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So You Want a Flame-Retarded Formulation... Guidance for the Novice, and Burning Questions You Should Be Prepared to Answer

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Flame-retardant polymer formulations play an important role in the manufacture and safe use of a variety of everyday products from television cabinets to office equipment and automobiles. There isn't a home or business that doesn't in some way come in contact with these materials. Many scientists responsible for the creation and development of flame-retardant (FR) formulations would probably agree that one of the more challenging aspects of their work is not in creating a product but in working effectively with the customers and sales staff to thoroughly define the necessary parameters for the product.

This article provides potential customers of FR formulations, whose knowledge of the area may be limited, with basic information to help them define their product needs. It is also intended to help sales representatives (SRs) of these products be more effective liaisons between the customer and the product development manager (PDM).

A good starting point is to imagine that you are the PDM who will need the product information to develop the appropriate FR formulation. One day, an excited colleague from the sales department comes in with a new opportunity.

"It's absolutely fabulous...a flame-retardant HDPE formulation for water jugs. Volumes start at one million pounds and are expected to ramp up quickly. The customer needs samples of the three best formulations you can develop within five days for molding trials next week."

Your mind is racing as you question your colleague.

PDM: "Why do they need FR for water jugs?!!"

Sales Rep: "I guess for the times they are empty."

PDM: "Do people drink the water from the jugs?"

SR: "No, I think they pour it into glasses first."

PDM: "What kind of flame-retardant rating are they looking for?"

SR: "I'm not sure, but my contact said something about a butane lighter and propane torch. So far everything is looking good! They're really excited!"

PDM: "I'm sure they are. Are there any other FR-based water jugs on the market?"

SR: "No. That's why this could be a gold mine if we get the business!"

PDM: "What other information do you have on the requirements for the product?"

SR: "Only that there are four other companies competing for this business. If we are to be successful, our formulation must be the lowest-cost and have superior physical properties. Did I mention that the samples need to be there next week?!"

(At this point, one of the fundamental and overriding laws of the universe pops into your head--The Law of the Unattainable Triad. Simply stated, it says, "There are three elements related to development: Good, Fast, & Cheap. You may have any two at the expense of the third.")

PDM: "Yes you did. What are the target physical properties?"

SR: "I don't know. The person who knows the person who has that information is on vacation and cannot be reached. He'll be back in a day or two."

With that, your satisfied colleague jumps to his feet and heads towards the door. Grinning as he leaves, he offers one more enticement: "Wait until you see those jugs. They are really sharp!"

In this modest exaggeration, the SR and customer contact expect these products to be created, produced, and shipped within five days but have not even provided enough information for the PDM to begin the project. The SR's key information is the volume and the promise of a fast customer evaluation time. The PDM's main concerns and questions are directed towards the key information needed to create this product. There is an obvious difference in priorities. It is unclear whether the SR knew what questions to ask the contact or if they were asked and the contact did not have all the answers. The contact here may be a buyer, who has no technical background, or a technical person with little or no knowledge of flame-retardants. Regardless of the contact's background, there are key questions that need to be addressed for the successful matching of their product requirements with an FR formulation.

At PMC Group-Polymer Products, we have extensive expertise in the development of flame-retardant formulations. We actively pursue the development of both FR compounds and highly loaded FR concentrates for many resin systems. Our Product Development teams have benefited and continue to benefit from close-working relationships with customers, raw material suppliers, and experts in plastics testing and testing equipment. Over the years, we have used application worksheets to assist our sales staff and customers in establishing the requirements for FR product-development projects. The key features related to these sheets are outlined in the table on pages 5 and 6 and discussed in the following paragraphs.

Economic Considerations

The main economic issue for the PDM is formulation cost. Price constraints will have a profound influence on the additives and resins selected for the formulation.

Basic Characteristics

Establishing the resin type and process information helps us hone in on the FR package we'll use and the possible need for other additives. For each resin there are several possible FR candidates. Subsequent questioning will further narrow down the options.

Flammability Standard Characteristics

It is not the purpose here to discuss the numerous FR testing standards but to exemplify what type of information might be required. Consider, for example, the most common FR test, UL-94. The basic test ratings for an FR-loaded product are V-0, V-1, V-2. Materials that do not meet the minimum V-2 fail. The main observations from the test are burn time, afterglow, dripping and whether cotton ignition occurs for samples that drip. In the base test, V-0 is the best rating. V-1 products exhibit longer flame or afterglow times than V-0. A V-2 rating has burn criteria similar to V-1 except that cotton ignition due to flaming drips is allowed. The key information required by the PDM is the desired rating and minimum thickness. It is important to note that a UL-94 rating does not mean that a product is UL certified. To obtain a "yellow card" for a product requires submission of test parts to UL for evaluation. UL certification adds time and expense to development costs. In addition to minimum thickness and flammabili ty rating, UL certification also specifies color.

