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Air and water permeability of sandwich panel joints – requirements and state of research –

Klaus Berner

Marc Rippel

EPAQ Congress Porto

16. – 17.09.2010

CE

01234

AnyCo Ltd, PO Box 21, B-1050
XYZ Co
06
01234-CPD-00234

EN 14509

Metal faced insulating panel for use in buildings.

Reference: KS1000. Insulation: PUR Density: 35 kg/m^3 Thickness: 80mm. Facings: Steel 0,5 mm external: 0,4 mm internal (EN 10326). Coating: PVC. Mass: 12 kg/m^2.

Use: Roofs

Thermal transmittance:	0,25 W/m^{2}K
Mechanical resistance:	
Tensile strength	0,12 MPa
Shear strength	0,10 MPa
Reduced long term shear strength	0,08 MPa
Shear modulus (core)	3,0 MPa
Compressive strength (core)	0,14 MPa
Creep coefficient t = 2000 h	2,0
t = 100000 h	7,0

Bending resistance in the span	
- +ve bending	3,70 kNm/m
- +ve bending, elevated temperature	3,50 kNm/m
- -ve bending	2,90 kNm/m
- -ve bending, elevated temperature	2,75 kNm/m
Bending resistance at an internal support	
- +ve bending	2,60 kNm/m
- +ve bending, elevated temperature	2,50 kNm/m
- -ve bending	3,00 kNm/m
- -ve bending, elevated temperature	2.80 kNm/m
Wrinkling stress (external face)	
- in span	100 MPa
- in span, elevated temperature	95 MPa
- at central support	80 MPa
- at central support elevated temperature	75 MPa
Wrinkling stress (internal face)	
- in span	100 MPa
- at internal support	90 MPa

Reaction to fire: B–s2,d0 (with steel flashing details)

Fire resistance: E240: EI 15 (load 1,5 KN)

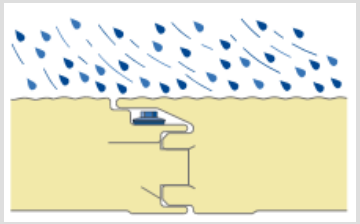
External fire performance: B_{ROOF} or $B_{ROOF(tX)}$

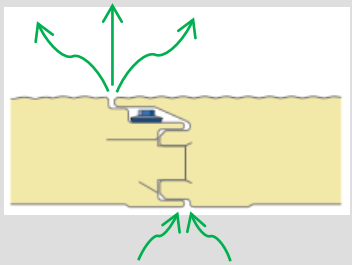
Water permeability: Class C

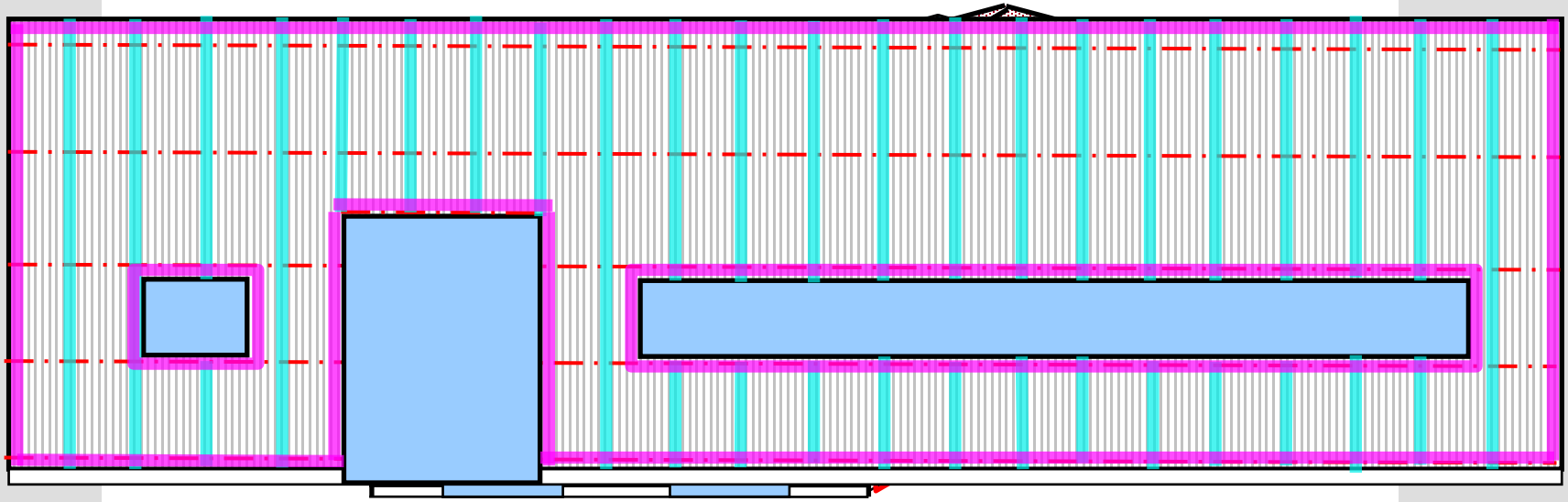
Air permeability: 10 m^3/h/m^2

Water vapour permeability: Impermeable

Airborne sound insulation: R_w (C:C_{tr})







individual designed joints for the special situation

sandwich-panel joints (longitudinal), layout relating to the product, only these joints are topic in the CE-mark

Type of panel-joints

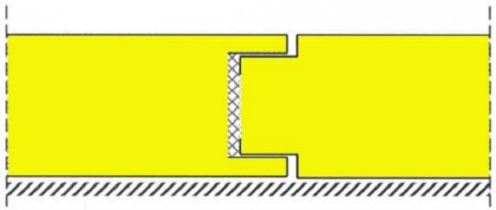


Figure A.17 – Joint type I

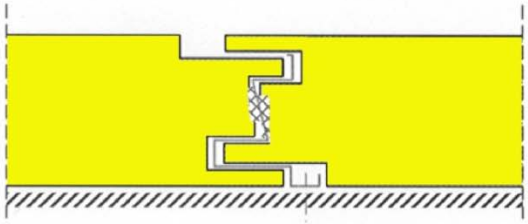


Figure A.18 – Joint type II

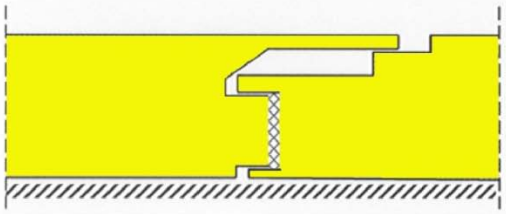


Figure A.19 – Joint type III

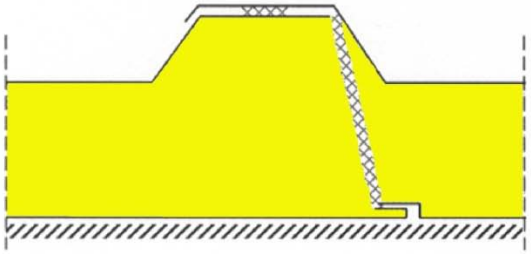


Figure A.20 – Joint type IV

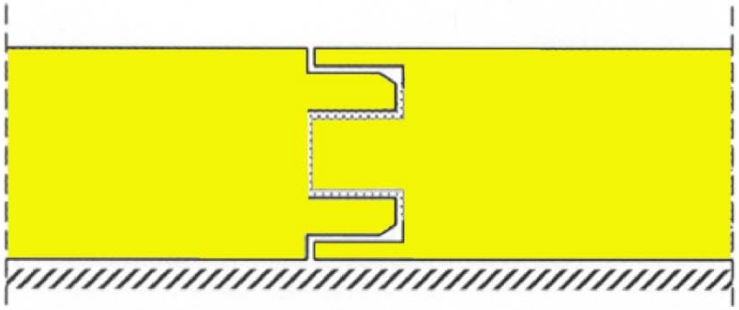


Figure A.21 – Joint type V (similar to type I but with a cut-to-shape joint without sealant)

EN 14509: A.11 Water permeability – resistance to driving rain under pulsating pressure

Where required, the resistance of a sandwich panel assembly to driving rain under pulsating air pressure shall be tested according to

EN 12865

One of the following three test classes shall be used:

- Class A: Demanding applications with heavy rain and wind.
  The assembly shall be watertight up to 1 200 Pa;
- Class B: Normal applications. The assembly shall be watertight up to 600 Pa;
- Class C: Low requirement applications. The assembly shall be watertight up to 300 Pa.

EN 14509: A.12 Air permeability

Where required, the air tightness of a sandwich panel assembly shall be tested according to

EN 12114

Calculations and results:

acccording to EN 12114

Why is the tightness of the joints so important?

The resistance to driving rain and the air tightness are official required, e.g. in national standards.

In Germany for air tightness:

- Change of air 1,5 or 3 per h
- Air permeability (air loss) < 0,1 $m^3/(m*h*daPa^{2/3})$

} minimal values

Very often more stringent requirements are demanded of the clients

- e.g. for cold stores, because of the nitrogen atmosphere
- costs of a loss of 100 litre nitrogen ca. 400 €

Example:

Store, ca. 30 000 m^3, 5 000 m^2 wall, 5 000 m joints

With 0,01 $m^3/(m*h)$ (=1/10 minimal value)

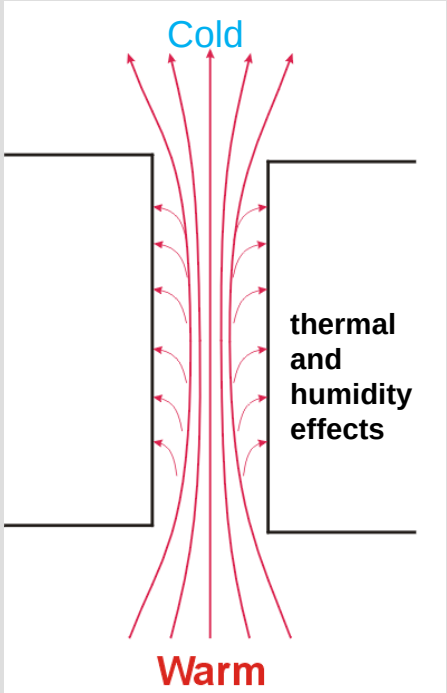
=> 50 m^3/h

=> 70 l nitrogen/h

=> 280 €/h

The physical situation regarding the tightness of joint is complicated:

Inside the joint moving particles are relevant as a dynamic fluid.



