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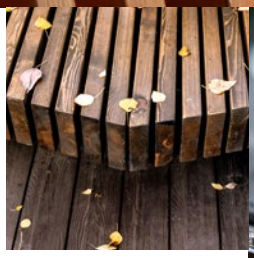

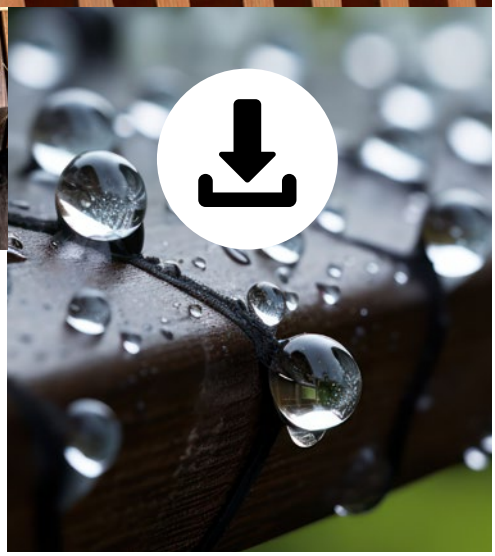

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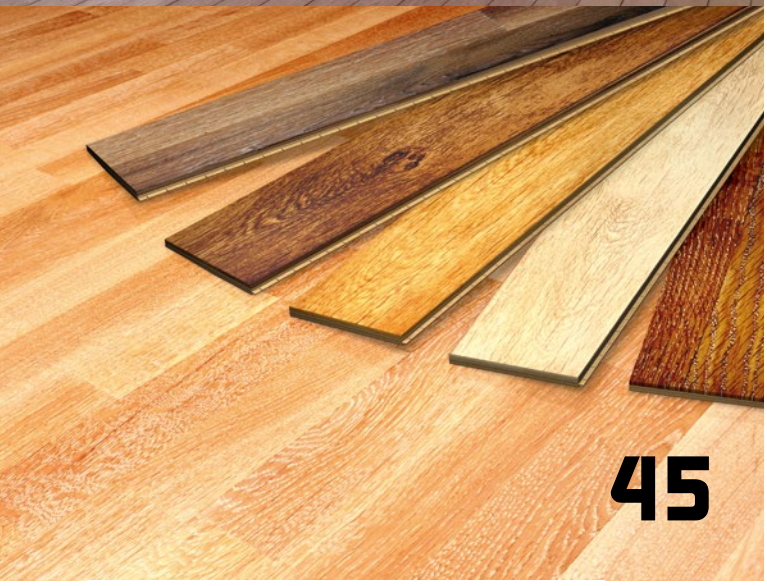

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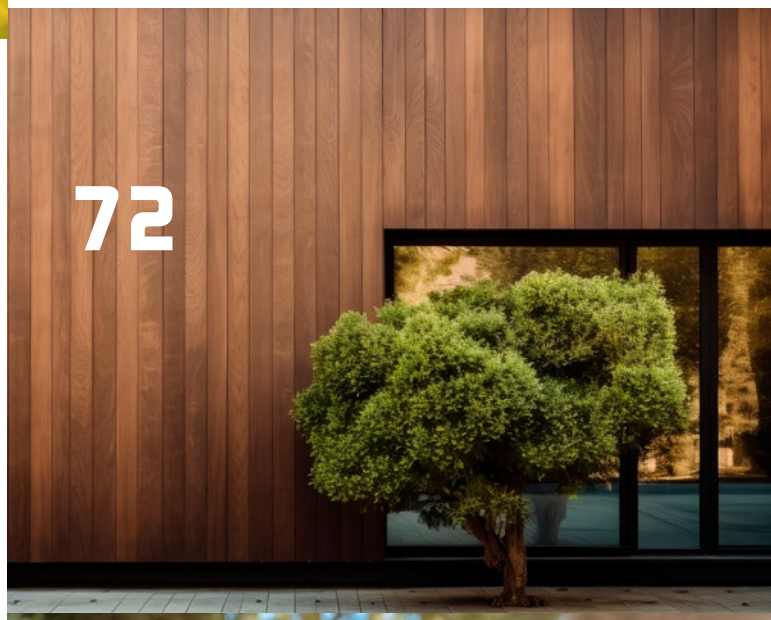

