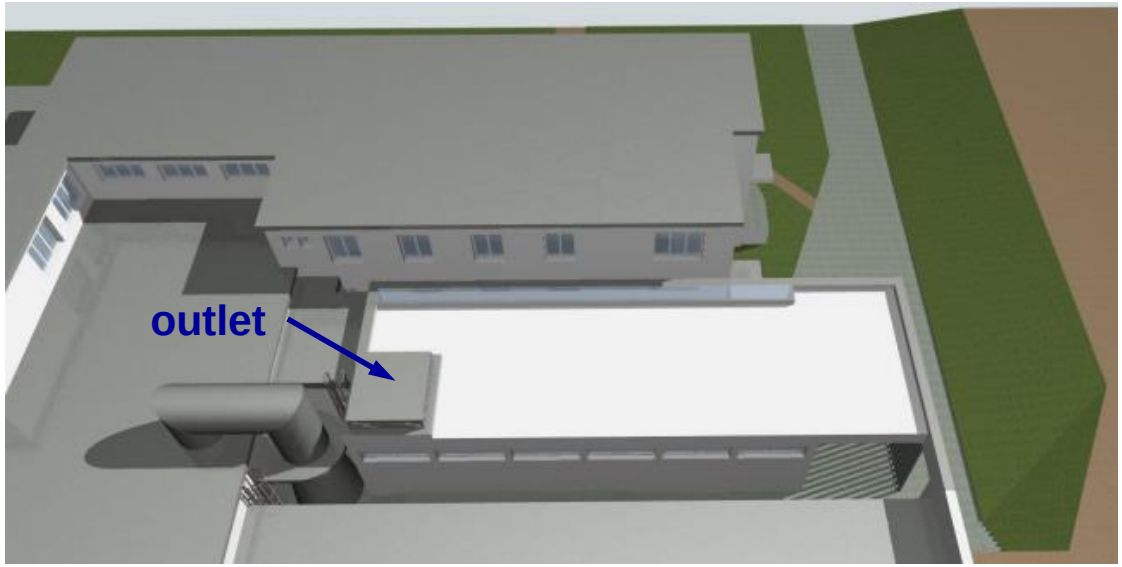


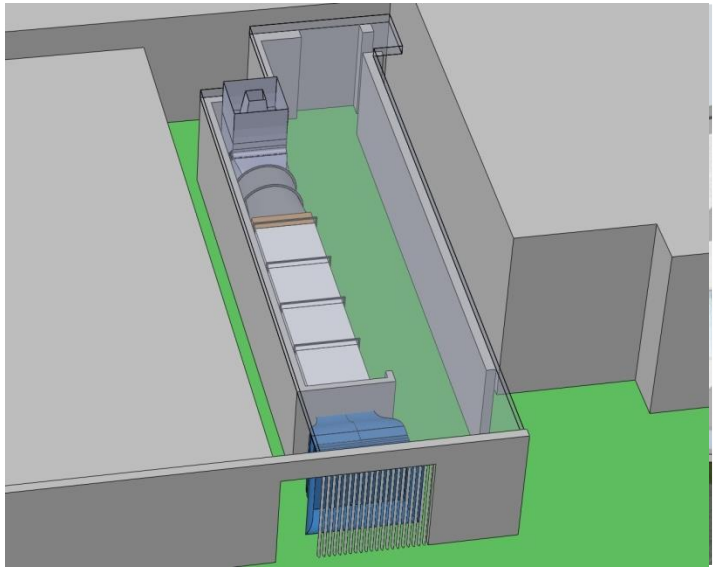
DESIGN VARIANTS

Version A

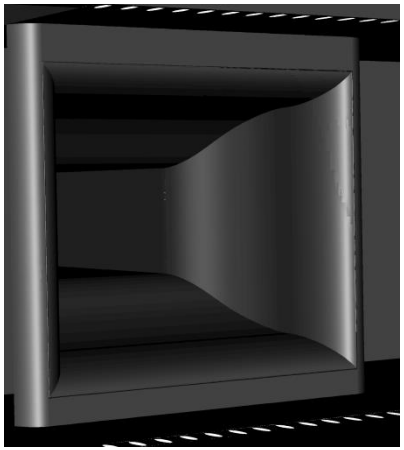






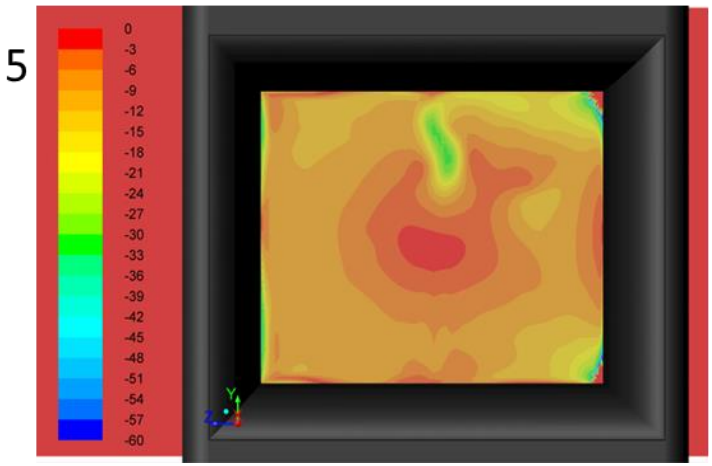


