

**Title: Water based Flame Retardant Coating**

Sachin Chavhan

The Sherwin Williams Company

4440 Warrensville center road,

Warrensville heights, OH-44128

**Abstract:** Rapidly growing trends in flame retardant coatings demand environmentally sustainable advancements in coating compositions. Non-halogenated water-based flame retardant coatings can address these concerns. These coatings allow for low flammability, low smoke density and low toxicity. Life Cycle Analysis suggests that these coatings can improve environmental impact by reducing global warming potential while showing superior performance and durability. This coating solution can offer significant application, safety and environmental advantages that reduce total ownership costs and increase structural protection during fire events.

**1. Introduction:**

Fire is the biggest threat for the crews in aircraft, ships, submarines, and land vehicles. As a result of such threats there have been use of fire/flame retardants coatings increased exponentially to curb economic and social consequences of fire [1]. There are various types of coatings available to fight against the fire. Two classes of fire protection technologies are being used currently, 1) Fire retardant and 2) Fire resistant. Fire retardant coatings are passive fire protection coatings where such coatings can slow down the spread of the flames allowing more time for evacuation and firefighting. Fire resistant coatings typically inhibiting the flame penetration or do not ignite upon in contact with fire [2].

When it comes to flame retardant coatings, various chemistries have been used in the coatings formulation to provide this retardancy from fire. Various flame retardant additives have been used such as, organophosphorus compounds, halogenated compounds, minerals such as Aluminum trihydrate, magnesium hydroxide, etc. Also, selection of polymers plays important roles in achieving the flame retardancy. Selection of polymers can be based on its mechanism to either insulate the incoming flame and prevent further spreading of the flame or based on the energy received by the flame, the polymer will chemically inhibit the flame spread.

MIL-PRF-24596B Formula 25A (F25A) is the flame retardant, halogenated, coating approved for use in interior habitable spaces aboard US Naval vessels. Halogenated compounds recently have

come under heavy scrutiny due to their toxicity, specially HBCD (hexabromocyclododecane) which have persistent, bioaccumulative, and toxic characteristics [3].

In this paper, the physical performance and flame properties results obtained on three colors of this new water-based flame retardant latex (WBFR) as per MIL-PRF-24596B Amendment 1 [3] document are discussed.

## 2. Experimental Procedure

- a. **Binder selection** – Prototypes were evaluated in accordance with the selection of non-halogenated latexes. Current F25A formula uses the binder based on polyvinylidene chloride polymer while this new prototype uses the alkyl phenol ethoxylates (APEO) free latex polymer.
- b. **Flame retardant selection** - Flame retardant alternatives for hexabromocyclododecane (HBCD) were released June 2014 by the EPA [4]. This report profiles three relevant alternative materials. However, all alternatives are brominated (e.g., butadiene styrene brominated copolymers), which operate upon smoke release for flame retardancy (when the material is burned, an abundance of smoke is released from the material which ultimately dilutes the atmospheric oxygen to prevent flame spread) and will contribute heavily towards optical smoke density. Alumina trihydrate and cyclic phosphonate esters and other non-halogenated additives were chosen for this product development.
- c. **Processing** – Flame retardant additives along with the other pigments selected in this formulation were processed on high speed dispermat and then blended with binder.
- d. **Quality check and performance testing** – Tests performed as per the MIL-PRF-24596B Amendment 1 requirement as shown in Table 1.