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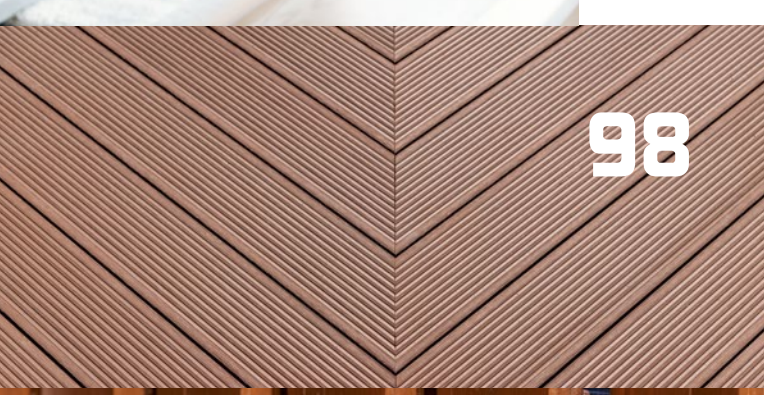

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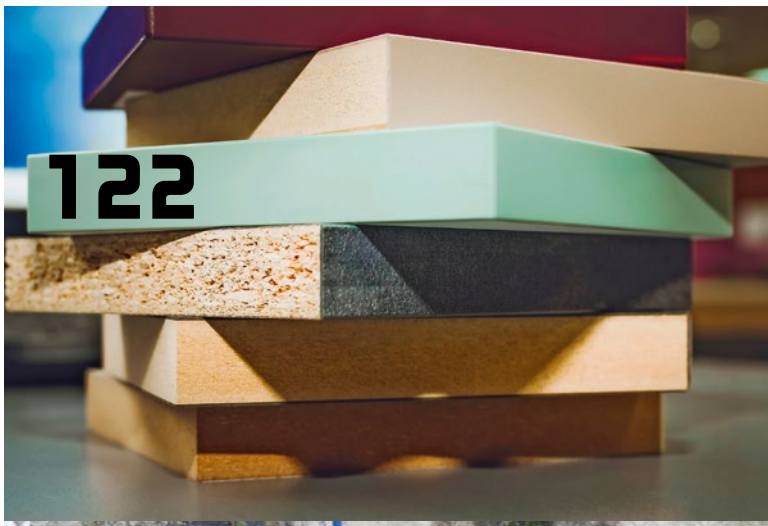