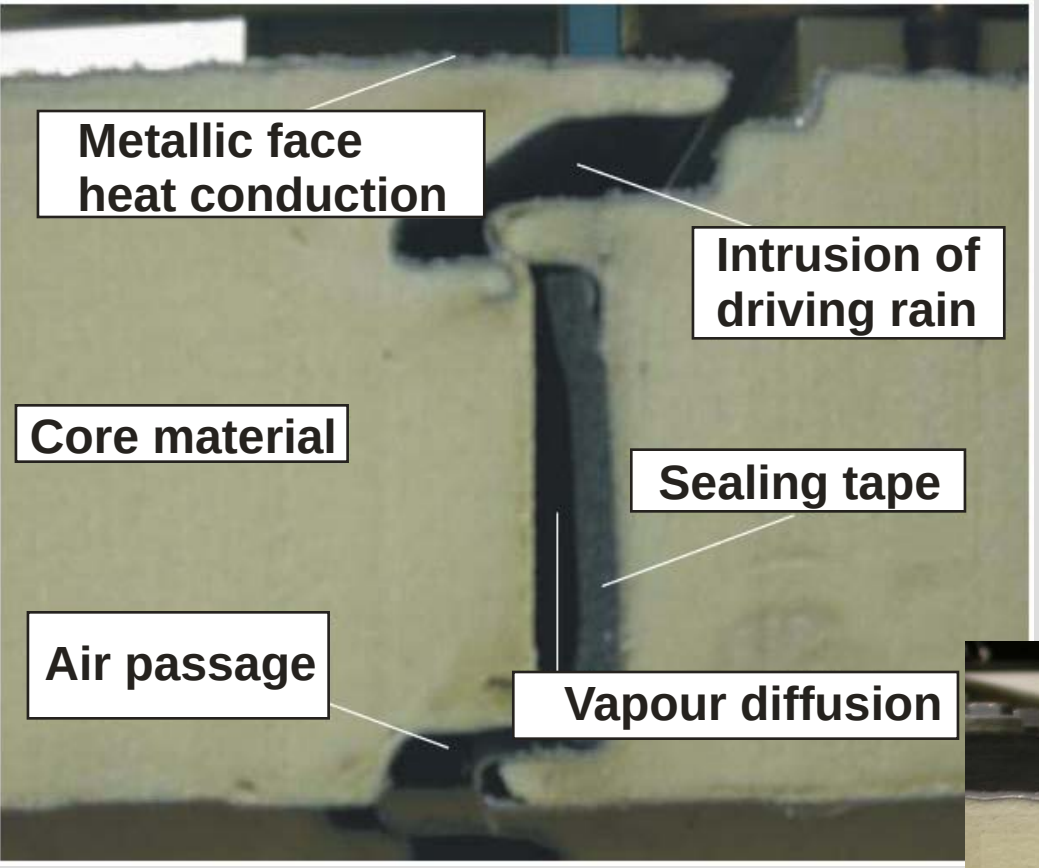
The tightness depends on

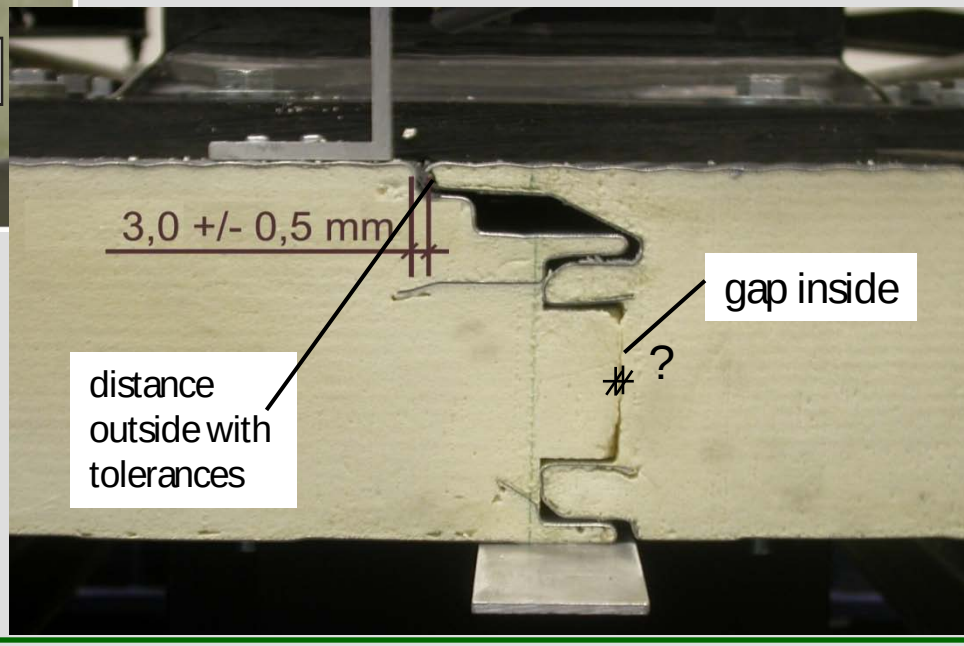
convection

- convection (lat. convehere = to take along, pick up) is the transport of material or physical characteristics due of the movement of particles

diffusion

- in a closed system the diffusion produces the decomposition of different concentrations to the point of complete mixing


Metallic face
heat conduction
Intrusion of
driving rain
Core material
Sealing tape
Air passage
Vapour diffusion


3,0 +/- 0,5 mm
gap inside
?
distance
outside with
tolerances

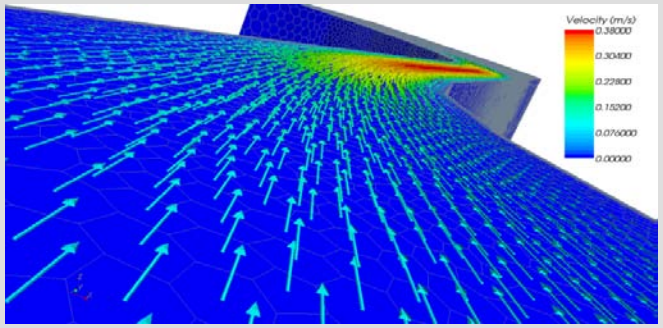
Research Project „DiFuSe“

„Research and Development of tight joints for sandwich panels used in building structures“

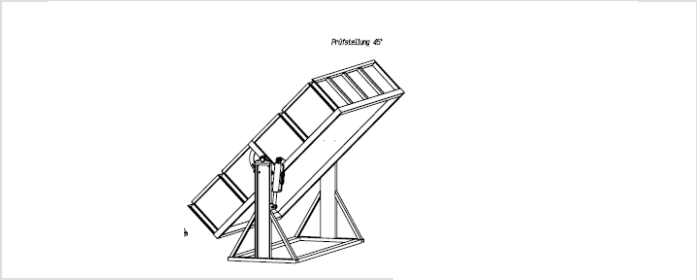
Project executing organisation	
Project executing research institut:	Institute for Sandwichtechnology (iS-Mainz), FH Mainz
Project leader:	Prof. Dr. Klaus Berner
Responsible research assistant:	Dipl.-Ing. Marc Rippel
Research partner:	15 industrial partners, e.g. ECP, FischerProfil, Hammersen, Romakowski, ThyssenKrupp, Trimo, etc.
Co-operation partner:	University Darmstadt (TU), Prof. Lange

Main focus of the research project „DiFuSe“, regarding the effect of panel-joints concerning the tightness:

1. Analysis by calculation using a computer program for computational fluid dynamic (CFD)
   Possibilities for e.g. efficient optimization of joint geometries or sealing strips without expensive tests



2. Analysis by tests using a test arrangement according to EN 12865 and 12114
   Possibilities to get official results for different types of joints, influence of different gaps or sealing strips



Test arrangement for checking
- resistance to driving rain according to EN 12865
- air tightness according to EN 12114

CEN TC 128 SC11, Working Group 1

Water and Air permeability, Annex A.11 and A.12

Statement:

- Horizontal standard is not clear enough regarding the configuration of the joints
- Testing should be clarified to improve the comparison between the test results of manufacturers

Proposal of Working Group 1 for the assessment of the joints in the tests

A11.3 and A12.3 Test specimens:

The length of the panel shall be 3 m or greater. At least 3 panels shall be used to create a minium of two vertical or horizontal joints.

The fixing of the panels shall be at 3 m (at the end of the panels) so that the panels bend independently from the frame.

Test arrangement for checking
- resistance to driving rain according to EN 12865
- air tightness according to EN 12114

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Mechanical resistance:	
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Reaction to fire: B–s2,d0 (with steel flashing details)

Fire resistance: E240: EI 15 (load 1,5 KN)

External fire performance: B_{ROOF} or $B_{ROOF(tX)}$

Water permeability: Class A [1)]

Air permeability: a = 0,014 m^3/(mhdaPa^{0,73}) [2)]

Water vapour permeability: Impermeable

Airborne sound insulation: R_w (C;C_{tr})

1) (Demanding applications with heavy rain and wind)
2) air permeability coefficient according to EN 12114

EPAQ European Quality Assurance Association for Panels and Profiles

Name of the expert

As an independent expert of EPAQ I confirm the following results to the water and air permeability:

Summary Nr. 2010-1

classification of water and air permeability

Object: sandwich panel, Type: ...

Manufacturer: ...

Classification

- Water permeability in accordance with EN 14509, A.11 or rather EN 12865:
  Class A — Demanding applications with heavy rain and wind
- Air permeability in accordance with EN 14509, A.12 or rather EN 12114:
  air permability coefficient a = 0,014 $m^3/(mhdaPa^{0,73})$
- specific regulation: (e.g.: special sealing strips)

Base: Test Report, No...., date...

Date ...

_____

This report is no type approval or product certification.

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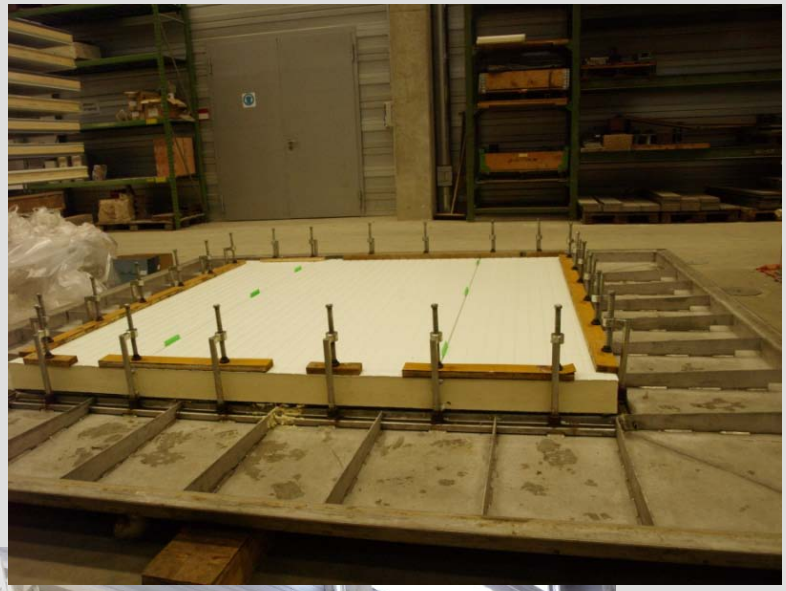
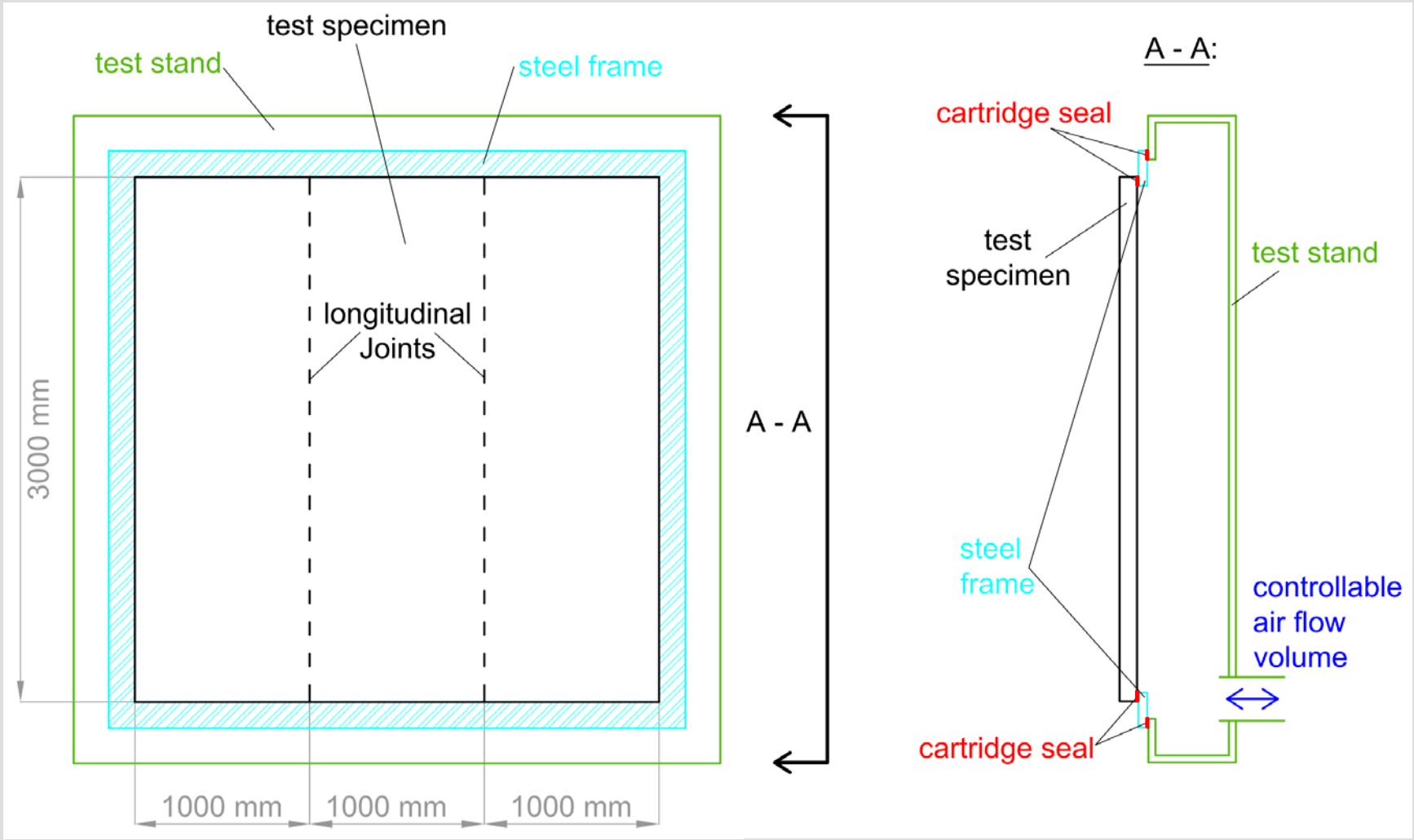


Air permeability



Regulation technology

Max. pressure in test chamber

- +/- 5000Pa (accuracy 1 Pa)

Realisable air flow volume:

- 0 to 1.3 m3/h (measuring range 0.0006 m3/h)
- 1.3 to 650 m3/h (measuring range 0.1 m3/h)