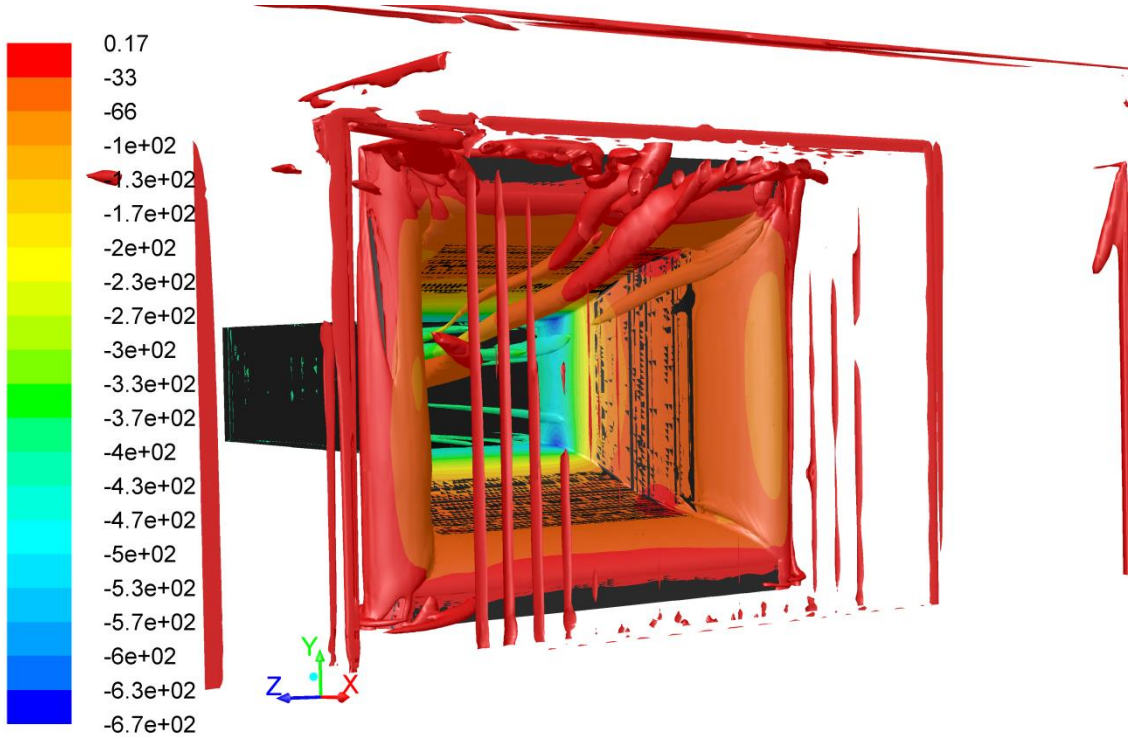
CFD SIMULATION OF THE INLET FLOW CONDITIONS AT VERSION A



Excerpt of CFD simulations performed by Péter Tóth

- Longitudinal vortex inside