

# Laboratory testing of the durability of airtightness products - Review and analysis of existing studies

Valérie Leprince – INIVE  
Tightvent Webinar 2020

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## Durabilit'air project

- 1st task of the Durabilit'air project



Cerema



ADEME



Agence de l'Environnement  
et de la Métrique de l'Energie

PLEIAQ

CETii

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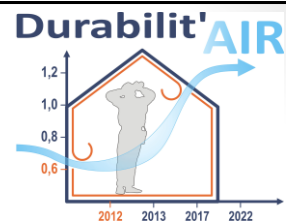
Ministère de l'Énergie,  
du Développement  
durable et des Énergies

- Objectives of the project:

- State of the art of major international research findings
- Characterizing the evolution over time in mid and long term scales by on-site measurement campaigns
- Developing a laboratory controlled method in order to test the accelerated ageing of airtightness systems;
- Disseminating the main results of this work to promote best practices.

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# Objective of the state of the art

- Learn from previous studies
- Improve the protocol for the other tasks of the project
  - Field measurements
  - Laboratory testing

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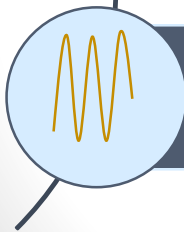
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## PART II: Durability tested in laboratory



Loads on the air-barrier



Laboratory testing

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## LOADS ON THE AIR BARRIER

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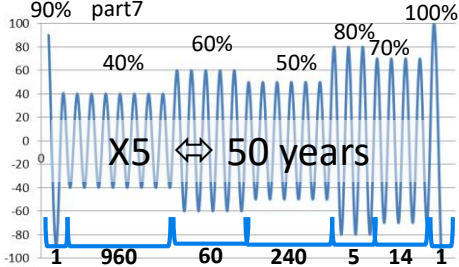
## Pressure load sustained by air barrier

60m/s : maximum wind speed in France  
41m/s maximum wind speed in inhabited area

$$P_{vent} = \frac{1}{2} \rho C_p v^2$$

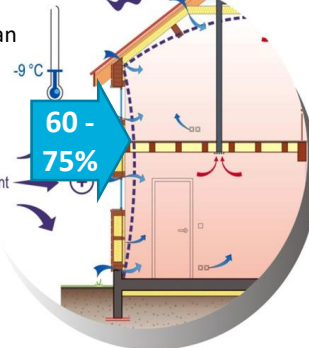
at **météorological station**

Wind cycles : BRE digest 346-part7



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Ackerman  
\_2012



[ 6 ]

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# Temperature and Humidity load

- Depends on the air barrier position
  - Inside (plaster board, etc.) or outside (plasters on masonry, some membrane) insulation
- Artificial ageing due to temperature variation: « time-temperature superposition principle »
  - Maintaining a polymer at high temperature (below glass transition temperature)
  - WLF model or Arrhenius law
  - Depends on material => **how to apply it to assembly?**
- **Heat treatment is not an ageing protocol**
  - **What predominate: physical, mechanical or chemical ageing?**

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# Equivalent ageing in stove

- Inconsistent information in literature (Ackerman\_2012)
- **Seems impossible to ensure an equivalence between natural and artificial ageing in the context of airtightness assembly**

Artificial aging at 65 °C / 80 % r.F. in days	Natural aging following ASTM D3611-89 [ 5 ] in years	Natural aging following SATAS [ 6 ] in years
21	10,5	3
40	20	5,7
80	40	11,4
120	60	17,1

Table 3. Correlation between artificial and natural aging

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# LABORATORY TESTING

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BRACKE_2014	Sherman_2004, Sherman_2003	Ylmén_2014	Langmans_2015	Michaux_2014	Antonsson_2015	Cahier 3710, CSTB_2015
45 à 70min	2 years	1year + 1 week at 30% RH	Test 1: 2 weeks Test 2: 12 days Test 3: 4 weeks	Few days	7 days	168h
⇔?	⇔30 ans	⇔50 ans	⇔?	⇔?	⇔?	⇔?