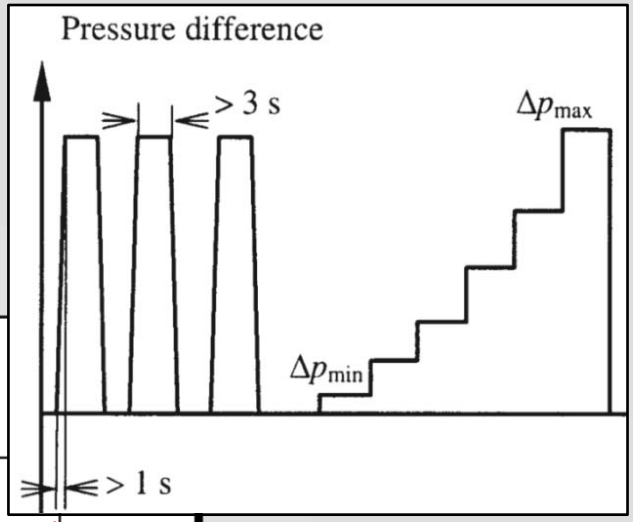
Water flow volume

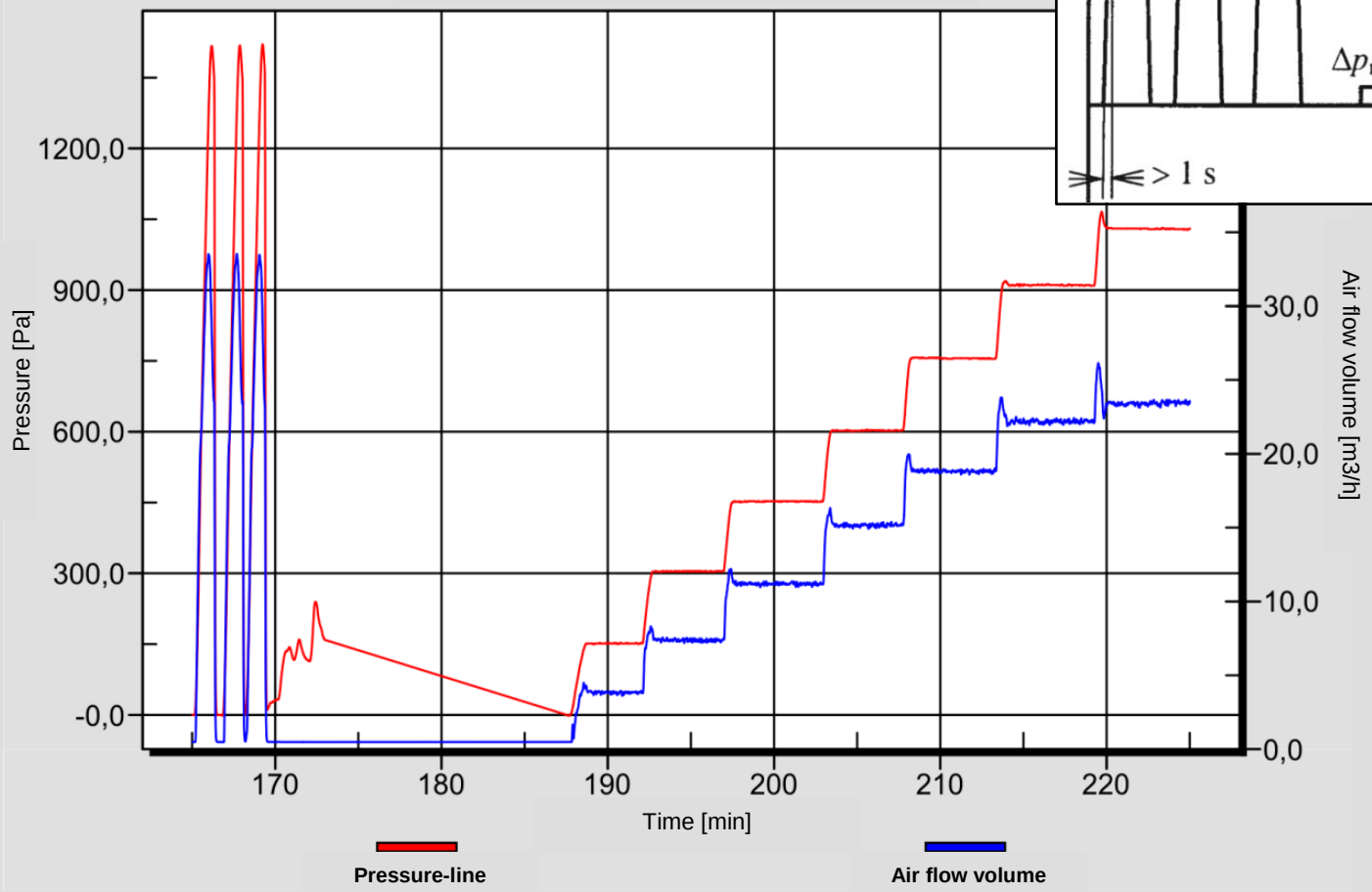
- 2 to 50 l/min (measuring range 0.1 l/min)
- Separable in run-off water and driving rain

Rotatability from 0 to 90°

Fog machine

Test procedure air permeability





Air permeability

Air permeability of longitudinal sandwichpanel-joints
-Determination of A-Value according to EN 14509-

Editor: | Date:

Producer: ....
Profil: ....

Ambient Pressure [Pa]:	103000	Lenght of joint [m]:	4
Temperature [°C]:	20,2	Surface area [m^2]:	4
Relative Humidity [%]:	53,1		

Conversation to reference conditions:

required if:
- air temperature <18°C or >22°C
- ambient pressure <1000mbar or >1020mbar
- rel. humidity <25% or >50%

$p_{W=}$ 1522,22 [Pa]
$\varrho_0=$ 1,1988 [kg/m^3]
$\varrho=$ 1,21632 [kg/m^3]

correction factor (k): 1,00728

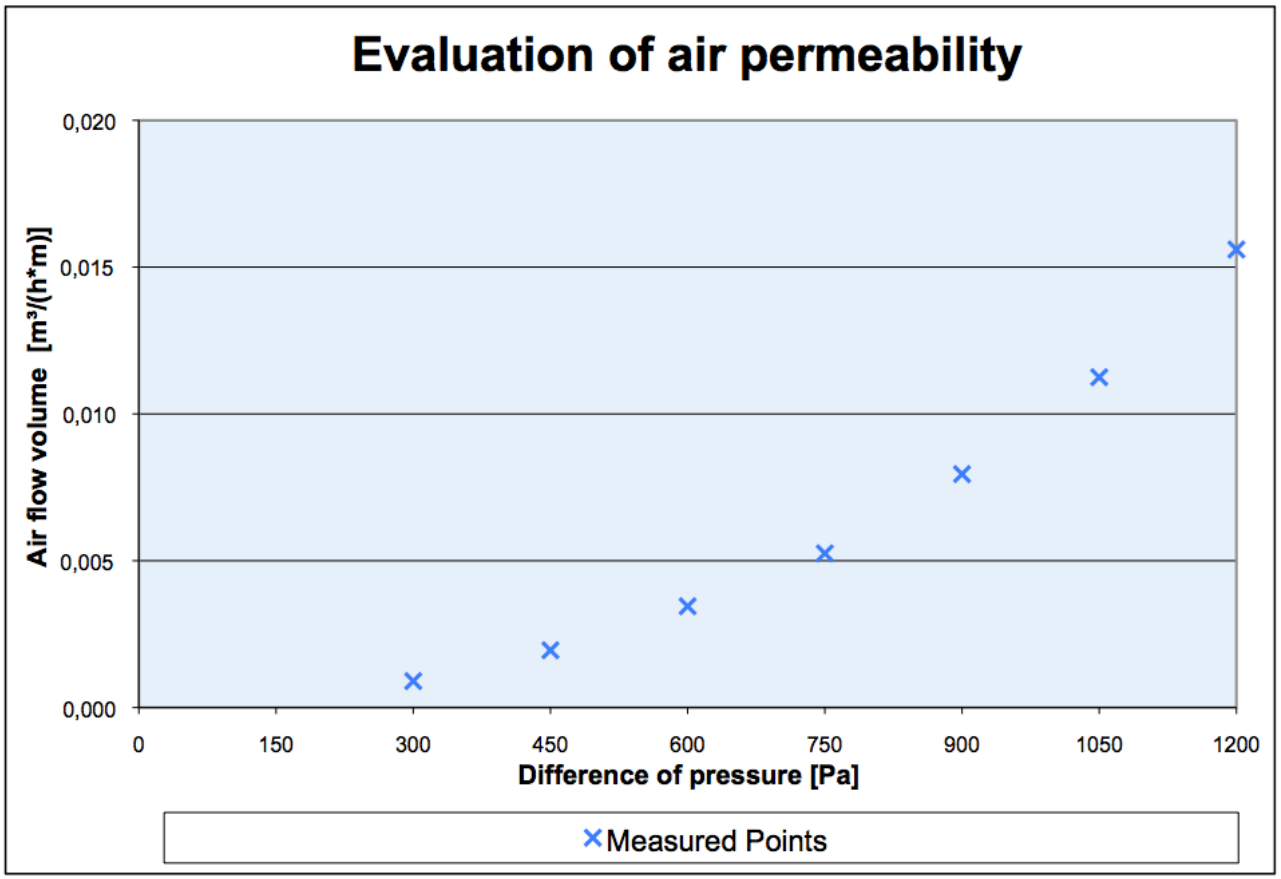
$\dot{V}_0 = k \cdot \dot{V}$

Stage	Press.-diff. [Pa]	Air flow volume (sealed) Press.-diff. [Pa]	Air flow volume (sealed) Air flow vol. [l/min]	Air flow volume (unsealed) Press.-diff. [Pa]	Air flow volume (unsealed) Air flow vol. [l/min]	effective air flow volume [m3/hm]	corr. effective air flow volume [m^3/hm]
1	150	150	60	150	80	0,000300	0,000302
2	300	300	90	300	150	0,000900	0,000907
3	450	450	120	450	250	0,001950	0,001964
4	600	600	160	600	390	0,003450	0,003475
5	750	750	200	750	550	0,005250	0,005288
6	900	900	250	900	780	0,007950	0,008008
7	1050	1050	300	1050	1050	0,011250	0,011332
8	1200	1200	360	1200	1400	0,015600	0,015714

Air permeability

Air permeability of longitudinal sandwichpanel-joints
-Determination of A-Value according to EN 14509-

Editor:		Date:	



Regression-method

$\bar{x} = \frac{1}{N}\sum_{i=1}^{N} x_i$ $\quad \bar{y} = \frac{1}{N}\sum_{i=1}^{N} y_i$

x_1=	5,01064	y_1=	-8,1045
x_2=	5,70378	y_2=	-7,0059
x_3=	6,10925	y_3=	-6,2327
x_4=	6,39693	y_4=	-5,6621
x_5=	6,62007	y_5=	-5,2423
x_6=	6,80239	y_6=	-4,8273
x_7=	6,95655	y_7=	-4,4801
x_8=	7,09008	y_8=	-4,1532

$\bar{x}$= 6,33621

$\bar{y}$= -5,7135

$s_x^2 = \frac{1}{N-1}\sum_{i=1}^{N}(x_i - \bar{x})^2$ s^2_x= 0,49476

$s_y^2 = \frac{1}{N-1}\sum_{i=1}^{N}(y_i - \bar{y})^2$ s^2_y= 1,80316

$s_{xy} = \frac{1}{N-1}\sum_{i=1}^{N}(x_i - \bar{x})(y_i - \bar{y})$ s_{xy}= 0,94227

$n = \frac{s_{xy}}{s_x^2}$ n= 1,90449

$\alpha = \bar{y} - n\bar{x}$ α = -17,781

$A = \exp(\alpha)$ A= 1,9E-08

Regressionskurve (Wertepaare)

$\dot{V} = A \cdot \Delta p^n$

0	0	600	0,00371
10	1,5E-06	650	0,00432
50	3,3E-05	700	0,00497
100	0,00012	750	0,00567
150	0,00026	800	0,00641
200	0,00046	850	0,00719
250	0,0007	900	0,00802
300	0,00099	950	0,00889
350	0,00133	1000	0,0098
400	0,00171	1050	0,01076
450	0,00214	1100	0,01175
500	0,00262	1150	0,01279
550	0,00314	1200	0,01387

C

A-value according to regression-method:

1,9E-08 $m^3/(mhdaPa^n)$

with n= 2

Joint distance:

ø [mm 5

Institut für SANDWICHTECHNIK iS-mainz Holzstraße 36 55116 Mainz Germany

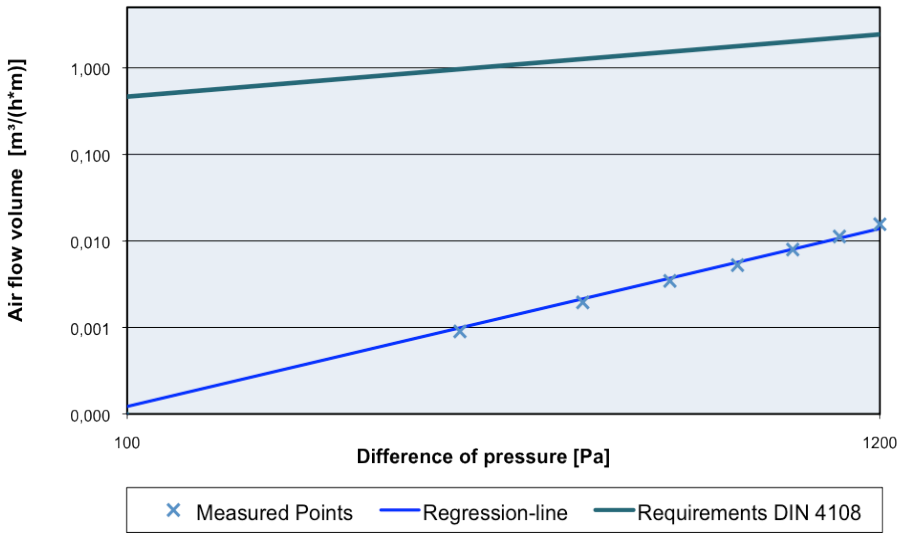
Air permeability of longitudinal sandwichpanel-joints

-Determination of A-Value according to EN 14509-

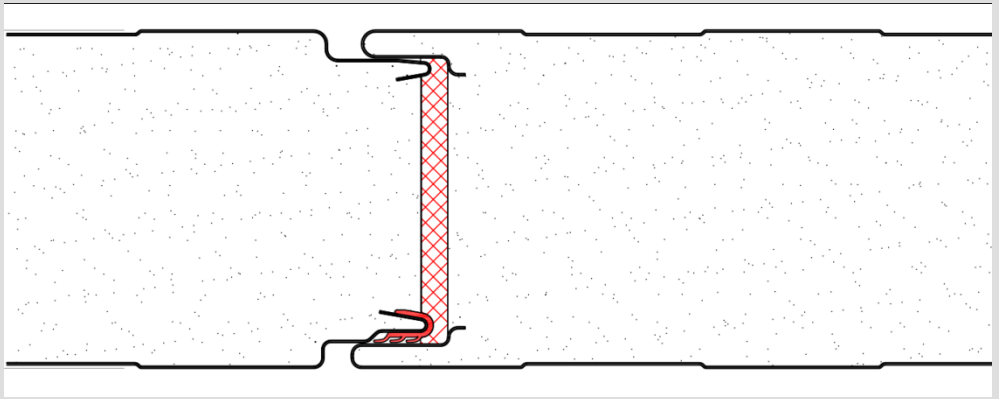
Editor:		Date:	