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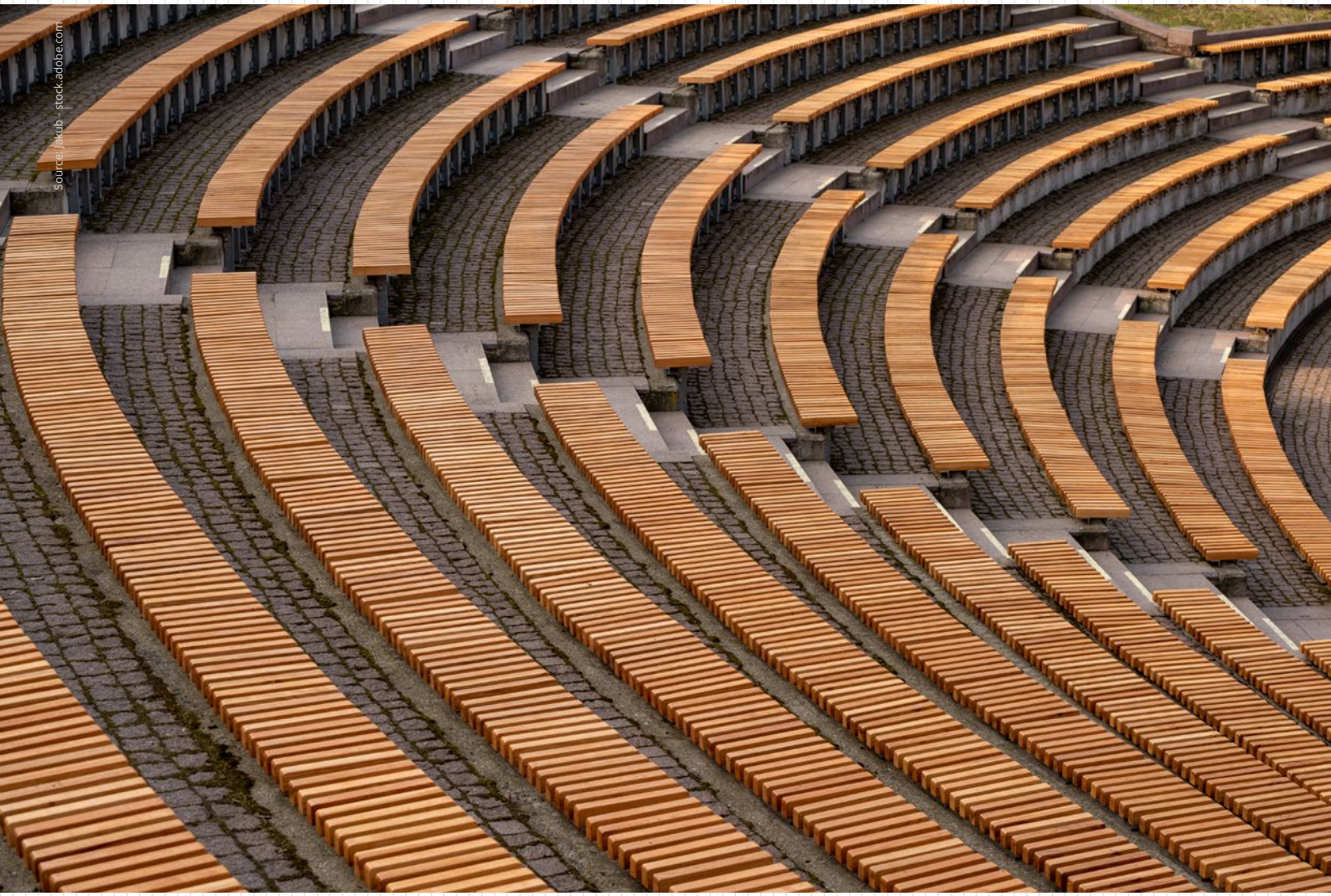
WOOD COATINGS

Due to the natural nature of wood, the factors that need to be considered when developing coatings for wood are different from those that need to be considered when developing coatings for metals, plastics, glass, etc. One important factor is water vapour permeability. The basics of wood coatings are presented in the introductory chapter, providing a good basis for the development of wood coating systems.



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3.2.3 Tasks and functions of wood coatings for outdoor applications

An adequate physical protection of wood can be achieved by translucently pigmented, UV-absorbing or opaque coating systems [449]. Furthermore, today a modern "organised" wood protection involves the application of constructive structural measures, the selection of suitable wood species and wood quality, the targeted utilisation of chemical agents only where it is really necessary, as well as the regular care and maintenance of the overall coating system [489]. Colourless coatings only are useful, if these properly are equipped with UV protection agents and radical scavenger. If the coating is damaged, grey to black spots at the damage points. The wood coatings essentially have the following tasks and function:

- Decorative effect
- Protection against UV light
- Humidity protection
- Protection against blue-stain and mould infestation
- Reduction of the swelling and shrinking movements

3.2.3.1 Coating systems for dimensionally stable and unstable components

In Europe, the requirements of the relevant standards and guidelines to grant a shelf life as long as possible [450–452] vary by region and the corresponding market conditions. In Southern Europe for example, a stronger focus often is put on the hardness or block resistance, respectively, as well as on the appearance of the coating in wooden windows for example. This may have negative properties on the weather resistance or durability, respectively. Another problem is that the wood qualities increasingly deteriorate (for example shorea bracteolata or pine with a high proportion of sapwood), or new cost-effective tropical woods are established on the market whereby these tropical woods rather are unsuitable for the construction of windows. Thus, it is a challenge for many manufacturers of coating materials and window manufacturers to develop a durable coating system or to achieve a durable coating system.