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# Important results

- In Swedish study
  - they observed no correlation between the ageing of the product alone (in term of peeling, etc.) and the durability of the assembly in term of airtightness
  - Due to
    - compatibility problems between film and tapes,
    - difference in the results for smaller and full scale specimens,
    - air channel appearing during the heat treatment.
- ⇒ Necessary to develop durability test of the complete airtightness systems on full-scale set-up
- ⇒ Done on a 3m\*3m wall
- ⇒ They also tested the impact of implementation in cold or dusty environment
  - ⇒ Big impact

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# Conclusion laboratory testing

- Results **varying from one study to another.**
- **No standardised protocol**
- General conclusions:
  - Results observed on **products alone** are not always consistent with ageing observed when they are **implemented**
  - Products' **results** with standard tests (peeling, etc.) **do not correspond to their airtightness ability**
  - Big impact of **implementation**
  - Products do not react the same way in extreme conditions and in usual conditions (temperature, humidity, pressure)
  - A standard is **missing** to characterise products and above all **assemblies in term of airtightness**
  - **Test of reproducibility are missing in studies**
    - Major limitation for scale 1:1 system: expensive and impact of implementation

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# Steps to define a protocol

- Design the testing facility considering that:
  - reduced scales may not be representative,
  - tests have to be repeatable and reproducible.
- Define implementation conditions (temperature, relative humidity, dusty area, etc.).
- Specify the loads on clear bases and considering:
  - worst conditions the air barrier undergoes in the field
  - preliminary tests to evaluate of which impact between steady worst condition or cycling prevails.
- Focussing on the comparison of products, not on actual ageing.
- Implement small scale preliminary tests to evaluate the feasibility and results.
  - However product characteristics may vary depending on the sample size

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## Conclusions



### Standardised protocols is missing for assemblies

- Find good balance between too reduced tests (that do not characterise airtightness) and too complexes (not reproducible)



### Loads on airtightness barrier

- Pressure loads defined
- Temperature/Humidity load to be defined

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Thank you for your attention!

Questions?

Source: AIVC 2017 –Nottingham:  
Publication available on Airbase

<https://www.aivc.org/resource/durability-building-airtightness-review-and-analysis-existing-studies>



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## Assessment of the durability of airtightness products in laboratory controlled conditions: *development and presentation of the experimental protocol*

Andrés LITVAK\*, Fabien Allègre, Bassam Moujalled and Valérie Leprince,

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- The French research project **DURABILIT'AIR (2016-2019)**

- ✓ *to improve our knowledge on the variation of buildings airtightness through onsite measurement campaigns (Task 2) and accelerated ageing in laboratory controlled conditions (Task 3)*

Lauréat de l'Appel à Projets  
de Recherche 2015  
« vers des Bâtiments  
Responsables à l'Horizon  
2020 »

## Projet DURABILIT'AIR



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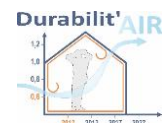
## Introduction



- Literature review (task 1) pointed the importance of **well defining the sample to be tested** (products assembly v/s product alone) and the **ageing protocol conditions**.
- Due to the diversity of airtightness products, it is probably **impossible to define an accelerated ageing universal protocol** that would be equivalent to a known amount of years of natural ageing.

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## Introduction



- No standardized protocol / General conclusions can be drawn:
  - ✓ **Implementation** has a strong impact on durability
  - ✓ Products do not have the same reaction **under normal** conditions as when they are subjected to **extreme conditions** (temperature, humidity or pressure);
  - ✓ A **standardized procedure** for the ageing of sealants is lacking to characterize products and especially **assemblies** regarding airtightness performance;
  - ✓ The results of ageing tests on **products alone** are not necessarily consistent with the ageing observed when these products are **put in situation**;
  - ✓ **Product performance** against conventional test procedures (peel, shear, etc.) does not necessarily correspond to their **performance in terms of airtightness**
  - ✓ The ageing strategy must be consistent with the **loads** of the products. The strategy may differ depending on the **position of the air barrier**.