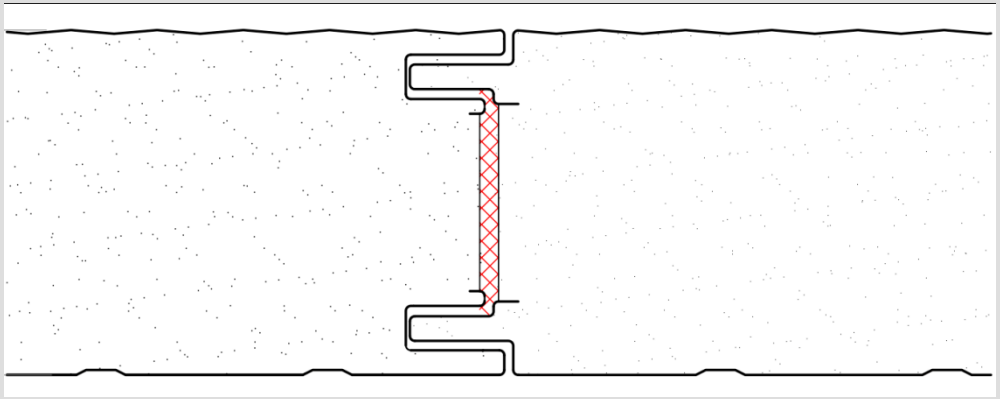
Evaluation of air permeability

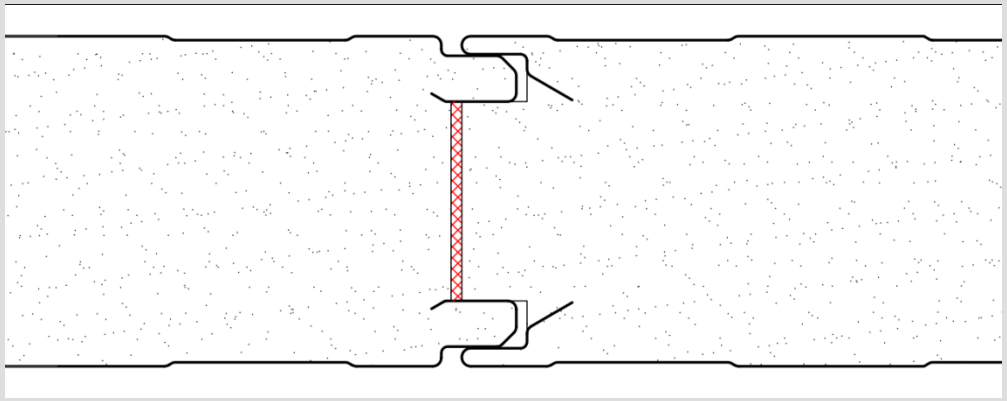
- linearised -

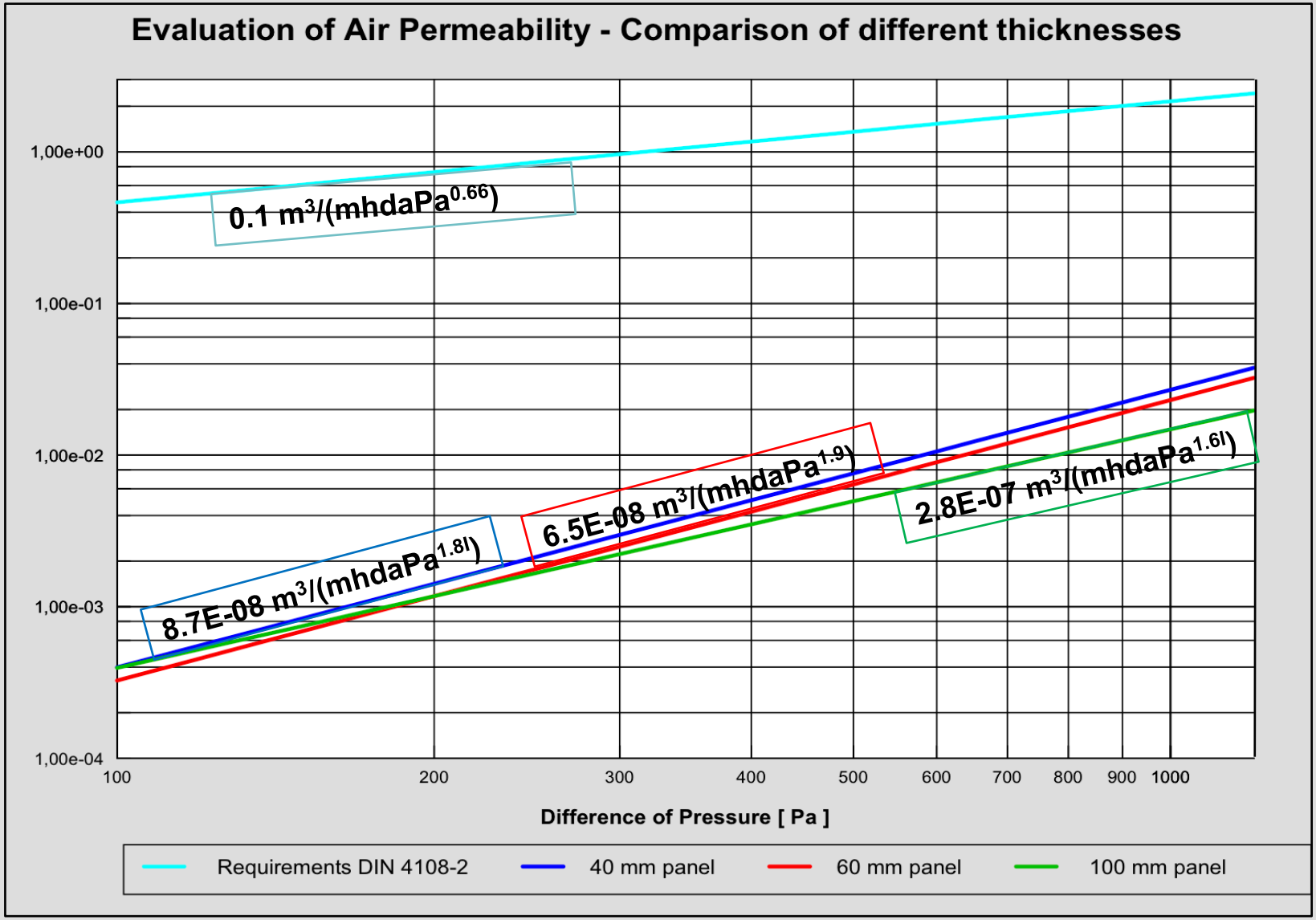


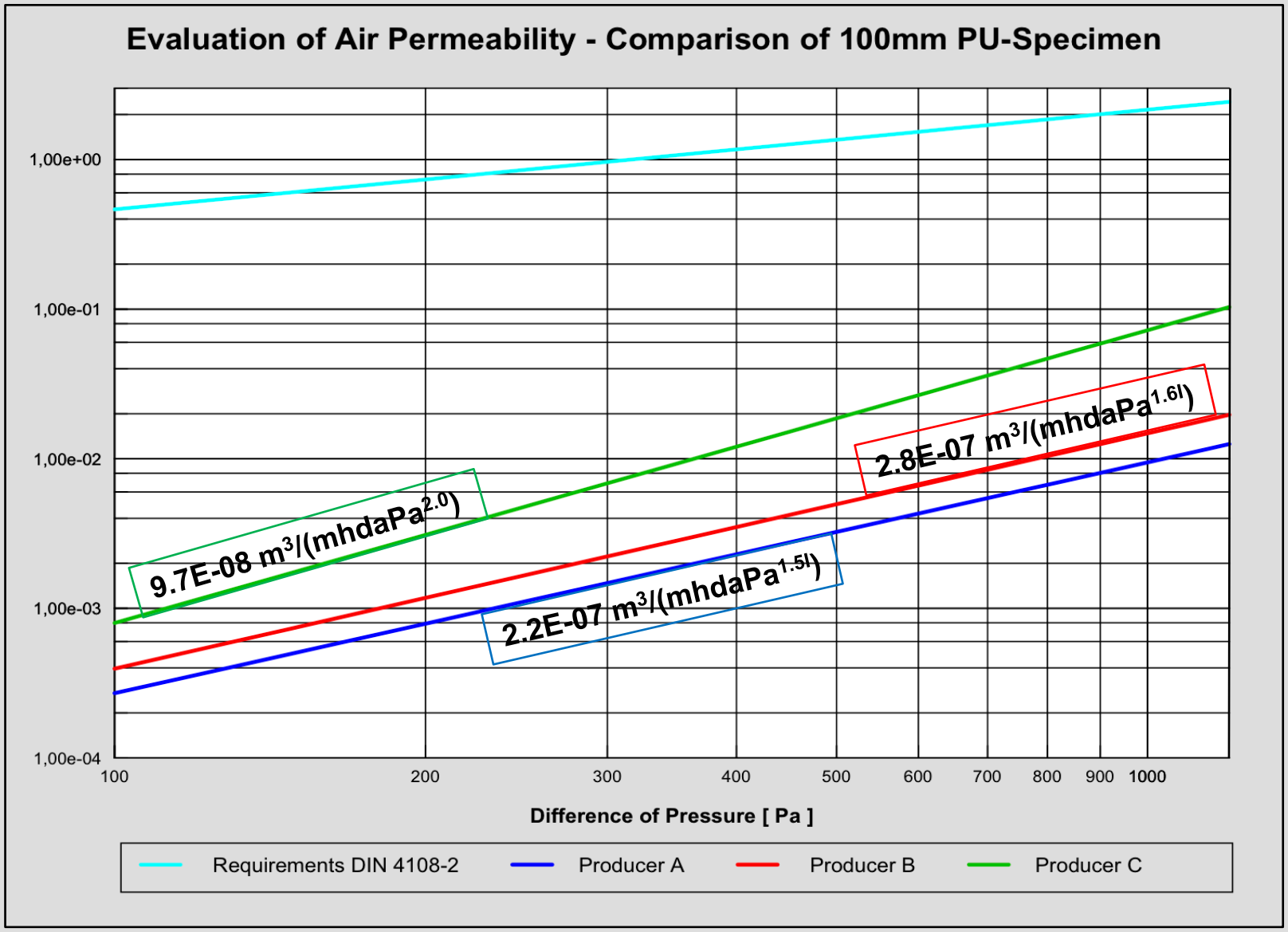
Geometries of tested joints



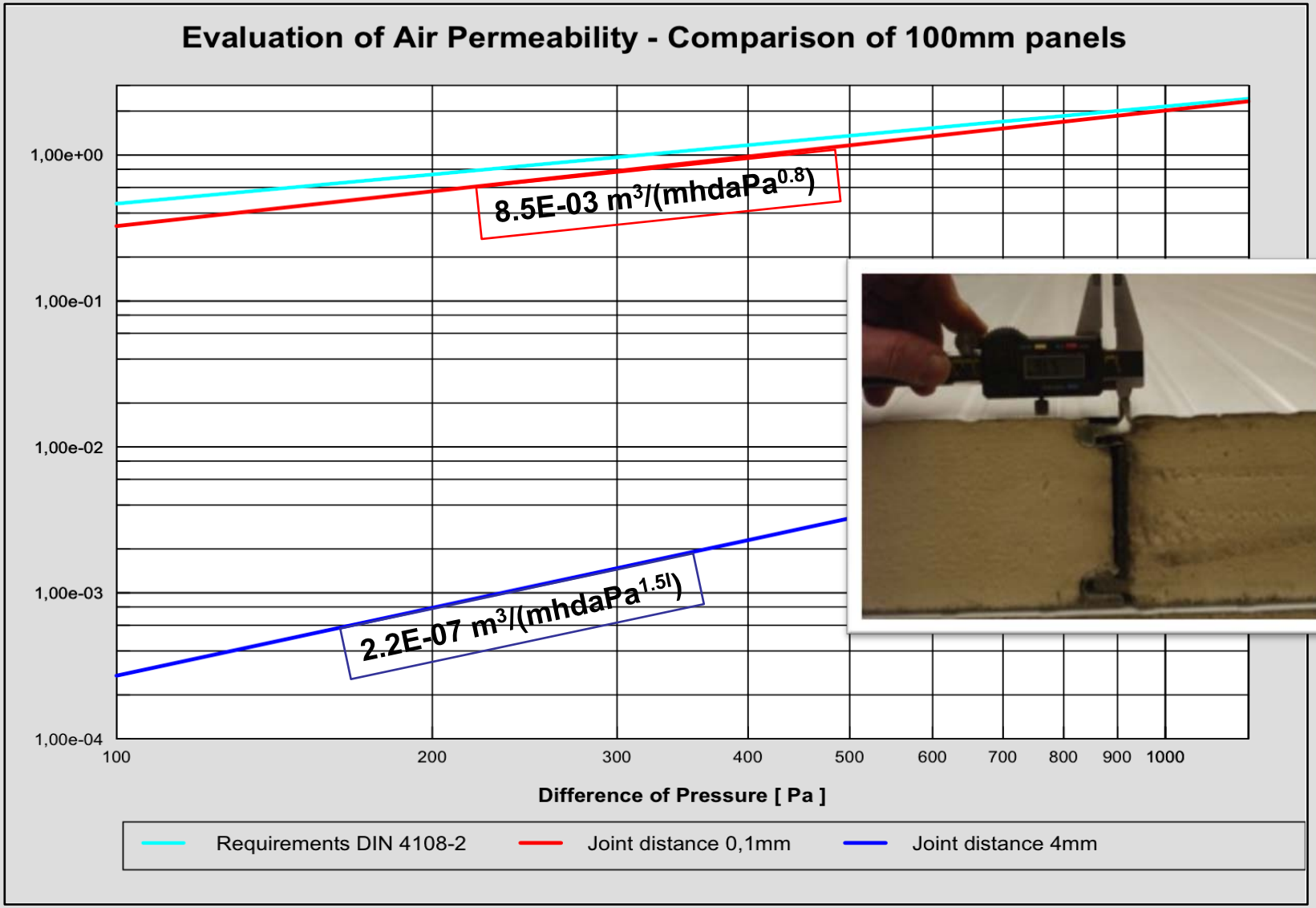




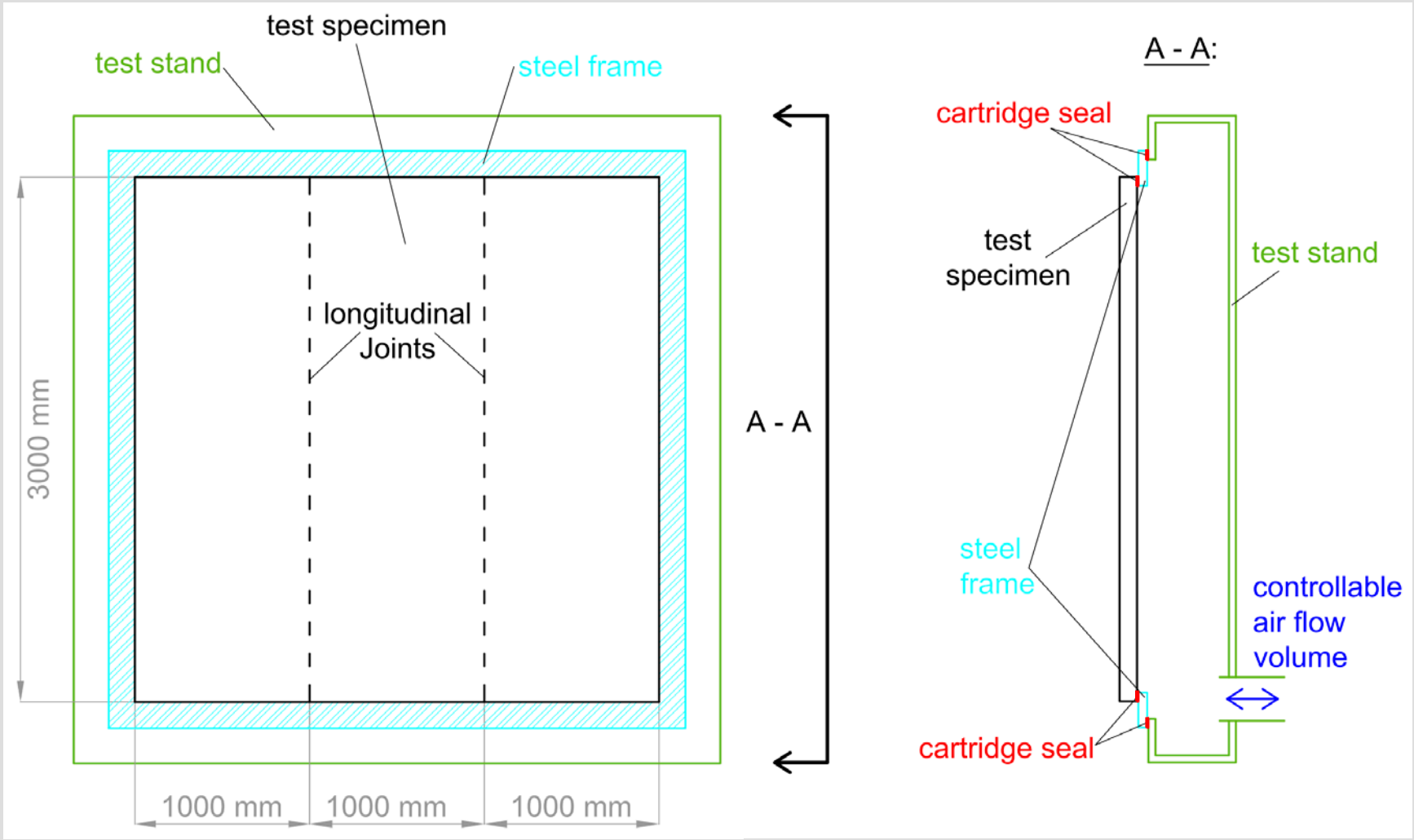




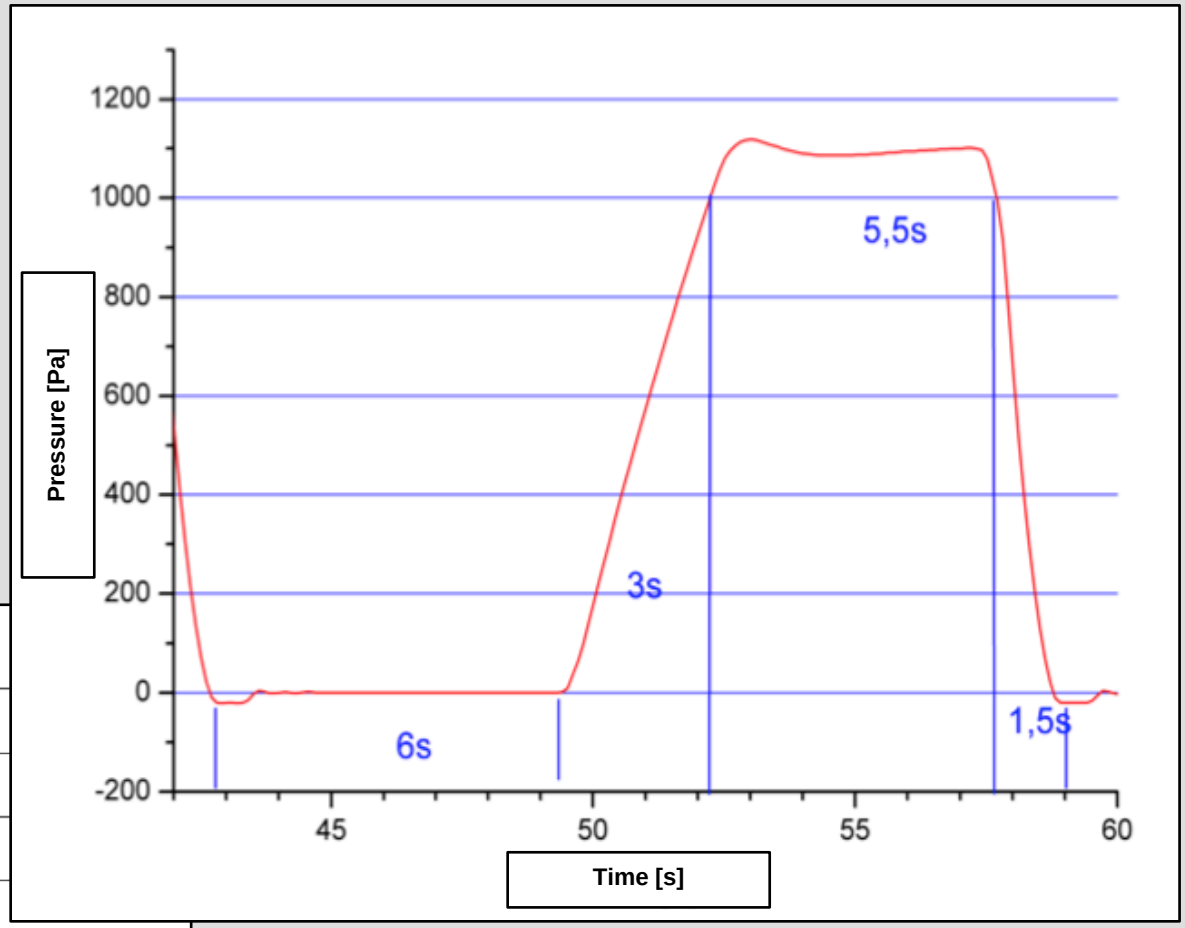
Evaluation of Air Permeability - Comparison of 60mm panels

