Flame Retardants for Water-Based Lacquer

Case Study

Summary

Application: **Protective wood coating ~ lacquer**
Additive: **ICL Industrial Products ~ TexFRon® 4002** Flame Retardant
Key benefits:
Water-based ~ Polymeric product ~ Translucent ~ Flame Retardant ~ Storage stability ~ VOC free

The Challenge

Flame retardancy is a must in construction products as there are many regulations and tests. The most famous ones are ASTM E84 and EN 13501. When these standards are applied on coated surfaces – the challenges are amplified since the coating layer is usually much thinner than the applied surface and, in most cases, more flammable. Adding to it, the fact that wood is being used more and more in construction (both for environmental purposes and aesthetic aspects) and requires the use of lacquer, results in a need for a suitable FR solution.

Therefore, the challenge is to provide flame retardant (FR) properties to the coating while maintaining a transparent/translucent appearance, good abrasion properties, cold solvent stability, and long-term efficiency in the film. In addition, the in-can and film stability must be good while having a sustainable profile.

The Solution

Flame retardant coatings are usually based on two types of FR mechanisms: Intumescent and non-intumescent.

The first one is based on a mechanism by which the film expands and creates insulating carbonaceous char. It involves an acid source, a carbon source that reacts with the acid to form a carbonaceous char and a blowing agent. One of the disadvantages of this type of coating is that the resulting formulation is opaque.

Non-intumescent coating type works in a different manner, depending on the type of FR added to the system. For example, when inorganic hydroxides are added, water vapor is evolved (cooling) and the gases are diluted. When organic phosphorous materials are added they work in the condensed phase (for example char development) and/or gas phase (inhibition of the flame). The first type requires high loading and the last one has stability issues when applied in water-based systems, although it usually offers good FR properties.

Brominated flame retardants are a highly efficient alternative. They work in gas phase via free radical quenching reaction. In some cases, synergists are added to reduce FR amount and/or to improve efficiency. One of the most challenging issues with halogenated FR's is their environmental and health profile.

Regarding the smoke toxicity profile, it was found after extensive research, that when the wood is unprotected and burns, it releases higher quantities of harmful gases. In comparison, flame retarded wood will extinguish/slow down the fire, thus producing much less toxic gas in total, even when halogenated FRs are used.

In addition, in the last years, ICL group, is focusing on developing brominated polymeric flame retardants, hence resulting in a safer solution. Polymeric products have low water solubility, are not prone to leaching or migration and due to high molecular weight, they do not penetrate living tissue eliminating the potential bioaccumulation. They are recognized by global regulatory bodies as the safe solution: http://www.epa.gov/reviewing-new-chemicals-under-toxic-substances-control-act-tsca/high-molecular-weight-polymers-new.

TexFRon® 4002

TexFRon® 4002 is a brominated polymeric flame retardant in powder form. It was the first-ever brominated molecule that gained Oeko-Tex approval.

TexFRon® 4002 has the benefits of halogenated flame retardants – meaning stability and high efficacy while maintaining good health and environmental profile.

In the last few years, ICL's R&D work was focused to study the implementation and the efficiency of TexFRon® 4002 in paints and coatings, especially in water-based wood coating lacquer.

To incorporate TexFRon® 4002 it is recommended to prepare a premix, which allows better dispersion of the powder in the final paint formulation. The premix composition can be solvent-free, depending on the additives in the system.

The premix can then be easily blended with a resin of choice. For our development acrylic resins were chosen to check the "worst-case scenario" from the flammability perspective since acrylic resin is very common in wood coating applications.

The formulated paint was applied by brush (3 layers) on pine wood and tested in small-scale fire testing procedure – via cone calorimeter. Cone calorimeter is the most common instrument used to study fire behavior of materials because it provides a large quantity of information using small samples (ASTM E1354). The basic principle is to measure the decreasing oxygen concentration of the combustion gases of a sample subjected to radiant heat. Based on the oxygen consumption, heat release rate, and various other flammability parameters the emitted energy and smoke are calculated.