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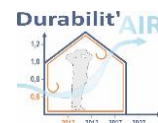
## Methodology



- We developed an experimental protocol for accelerated ageing of airtightness assembled products.
- The protocol definition consisted in :
  - 1) *developing an experimental chamber,*
  - 2) *choosing representative samples,*
  - 3) *defining the accelerated ageing conditions.*

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## Methodology



- Environmental chamber
  - ✓ *An accelerated weathering chamber (see A)*
  - ✓ *A pressure test bench for differential pressure exposure and airtightness measurement (see B)*
  - ✓ *A sample holder, between both enclosures (see C)*

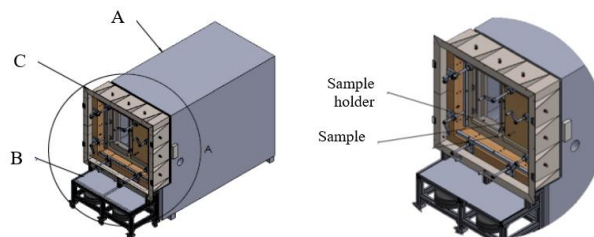


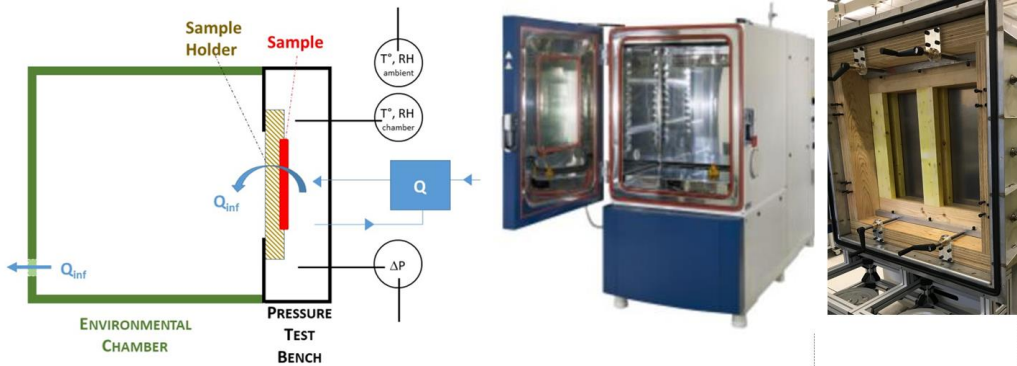
Figure 1: Environmental chamber

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# Methodology

## Environmental chamber



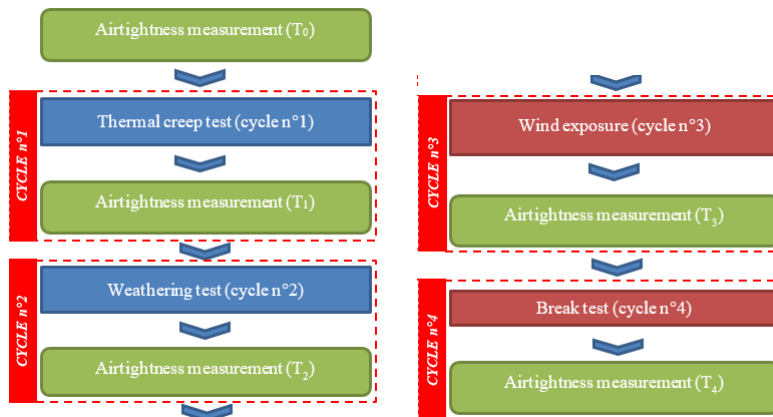
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# Methodology

## Exposure cycles and airtightness measurements



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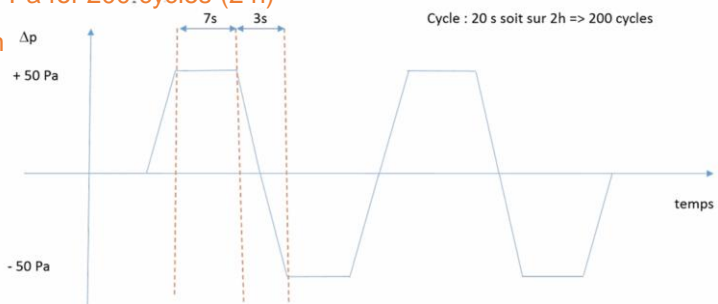
## Methodology



### ■ Exposure cycles and airtightness measurements

#### **Cycle n°1 : « Thermal creep test »**

- ✓ 60°C & 50%RH (for 21h)
- ✓ Wind cycle  $\pm 50$  Pa for 200 cycles (2 h)
- ✓ Duration :  $\approx 24$ h



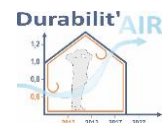
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## Methodology



