FINISH PERFORMANCE TODAY/TOMORROW MAINTENANCE FREE MYTH OR REALITY

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INTRODUCTION

The purpose of this paper is to examine current and future coating performance on wood substrates, the variety of factors that influence coating performance and discuss future challenges and opportunities that the coating and wood industry mutually share. We will examine typical coating systems and how they are judged as to their performance with anticipated future trends. Due to the multiple number of coatings, wood substrates and desired end uses, this paper will attempt to address coating performance in general, but relevant terms.

MATERIAL

Coating Finish Types

In general, there are two categories of commonly used coatings. Trade Sales Coatings are those which are formulated for general use areas and sold through primarily retail outlets such as conventional house paints. These coatings are formulated with flexible application, drying, handling and storage characteristics to accommodate for the variety of conditions in which they are used. The second category are those coatings which are formulated for specific uses and applications. Because the formulator knows the end use, application and drying method more definitely, it is possible to produce a better performing coating under these conditions. These coatings could include industrial, OEM original equipment manufacturer, and heavy duty maintenance products.

Table 1 & 2, Types of Coating Used and Types of Coating Made (1) illustrate typical coating types. Their percent used and manufactured from 1989 and projected through 1993 by Industrial Finishing Magazine 1. Factors ranging from emerging technology to environmental issues are impacting the types of coatings used and their ultimate performance. Conventional coatings should experience a moderate decline primarily due to environmental restrictions. In general, this is resulting in some decline in long-term durability due to formulation tradeoffs. High solids finishes are experiencing growth in markets where applications fit such as V.O.C., Volatile Organic Compound, regulated areas. Powder coatings are continuing to expand due to a no solvent feature and high transfer efficiency and recyclability. To date, powder coatings have limited applications with wood substrates due to the non-conductivity of wood and high cost of available systems. Waterborne coatings are and will continue to grow due to environmental

restrictions, emerging technology and flexibility in formulation and reasonable cost. Radiation Cure and Electron-Beam Cure coatings will remain at roughly the same level with limited applications such as interior wood flat lines and pretreatments. Future advances will be discussed later in the paper.

Table 1. Types of coating used
(Percent of total volume)

	1989	1990	1991	1993
Conventional	47.8	46.0	41.6	32.5
High-solids	14.9	16.5	16.4	16.3
Two-component	12.2	12.9	11.6	11.5
Powder	11.1	11.5	12.8	16.7
Waterborne	9.1	11.2	11.8	16.9
Vapor-cure	1.6	.7	1.4	1.1
Radiation-cure	1.4	.9	2.0	2.3
Other	1.9	3.3	2.5	2.5

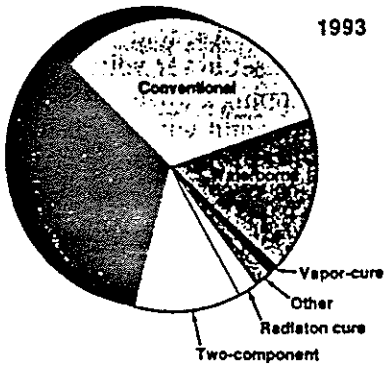
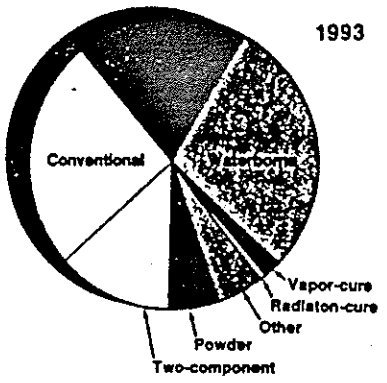


Table 2. Types of coating made
(Percent of total volume)

	1989	1990	1991	1993	
Conventional	42.0	34.8	35.6	25.8	−
High-solids	16.5	16.0	13.3	16.6	+
Two-component	9.2	10.9	12.7	12.9	
Powder	3.1	5.1	5.7	6.1	+
Waterborne	21.2	22.5	24.5	30.1	+
Vapor-cure	1.0	.4	.2	.1	
Radiation-cure	2.0	2.0	2.0	2.3	+
Other	4.9	8.3	6.1	6.1	



Challenges of the paint film

In order to "perform," a paint film must provide instant beauty and aesthetic qualities, maintain its film integrity and protect the underlying surface for extended durations. In addition, it may be asked to exhibit specific characteristics such as controlling the natural oils, dyes and resins in wood and control moisture intrusion.