the contraction caused by assymmetric inflow
- Reduction of vortex strength through contraction design changes





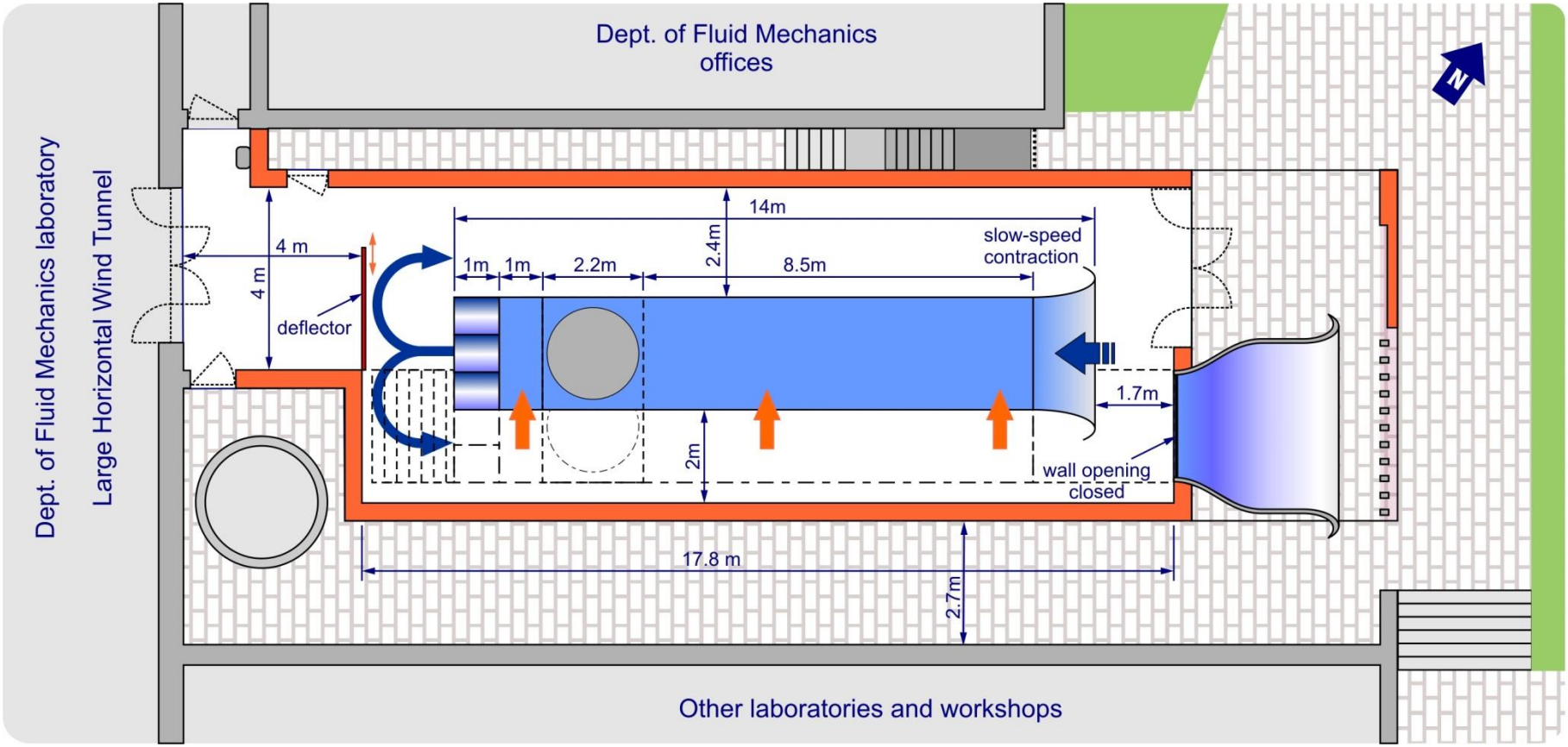
Contours of Static Pressure (pascal)