### ■ Exposure cycles and airtightness measurements

#### **Cycle n°2 : « Four seasons »**

- ✓ Summer : 30 °C & 45 % RH (24 h)
- ✓ Autumn : 5°C (24 h)
- ✓ Spring : 15°C & 60 % RH (24 h)
- ✓ Winter : -10°C (24 h)
- ✓ Stabilization period (12 h)
- ✓ Duration : (4,5 days)



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# Methodology



## ■ Exposure cycles and airtightness measurements

### **Cycle n°3 : « wind test »**

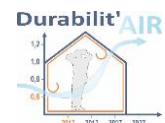
- ✓ Pressure cycles from -250 Pa to +250 Pa, (50 Pa steps)
- ✓ 8 hour cycles / 3 times
- ✓ total duration = 24 hours

### **Cycle n°4 : « Break test »**

- ✓ Temperature increase : 1°C/min until T < 180 °C
- ✓ If no leakage, T = 180 °C for 1 hour

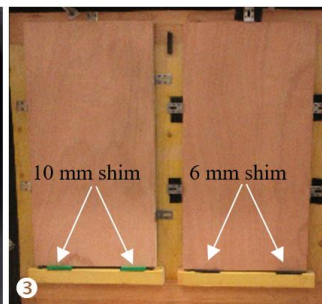
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# Methodology



## ■ Samples :

- ✓ Expansive weather seal foam ;
- ✓ Sealant (mastic) with backing foam
- ✓ Adhesive and membrane complex.



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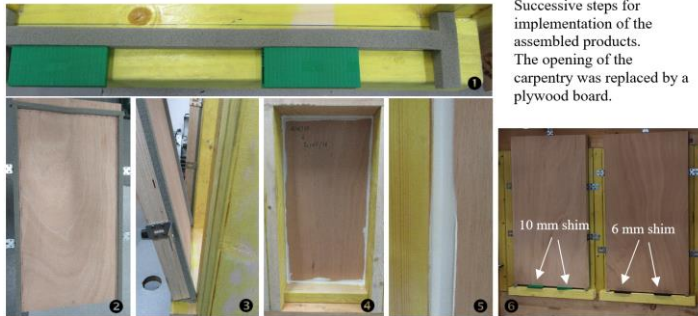


## Methodology



### ■ Samples :

- ✓ Expansive weather seal foam ;
- ✓ Sealant (mastic) with backing foam
- ✓ Adhesive and membrane complex.



Successive steps for implementation of the assembled products.  
The opening of the carpentry was replaced by a plywood board.

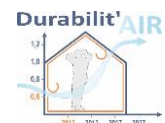
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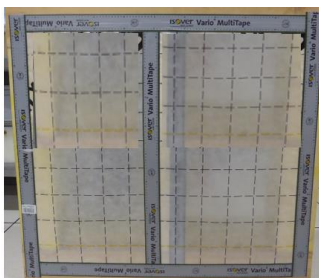
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## Methodology



### ■ Samples :

- ✓ Expansive weather seal foam ;
- ✓ Sealant (mastic) with backing foam
- ✓ Adhesive and membrane complex.



- the cut-out membrane was positioned flat on the sample support at 3 cm from the edge of the left upright and centered in height
- the membrane was stapled on all edges by positioning a staple every 5 cm around orienting the staples at 45 °
- Adhesive tape was pasted on the central part taking care not to fold

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## RESULTS

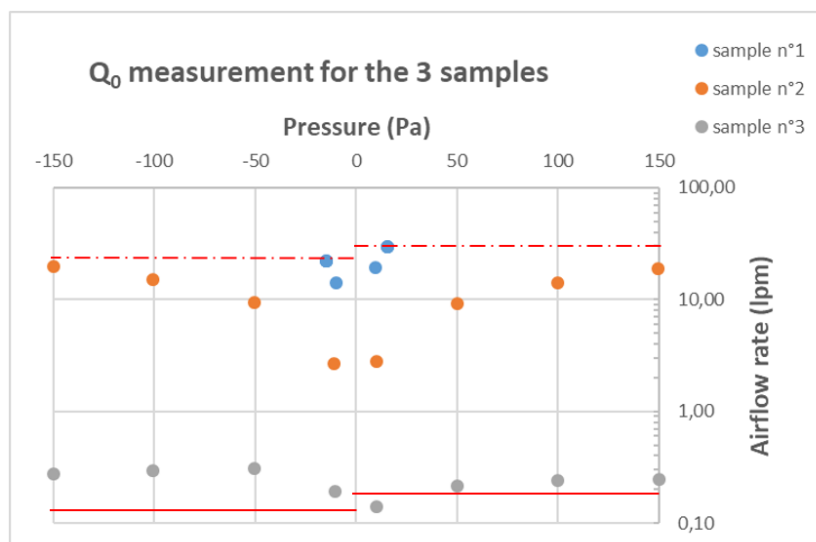
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## Initial measurements :