Multiple formulations were evaluated, and the FR was tested with and without synergists to assess the effect of addition. Two synergists were used APO which is antimony pentoxide, and FR-20 which is magnesium hydroxide.

Adding TexFRon® 4002 to the acrylic resin (in this case Alberdingk 2523 AC) has improved the fire performance index (calculated from time to ignition and peak heat release rate) and reduced the smoke parameter (calculated from peak heat release rate and specific extinction area).

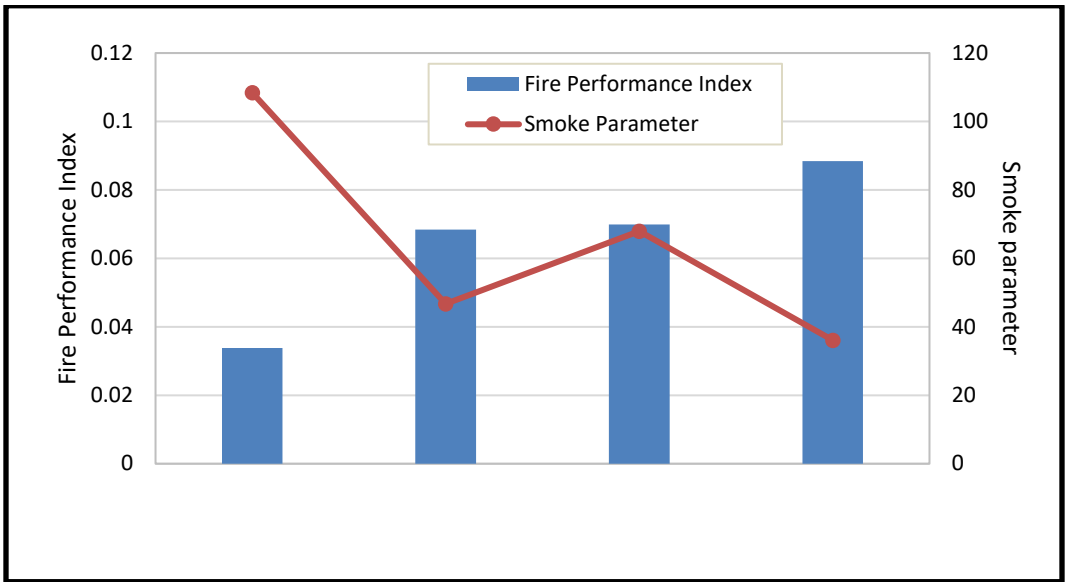

Figure 1. Cone calorimeter testing results

Moreover, the addition of the traditional APO synergist for brominated FR, had an inferior effect on the smoke parameter with no improvement in the fire performance index. In comparison, the addition of FR-20 improved both the fire performance index and the smoke parameter.

The next stage was testing the same formulations at a large-scale testing – ASTM E84, Steiner Tunnel Test which is commonly used in American building codes. The goal was to see whether the flame retardancy has also a similar effect on the flame spread and not only on the energy emission.

The test was conducted on coated (3 layers) Douglas Fir Plywood which was placed in a horizontal tunnel. The burner inside the tunnel was ignited and the coated wood remained in the tunnel for 10-minute test. The results were reported as Flame Spread Index (FSI) and Smoke Developed Index (SDI). The ASTM E84 test recognizes three classes of flammability based on the two indexes, as indicated in Table 1.

Class	Flame Spread Index	Smoke Development Rating
Class 1 or A	0 – 25	450 maximum
Class 2 or B	26 – 75	450 maximum
Class 3 or C	76-200	450 maximum

Table 1. ASTM E84 class rating criteria

The results showed that by adding TexFRon® 4002, the FR classification has improved from class C (the lowest score) to class B, and the flame spread index was cut by nearly half. There was an observable increase in the smoke-developed index, however, it is very far from the 450 limit for each of the classes. To be noted is that these results were achieved without optimization of the resin, as acrylics are flammable. Those results can be likely improved with better resin selection.