Wood species and wood protection

The selection of wood species [449] for the window production, for example, is described in the fact sheets HO 02 and HO 06 [453, 458] (wood species list) or in the corresponding table in the BFS leaflet no. 18 [461] as a guidance. Knot free profiles should be used. this is realised by laminated profiles or profiles which are produced with finger-jointed assemblies in length. One should pay attention to a proof of suitability. The variety of wood species provides a material for almost any field of application. Apart from the mechanical properties, the content of wood ingredients and consequently the resistance classes are decisive. The basic standards hereto are described in Chapter 2.4.2. If timbers whose resistance for the corresponding intended application are insufficient are selected, these timbers have to be coated with a prophylactic chemical wood protection according to DIN 68800-3 (Wood Preservation for building construction – Part 3: Preventive chemical wood protection). However, this only is prescribed for structural components according to the Building Act. These wood preservatives must have a general building inspection approval of the Deutsches Institut für Bautechnik (DIBt). The standard DIN EN 460 (durability of wood and wood-based products) describes which wood protection is required. A wood protection against blue stain (B) and wood-

Table 3.64: Levels of application and examples for dimensionally stable, restricted dimensionally stable and non-dimensionally stable components

Levels of application	Allowed dimensional stability	Typical examples of the levels of application
Non-dimensionally stable	Non-restricted	Overlapping wooden panelling, fences, garden sheds
Restricted dimensionally stable	Approved to a limited extent	Wooden panelling with tongue and groove, wooden buildings, garden furniture
Dimensionally stable	Approved to a very limited extent	Wood components incl. windows and doors

destroying fungi (P) is required according to the standard DIN 68800-3 for non-structural components such as new windows and exterior doors, if the timber applied do not correspond to the durability class 1 or 2, respectively, and if the standard DIN 68800 is agreed between the contractor and the client. This is approved in the VOB for carpentry works. Thereby, examinations for blue staining are performed according the standard DIN EN 152.1 (Testing of Wood Preservatives; Part 1: Application in coating method), while examinations for wood-destroying fungi (rot fungi) are performed according to DIN EN 113 (Testing of Wood Preservatives). In the industrial wood coating, a penetration depth of a few microns up to a few millimetres is obtained by impregnation depending on the type of the wood. The suitability of these wood preservatives can be detected by using a mark of conformity of the RAL Quality Mark Association Wood Preservatives. By way of derogation from Germany, in Austria mainly the protection against blue-staining is required.

Thereby, the wood preservative has to be compatible with the subsequent coating system (see manufacturer specifications). In the event of anti-blueing agents on pine tree sapwood, the penetration depth (blue stain free zone) has to be greater than 1.5 mm (DIN EN 152). This is particularly important in order to have a sufficient security against blue stain with emerging higher moisture contents of the wood. Thus, an increased infestation by blue stain may result at wood moisture contents of more than 20 % (as in many other types of sapwood) as well as at an insufficient protection against blue staining.

Components

The selection of the coating and coating system depends on the selection of the wood for the components and the intended application or use of the component, respectively. Thus, the selection of wood is an important basis for the functionality and durability of the intended system-compatible coating system. It practically forms the basis for a long life of the whole construction. In this regard, a distinction is made between different 'classes of component' depending on the function.

Components whose usability does not depend on the compliance with tight shape tolerances are referred to as non-conformance components. These include fences, overlapping wooden panels, freestanding pillars and pergolas. The experts disagree whether such components are to be painted with diffusion permeable or diffusion impermeable coatings if they are even coated.

Components which require an enhanced moisture protection in comparison to non-dimensionally stable components, are designated as dimensionally stable in order to remain fit for use. These are wooden panellings (tongue and groove), for example.

Table 3.65: Standard DIN EN 927-1: Classification according to stress groups

Construction	**Climatic conditions**		
	Moderate	**Strict**	**Extreme**
Protected	Weak	Weak	Medium
Partly protected	Weak	Medium	Strong
Not protected	Medium	Strong	Strong

Table 3.66: Standard DIN EN 927-2: Threshold values for evaluation criteria – outdoor weathering and water uptake.

	Dimensionally stable	**Limited dimensionally stable**	**Dimensionally instable**
Blistering	0.3	0.7	1
Crack formation	0.7	1.7	3
Exfoliation	0.3	0.7	1.3
Adhesive strenght	0.7	1.7	2.7
Maximal total value	6	12	18
Maximal difference, so that the test is valid	2	3	4
Value of water uptake according to EN 927	≤175 g/m²	≤250 g/m²	No threshold value

However, a clear distinction between these two types of components is not always possible, in practice. High quality fences consisting of heavy tropical timber and correspondingly coated in comparison to cost-effective fences made of spruce wood with dipcoat-priming are an example. In the first case, the component can be described as dimensionally stable, while in the second case the component is not dimensionally stable.