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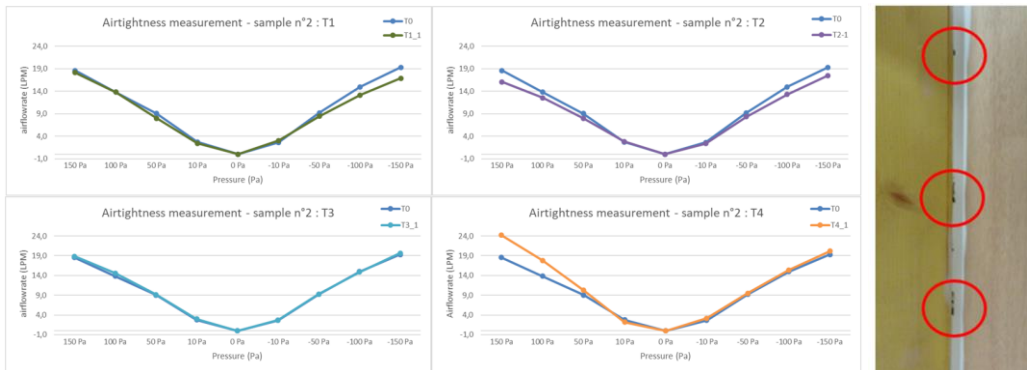


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## Evolution of air permeability flowrates for sample 2 for the weathering cycle (4 tests):



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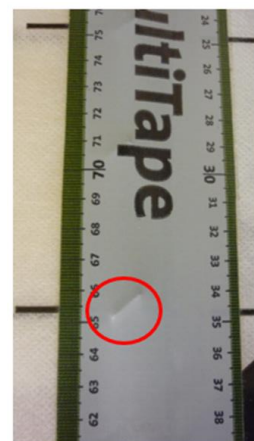


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## Evolution of air permeability flowrates for sample 3 for the weathering cycle (4 tests):

- Sample 3 was very airtight, thus, it was very sensitive to pressure variations (both positive and negative).
- We did not notice any significant deterioration of the air permeability flowrates for the first 3 tests of the cycle.
- For the break test (test n°4), the rupture occurred after 40 min, at the temperature of 60°C.



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## CONCLUSION

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## Conclusions

- The three types of samples made of assembled products as treatments of carpentry airtightness showed very different results, according to the maximum compensation capacity of the air permeability flow rate of the bench.
- Sample 1 (expansive weather seal foam) appeared to be too porous for our equipment, whereas Sample 3 (adhesive and membrane complex with staples) appeared to be too airtight.

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## Conclusions

- **Sample 2** : The rupture occurred at 120 ° C and showed a significant decrease of the airtightness of the sample.
- We measured a slight deterioration of airtightness of up to +7%.
- Nevertheless, we could not draw any conclusion about the artificial ageing of the protocol, due to the elevated temperature of rupture. (the experimental conditions of test n°4 for sample 2 may probably contradict the statement “Never test products beyond their real life exposure conditions”)

## Conclusions

- The improvement airtightness during the ageing cycle of sample 2 is probably due to the humidity for the “thermal creep test” and the “weathering test” ; thus we recommend to use inert materials as sample holders for future works.
- Field measurement results from Task 2 about airtightness durability showed that wood structure houses tend to improve over years (Moujalled, 2019) ; probably due to the expansion of the wood with the humidity, that would clog leakages.



## Conclusions

- The wind exposure test 3 of the ageing cycle on sample 2 shows a very moderated increase of air permeability. We think that the duration of this cycle was too short, and that exposure durations of at least 1000 h (approximately, 1.5 month) should be necessary.
- For future works, we plan to investigate a better **compromise** between **signal stability**, **usage range** and **control reactivity** on airflow rate, and the exposure protocole conditions.