Oct 12, 2012
ANSYS FLUENT 14.0 (3d, pbns, sstkw)

DESIGN VARIANTS

Version B – improved design

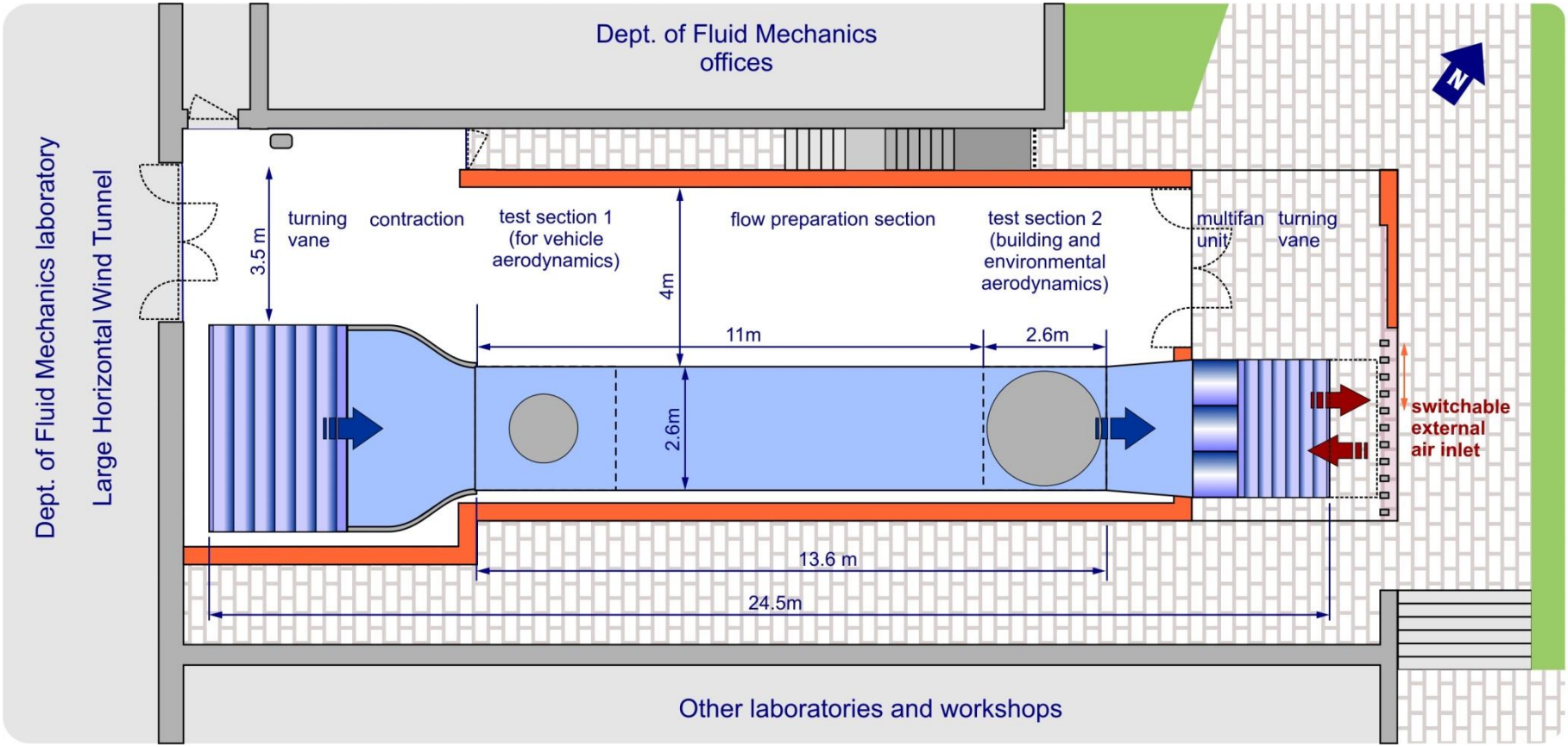
- Same as A, but:
- Movable wind tunnel : winter operation with internal air (speed limited)

