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A Brief Introduction to Flame Retardants (FRs)

Mission: Fire can be a friend to man, but it can also be a major enemy to man when it is out of control. The three major components to a fire condition are air or a source of oxygen, heat of combustion, and a source of fuel due primarily to the substrate; any two of the three are sufficient to cause a fire. The mission of a flame retardant (FR) is to reduce the loss of life and destruction of property by disrupting the nature of this energy source and allowing a sufficient amount of time for people to flee from the threat.

Consideration should also be made for the quantity and toxicity of smoke evolution during this process. The ideal flame retardant should be able to delay (or even prevent the ignition) the spread of fire as long as possible, generate minimal amount of smoke, and remain a non-toxic factor to human life and its environment.

Fire Fighting Systems: Flame retardancy can be best described by class as being active or passive or a combination of both systems.

An overhead sprinkler system would be an example of an active system. Portable fire extinguishers, located in nearby work stations, use foam as another mechanism to suppress flame spread. Lastly, first responder fire fighting units are generally available upon emergency calls of distress.

Passive systems include the flame retardant family of products, either incorporated within the substrate or adhering to the surface of the composition. These FRs usually come in liquid or powder form. A flame retardant to be used in a particular application should also not radically detract from the properties of the host substrate. For example, a textile fabric which features suppleness and good hand properties would be incompatible with a flame retardant coating that would impart a stiff or cardboard like texture to the touch of a hand.

Major FR Types: There are three major classes of passive flame retardant products.

First there is a family of halogenated materials that are generally used in combination with a synergist such as antimony trioxide. These products function by vapor phase mechanism, which essentially produces copious quantities of bromine or chlorine based off gases just above the host substrate, interfering with the oxygen source to the fire in the combustion process. By class, sales for the brominated flame retardants represent the leading source of revenue in our market and still dominate in electronics, the leading end use in the U.S. Some polymers offer varying degrees of flame retardancy, i.e. polyvinyl chloride (PVC).

The second class of FR materials are represented in the family of mineral filler products, and the two leading products sold to this market are ATH (aluminum trihydrate) and magnesium hydroxide. These products function solely in the condensed phase on the surface of the substrate, mainly by diluting the quantity of the fuel source plus cooling the surface of the host polymer with release of water of hydration. In some cases, 70% of the polymer is replaced by the mineral filler. These flame retardants represent the largest segment of FRs sold by volume. A strong case is made for mineral filled products being much more environmentally acceptable flame retardants; yet, key physical properties of the host polymer suffer greatly (impact resistance of a molded product, tear strength of a film, and flexibility of an extruded product). Conversely, bromine based FRs, although recognized as very efficient, emit copious quantities of irritating smoke by product gas.

Phosphorous and nitrogen containing flame retardants (P & N FRs) represent the third major class. Unlike the above, these products come in either a liquid or powdered form, dependent on its individual molecular structure. Generally, they considered more environmentally acceptable alternatives to the halogen flame retardants; and they are used at much lower concentrations than mineral filler FRs, thus giving rise to better physical properties of the host polymer. An interesting fact to note is that the phosphorous and nitrogen atoms (along with those of carbon, hydrogen, and oxygen) are all part of our human anatomy. Bromine, chlorine, antimony, aluminum, and magnesium are considered foreign bodies to our anatomical makeup. Inorganic and organic flame retardants derived from these atoms are generally two to three times heavier than most phosphorous – nitrogen FR derivatives; and as a result, they persist in the environment for longer periods of time.

P & N FRs

Phosphorous and nitrogen flame retardants (P&N FRs) are widely used in olefin and urethane polymers for such applications as wire and cable and film (olefin) and foam and thermoplastic elastomers (urethane). They dominate the textile industry in coatings, but they are not often used in styrenic polymers because of the non-charring nature of those particular plastics. The performance of the P&N FRs depend primarily on charring or carbonizing the surface of the substrate whether it be a coating or a plastic polymer. This phenomenon “seals” the surface from the flame source and the surrounding air to feed the fire condition. This is easier to accomplish with polyethylene, polypropylene, polyamide, and polyurethane chemistry than it is with high impact polystyrene (HIPS). TV cabinet backings are still the largest use for brominated flame retardants. Nonetheless, there are still some end uses for P&N FRs in styrene copolymers such as latex resin binders for coatings and certain selected foam applications.

Intumescent Coatings

Intumescent coatings are a subset within the phosphorous family of FRs. To the casual observer, these homogeneous liquid products have the appearance of any ordinary household paint. Most products can be pigmented to any color and have an inherent resistance to UV light. Because of their relatively low viscosity, they are easily applied through any technique, i.e., brushing, rolling, dipping, or spraying. The difference, of course, are the effects when the intumescent coating is subjected to a heat flux of a fire condition. The coating swells or intumesces from its original thickness of 5 mils out to 50 mils, depending on the formulation. The foamed char also entraps gaseous by-products. A single sheet of writing paper, for comparison, has a thickness of 5 mils or 0.005 inches.

The general science of intumescent coatings in general has been well known for over 40 years now. The earlier mainstay products were commonly referred to as paint materials that promoted the charring mechanism of a foamed protective insulation barrier, sealing the surface of the substrate from the effects of a fire. While these earlier products exhibited a high quality of flame retardancy along with good smoke suppression, they also had their limitations with regard to effects of humid aging, loss of adhesion, poor flexibility and resistance to abrasion, and outdoor weathering. These flame retardant products, referred to as intumescent blends, are comprised of three primary materials – a phosphate dehydration catalyst, a polyhydric alcohol carbon source, and a blowing agent.