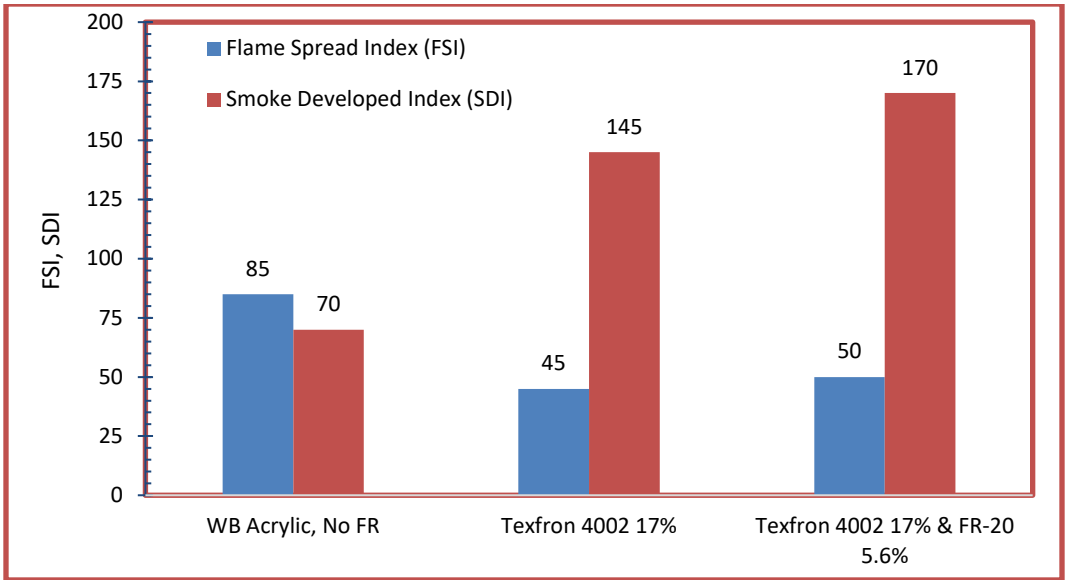

Figure 2. ASTM E84 testing results

The added value

Although having good flame-retardant properties is essential for wood coating – the appearance is also crucial and is one of the main challenges, along with paint stability.

The application of TexFRon® 4002 resulted in a translucent, semi-gloss appearance which allows both protecting the wood from the fire and maintaining its "look" and texture. An example on the appearance of the coated wood can be seen in Figure 3, with the formulated coating being used on the bamboo sample.

Figure 3. Bamboo surface covered with water based acrylic paint with TexFRon® 4002

In addition to appearance, abrasion tests and Cold liquids exposure according to EN1270 standard showed no decrease in film properties. The formed paint formulation is stable from application and efficiency properties for at least 12 months. The recommended loadings are 5-20%, and are resin, substrate and standard depend. Typical formulations for the TexFRon® 4002 Premix and final coating are given below in tables 1 and 2. They should be used only as an indication and should be adjusted based on individual needs.

Formulation Proposal:
FR paint based on TexFRon® 4002 with Alberdingk 2523

Commercial name	Wt%
Water	35.50
Propylene glycol	23.50
DISPERBYK-2010	2.89
BYK 093	0.50
TexFRon® 4002	37.00
BYK 420	0.61

Table 2: TexFRon® 4002 Premix

Commercial name	Wt%
Alberdingk 2523 AC	51.2%
BYK 093	0.8%
BYK 346	0.3%
DISPERBYK-2010	1%
TexFRon® 4002 PREMIX	46.2%
BYK 420	0.5%

Table 3: Water-based paint with TexFRon® 4002

Conclusion

TexFRon® 4002, by ICL Industrial Products, offers a sustainable and effective solution for flame retardant coating, especially in cases which wood texture appearance is required.