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## Thanks...

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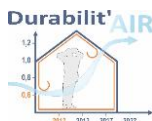
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de Recherche 2015  
« vers des Bâtiments  
Responsables à l'Horizon  
2020 »



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avec le financement de



➔ internet website (  ) : [www.durabilitair.com](http://www.durabilitair.com)

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# TightVent Webinar

**Determination of durability of adhesive tapes and adhesive masses for the establishment of airtight layers**

**New standardisation project**



## Structure

- Principles of standardisation work
- Example for a national product standard – DIN 4108-11
- New standardisation project „Airtight adhesives“



## Principles of standardization work



### Test standards

- Single test methods
  - Conditioning
  - Test specimen dimensions
  - Test speed
  - ...
- Examples
  - EN 12311-1

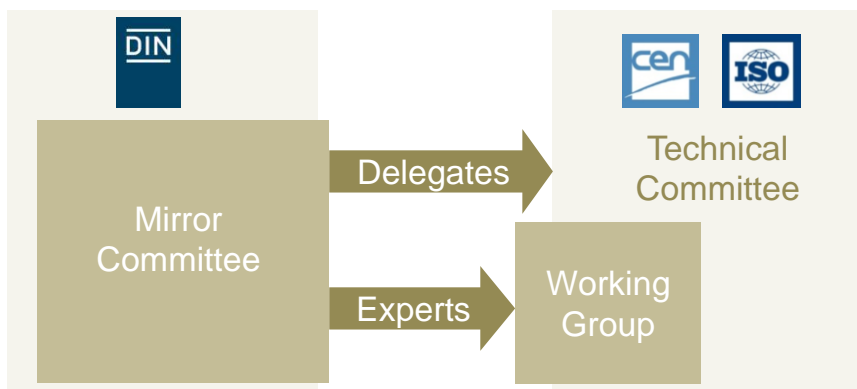
### Product standards

- Product (-group)
  - hEN (harmonised) vs. EN
  - How to evaluate the performance of the product
- Examples
  - DIN 4108-11
  - No EN XXXX for airtight adhesives

### Application standards

- Constructions
  - Construction guidelines
  - Minimum requirements for material properties
- Examples
  - NF DTU 31.2 P1-2

## Principles of standardization work





## Principles of standardization work



- Consequences of european (product) standards
  - Based on consensus of all involved parties
    - Sometimes hard to reach
    - Makes standardisation work longlasting
  - National product standards have to be withdrawn in case of a european standard
  - No minimum requirements / thresholds → solely information „how to“ evaluate the performance of a product

## National product standard – DIN 4108-11



- Published 2018

**Thermal insulation and energy economy in buildings — Part 11:  
Minimum requirements to the durability of bond strength with adhesive  
tapes and adhesive masses for the establishment of airtight layers**

**Wärmeschutz und Energie-Einsparung in Gebäuden — Teil 11:  
Mindestanforderungen an die Dauerhaftigkeit von Klebeverbindungen mit  
Klebebändern und Klebemassen zur Herstellung von luftdichten Schichten**

**Protection thermique et économie d'énergie dans la construction immobilière —  
Partie 11: Exigences minimales à la durabilité des joints collés avec des rubans  
adhésifs et des masses adhésives pour la fabrication des couches étanche à l'air**



# National product standard – DIN 4108-11

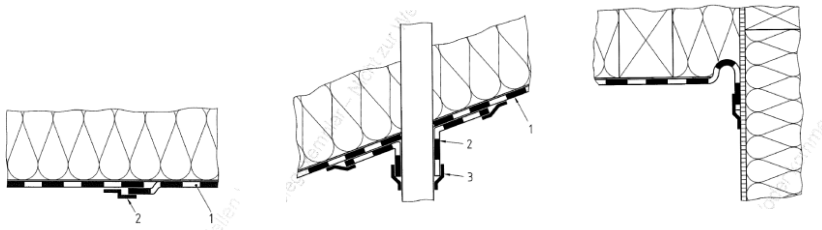


## 1 Scope

- Clarifies the desired applications ...