A paper presented by Mr. Thomas E. Hill of the Pratt and Lambert Company, Buffalo, New York, at a Wood Coatings Symposium several yeas ago, effectively illustrates the demands of a paint film. I quote, "The extraordinary demands placed on a paint film is an additional reason for the use of quality coatings. A conventional latex house paint, when applied at a normal spreading rate, will give slightly less than one mil of dried film. This is approximately 25.4 microns. To put this into perspective, the skin on your body averages over 1,000 microns thick. That's one millimeter. Two coats of a conventional latex paint applied at a normal spreading rate will give a dried film of approximately 1.5 to 2 mils, or a little over 50 microns. This means the skin on your body is twenty times thicker than the paint that goes on a house. Did you know all of the skin on your body is replaced entirely once every seven years? Additionally, the skin on

your body is expected to yield to the vagaries of time. What do I mean by that statement? Well, some people have wrinkles. There are some people with abrasions, some people may even have some cracked and peeling skin. None of you have returned to the manufacturer for a refund. It is a defect for aged paint to crack, check or peel with time. The demands placed on this very thin paint film are truly extraordinary. It is no wonder that paint chemists are prematurely gray or bald. Paint chemists are expected to design a coating that outperforms the coating designed by the Lord." (2)

The thrust of this paper was to define a quality paint and the value associated. For long-term paint performance a quality coating must be used. According to the PDCA, Paint and Decorating Contractors of America, the average coating cost on a house is 8% of the total, with labor accounting for 92%. Saving a dollar or two on the cost of the coating does not make good economic sense. (3)

Factors influencing paint performance

There are a number of other factors that impact paint performance as much as the actual coating. It is critical to match the specie of wood and performance expectations to the type of coatings used. For example, due the differences in dimensional stability, natural decay and insect resistance and resin/pitch and extractive content, it may be necessary to use a different primer/topcoat system on Eastern White Pine, Ponderose Pine, Southern Yellow Pine, etc. than would be used on Western Red Cedar or Redwood for best results. The wrong system may not provide proper moisture resistance, breathability, flexibility, and can solluabilize extractives or resins to the surface. Moisture content of the internal substrate is critical for proper adhesion, film formation, stability and reduces the chances for extractives and resin migration. All wood to be coated should be of a moisture content of 19% or less which is considered KD, kiln dried. Proper application and drying to a sound surface are obvious considerations for paint performance. The weathering of unprotected/untreated wood dramatically impacts the performance and longevity of coatings. Weathering results from a modification in wood's molecular structure. This is caused by a combination of chemical, biological, mechanical and light induced changes occurring simultaneously. The common elements are ultra violet light, moisture, and atmospheric conditions.

The combined weathering action of sunlight and water quickly changes the surface of wood and can change color and become rough. Staining microorganisms (fungi) are the main causes of the gray color of weathered wood.

Weathering is not associated with decay (rot) but is caused by chemical changes in some of the wood's components. In general, for softwoods like pine, cedar, redwood and spruce, about one-fourth inch of wood thickness weathers away every 100 years. The maximum weathering rate reported is sixty-five one-hundredths inch per 100 years for slow-grown (24 annual rings per inch) western red cedar exposed vertically facing south. For dense hardwood like the oaks, the rate is only about thirteen one-hundredths (one-eighth) inch per 100 years.