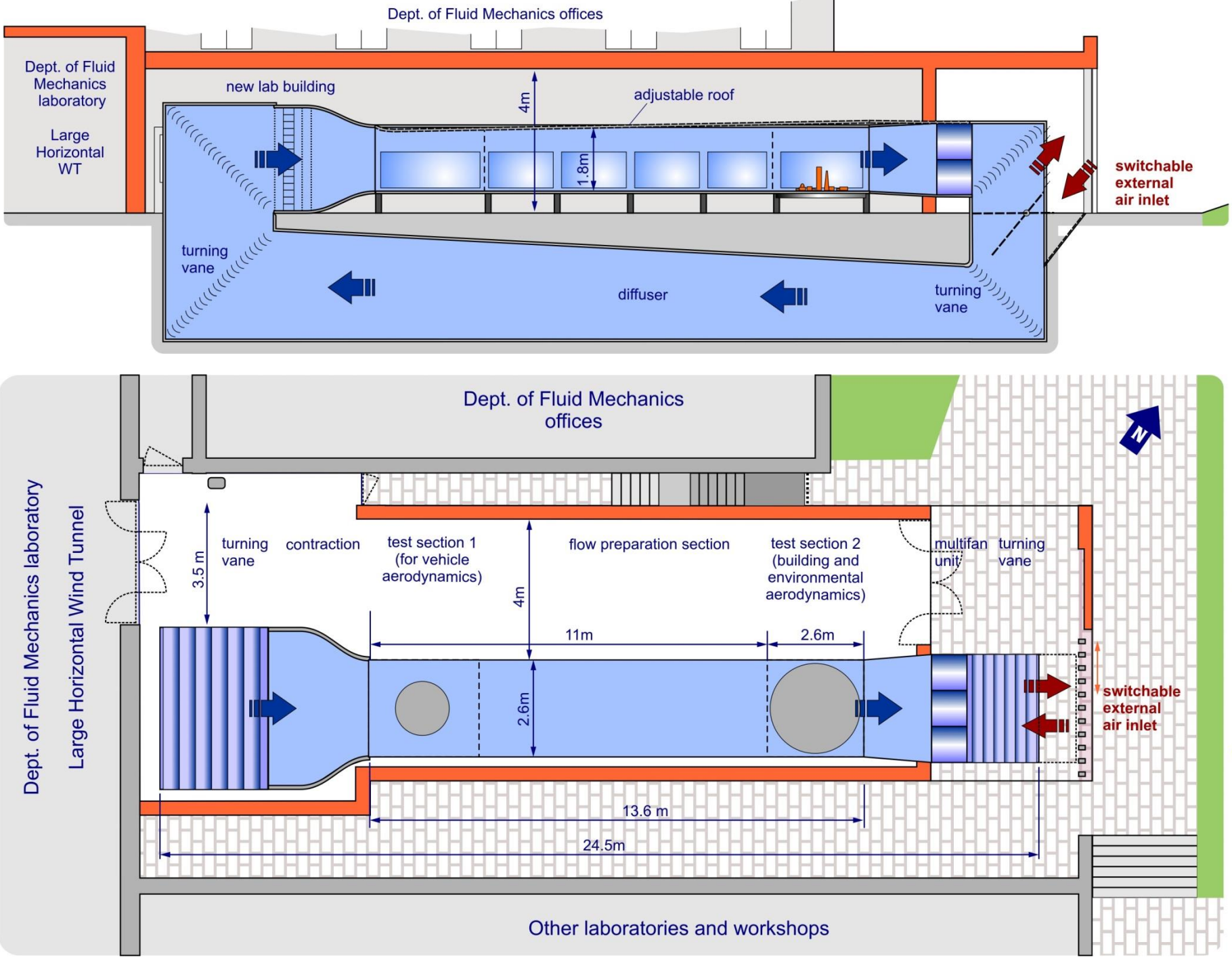


FLOW FIELD WITH USE OF EXTERNAL AIR

Version C

- New closed-circuit wind tunnel (returning leg under ground level)
- Use of external air optionally
- Vertical wind tunnel abandoned




Dept. of Fluid Mechanics offices
Dept. of Fluid Mechanics laboratory
Large Horizontal WT
new lab building
4m
adjustable roof
1.8m
switchable external air inlet
turning vane
diffuser
turning vane
Dept. of Fluid Mechanics offices
Dept. of Fluid Mechanics laboratory
Large Horizontal Wind Tunnel
N
3.5 m
turning vane
contraction
test section 1 (for vehicle aerodynamics)
4m
flow preparation section
test section 2 (building and environmental aerodynamics)
multifan unit
turning vane
11m
2.6m
2.6m
switchable external air inlet
Campus promenade
13.6 m
24.5m
Other laboratories and workshops

CONCLUSIONS

ANSWERS

1. All 3 boundary layer wind tunnel types can be realized at the site
2. Open return comes with serious compromises at the specific site
3. Closed circuit tunnel is the ultimative solution however at high costs and with abandonement of the vertical wind tunnel