**Table 1: Tests Requirements for MIL-PRF-24596B Amendment 1**

| <b><u>Test Description</u></b>          | <b><u>Test Method</u></b>              |
|-----------------------------------------|----------------------------------------|
| Yellowness                              | ASTM E313                              |
| Smoke Density                           | ASTM E662                              |
| Resistance to Ignition                  | Appendix A of MIL-PRF-24596B           |
| Flammability/Flame Spread/Radiant Panel | ASTM E162                              |
| Shelf Life                              | P201.00 (testing per Conformance test) |
| Resistance to Mold                      | ASTM D3274                             |
| Condensation Blister Resistance         | ASTM D2247                             |
| Salt Spray Resistance                   | MIL-PRF-24596B (para 4.6.13)           |
| HAPs                                    | ASTM D3272/ ASTM E260                  |
| VOC                                     | T299.00 (EPA Method 24)                |
| Recoatability                           | MIL-PRF-24596B (para. 4.6.18)          |
| Freeze-Thaw                             | ASTM D2243                             |
| Flash Point                             | ASTM D93 or D3278                      |
| Gloss                                   | ASTM D523                              |
| Flash Rust Resistance                   | MIL-PRF-24596B (para. 4.6.17)          |
| Exudate Formation                       | MIL-PRF-24596B (para. 4.6.15)          |
| Drying Time                             | ASTM D1640                             |
| Set to Touch                            | ASTM D1640                             |
| Viscosity                               | T331.00 (per ASTM D562 , para. 4.6.1)  |
| Dry Hard @77F/50% RH                    | P384.00 (per ASTM D1640)               |
| Dry to Touch                            | P385.00 (per ASTM D1640)               |
| Contrast Ratio                          | P382.00 (ASTM D2805, para. 4.6.1)      |
| Condition in Container                  | Fed-Std-141 Method 3011                |
| Knife Test / Adhesion                   | Fed-Std-141 Method 6304, para. 4.6.10  |
| Tantalum and Tungsten content           | Para. 3.5.4                            |
| Toxicity                                | Para. 3.10                             |
| Hazardous Pigment                       | Para. 4.6.4                            |

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### 3. Results

**Description of Coating:** The WBFR series was developed to meet the requirements of MIL-PRF-24596B Amendment 1. As per the MIL-Spec, this coating is non-flaming, fire retardant, and non-intumescent. The goal was to qualify for Class 1 & 2 (surface ship general use & submarine general use respectively), Grade A which requires the coating to be water-based air dry at temperatures less than 38°C with maximum volatile organic content (VOC) of 175 g/L. This coating is also offering Applications A & B C, D, E for steel, aluminum, fiber reinforced plastics, solid wood, and insulating foams, surfaces respectively. After careful analysis of the formula, this WBFR product showed environmental advantages that reduce total ownership cost, increase crew and vessel protection in the event of a fire.

**Composition and coatings properties:** The principal constituents of this water-based coatings are latex polymer, flame retardant additives, titanium dioxide, defoamers, coalescence agent etc. Three colors Soft White 27880, Pastel Green 24585, and Bulkhead Gray 26307 all were developed and matched as per the FED-STD-595 color standards. The principal ID characteristics are provided in Table 2. All these three colors are less than 175 g/L for VOC. Application of these products using spray, brush and roll were excellent. These products were easy to flow, had excellent hiding when applied over alkyd primer TT-P-645C formulated to be used in marine, industrial and offshore platforms.

**Table 2: WBFR Product Characteristics**

| Property                                          | Soft White Prototype                                         | Pastel Green Prototype                                       | Bulkhead Gray prototype                                      |
|---------------------------------------------------|--------------------------------------------------------------|--------------------------------------------------------------|--------------------------------------------------------------|
| Total Solids, wt%                                 | 60.05 +/- 2                                                  | 60.16 +/- 2                                                  | 60.54 +/- 2                                                  |
| VOC g/L                                           | 114                                                          | 114                                                          | 110                                                          |
| Volatile, wt%                                     | 39.95 +/- 2                                                  | 39.84 +/- 2                                                  | 39.46 +/- 2                                                  |
| Viscosity, KU                                     | 65-75                                                        | 65-75                                                        | 65-75                                                        |
| Flash Point                                       | > 212 F                                                      | >212 F                                                       | > 212F                                                       |
| Dry Touch (hours)                                 | < 2                                                          | < 2                                                          | < 2                                                          |
| Dry Hard (hours)                                  | < 6                                                          | < 6                                                          | < 6                                                          |
| Specular Gloss (60°)                              | 49.6                                                         | 49.1                                                         | 49.3                                                         |
| Hiding Power (contrast ratio)                     | 0.98                                                         | 0.98                                                         | 1.0                                                          |
| Color (dE <1.0) CIE LAB                           | 0.25                                                         | 0.90                                                         | 0.82                                                         |
| Application Instructions - Spray. See data sheet. | Airless 45:1 / Spray tip – 515 / Pressure 1800 psi / DFT 2-3 | Airless 45:1 / Spray tip – 515 / Pressure 1800 psi / DFT 2-3 | Airless 45:1 / Spray tip – 515 / Pressure 1800 psi / DFT 2-3 |
| Shelf Life (months)                               | 24                                                           | 24                                                           | 24                                                           |

**Hazardous Pigments and Additives:** All three colors were submitted to third party testing labs to evaluate for hazardous pigments and additives as per 3.5.4 in MIL-PRF-24596B. The metal contents in each dry coating film were below the maximum allowable limit as shown in Table 3. Total detected

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