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COATING PERMEABILITY ON WOOD

Developing effective methods to measure the permeability of coatings on wood. By Peter Svane, Coating Consultancy Copenhagen and Dr Gerhard Grüll, Holzforschung Austria, Vienna.

Water vapour permeability of wood coatings is an essential property to steer moisture dynamics and to enable entrapped water to escape. Ideally, permeability measurements are made on a wood substrate, but the variability of the material poses a problem. Two methods are presented that overcome the difficulty of wood substrate variability and offer simple and flexible ways of sample preparation and measurement.

Coatings interact with their substrate. The interaction with wood is particular as the coating material partly penetrates the substrate and the coating has a key influence on wood moisture. Wood moisture in turn also influences the coating. Wood shrinks and swells with changing moisture content, causing stresses and eventually cracks both in the wood and in the coating film. Coating systems must be able to "breathe" to some extent; ideally, they also need to protect against rain and allow water to evaporate from the substrate. Another issue is the risk of wood decay at high moisture levels. The interaction between moisture and wood is referred to as "moisture dynamics", a subject that has been the focus of numerous investigations, however without achieving complete clarity. Finally, a coating's adhesion depends on the humidity level at the interface between coating and wood.

EN 927-2 [1] gives some guidance as to liquid water absorption when measured by EN 927-5 [2]. For "stable" wood constructions, i.e. windows and doors, an interval between 30 and 175 g/m^2 x 72 h is specified. The method is a "dip-and-weigh" test, and it mimics how water, for example, from rain, may penetrate the wood through the coating. EN 927-2 however has no specifications for the transmission of "non-liquid" water, i.e. for water vapour diffusion resistance. This property relates to how entrapped moisture can escape from the substrate through the coating. The EN 927-series does not even contain a test method to determine the diffusion resistance of wood coating systems. One might argue that there is no need for such a method if the basic question of moisture dynamics is not completely understood. However, a measurement method is a prerequisite to understanding the complex mechanism behind the inward and outward movement of water through a coating film ("If you cannot measure it, you cannot improve it" – Lord Kelvin (1824-1907)).

NATURAL WOOD VARIATION POSES MEASUREMENT PROBLEM

ISO 7783 describes how to measure water vapour permeability of coatings using the so-called cup method [3]. The coating film is placed

RESULTS AT A GLANCE

➞ Measurements of water vapour permeability are made according to ISO 7783 but on real wood substrates.

➞ The presented methods ensure equal substrate properties for coated and uncoated wood samples in cup tests.

➞ The Austrian measurement method has proven to be highly flexible as different wood species can be used as well as varying surface machining.

➞ The CCC method to measure diffusion is simple, inexpensive and reasonably precise. It also eliminates any uncertainty caused by different wood samples.

➞ It is hoped that these approaches may contribute to future standardisation of methods to measure coatings for this substrate.

as a "lid" on a "cup" containing either a desiccant (dry cup) or a saturated salt solution (wet cup), and placed in a climate chamber. The diffusion rate is tracked by weighing the cup at intervals. Knowing the weight change over time, the moisture gradient across the film, and the area of diffusion, the permeability of the film can be calculated.
ISO 7783 also provides for the application of coatings on a substrate. However, the substrates mentioned in the standard (glass frits or ceramic tiles) are so different to wood that it is unlikely that a wood coating system would achieve the same performance on the specified materials as would be expected on wood. Coating systems for wood should of course, in principle, be tested on wood.
To measure the permeability of a coating system on a substrate, firstly the diffusion resistance of the substrate is determined, then the resistance of the coated substrate. Finally, the one resistance value is subtracted from the other to provide an approximation of the coating's own resistance. ISO 7783 recommends that the diffusion resistance of the substrate should be low in comparison with that of the coating; more specifically the water vapour diffusion rate of the substrate should exceed 240 g/(m^2 x 24 h). This value corresponds to a 1-2 mm thick layer of spruce.
A major difficulty using wood substrate in permeability measurements is the inhomogeneity of the material; no two pieces of wood are alike and neither is their permeability. This is quite different from the suggested substrates in the standard: glass frits and ceramic tiles, which are uniform and homogeneous industrial compounds. Wood is a naturally grown material with great variation.
Therefore, when using wood as the substrate in permeability measurements, some aspects must be considered:

› 1. The wood substrate should be as thin as possible to suit the recommendations of ISO 7783 (high water vapour diffusion rate)
› 2. The same piece of wood should preferably be measured with and without the coating (to exclude variations from the substrate)

Figure 1: Panel of spruce wood with coating on top, ring grooves drilled to prepare coated disc samples.