Components which tolerate only small dimensional changes in order to preserve their usability are referred to as dimensionally stable components. The standard DIN EN 942 (wood in carpentry works – general requirements) as well as the DIN EN 133047 and the leaflet HO 02 of the Association of Window and Facade Manufacturers are valid for dimensionally stable components such as windows. Dimensionally stable types of wood are described here. The dimensionally stable components require a special moisture protection, for example.

Requirements for coatings

The specific requirements on wood coatings for dimensionally stable components [454–457, 459, 460] such as wooden windows or wooden doors are described in the guidelines of the Institut für Fenstertechnik (also referred to as Rosenheimer guidelines) as well as in the guidelines of the Association Window Fascade (VFF) – for example leaflets HO 01 and HO 03 – or the Initiative *'Pro Holzfenster'*, which significantly was elaborated by the Wilhelm Klauditz Institute (WKI Fraunhofer Institute, Braunschweig). The standard EN 927-1 up to 8 as well as the standard ÖNORM C-2350 coating materials for coatings on dimensionally stable outdoor components consisting of wood – minimum requirements and verifications) describe the key components of the catalogue of requirements for wood coatings in the outdoor area.

Additionally, recommendations for the factory final treatment (coating) of wooden windows and wooden front doors were elaborated by the working group Surface of the IPH (Initiative Pro Holzfenster) in March, 2003 [469]. In addition, a RAL quality mark was established for wooden windows in order to improve and protect the quality of the wooden window. The BFS leaflet No. 18 'Coatings on dimensionally stable external construction components consisting of wood, especially windows and exterior doors' contains application instructions with checklists for painter applications, especially for reconstruction.

Climate stresses

The durability as well as the protective effect of the overall wood coating depend on the intensity of the stress caused by different climatic zones. In Central Europe, it is believed that the weather stresses on the north side of buildings are lower than the weather stresses on the southwest side, the so-called weather side. Thereby, the construction of the object as well as the possible protective effect resulting from this also play a role. These aspects also are considered in the standard DIN EN 927 Part 1, and the selection of the wood coatings are divided in three stress groups as it is illustrated in Table 3.65. Simplified, one has defined three climatic conditions in the standard DIN EN 927 Part 1. Thereby, the structural conditions also are considered.

Humidity protection and layer thickness

One of the main tasks of the coating system is the adequate protection of the structure against the penetration of liquid and vapour water. This shall ensure the dimensional tolerance of the dimensionally stable woods. A moisture penetration of more than 20 % as well as the related risk of fungal infestation and cracking have to be avoided. For this purpose, there are a variety of investigations. Liquid water usually is kept from. On the one hand, the fundamental property of the resin plays an important role, while the coating formulation determines the water uptake as well as the diffusion behaviour of water vapour on the other hand. The testing procedures as well as the details concerning performance indicators are described in the Standard DIN EN 927 Part 4 and 5. Table 3.66 presents the currently valid limiting values.

In doing so, the water uptake usually is expressed in g/m². In the case of the diffusion of water vapour, the permeability of water vapour can be expressed in kg/m² after 14 days (WD 14) analogous to the standard DIN 927-4A or as the diffusion resistance factor μ or p and – calculated from this – diffusion equivalent layer thickness Sd in m (Sd value = μ value x layer thickness in m) (see also DIN EN ISO 12572:2017-05). Apart from the composition of the coating material, the dry film thickness greatly affects the moisture behaviour. Sufficient layer thicknesses for a good moisture protection are important especially at the edges. A curvature of the edges (radius of curvature r > 2 mm) as well as lowest possible air inclusions (lower dry film thickness of air bubbles) have to be considered.

The water vapour permeability on the inside of wooden windows shall not be larger than the water vapour permeability on the outside in order to avoid a penetration of moisture and to avoid blistering on the outside. In principle, solvent-borne systems behave less problematic than water-borne systems. The initially good protective effect of alkyd systems against moisture is reduced in the course of weathering with degradation phenomena followed by cracking and spallings. Water-borne systems based on polyacrylate dispersions are permanently elastic. The initially pronounced hydrophilicity is reduced in the course of weathering due to leaching of the hydrophilic ingredients (emulsifiers, dispersing agents etc.).