Intumescent Coatings Breakthrough

Broadview Technologies: This Newark, New Jersey based company manufactures a family of unique intumescent flame retardant products. Like the conventional blends, these materials are also finely divided white powders that function with the same rapid char development-swelling response under a fire condition, which seals the substrate from further flame propagation while entrapping gaseous by products of combustion.

However, this is where the difference ends. In the year 2004, **Broadview Technologies received international patent recognition (patent #WO 2004/009691 A2-PCT) with their novel composition of matter technology, which no longer requires the use of the carbon source and blowing agent synergists.** In short, this synergism is self contained in a different form within the phosphate flame retardant agent, and we describe this as "catalyst activated phosphate". Since there is no longer a need for component materials, one doesn't have to be overly concerned about uniform mixing or phase separation of secondary organic chemical products (varying weights due to different densities) such as in a liquid form like the Intumax® Lay 41 FL latex coating (**commercially sold as Innova-FR® 41 AG**). Most, if not all, of the above deficiencies that were associated with the older, first generation, conventional intumescent blend technology have now been resolved.

Intumax® is a registered trademark to all the powdered flame retardants and liquid coating products that Broadview Technologies produces (sold through Selective Technologies's network as Innova-FR®). Broadview;s history goes back to the 1970s when they were actively engaged on a joint development with NASA and the Apollo space vehicle program. The heat insulation tile project for vehicle re-entry was the specific program they were focused on together. However, it wasn't until the late 1990s that Broadview saw a path to this new catalyst activated technology. The process was refined over the next two years until their initial patent filing was made in 2002 and patent awarded in 2004. **The shortcomings of the conventional, first generation intumescent FR technology now appear to be resolved.**

Innova-FR® 41 AG

Innova-FR® 41 AG is a one component, water based, flexible flame retardant coating, containing 60% active solids. Its appearance is white to off-white in color with low hiding power, capable of being easy to pigmented.

Typical Physical Properties

% Active Ingredients (wt):	60
Viscosity, cps:	2,500 ~ 3,000 (Brookfield #4 @20 rpm)
Specific Gravity (g/cc):	1.20
Tack Free Time*:	6 hours
Cure Time*:	24 hours
Packaging:	5 gallon pails; 55 gallon drums; tote bins.

*: Standard conditions of 23°C temperature and 50% relative humidity.

Comparative Analysis – Features

A cross comparison of FR coatings representing Innova-FR to other non-halogen intumescent blends and finally to generic bromine/antimony follows below.

(Property)	*(Innova-FR)*	*(Non-hal FR blends)*	*(Br/Sb FR)*
Activation time:	Good to excellent	Fair	Excellent
Char yield:	Excellent	Good	Poor
FR efficiency:	Good	Fair to good	Excellent
Smoke yield:	Excellent	Good	Poor
Stability-water:	Good to excellent	Poor to fair	Excellent
Stability-thermal:	Good	Good	Excellent
Stability-UV	Good to excellent	Good	Poor to fair
Recycling:	Good	Fair to good	Very good
Adhesion:	Excellent	Poor to fair	Good
Hand-texture:	Excellent	Poor to fair	Fair to good

Property analysis (Innova-FR): Benefits:

Activation time: The catalyst within Innova-FR® speeds response for initial flame inhibition.
Char yield: The Innova-FR® catalyst regenerates 30 to 80% more gas by product into char.
FR efficiency: Directly related to activation time, as in the first response to flame spread.
Smoke yield: Inversely proportional to char yield; Innova-FR® smoke values are exceptionally low.

Hydrolytic stability, flexibility, and outstanding adhesion are several key properties that clearly delineate the difference between the Broadview based coatings versus those from the old fashioned, conventional non-halogen ammonium polyphosphate based chemistry.

HS&E considerations: Some of the above discussion has already addressed the safety and health issues regarding the "friendly versus foreign" elements that comprise today's market's of commercial flame retardants. To briefly summarize, the non-volatile organic P&N derivatives, produced by Broadview Technologies, are generally considered to be "safe" materials. Unlike some brominated materials, they comprise a certain molecular weight range not considered susceptible for possible absorption into human fatty tissue.

There is one such FR active material that Broadview produces which has sufficient laboratory toxicology in that the U.S. EPA has now labeled it as a "non PBT" (non-persistent, non-bioaccumulating, non toxic) substance. Broadview's other derivatives are generally of the same chemical make up, but there is still insufficient test data available to make the above claim. Innova-FR® flame retardant actives are made exclusively by Broadview Technologies and do not contain any residual heavy metals, such as antimony, arsenic, cadmium, chromium +3, mercury, or lead. The Broadview coating products also have a complete and full clearance with regard to any carcinogenic issues.

Fire fighting issues: It's a well known fact that the quantity and toxicity of smoke propagation is by far the leading cause of human fatalities in a fire condition. It's not the fire itself. It's also well documented that the vapor phase mechanism of bromine and antimony oxide based flame retardant systems causes voluminous amounts of smoke to be evolved. Smoke is simply the product of particulates emitted from the burning substrate and suspended in air and the surrounding environment. In the above case particularly, we are referring to "dark" smoke, quickly obscuring a clear path for safe exit. Halogen produced smoke is also very disorientating and can be extremely irritating to the eyes, throat, and nasal passageway to the lungs.

The key element with the Innova-FR® coatings subjected to a fire condition is that the flame spread is localized and the amount of smoke generated is a relatively small fraction (roughly 20%) of that compared to bromine / antimony based flame retardant coatings. Allowing for better visibility given an exiting fire condition and severely reducing the amount of smoke evolution through char formation supports the mission on the use of these products. This alone is the major concern of first responder fire fighters.

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