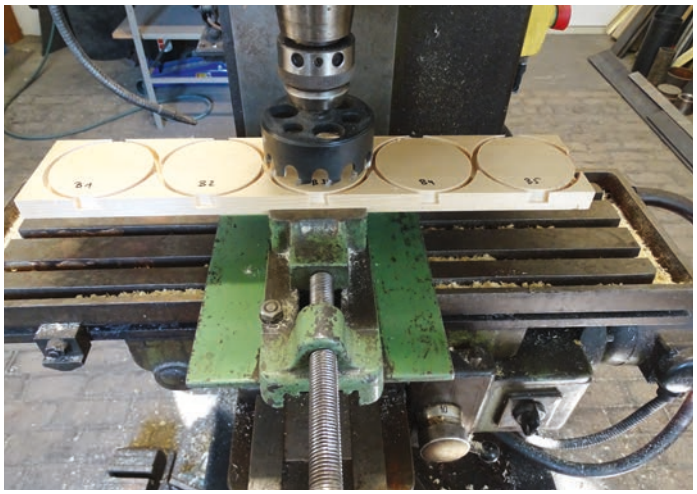
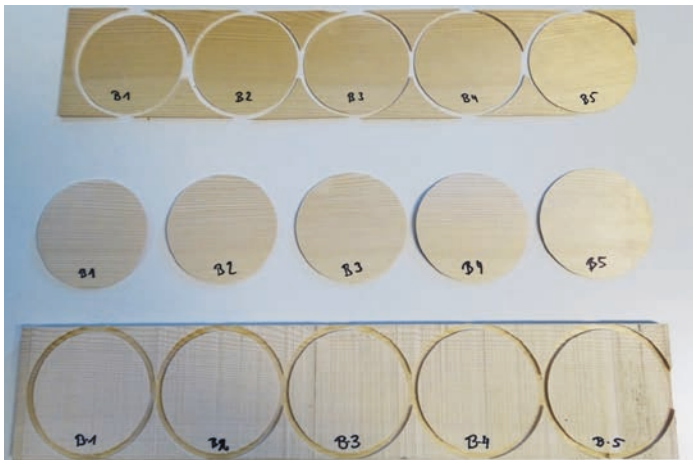


Figure 2: Samples produced from the coated wood panel, coated discs and coated residual material (top), uncoated discs (centre), rest of the panel (bottom).



› 3. If different pieces of wood are measured with and without the coating, care should be taken to select substrates that are as uniform as possible
› 4. The method should allow for coating application on different wood species and by different application methods commonly used in the industry

It goes without saying that the test method ought to be reasonably simple to perform, and sufficiently precise.

TWO APPROACHES

Paint companies and institutes in Europe conduct permeability measurements on coatings for wood – some with wood as the substrate, some on free films, some on paper.
Holzforschung Austria (HFA) in Vienna has several years' experience with a cup method using circular wooden discs of 90 mm diameter and 1.7 mm thick.
Coating Consultancy, Copenhagen (CCC) has recently developed a simplified method using commercial grade 0.7 mm thick spruce veneer on rectangular cups approx. 120 mm x 180 mm.
The two institutions have agreed to briefly present their two different approaches to the paint industry as a contribution to discussion, and may-

Figure 3: Vacuum holder and sanding machine for parallel sanding of the samples from the reverse side to a defined thickness.

be as an inspiration to future standardisation. The methods described in extenso may be found on the homepage of the contributors [4, 5].

A FLEXIBLE METHOD

The Austrian method makes it possible to test a full multi-layer coating system applied with the same methods that are used in practice, such as dipping, brushing, flow coating, spraying, roller coating or others. This is done on a normal wood panel of selected quality and the coating is dried and cured under normal conditions for testing or in practice. After the coating is cured, thin plates of coated wood are machined out of the surface of the panel which are used for permeability testing. A second set of thin plates is taken from the same areas of the panels, beneath the coated ones, to serve as the uncoated reference substrate. This is then made of the same growth rings as the substrate of the coated samples.
Boards of spruce wood are selected to produce panels with growth rings perpendicular to the test surface, free from knots, straight grained and without any defects. The panels are machined to a size of 500 mm x 100 mm x 20 mm and conditioned in a climate chamber at 20 °C/65% relative humidity. The wood coating system under test is applied to one side of a panel according to the manufacturer´s specifications. Multi-layer systems can be applied easily using various methods, spreading rates and intermediate sanding.
When the coating is finished and cured, five ring grooves are machined into the coated surface of the panel with a diameter of 90 mm (inner

Figure 6: Suitable “cup”. Supplier: Hofstätter & Ebbesen (www.ultraplast.dk).