Table 3.67: Minimum dry layer thickness of coatings for windows and front doors

	Opaque	**Translucent**
Intermediately coated windows before installation at final coating at the object	Not less than 50 µm	Not less than 50 µm
Blind frame, construction connection range	Not less than 50 µm	Not less than 50 µm
Hidden surfaces such as glass rebate	Not less than 30 µm	Not less than 30 µm
Blades, blind frame	Not less than 100 µm	Not less than 80 µm

Table 3.68: Categorization of the coatings according to plenty (layer thickness) analogous to EN 927

Minimal	**Medium layer thickness below 5 µm**
Low	Medium layer thickness between 5 µm und 20 µm
Medium	Medium layer thickness between 20 µm und 60 µm
High	Medium layer thickness above 60 µm

The humidity also affects the adhesion strength. Thus, a wet adhesion of the coating material is required for a good weather resistance and adequate protection against moisture. The risk of blistering and spalling thus are minimized. Here, too, there are a number of investigations [452, 454, 463, 464]. This disadvantage of water-borne systems was almost compensated by modifying the polymers, for example by incorporation of wet adhesion promotors (such as silanes) in polyacrylic dispersions as well as by a relatively low particle size. The today's water-borne systems offer a better long-term protection against moisture in comparison to traditional alkyd systems.

The total layer thickness is important for the functionality of the coating structure and, in particular, the moisture protection. Here, the non-dimensionally stable or limited dimensionally stable components require a lower layer thickness in comparison to the dimensionally stable components. For the latter, usually a 3 to 4-layered coating system is required. A two-layer coating system is sufficient for non-dimensionally stable components and limited dimensionally stable components. In this context, dry film thicknesses of coatings have been defined for the factory treatment of wooden windows and wooden front doors are defined [447].

However, the layers should not be significantly thicker than 150 microns and, thus, penetrated moisture also may diffuse out again. It has to be ensured that the moisture content is not permanently above 20 % (risk of blue-stain fungal infestation with subsequent problems).

Many ring trials have shown that the water uptake through the coating as well as the wet adhesion are crucial criteria. This applies to the currently used water-borne coating systems. For this, various coating systems have been tested in the project AIR (1994 to 1998) with European research institutes. The focus was on low-solvent, that means water-borne coating systems. Systems based on polyacrylate dispersions and alkyd-polyacrylic hybrids achieved the best results. Thus, the usability of the water-borne systems was confirmed. In the standard DIN EN-927, the coatings are classified in classes according to the fullness (layer thickness) as illustrated in Table 3.68.

It therefore follows that only coatings with a high abundance, i.e. a high film thickness, meet the requirements for an industrial coating of windows according to the Rosenheim specifications for wooden windows. However, in the new VFF leaflets these layer thicknesses are

enshrined only for industrial applications since these layer thicknesses for wooden windows, for example, only can be achieved with a disproportionately high effort for application in coating, or the coating systems are not practical for this purpose due to the different rheological properties. Generally, it should be noted that the type of wood usually has a greater impact on the moisture behaviour of a component in comparison to the component.

Colour shade of the behaviour

At the latest during the tendering of a building, the colour shade of the surface coating is set. During the exposure to the sun, the selection of a suitable wood for wooden windows, for example, is associated with the surface heating induced by the colour shade of the coating material. Both have to be coordinated in order to ensure a long lifetime of the component. Very dark coatings may attain surface temperatures of approx. 80 °C. The wood as well as the total construction including the adhesive joints thus are subject to a higher strain. Due to the poorer UV protective effect, bright glaze colours usually have a lower durability and require shorter maintenance intervals (also see 'ift leaflet' [454]).

Wood processing, wood working and preparation (frame connections)

The processing of the wood prior to the coating is a prerequisite for a durable and long functional coating system. The quality and testing regulations RAL-RG 424/1 have been proven for wooden windows. Thus, the profiles of the wooden windows are processed with slicing (hydro slicing). It should be noted that smaller wood fibres are not removed completely by grinding. This only is possible after an impregnation and subsequent intermediate sanding. Restored wood damages (such as screw anchors) have to comply with the standard DIN EN 942 (wood in carpentry works – general requirements). All frame connections must have an adhesive bonding corresponding to the stress group D 3 with regard to DIN EN 204 (classification of thermoplastic wood adhesives for non-structural applications). The frame connections also have to be sealed (see also the 'ift guideline' Bonding of wooden windows – Part 2: Bonding of frame corner connections). The proof of the temperature resistance according to the standard DIN EN 14257 (WATT '91) is connected with this.