„[...] durability of adhesive joints prepared by means of adhesive materials [...]“

„[...] airtight layers according to DIN 4108-7 [...]“



# National product standard – DIN 4108-11



## 1 Scope

- ...and exceptions.

This standard does not cover test methods for:

- pre-compressed sealing tapes and sealing profiles which will be mechanically secured;
- butyl-based adhesive tapes or adhesive masses;
- sheet joints of wood-based panels or gypsum plasterboards with adhesive masses or filler systems;
- joints and joint bondings of bitumen sheets;
- joints of self-adhesive tapes;
- adhesive masses from reels. Adhesive masses from reels are cured viscoelastic adhesive masses which are used in the same field of application as adhesive masses.



# National product standard – DIN 4108-11



## 2 Normative References

## 3 Terms and Definitions

## 4 Symbols and Units

## 5 Testing

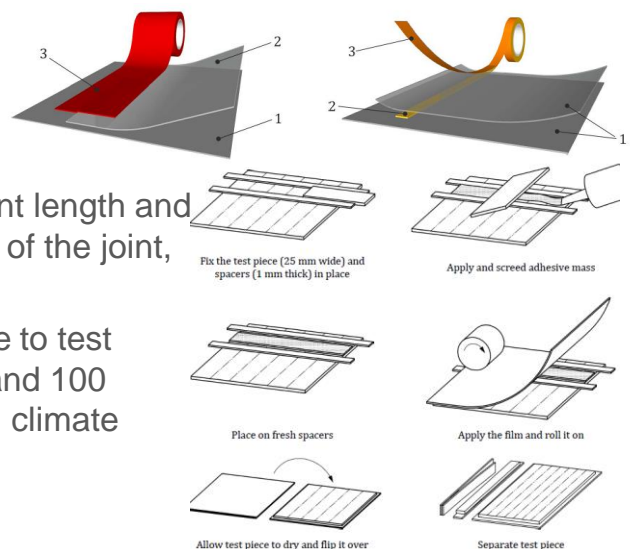
- Reference substrates
  - boPET sheet
  - Beechwood
- Product combinations
  - Specific combinations

# National product standard – DIN 4108-11



## 5 Testing

- Definitions about
  - Apparatus used
  - Specimen preparation (joint length and width, cutting, preparation of the joint, etc.)
  - Test procedure (Reference to test standard, test speed (10 and 100 mm/min, pre-load = 0.5 N, climate conditions, etc.)





## 5 Testing

Table 2 — Sample preparation, conditioning and test procedures for testing adhesive tapes

Test description	No.	Number of test series with 5 samples each	Substrates according to 5.2.1 to be used for reference test	Test duration	Test temperature	Test humidity	Test atmosphere	Test speed
		A	B					
T-peel test without artificial ageing $F_{5,MIN}$ $F_{5,MAX}$	I	2	boPET and boPET	120 d	$(65 \pm 2) ^\circ\text{C} / 80 \%$			
T-peel test with artificial ageing $F_{5,MIN,120}$ $F_{5,MAX,120}$	II	2						
Static peel strength in the 90° peel test	III	1	Beech with boPET					

NOTE "boPET" and "beech" designate the reference substrates according to 5.2.1.

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21.02.2020

## 5 Testing

Tape single-sided	Tape double-sided	Adhesive masses
<b>T-Peel (10 and 100 mm/min)</b> 	<b>T-Peel (10 and 100 mm/min)</b> 	<b>180° peel (10 and 100 mm/min)</b> 
<b>Static peel test (30°C, 24 h, 0.3 N)</b> 	<b>Static peel test (30°C, 24 h, 0.3 N)</b> 	<b>Static peel test (40°C, 24 h, 0.3 N)</b> 

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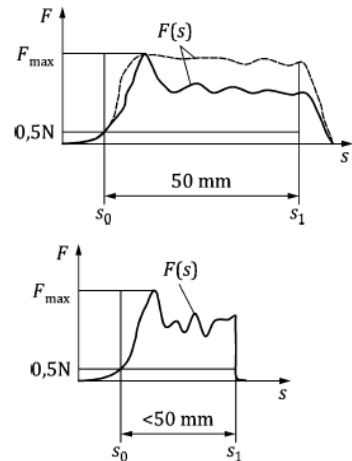


