A Novel, Clear Fire Retardant Waterborne Coating System for Wood Substrates

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ABSTRACT

Clear intumescent coatings were developed to allow for presentation of the natural wood visual, but have struggled to achieve an acceptable E84 Class A rating, while also having a plastic-type look to the visual. Many of the current clear, intumescent coatings require application of a solvent topcoat to prevent moisture from contacting the base coating, and/or creating a visual that has some haziness to it. Armstrong World Industries has developed a patent pending novel, clear fire retardant waterborne coating system that has consistently achieved Class A (25 flame spread index/50 smoke developed index) rating with the ASTM E84 Tunnel Test on solid wood substrates, while still presenting a true wood visual. Armstrong's patent pending, new Class A clear coating system is a significant development in the fire-retardant coatings market for wood substrates. This technology was approved in a manufacturing environment.

1. INTRODUCTION

Inherent deficiencies with the traditional, clear, intumescent coatings restrict them from achieving a 25 (SDI)/50 (FSI) rating in the E84-18b Steiner Tunnel test. This lack of performance indicated the need to develop a novel, waterborne coating system that provides protection to the underlying wood substrate to achieve a rating of 25/50 in the ASTM E84-18b tunnel test, allowing for the use of Armstrong's new clear coating system on return air plenums. Armstrong's novel, inorganic coating system offers this performance while providing a clear visual appearance that does not resemble a plastic visual, while providing water repellency, hardness with flexibility, and excellent adhesion. Ease of use and application were also improved, as well as clean-up, since the coating system is completely waterborne with a near 0 g/L VOC level.

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2. EXPERIMENTAL AND TEST METHODS

2.1 ASTM E84-18b Steiner Tunnel Test

ASTM E84-18b details the requirements for testing the flame spread index and the smoke developed index. The flame spread index is "the relative rate at which flame will spread over the surface of a material". The test material is face down toward the flame and the test lasts for 10 minutes.

Based on the FSI and SDI results, ASTM then places the material into one of three classifications. The ASTM E84 test also limits, by code, the SDI to 450.

Classification	FSI Range
A	0 – 25
B	30 – 75
C	80 - 200

Table 1: ASTM E84 FSI Classifications

The classifications shown in Table 1 determine the rating a material achieved during the E84-18b Tunnel Test. SDI classification is based on the International Mechanical Code (IMC)[2] on values obtained from the E84 Steiner Tunnel Test.

Armstrong World Industries (AWI) developed a novel, clear, waterborne fire retardant (NWC) coating system that allows for application onto wood substrates that can then be used in even return air plenum spaces. When evaluated both as a clear, non-tinted sample and tinted samples, FSI was below 25 and the SDI was under 50.

2.2 Hardness Evaluation

Hardness of the coatings were evaluated per ASTM D3363-05 method, Standard Test Method for Film Hardness by Pencil Test

2.3 Adhesion Evaluation

Adhesion of the coatings to each other and the substrates were evaluated per ASTM D3359-17, Standard Test Methods for Rating Adhesion by Tape Test, Method B.

2.4 Water Repellency

The evaluation of water repellency on a coated substrate was done by placing water onto the test surface and recording the time until the water starts absorbing into the substrate. The longer the time, the better the repellency of the coating system.

3. RESULTS & DISCUSSIONS

3.1 Wood Species Fire Performance

Wood material can give a range of FSI readings, as shown in Table 2:

Solid Wood Material	ASTM E84 Flame Spread Index (FSI)	ASTM Flame Spread Classification	ASTM E84 Smoke Developed Index (SDI)
Cedar, Western Red	45	B	125
Cypress	75	B	200
Douglas Fir	70	B	80
Hemlock, Western	40	B	60
Oak, Red	100	C	100
Pine, Eastern White	70	B	110
Poplar, Yellow	125	C	125
Spruce, Eastern Red	65	B	170
Walnut	75	B	125

Table 2: Reported Flame Spread Indices of Solid Wood Products[1]

Reported flame spread indices of various solid wood products are shown in Table 2. The FSI can vary greatly from a low of 45 with Western Red Cedar, to a high of 125 for Yellow Poplar. Variations in the SDI can range from a 60 with Western Hemlock, to a high of 200 with Cypress. When pigmented intumescent or fire retardant coatings were evaluated, the added pigment tended to suppress the effects of variation in the different wood substrates, protecting the various woods. However, with the desire for clear intumescent, and fire-resistant coatings, the choice of substrates becomes more important because the lack of fire-retardant pigments limits the protection offered.