Colourless wood impregnations

As an outdoor application, wood impregnations are applied as a first surface treatment and adapted to the type of wood. The standard DIN 68800 part 3 requires an impregnation against blue stain and fungal attack for all types of wood which are not classified in the resistance classes 1 and 2 with respect to the standard DIN 68364 (characteristic values of wood species – bulk density, modulus of elasticity and consistencies). The efficacy has to be demonstrated and documented with respect to the standards DIN EN 152 and DIN EN 113 as well as by awarding the quality mark RAL GZ-830. This is true for wooden windows directly exposed to weather. Wood-aluminium windows do not require this protection; here, a pure protection against blue-staining is sufficient. These wood impregnations are non-pigmented low viscous and have a low non-volatile content (between 3 and 10 percent by weight). Non-resistant types of wood contain blue stain inhibitory as well as rot fungus inhibitory additives. These shall penetrate into the wood as much as possible, so that the active substances such as fungicides or also the hydrophobising agents may penetrate good into the wood matrix and solidify the wood matrix. In addition to the wood-protective agents, these materials may contain additives of special algicides and fungicides in special formulations for the so-called film protection.

Thus, already here the wood fibres are bonded well in order to smooth the wood surface even optimally in the subsequent grinding process after application of the primer or intermediate coating, respectively, if necessary. The wood fibres are applied prior to the application of colourless or transparent as well as opaquely pigmented coating system. However, it must be ensured that the surface of the wood does not become too hydrophobic after drying of the primer – for example by application of hydrophobic additives – in order to avoid adhesion problems with their unpleasant consequences (such as detachments) during the application of subsequently applied water-borne coating materials. Usually, the impregnations are applied with the immersion method, flow coating procedure or also by the spray process. It should be considered that the minimum drying times specified by the paint manufacturer have to be fulfilled after application of the primer. A distinction is made between solvent-borne and water-borne impregnations.

Solvent-borne impregnations

Solvent-borne primers have a very good penetration capability. The anti-fugal or fungicidal active ingredients also are dissolved in the primers very well and thus are distributed in the wood

Components	Parts by weight [%]
Alkyd resins, long or medium oil 100 % [1]	60.0
Combination of dryer (cobalt, zircon, calcium)	Approx. 5
Butyl diglycol	100
Wood preservatives (biocides) [2]	Approx. 4–20
De-aromatised hydrocarbons 180–220	815–831
	Approx. 1000

1) For example “Worleekyd” L 7904 (producer: Worlée)
2) Specifications as active ingredient concentration. The added amounts depend on the type of biocide or biocides, respectively, as well as on the application quantity of the impregnation (depending on the requirements for example according to the standard EN 113 or EN 152). The active ingredient has to be well predissolved or premixed prior to its addition to butyl diglycol, for example. Usually, the addition of a viscosity stabilising, oxime containing additive is essential.

Figure 3.147: Schematic formulation of solvent-borne, non-pigmented impregnation

Components	Parts by weight [%]
Acrylate dispersion, fine-particle (approx. 50 nm), approx. 34 % [1]	295
Wetting agent AMP 90	2
Substrate agent/water (1:9)	5
Defoaming agent	
Water	624–640
Preservative agent	2
Wood preservative (biocide) [2]	Approx. 4–20
Butyl diglycol	50
	Approx. 1000

The impregnating properties even can be improved by an addition of water-borne alkyd resins (producer: Cytec).

1) for example Mowilith LDM 7667 (producer: Celanese Emulsions GmbH)
2) Specifications as active ingredient concentration. The added amounts depend on the type of biocide or biocides, respectively, as well as on the application quantity of the impregnation (depending on the requirements for example according to the standard EN 113 or EN 152). The active ingredient has to be well predissolved or premixed prior to its addition to butyl diglycol, for example.

Figure 3.148: Schematic formulation of water-borne impregnations