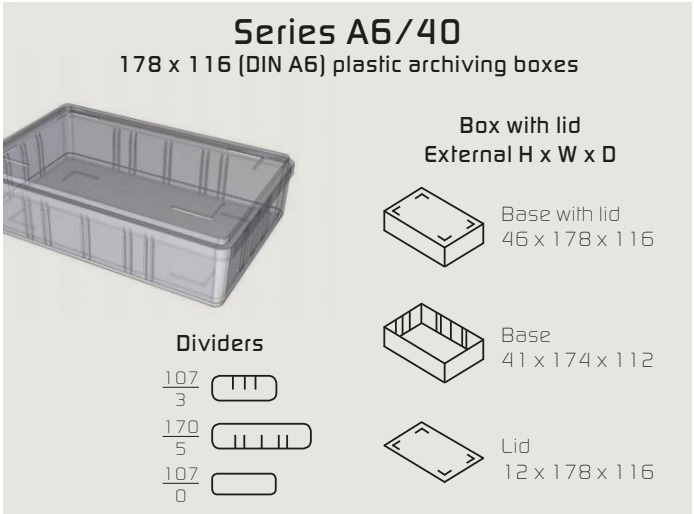


Figure 4: Cutting veneer to appropriate size.

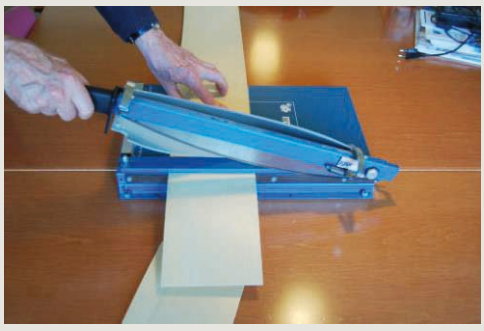


Figure 5: Sealing cup to veneer substrate. Cup upside down.

circle) and a depth of approx. 12 mm (*Figure 1*). The surface of the panel is then cut off with a band saw to a thickness of approximately 2 mm, giving five coated wood discs of 90 mm in diameter and approx. 2 mm thick. It also yields some residual material of the coated surface which is used for dry film thickness measurements. On the rest of the spruce panels there is a rough sawn surface and the drilled ring grooves are still present. This wood surface is planed smooth and once again, a layer of approx. 2 mm is cut off with a band saw, yielding five uncoated wood discs, 90 mm in diameter and approx. 2 mm thick, made of the same growth rings of wood as the coated ones (*Figure 2*).
The next step is to sand all the disc samples from the rough sawn reverse side using a vacuum holder and a sanding machine with parallel guide to a thickness of 1.7 mm (*Figure 3*). The samples can then be conditioned before they are tested in suitable cups according to ISO 7783. This method is highly flexible because the panels can be made of different wood species and may include variations of (industrial) surface machining such as different grades of sanding, intermediate sanding and some surface structuring such as brushing. However, with structured surfaces care must be taken to seal the samples properly when installed in the cups for testing. This might require additional liquid sealants. This flexibility of the method was demonstrated in a study on industrially applied non-film forming coatings on wood flooring of different wood species and surface machining as well as thermally modified wood [6].

SIMPLIFIED AND PRECISE MEASUREMENT

CCC's method is a simple, cheap and reasonably precise laboratory method utilising 0.7 mm normal spruce veneer as the standard substrate, and commercially available transparent polystyrene archive boxes as diffusion cups. Apart from a climate chamber providing 23 °C/50% relative humidity, no special equipment is required, and a laboratory scale that weighs to 0.01 g is sufficient for the determination. As in the Austrian method, the diffusion measurement is carried out as a "wet cup" experiment according to ISO 7783. The procedure includes the following steps:

- 1. 0.7 mm thick spruce veneer is cut on an ordinary office paper guillotine (*Figure 4*). The dimensions 122 mm x 185 mm are suitable.
- 2. The veneer substrates are conditioned some days at 93% relative humidity and ambient temperature. Conditioning can be performed, for example, in a desiccator with saturated $NH_4H_2PO_4$ at the bottom.
- 3. The veneer is sealed to the "cups" with a joint sealant (*Figure 5*). A suitable cup is shown in *Figure 6*. Any cup of hard polystyrene may do. Hard polystyrene is chosen because it is almost impermeable to water vapour diffusion. "Sikaflex 11FC" has proven to be a reasonable sealant (Sika AG). The sealant must cure for 24 hours.
- 4. The cup is filled with the proper amount of saturated $NH_4H_2PO_4$ through a small hole in the side of the cup (*Figure 7*). Afterwards the hole is sealed with a piece of aluminium tape.
- 5. At this stage, the diffusion resistance of the substrate (without coating) can be determined according to ISO 7783. Weighing results must be corrected because there is a little "leak" along the edge of the cup, which is the unsealed rim of the veneer. The correction has been experimentally determined once, and it is applied to all measurements.
- 6. The coating system is then applied by brush, roller or by spraying according to specifications (*Figure 8*) directly on the cup. Intermediate sanding may be carried out.

› 7. When the coating is dried and cured, the diffusion resistance of the coated substrate can be determined according to ISO 7783.
› 8. The diffusion resistance of the coating system is calculated as the difference between the value for substrate with coating and for the substrate alone.

The advantage of the method is its simplicity, and the large area of veneer increases precision. Furthermore, the diffusion resistance of the substrate and of the coated substrate is measured on the same piece of veneer, which eliminates uncertainties caused by different wood samples.

REFERENCES

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2. EN 927-5: Paints and varnishes – Coating materials and coating systems for exterior wood – Part 5: Assessment of the liquid water permeability
3. ISO 7783: Paints and varnishes – Determination of water-vapour transmission properties – Cup method
4. Coating Consultancy, Copenhagen: www.overflade.dk
5. Holzforschung Austria: www.holzforschung.at
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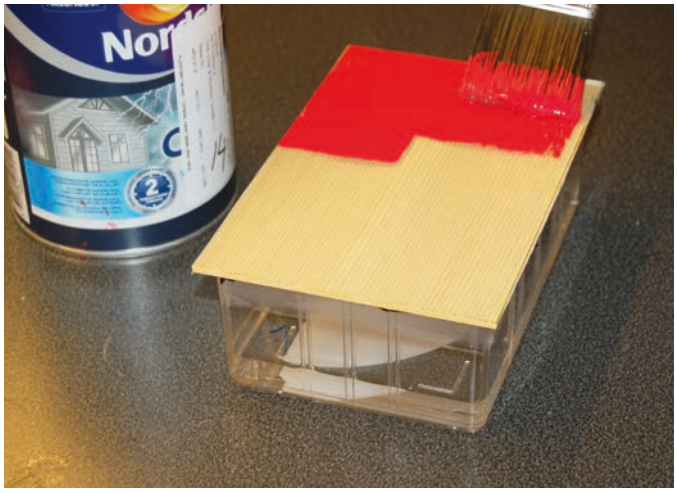
Figure 7: Filling with saturated salt solution though a 3 mm hole drilled in the side of cup.

Figure 8: Application of coating system directly on the cup.



Peter Svane
Coating
Consultancy
ps@overflade.dk

"There must be no leaks anywhere"

3 questions to Peter Svane

In how far does the sample preparation influence the diffusion behaviour of the sample? *The main thing is to determine the diffusion resistance of the uncoated sample and of the coated sample as precise as possible. That calls for a uniform substrate and a uniform application of the coating system; and of course, there must be no leaks anywhere. Another important issue at sample preparation is the determination of the dry coating's film thickness (DFT). This can be achieved by weighing the applied amount of coating(s), provided the dry matter content and the density are known, but as coatings may penetrate wood to some extent one might prefer to determine the DFT by microscopy according to ISO 2808 Meth. 6A.*

What impact does the structure of the wood surface, which results from the sanding process, have? *The structure will influence the surface area. A very rough surface will have a larger area than corresponding to the apparent size (as measured with a ruler). And as the area of diffusion enters into the calculation of diffusion resistance, the figure should be as correct as possible. Whether a surface is sanded or planed however, is of minor importance, as most coating systems will fill the microscopic irregularities in the surface anyway, i.e. in this case the apparent area is the same as the directly measured area.*

How can a comparability of coating properties be achieved, considering the diffusion protection and the reversible swelling behaviour of wooden substrates? *Wood swells and shrinks depending on its humidity content. A coating on wood is able to follow these movements. These variations however are limited to a few per cent, and probably without any significant influence on the diffusion properties of a coating system. Another theoretical complication is that the permeability of the wood substrate changes with its moisture content, however the diffusion resistance of the substrate itself normally is so much smaller than that of the coating, that these variations will have a negligible influence on the final calculation.*