The rate of weathering is affected by climatic conditions, the severity of exposure, wood density, the amount of early wood and late wood and ring orientation, as well as the rate of growth and lignin and extractives content. In general, the less dense the material the more severe the exposure, the faster the weathering and erosion rate. Treated wood with moisture resistant properties can extend wood life by slowing down weathering.

Water-repellent preservatives contain a fungicide, a small amount of wax as a water repellent, a resin or drying oil and a solvent such as turpentine or mineral spirits. Some water-borne formulations are also available.

The wax in the formula reduces the absorption of liquid water by the wood and somewhat reduces the erosion due to weathering. The preservative prevents wood from darkening (graying) by inhibiting the growth of mildew, mold and decay organisms.

This treatment keeps rain or dew from penetrating into the wood, especially at joints and on end grain, thus decreasing the shrinking and swelling of the wood. As a result, less stress is placed on the paint film, and its service life is extended. This stability is achieved by the small amount of wax present in the water-repellent preservative.

If the entire board has been treated, the wax also decreases the capillary movement of water up the back side of lap or drop siding. Fungicide in this treatment inhibits surface decay, mold and mildew.

Water-repellent preservatives will not protect the surface from ultraviolet light damage unless ultraviolet light inhibitors are added to the finish.

Water repellents are simply water-repellent preservatives with the fungicide left out. Water repellents are not good natural finishes because they will not control the growth of staining organisms, but they can be used as a stabilizing treatment before priming and painting. They can also provide some decay resistance. (4)

Adhesion of paint to weathered wood

Numerous field tests have concluded that wood that has been untreated/unprotected for less than two weeks can cut the coating's life in half and result in premature failure.

Following outdoor weathering for up to 16 weeks, western redcedar (Thuja plicata Donn) boards were painted with alkyd oil or acrylic latex primer paints and tested to shear or tension to determine paint adhesion. The tensile strength of the paint/wood bond dropped 50 percent from approximately 300 pounds per square inch (psi) (2,068 kPa) on wood weathered for 4 weeks to 150 psi (1,034kPa) on wood weathered for 16 weeks. Shear strength dropped 33 percent from approximately 750 psi (5,171 kPa) to 500 psi (3,447kPa) after similar weathering periods. (5)

CURRENT FINISH AND SUBSTRATE PERFORMANCE PARAMETERS AND RATINGS

Finish and Substrate Performance Evaluation Parameters

Various criteria are used to determine the performance ratings of the various pretreatment/finish systems on wood, hardboard, plywood, and other substrates. Many of the evaluation methods are based on American Society for Testing and Materials (ASTM) Standards and are related to the following performance and appearance factors:

Mildew and discoloration
Flaking, erosion, and cracking of the finish
Cracking, checking, and loss of surface fibers or particles on the substrate
General appearance (a subjective visual assessment)
Resin/extractive/pitch migration control

Some of the specific evaluation methods and inspection criteria are shown below:

Evaluation	Method
Non volatile content	ASTM D 2369-81
Mildew	ASTM D 3274-82
Discoloration	Subjective visual assessment similar to ASTM D 3274-82
Finish	
Flaking	ASTM D 772-47
Erosion	ASTM D 662-44
Cracking	ASTM D 661-44
General appearance	Subjective visual assessment
Substrate checking	Similar to ASTM D 660-44

For illustration and simplicity of presentation, the various performance criteria are often combined into a single value called the overall performance rating. This rating is an average of the elements of the rating system, each evaluated on a scale of 10 to 1. An overall performance rating value of 10 indicates no change from the original unweathered condition; 5 represents a condition at which refinishing would normally be required but without extensive preparation of the substrate surface; and 1 represents total failure. The time required for a finish to reach an overall performance value of 5 is a convenient measure of durability.