When evaluating Armstrong's NWC system, all testing was completed on yellow poplar wood. This enables an evaluation that is harsher than those used by current intumescent or fire retardant coating companies on the market today. Many of those coatings were evaluated on Douglas fir, Oak, cement board, or metal, and just evaluated the coatings themselves and not the entire system.

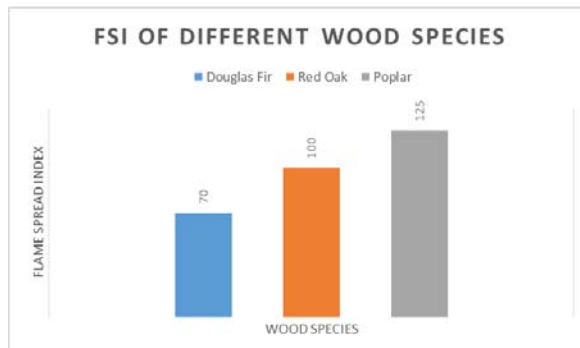

Figure 1: Comparison of FSI of Common Wood Substrates[1]

The comparison of the flame spread indices of common wood substrates is shown in Figure 1. If a Douglas fir specimen is coated with a fire retardant coating system a reduction of 45 FSI units would be required before it would be considered Class A. Whereas the Yellow Poplar wood specimen would have to have its FSI reduced by 100 units to achieve a Class A rating. This may require a more robust coating system than that used on the Douglas fir substrate.

Figure 2: Comparison of SDI of Common Wood Substrates[1]

The SDI ratings of different wood species presented in Figure 2 shows that the Yellow Poplar wood substrate has the highest SDI while the Douglas fir substrate has the lowest SDI. With Douglas fir having a lower SDI to start with than the Yellow Poplar, a coating system that works on the Douglas fir may not work with the Yellow Poplar.

3.2 AWI Clear Coating System

Coating	FSI	SDI	Time Conditioned (days)
NWC System	15	30	3
Sample A	25	85	937
Sample B	25	250	42
Sample C	25	400	2
Sample D	20	165	3
Sample E	25	300	Not Reported
Sample F	15	350	14

Table 3: FSI, SDI and Days Conditioned

The results on Table 3 show the various reported values for the FSI (Flame Spread Index), SDI (Smoke Developed Index) and Time Conditioned, as reported by the testing laboratories per ASTM E84 Tunnel Test. Only Armstrong's NWC system offers the results that achieve a Class A rating of 25(FSI)/50(SDI) out of all the samples evaluated.

Figure 3: Armstrong's Class A Coating After Successful E84 Steiner Tunnel Test

Figure 3 shows the results, after a successful E84 Tunnel Test, of Armstrong's NWC system protecting the underlying substrate from further exposure to fire. The large bubbles, unlike intumescent coatings, do not continue to burn, or char. Instead, the large bubbles protect the underlying substrate while being resistant to the high heat generated by the fire. This, in turn, greatly reduces that development of smoke, allowing for a Class A rating of 25/50 on Poplar substrates.

3.3 Repeatability of NWC Fire Performance

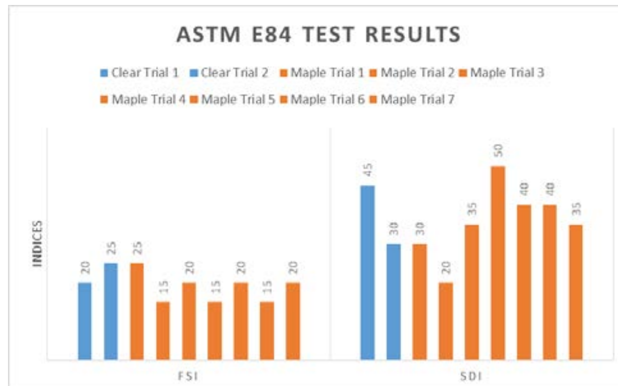

Figure 4: Repeatability of Fire Resistance with Armstrong's NWC Systems

The FSI and SDI results are shown in Figure 4. In the above trials, the FSI was at, or below, 25, which indicates a Class A rating. In addition, the SDI results showed, for both clear and maple tinted coatings, that all the above coatings achieved a 50 or lower rating. These results indicate a Class A 25/50 rating for both clear and tinted coating systems.