Flame-Retardant Package Characteristics

"Halogenated or non-halogenated? That is the debate." There is considerable interest in nonhalogenated products because of the safety and environmental concerns associated with halogenbased products, notably for companies supplying European markets. The main issues associated with non-halogenated materials depend on the nature of the FR additive but generically are combinations of higher loadings, higher costs, and more significant physical property degradation relative to halogenated materials. Additionally, many non-halogenated raw materials are not capable of being compounded into concentrates.

Molecules based on bromine and to a lesser extent chlorine are the workhorses of many FR formulations. There are usually several different FR options for a given resin system. The choices are readily narrowed down by the information supplied by the customer: FR rating, price, bloom, UV stability, and the desired physical properties of the final product. The choice might also depend on performance trade-offs, quality, chemical compatibility, availability, or customer preference.

Customer preferences regarding FR selection have usually indicated a desire not to have a particular FR in the formulation. The most common of these are the brominated diphenyloxides such as decabromodiphenyloxide and octabromodiphenyloxide. These are often referred to as deca, octa, BBDPE's, BBDPO's, DBBPE, DBBPO, ODBBPE, as well as a number of other descriptors. Customers may also indicate that they want a non-deca product. This usually means that they want a brominated FR but not a diphenyloxide. People occasionally confuse non-deca with nonhal. All you need to remember is that not all nondeca formulations are non-halogenated but all nonhalogenated formulations are non-deca.

Additive Package Characteristics

In addition to the FR package, other additives may be incorporated into the final formulation to enhance appearance, processing, stability, or physical properties. These additives may include antioxidants, UV stabilizers, processing aids, impact modifiers, and pigments. PDMs also need to know if other materials might be added during your processing. This knowledge allows the PDM to determine whether the FR characteristics of the formulation need to be enhanced. Keep in mind also that these other additives may be more effective if incorporated at the initial compounding stage.

Physical Property Characteristics

Incorporating additives into plastics affects the properties of the resin. The effects may be minimal or they may be significant. They may be positive, negative, or a combination of both. Knowledge of the effects of the additives used coupled with a detailed physical property profile of the final product enables the PDM to select an appropriate base resin for the formulation. Occasionally it may not be possible to obtain all of the desired physical properties. In such instances, it may be necessary to determine if trade-offs can be made regarding the properties. It would be beneficial to identify early in the process what factors are critical rather than desired.

Color Characteristics

For those instances where a specific color is desired, the customer should supply a part or chip of the desired color along with acceptable tolerances for the match. In the most common specification, color variation is expressed as a dE (delta E) value.

Concentrate vs. Compound

Thus far, the discussion has dealt with providing a finished compound. Many of Polymer Products' customers have found substantial benefits and savings through the use of our highly loaded FR concentrates. The evaluation process that the PDM employs and the information needed are the same as described above. However, instead of a finished product, the net result would be a recommendation specifying a particular FR concentrate and a resin that when used with the concentrate at a specified letdown ratio would afford a product with the desired properties.

The Development Process

Let's assume that the customer and SR have provided the PDM with adequate information. What happens next? The PDM will first determine whether an existing product in the company would satisfy the requirements or serve as a good starting point. At Polymer Products, we also have the benefit of considerable physical property data derived from letdowns of our FR concentrates. If a product is readily available, it is sampled. If development work is required, then a development project is initiated. The endpoint of the initial development is to arrive at a product that, as closely as possible, meets the project requirements. The information is shared with the customer, and a mutual decision regarding scale-up for an initial sample is made. The customer should be prepared to provide information regarding the size of the sample required and when they will evaluate the material. Prompt customer feedback after the evaluation is critical to the process, especially if tweaks to the formulation are required. Once the form ulation is finalized, larger scale-ups may occur before final product commercialization. Prior to this commercialization, a mutual decision will have to be made regarding release testing and specification ranges for the product.

Final Comments

The above discussion is intended to be a guide to facilitate defining customer product requirements for flame-retardant formulations. The extent to which it is applied will affect the potential and timeliness for a successful product match.

Product Characteristics	Questions
Economics	• Pricing constraints on formulation?
Basic Characteristics	• What is the application resin? LDPE, HDPE, HIPS, ABS, etc.
	• What is the customer's process? Injection molding, sheet extrusion, etc.
	• What is the part or product that is being made?
	• What is the process temperature range for the material?
Flammability Standard Characteristics	• Does the application require meeting a flammability standard?
	• If yes, which test and what rating?
	• What is minimum thickness for the rating?
	• Will the product require UL or other agency certification?

Flame-Retardant Package Characteristics	• Does the application require a non-halogenated flame retardant? • Is there any concern with the materials that might be used in the flame-retardant package? i.e., are there any materials we cannot use because of the specific application? • To what other environmental factors, such as UV or heat, will the product be exposed?
Additive Package Characteristics	• The customer should realize that other additives might be included in the formulation to improve processing, stability, appearance, or physical properties. Are there any such materials that would be undesirable for their specific application?
Physical Property Characteristics	• What are the physical property requirements for the formulation? i.e., tensile, flex, impact, melt flow, specific gravity, etc. • Which properties are the most critical and which are dispensable?
Color Characteristics	• What are the criteria for a color specification?
Compound vs. Concentrate	• Could a highly loaded concentrate be utilized in this application?

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