## National product standard – DIN 4108-11



### 5 Testing

- Results are given in N/10 mm
- Evaluation of maximum and mean peel force
- Different stop criteria
  - Maximum peel length of 50 mm without break
  - Failure of adhesive or substrate < 50 mm



## National product standard – DIN 4108-11



### 6 Minimum requirements for adhesive tapes and adhesive masses

		Peel strength				90° peel strength load 0,3 N
		Crosshead speed 10 mm/min		Crosshead speed 100 mm/min		
		$F_{S,max}$ N/10 mm	$F_{S,m}$ N/10 mm	$F_{S,max}$ N/10 mm	$F_{S,m}$ N/10 mm	
Adhesive tape (T-peel test)	boPET	≥ 2,6	≥ 1,3	≥ 5,9	≥ 3,4	passed
	System		≥ 1,3	≥ 4,7	≥ 2,7	passed <sup>a</sup>
Adhesive masses (180° peel test)	boPET	≥ 3,0	≥ 1,5	≥ 6,0	≥ 3,2	passed
	System	≥ 2,4	≥ 1,2	≥ 4,8	≥ 2,5	passed

<sup>a</sup> according to adhesive tapes.

**Mutually not possible in a european product standard**

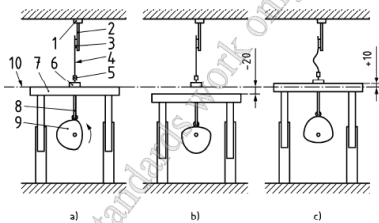


## National product standard – DIN 4108-11



### Annex B (informative) – Alternating load method for testing the durability of adhesives

- System related tests under practical load conditions
  - Total 6400 load cycles acc. to mean wind speed (1300 g/25mm)
  - 5 load cycles acc. to max. wind speed (2500 g/25mm)



## European product standard – PWI „Airtight Adhesives“



- No mandate / Sreq for airtight adhesives – EN XXXX
  - No CE marking possible based on the standard
  - If no other assessment documents (ETA) → Mutual recognition
- Preliminary work item (PWI) description

English title: Determination of durability of adhesive tapes and adhesive masses for the establishment of airtight layers

### 8. Scope

This document specifies definitions and characteristics of adhesive tapes and adhesive masses for airtight connections of building materials used for the airtight layer of the building shell. The document specifies the use requirements and test methods and provides for the evaluation of conformity of the products with the requirements of this document.



## European product standard – PWI „Airtight Adhesives“



### 11. Environmental aspects

- |  |   |  |
|--|---|--|
| <input type="checkbox"/> Discharges to soil                            | <input type="checkbox"/> Discharges to water      | <input checked="" type="checkbox"/> Emission to air    |
| <input checked="" type="checkbox"/> Heat                               | <input type="checkbox"/> Noise/Vibration          | <input type="checkbox"/> Other effects on biodiversity |
| <input type="checkbox"/> Radiation                                     | <input checked="" type="checkbox"/> Use of energy | <input type="checkbox"/> Use of land                   |
| <input type="checkbox"/> Use of material                               | <input type="checkbox"/> Use of water             | <input type="checkbox"/> Waste                         |
| <input type="checkbox"/> Risk to the environment from accidents/misuse |   |  |

☒ Other:

Durable airtight connections, characterized by the methods defined in the standard that shall be developed, are key to guarantee the long-term functionality of the insulation material and the construction work and therefore help to save energy and resources over the whole life time of the building. Also, the condensation damage protection is an important task of the airtight layer thereof interdependencies to the life-time of the building and also health aspects for the users of the building can be derived.

As airtight barriers are positioned on the internal side of the insulation, potential emissions to the indoor air shall be considered

## European product standard – PWI „Airtight Adhesives“



- Topic was introduced to TC89 – next steps:
  - Ballot for two months based on the PWI
  - Call for experts and convenors
  - Call for a secretariat
  - Start of the work – WG meetings



## European product standard – PWI „Airtight Adhesives“



- Potential discussion for the work progress
  - Mechanical tests vs. airtightness tests
  - Constancy of product related performance vs. system tests
  - For system tests: Influence of the craftsmanship
  - Artificial ageing procedures
    - Relevant influences (T, r.h., mechanical stress) may differ according to climatic and construction differences
    - Definition of useful accelerated ageing conditions
    - Definition of time frame for the ageing