3.4 Other Performance Properties

While clear coatings are used to show the natural wood surface, tints and colorants are used to improve the visual of the wood surface, change the characteristic looks of the underlying surface, or add texture and depth to the material that would otherwise not be observable. The main drawback of using tints and colorants is the additional surfactants presenting in the material that could 1) leach out of the coating when exposed to water or high humidity if not fully cured, and 2) adds additional organic chemicals that could increase the flame spread index and smoke developed index of intumescent or fire retardant coatings, restricting the classification of said coatings.

Evaluation	Results		
	NWC Maple	**NWC Clear**	**Product A (Maple)**
Hardness (ASTM D3363-05)	3H	3H	2H
Adhesion (ASTM D3359-17)	5B	5B	3B
Water Repellency	210+ minutes	210+ minutes	210+ minutes
Color Data (Spectrophotometer)			
L	67.69	80.0	65.47
A	13.66	2.6	13.95
B	38.45	25.0	36.61
Fire Test Results (E84)			
FSI	19	23	190
SDI	36	38	120

Table 4: Physical Properties

The physical properties of the two different Armstrong NWC coating systems as well as a competitive product are shown in Table 4. Product A, a commercially available system for wood substrates, had good pencil hardness, but average crosshatch adhesion. However, it achieved a Class C rating on the ASTM E84 Tunnel Test, with a FSI of 190 and an SDI of 120. All testing was done on Yellow Poplar wood.

3.5 Application

Evaluations were carried out that compared the various application methods to determine the optimum coating method. The ability to apply different application amounts, change coatings, and cleanup is important. Spray application was determined as the best method of application for this evaluation, but other application methods could be used, such as dip-coating, curtain coating, roll coater, etc.

Two different coating spray methods were evaluated:

A conventional spray gun with a syphon cup. This spray gun setup allowed for a rapid amount of coating to be delivered to the wood substrate, but tended to allow for a rough surface, affecting the gloss and leveling of the coating.

A HVLP spray gun with a gravity cup attachment. The HVLP spray gun setup allowed for better application and layup of the coatings onto the wood substrate, while achieving a smooth, glossy visual.

Once the coatings were applied, two different curing mechanisms were evaluated:

Air cured at room temperature. After application of the coatings, they were then allowed to air dry/cure until no tackiness was observed.

Oven cured at an elevated temperature for short periods of time. This allowed for rapid evaluation of samples, and would be able to provide for a higher volume production run compared to the air cured procedures.

IR curing was evaluated. The coatings quickly blistered when placed in high heat, or did not fully cure when placed under low heat. The amount of time did not seem to factor into the curing of the different coating layers.

4. CONCLUSIONS

With the transition from opaque, intumescent or fire retardant coatings, to a clear visual coating that provides fire protection, the current coatings rely on technology that creates more smoke than the base material itself, while reducing adhesion of the coatings to the substrate. The novel, clear, waterborne fire retardant coating from Armstrong World Industries showed a tremendous reduction in the SDI levels from the base material, while providing excellent fire protection and fast curing. This patent pending, manufacture tested NWC system can achieve an ASTM E84 rating of Class A 25/50, a first for the industry, while maintaining a true wood visual.

5. REFERENCES

1. American Wood Council. Flame Spread Performance of Wood Products Used for Interior Finish. Design for Code Acceptance. American Wood Council, Leesburg, VA, 2017

2. International Mechanical Code. Materials within Plenums. Section 602.2.1. International Code Council, Country Club Hills, IL, 2018