Resin/Finish Performance for the 90's

- From the point of view of resources, modified alkyds will continue to be widely used.
- Solvent-free systems have become firmly established in the form of powder coatings and radiation-curing paints and their usage is increasing. Their free monomer content will have to be completely eliminated.
- Water-based paints are based exclusively in resins which are free from co-solvents and amines. Crosslinking water-based paints will have to be free from decomposition products and be disposable.
- Physically drying paints based on reversible, re-usable resins will become increasingly important as soon as the properties of these resins are further improved. (7)

Advancements are anticipated using blends of waterborne resin systems which should result in improved performance. This will include split polymer acrylics, modified urethanes, cross linking molecular systems and wide use of alkyd/alkyd emulsion systems. Future paints should exhibit improved adhesion properties, tighter yet breathable films, with excellent durability, flexibility and color retention which are critical attributes for wood surfaces. Improved technology, proper applications and marketing of higher end paints should result in typical systems life expectancy under normal conditions of an average of 10 years or longer. There are anticipated advancements in the clear or natural tone, lightly pigmented, semi-transparent finishes in film integrity, color retention and UV protection. Primary acrylic and trans-oxide systems are expected to be typical systems with these finishes. These will provide excellent durability and long-term performances as compared to conventional like products.

There should be continued improvement in primers for wood surfaces and finish systems which will improve moisture resistance, control of resin, extractive and oil migration, board stability and adhesion of topcoats. There will be increased emphasis and improvement of factory applied pretreatments and finishes utilizing water repellent preservatives, primers and topcoats. Improved thermoplastic and thermoset finish systems will result in more mar and block resistance, good flexibility, color retention and excellent long-term durability which will allow pretreated + prefinished wood products to effectively compete with non-wood materials.

Perhaps one of the most significant areas for improved paint performance will result from improved use of available paint products. More emphasis and communication from coatings manufacturers and the wood industry in a cooperative fashion in using quality products and proper application methods, will result in significantly improved paint performance as determined by the end user. It is certainly in the best interests of both industries to increase the awareness that wood products, properly finished, provide the value, long-term performance, flexibility and beauty the public desires.

MAINTENANCE FREE/MYTH OR REALITY

Market's Response

The U.S. exterior siding market shows that the share of wood siding is dropping. As the George Carter study shows, the areas that are growing are perceived as maintenance free, such as vinyl. At the same time, environmental supply and cost issues are impacting the use of wood products and how they are marketed and sold. By improving the coating systems and application methods, wood products can compete with non-wood products. Numerous studies show that the variety of non-wood products such as vinyl, aluminum, plastics, cementetious and others are not necessarily maintenance free. Many of these products are subject to the same stresses as wood, i.e., color fade, changes in dimensions, cracking under exposed conditions and others. Furthermore, it is questionable if there are any 100 year old structures still performing like wood structures made with these materials.

What is maintenance free?

This question is very subjective depending upon who you ask and what they consider as requiring maintenance or a failure. We concentrated on painted/coated wood structures in exterior use in an attempt to answer this question. Under a variety of conditions we asked focus groups comprised of consumers, builders, developers and building material dealers how long is maintenance free for a painted/coated surface. A failure was defined as non-routine, i.e., cleaning or physical damage or requiring repainting. The overwhelming consensus was that a product that performs as defined for 7-10 years is considered maintenance free.

CONCLUSIONS

The available current coatings technology with proper applications provide excellent paint performance. Pretreated and Prefinished products are available with outstanding long-term "maintenance free" features. The combination of improved coatings technologies and systems and cooperation of the wood and coatings industries in marketing quality products puts wood in a very competitive position with an excellent future.