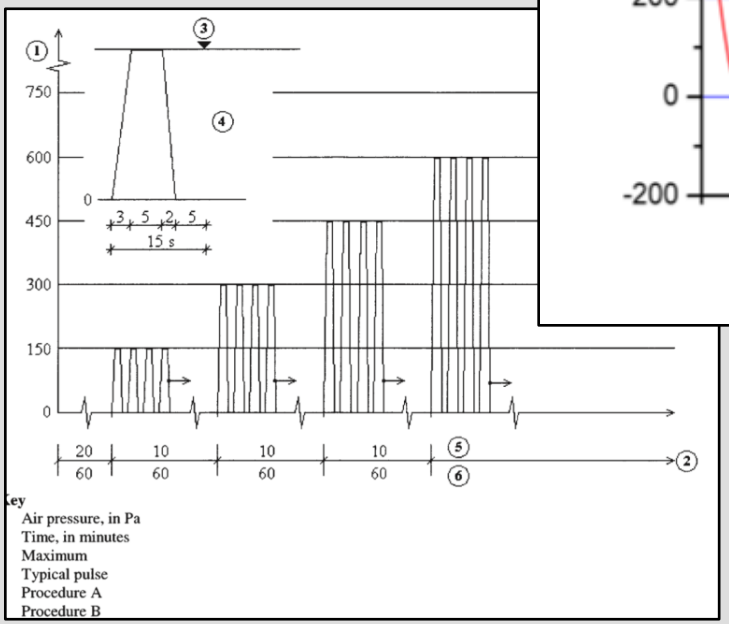


Air permeability

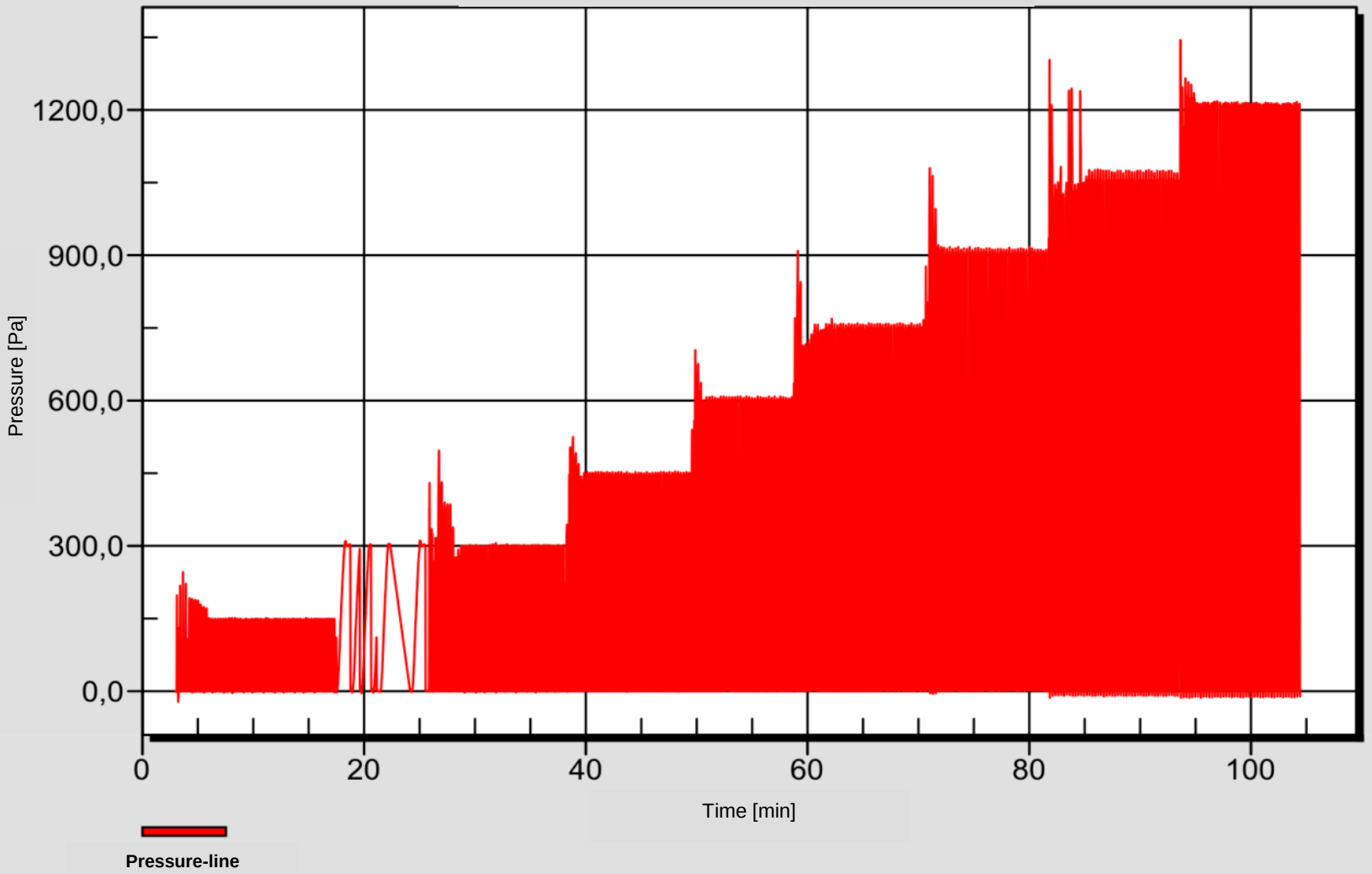


Water permeability





Test procedure water permeability



Results of water permeability

Classification

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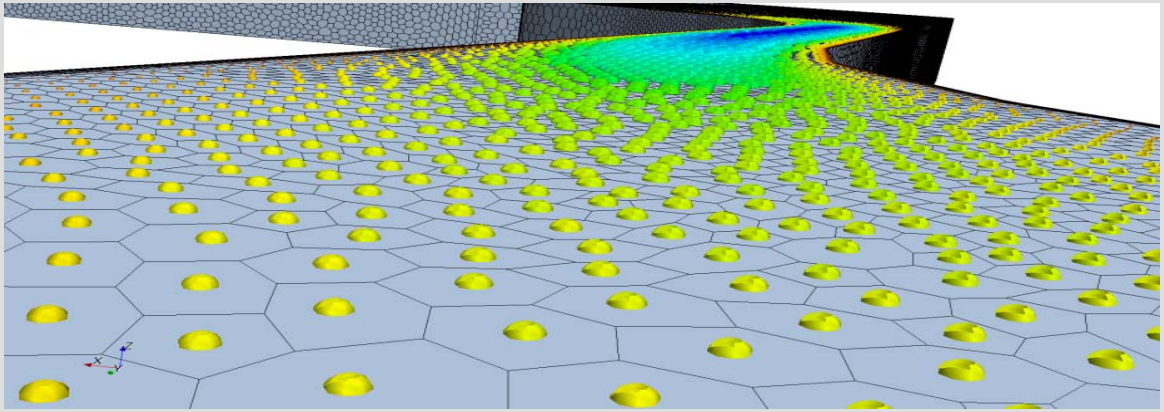


CFD…

…is an established method of fluid mechanics

…is able to simulate realistic movement of fluids including the existance of unsteady flow or non-laminar flow

…uses numerical methods and algorithms to solve and analyze problems that involve fluid flows

…solves complex systems of non-linear equations which describe the motion of fluid substances (Navier-Stokes) by computation

…enables to visualize movement of any kind of fluid or gas in or around material systems (simulation)

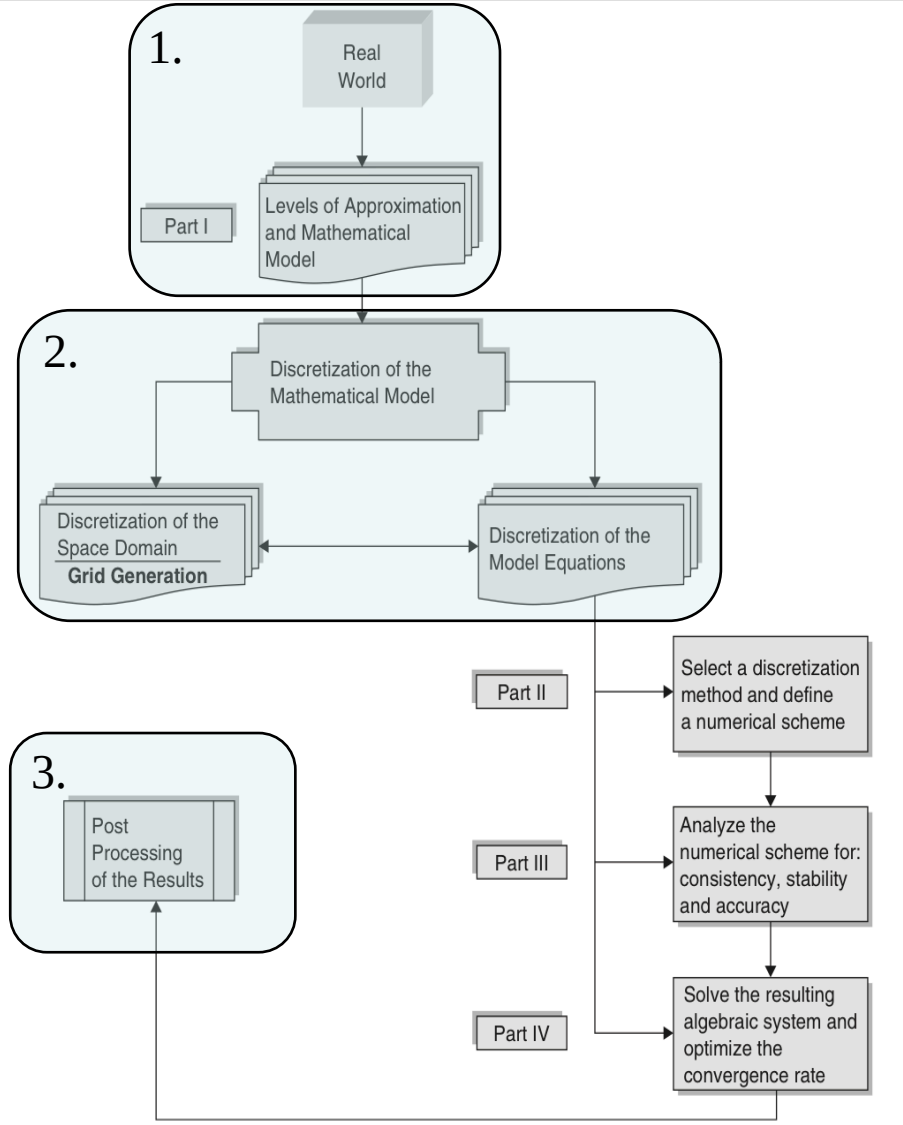
…performs millions of calculations to simulate the interaction of liquids and gases with surfaces defined by boundary conditions

1.
Physical properties
Equations of fluid mechanics under assumption of a newtonian fluid (Navier-Stokes), material properties, turbulence model
Geometry
Import, Defining regions (solid/ fluid)

2.
Discretization of geometry →"meshing"
Surface Mesh/ Volume Mesh

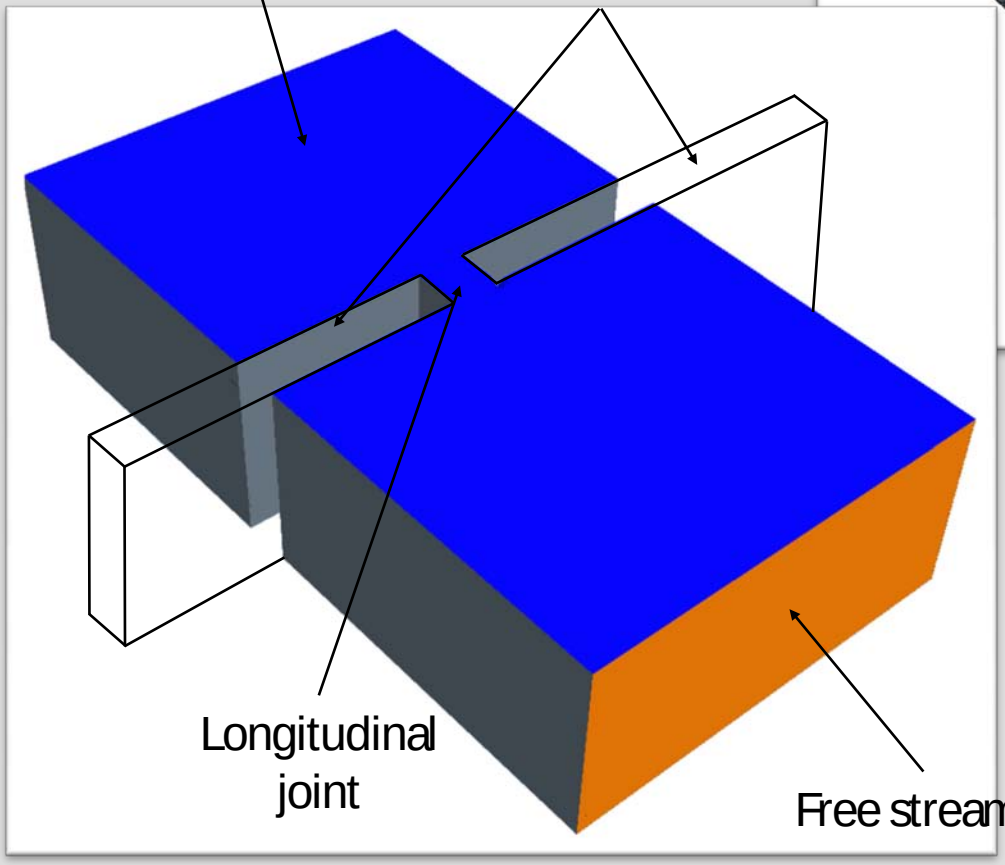
Discretization of physics →
Transformation of differential equations into algebraic functions (by FVM)
Construction of an solvable algebraic system of equations (similar number of equations and unknowns)