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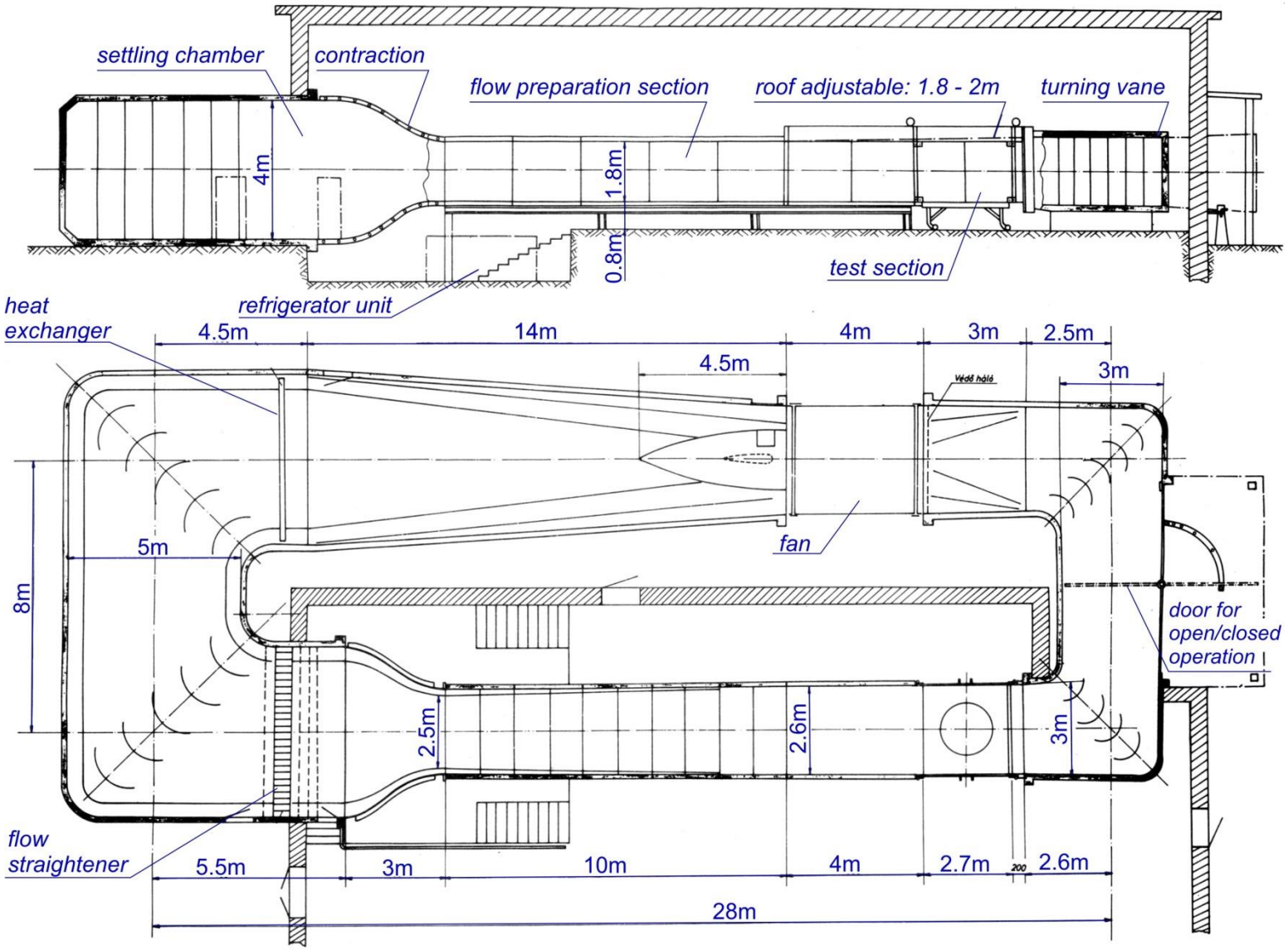
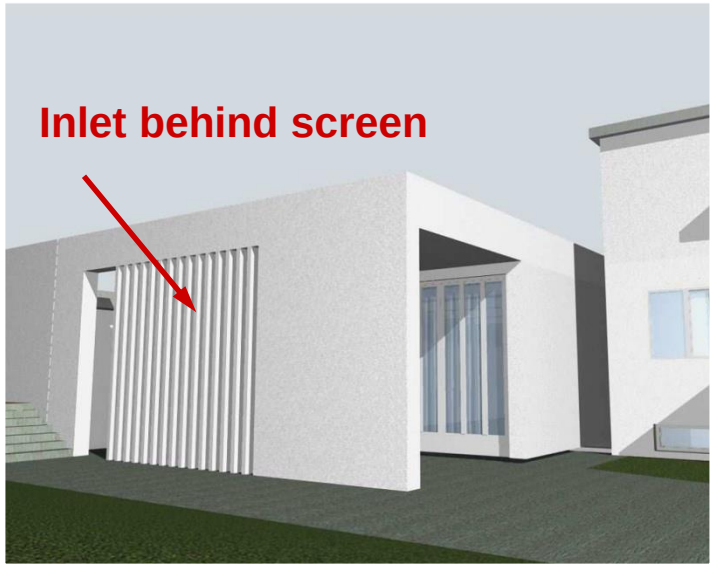
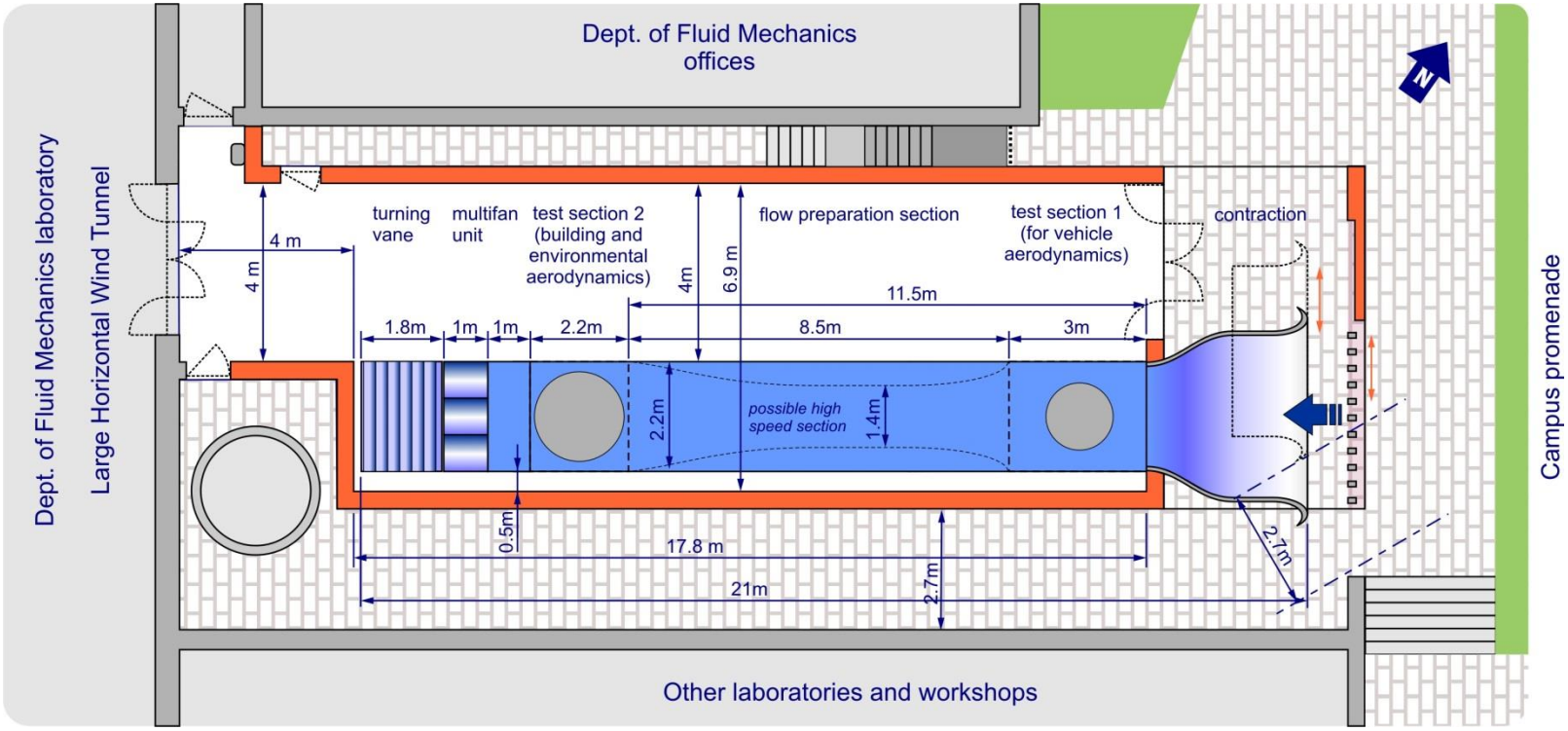
Wind Tunnel Laboratory

WIND TUNNEL DESIGN OF ÉTI (1978)




inlet


Inlet behind screen


Dept. of Fluid Mechanics
offices
Dept. of Fluid Mechanics laboratory
Large Horizontal Wind Tunnel
turning vane
multifan unit
test section 2 (building and environmental aerodynamics)
flow preparation section
test section 1 (for vehicle aerodynamics)
contraction
4 m
4 m
4m
6.9 m
11.5m
1.8m
1m
1m
2.2m
8.5m
3m
2.2m
possible high speed section
1.4m
0.5m
17.8 m
21m
2.7m
2.7m
N
Campus promenade
Other laboratories and workshops