REFERENCES

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4. Forest Products Lab Technical Report, FPL-GTR-69
5. Photodegration and Photoprotection of Wood Surfaces, Shang-Tzen Chang, David N. J. Hon and William C. Feist. Society of Wood Science and Technology, 1988r.
6. KTA Tator/PPG Industries/Forest Products Lab.
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TYPE OF EXTERIOR WOOD SURFACE	Water-repellent Preservative and Oil		Semitransparent Stain		Paint and Solid-Color Stain				Acrylic Semi-transp.	Pre-finish
	Suit-ability	Expected Life (years)	Suit-ability	Expected Life (years)	Suit-ability	Expected Life (years)			Expected Life (years)	Expec Life (year
						Paint		Solid Color Stain		
						1 Coat	2 Coats	1 Coat		2 Coa
Siding										
Cedar and redwood										
Smooth (vertical grain)	High	1-2	Moderate	2-4	High	4-6		3-5	3-5	10-15
Roughsawn	High	2-3	High	5-8	Moderate	5-7		5-7	5-7	15
Pine, fir, spruce										
Smooth (flat-grained)	High	1-2	Low	2-3	Moderate	3-5	7-10	3-4	5	10-15
Rough (flat-grained)	High	2-3	High	4-7	Moderate	4-6	8-10	5-7	5-7	10-15
Shingles										
Sawn	High	2-3	High	4-8	Moderate	3-5		3-4	4	10-15
Split	High	1-2	High	4-8	--	3-5		3-4	4	10
Plywood (Douglas Fir and Southern Pine)										
Sanded	Low	1-2	Moderate	2-4	Moderate	2-4	5-7	2-3	5	10
Textured (smooth)	Low	1-2	Moderate	2-4	Moderate	3-4	6-8	2-3	5	10
Textured (roughsawn)	Low	2-3	High	4-8	Moderate	4-6	6-8	3-5	5-7	10
Medium-density overlay	--	--	--	--	Excellent	6-8	8-10	5-7	5-7	10
Plywood (cedar and redwood)										
Sanded	Low	1-2	Moderate	2-4	Moderate	2-4	6-8	2-3	5	10
Textured (smooth)	Low	1-2	Moderate	2-4	Moderate	2-4	6-8	2-3	5	10
Textured (roughsawn)	Low	2-3	High	5-8	Moderate	4-6	6-8	3-5	5-7	10
Hardboard, medium density										
Smooth										
Unfinished	--	--	--	--	High	4-6	8-10	3-5	--	10-15
Preprimed	--	--	--	--	High	4-6	8-10	3-5	--	10-15
Textured	--	--	--	--	High	4-6	8-10	5-7	--	10-15
Unfinished	--	--	--	--	High	4-6	8-10	3-5	--	10-15
Preprimed	--	--	--	--	High	4-6	8-10	5-7	--	10-15
Millwork (usually pine)										
Windows, shutters, doors, exterior trim	High	--	Moderate	2-3	High	3-6	7-10	3-4	5	10-15
Decking										
New (smooth)	High	1-2	Moderate	2-3	Low	2-3	--	1-2	--	--
Weathered (rough)	High	2-3	High	3-6	Low	2-3	--	1-2	--	--
Glued-laminated members										
Smooth	High	1-2	Moderate	3-4	Moderate	3-4	--	2-3	5	10-15
Rough	High	2-3	High	6-8	Moderate	3-5	--	3-4	5	10-15
Oriented strandboard	--	--	Low	1-3	Moderate	2-4	7-10	5-7	--	10-15

- These data were compiled from the observations of many researchers. Expected life predictions are for an average location in the continental United States; expected life will vary in extreme climates or exposure (such as desert, seashore, and deep woods).
- Development of mildew on surface indicates need for refinishing.
- Expected life of two coats, one primer and one topcoat. Applying a second topcoat (three-coat job) will approximately double the life. Top-quality acrylic latex paints will have the best durability.
- Medium-density overlay is generally painted.
- Semitransparent stains are not suitable for hardboard. Solid-color stains (acrylic latex) will perform like paints. Paints are preferred.
- Two coat systems consist of one prime (4 sides) one topcoat of approximately five-six wet mils.
- Prefinished (KTA Tator/PPG Industries Forest Products Laboratory) (6)