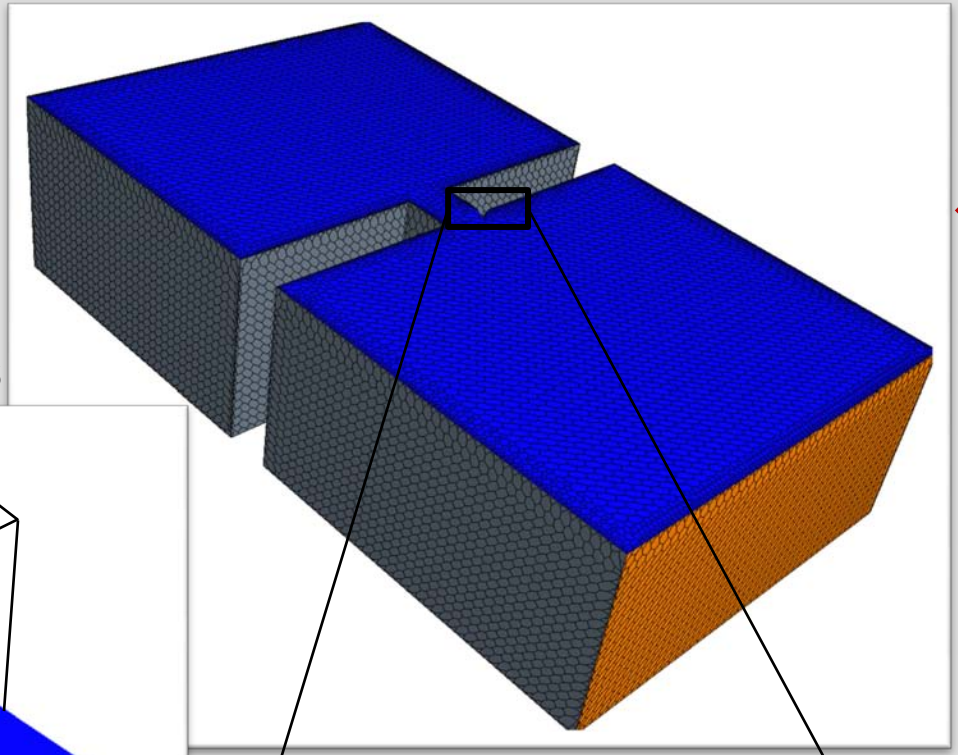
3.
Post processing (exposition of results)

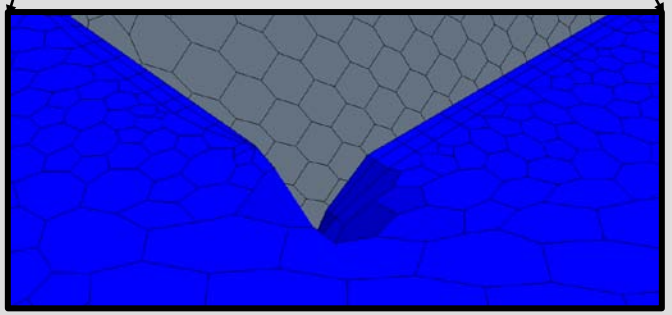


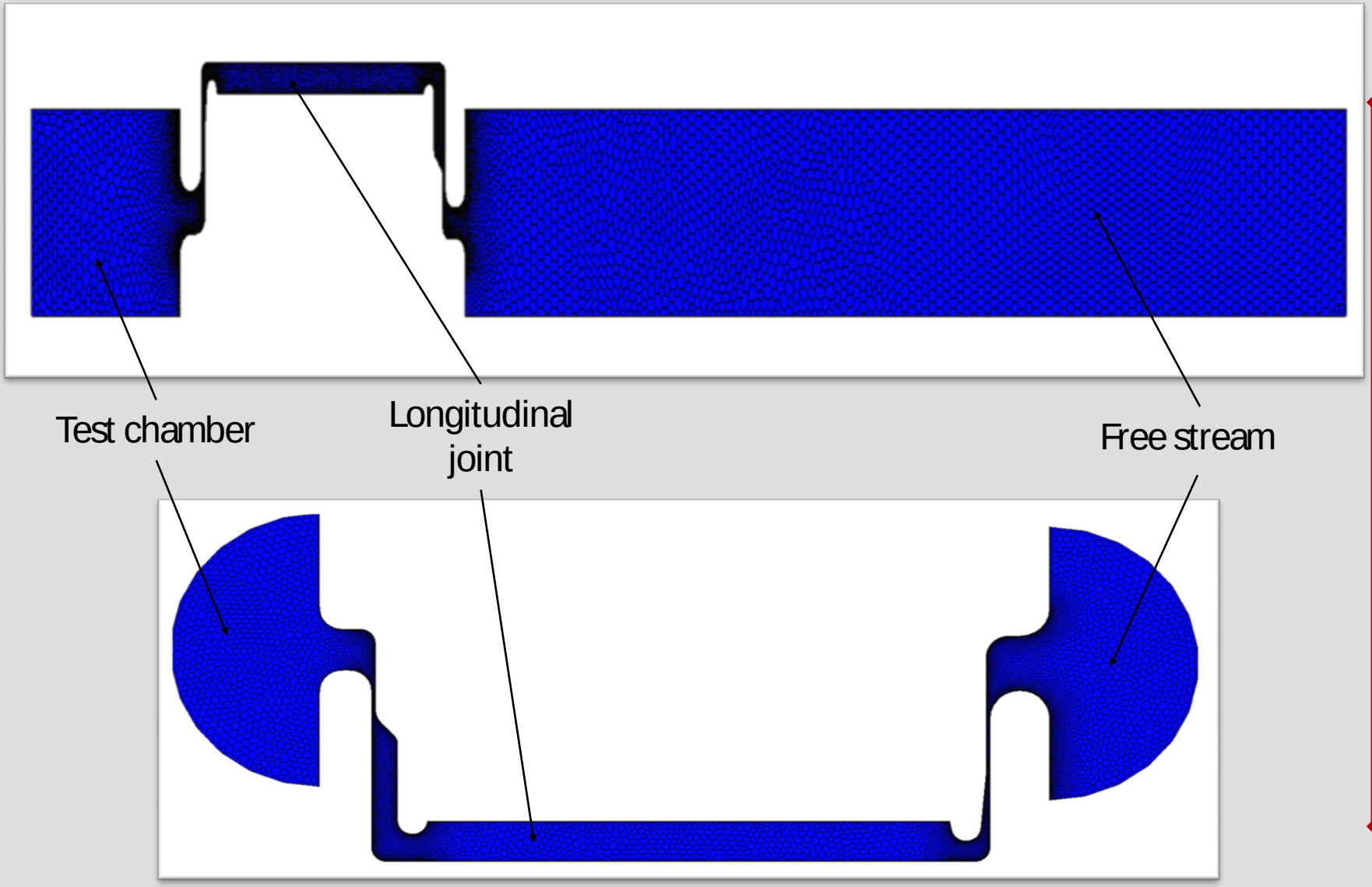
Structure of a CFD simulation system

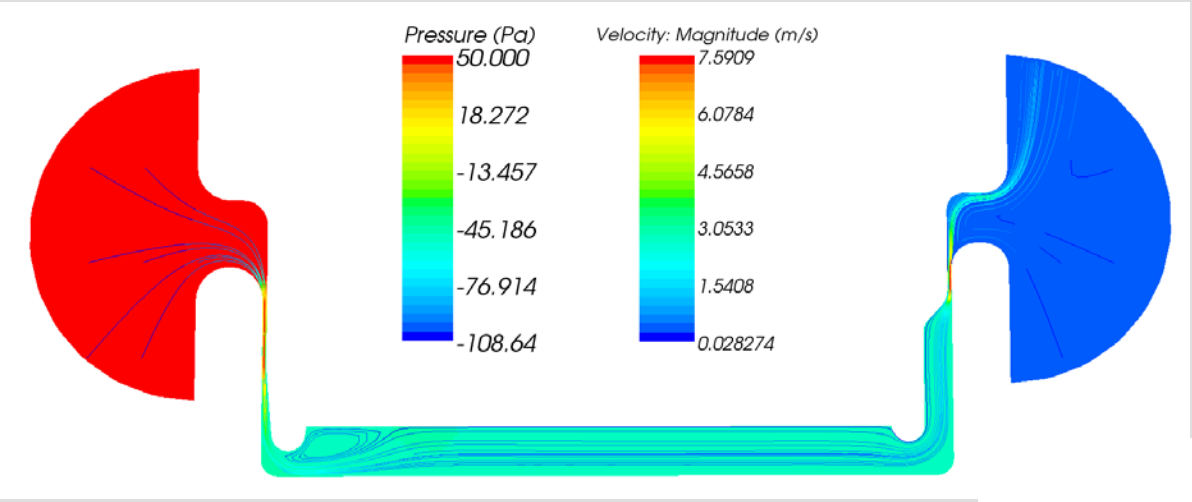
1. Test apparatus
2. Test procedure
3. Test Results
4. CFD
5. Conclusion

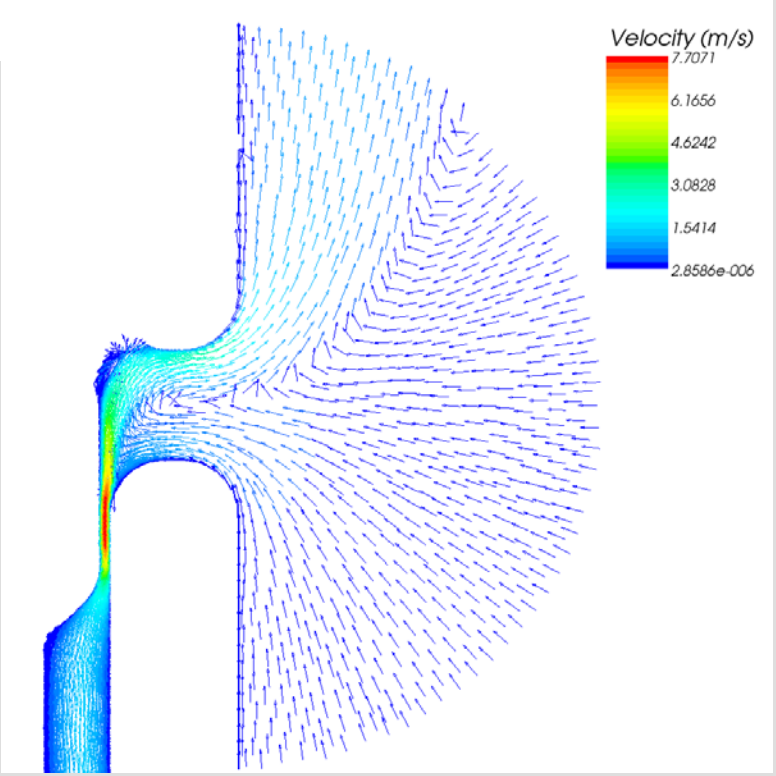


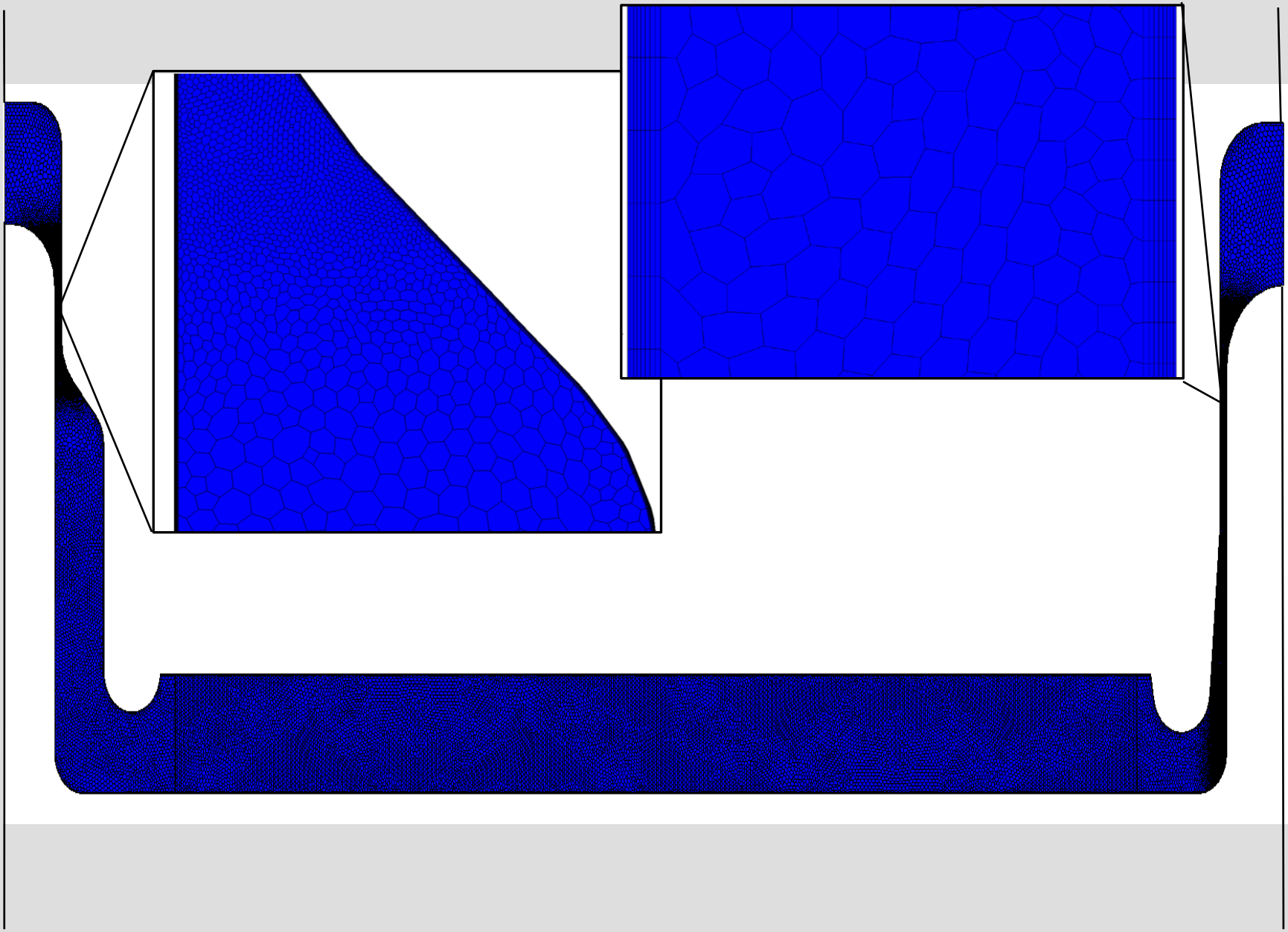


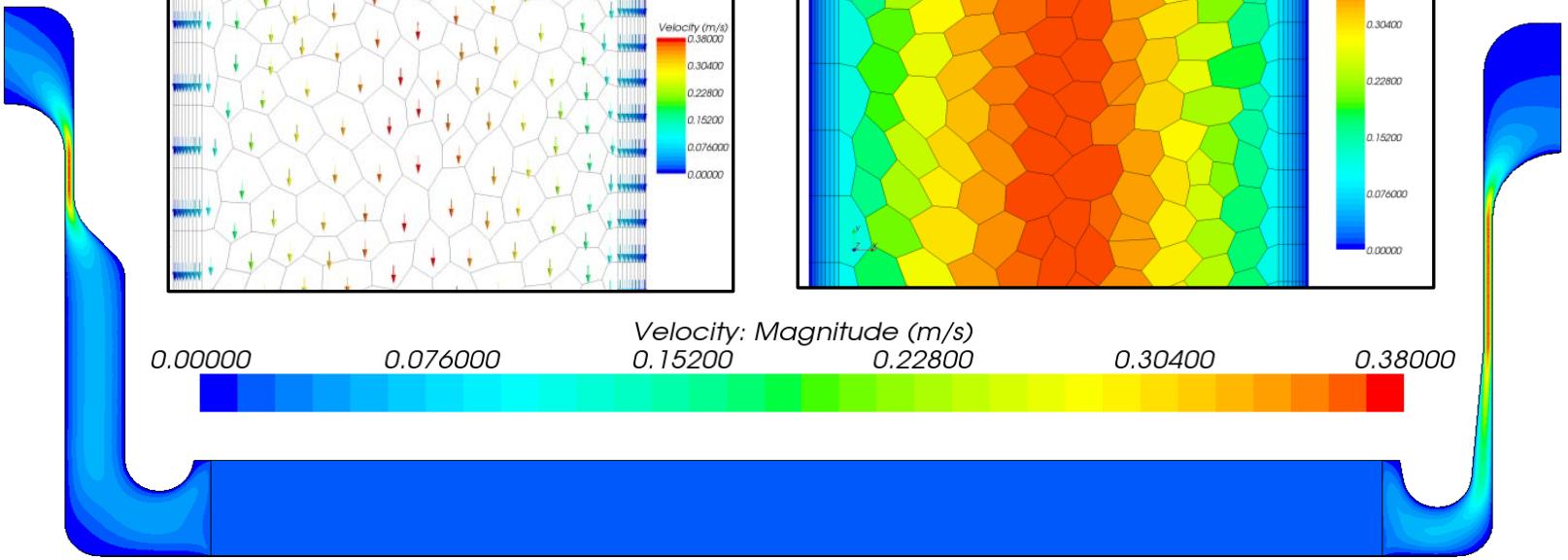


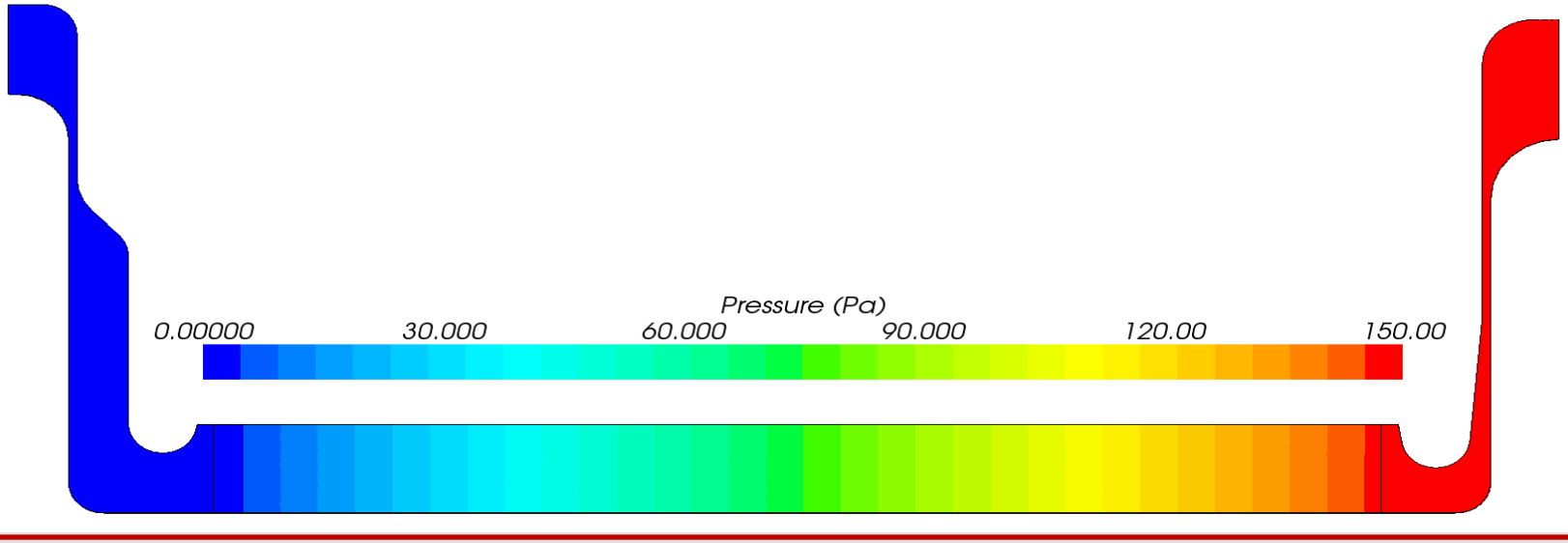






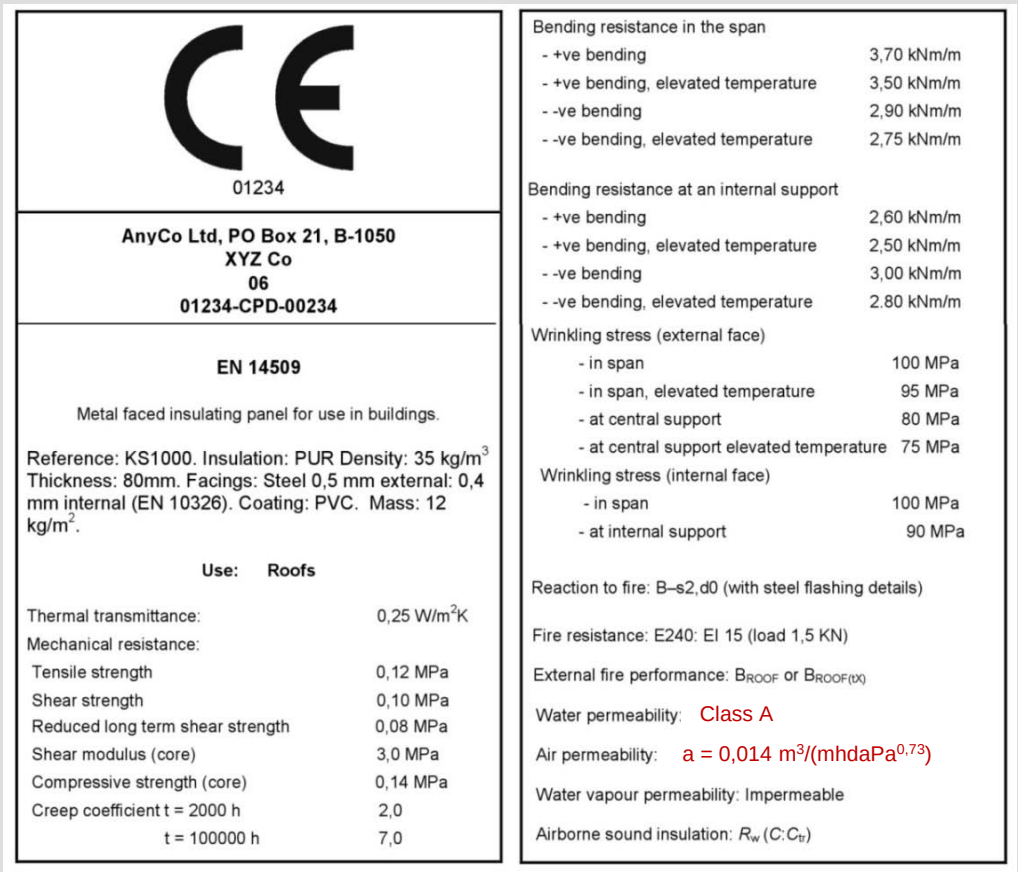






State of the art concerning joint permeability

- Possibility of testing according to EN 14509 to get official results (A-value, class of water-tightness)
- Possibility of computer-based calculation (CFD) to get results, in particular for efficient optimization of joints without expensive tests



CE

01234

AnyCo Ltd, PO Box 21, B-1050
XYZ Co
06
01234-CPD-00234

EN 14509

Metal faced insulating panel for use in buildings.

Reference: KS1000. Insulation: PUR Density: 35 kg/m^3 Thickness: 80mm. Facings: Steel 0,5 mm external: 0,4 mm internal (EN 10326). Coating: PVC. Mass: 12 kg/m^2.

Use: Roofs

Thermal transmittance:	0,25 W/m^{2}K
Mechanical resistance:	
Tensile strength	0,12 MPa
Shear strength	0,10 MPa
Reduced long term shear strength	0,08 MPa
Shear modulus (core)	3,0 MPa
Compressive strength (core)	0,14 MPa
Creep coefficient t = 2000 h	2,0
t = 100000 h	7,0

Bending resistance in the span	
- +ve bending	3,70 kNm/m
- +ve bending, elevated temperature	3,50 kNm/m
- -ve bending	2,90 kNm/m
- -ve bending, elevated temperature	2,75 kNm/m
Bending resistance at an internal support	
- +ve bending	2,60 kNm/m
- +ve bending, elevated temperature	2,50 kNm/m
- -ve bending	3,00 kNm/m
- -ve bending, elevated temperature	2.80 kNm/m
Wrinkling stress (external face)	
- in span	100 MPa
- in span, elevated temperature	95 MPa
- at central support	80 MPa
- at central support elevated temperature	75 MPa
Wrinkling stress (internal face)	
- in span	100 MPa
- at internal support	90 MPa

Reaction to fire: B–s2,d0 (with steel flashing details)

Fire resistance: E240: EI 15 (load 1,5 KN)

External fire performance: B_{ROOF} or $B_{ROOF(t\chi)}$

Water permeability: Class A

Air permeability: a = 0,014 m^3/(mhdaPa^{0,73})

Water vapour permeability: Impermeable

Airborne sound insulation: R_w (C;C_{tr})

Benefit manufacturer:

- marketing potential
- product related charachteristics of joint permeability

Benefit clients:

- transparency regarding to joint permeability
- comparability

Thank you for your attention!

Klaus Berner
Marc Rippel

www.sandwichtechnik.com