

**PRESENTATION
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**BASICS OF POLYURETHANE FOAM
AND THE USE OF COMBUSTION MODIFYING ADDITIVES**

FOAM TECHNOLOGY

Flexible Polyurethane Foam (FPF) is made by either the “slabstock” or the molding process. Slabstock accounts for the largest portion. Molding is primarily used for some furniture and most automotive cushioning. The slabstock process produces large continuous buns of foam, which are then converted by various fabricating processes into the desired shapes and sizes of FPF products.

The slabstock process consists of precisely metering, temperature controlled ingredients of the formulations to a mixing head and then depositing the liquid mixture onto a moving conveyor. The chemical reactions involved generate the foaming mass as well as the heat necessary to cure the resulting foam. During this reaction the initially closed cell structure is converted to an open cell structure. The major ingredients involved are a Polyol, a Diisocyanate (usually Toluene Diisocyanate –TDI) and water. Other ingredients include an emulsifier to stabilize the rising foam, several catalysts to control the reaction rates, and a number of optional ingredients such as colors, combustion modifying additives, auxiliary blowing agents, fillers and other materials as needed to achieve special properties for the FPF.

The Toluene Diisocyanate (TDI) chemically reacts with the water to produce Carbon Dioxide gas (the primary foaming agent) and chemical structures called ureas. It also reacts with the polyol to produce chemical structures called urethanes, which give the product its name.

All of these reactions are precisely controlled to form the desired FPF product. Many different types of FPF for a large variety of end uses are produced by variations in the constituents and formulations producing the desired physical properties of the end product.

It is common practice for a foam machine during a daily production run to produce a large number of different foams by such variations without shutting down the machine between production of different grades.

FLEXIBLE FOAM USES

The number of end uses for FPF is virtually infinite. The largest volumes are in the area of carpet padding, upholstered furniture, automotive and bedding followed by many others including sponges, toys, packaging, sound deadening etc.

The area of carpet padding deserves special mention. In addition to the slabstock process outlined above the majority of this product (there are many different grades) is made from scrap foam by mechanically chopping it into small pieces and rebonding the mixture into new blocks of foam, which are then cut into desired length and width as needed. In the US this process consumes virtually all of the scrap generated during both the manufacturing and fabrication steps and thus keeps that scrap out of the waste stream. Demand for scrap is large enough that large volumes of foam scrap are imported into the US for the manufacture of carpet pad. More recently post consumer scrap recycling, particularly of used carpet padding has been feeding the rebond process.

Further growth for recycling of FPF is limited by the ability to economically collect the post consumer scrap. This is a major problem in the USA. Automotive scrap recovery is developing particularly in Europe. (See also section on recycling below.)

FLAME RETARDANTS – COMBUSTION MODIFIERS

Although the term “flame retardants” is often used, the polyurethane foam industry prefers the term “combustion modifiers” (CM). CM FPF will burn when exposed to a sufficiently intense ignition source. This ignition behavior is like all other carbon containing compounds including paper, wood, wool, cotton and almost all plastics.

Consumer activism and concern about flammability of various standard household and automotive items in the late 1960s resulted in various regulations at both the state and federal levels. Early standards to define performance from exposure to small ignition sources included the Federal Mattress standard (cigarette smoldering only), automotive (FMVSS 302), and a number of others. A voluntary industry standard developed by the Upholstered Furniture Action Council (UFAC) has been in effect for many years addressing the potential for cigarette ignition of upholstered furniture. The growing use of FPF as major items of the construction of these consumer items prompted review of their impact on the flammability characteristics of the item. Most of these early regulations either did not require use of combustion modifiers or only small amounts in the FPF used to make the item, although some others such as the Underwriters Standard 94 for use in the vicinity of electrical equipment required larger amounts of CM additives..

The CM additives used initially were mainly compounds called aliphatic chlorinated phosphate esters, because they worked and were compatible with foam processing, although they tended to produce undesirable softening and some degradation in other performance requirements. They also tended to produce internal “scorch” or discoloration during manufacture of the foams.

The advent of the California furniture standard (Cal TB 117) which required both smoldering resistance and resistance to a small open flame ignition source substantially increased the amount of combustion modifiers used by the FPF industry. The availability of pentabromodiphenyl oxide (Penta) in a mixture with an aromatic phosphate ester led to its acceptance in the industry because of improved physical performance and resistance to scorch. Because of the nature of the production process as described above the trend is to use only one combustion modifier for all products needing to be combustion modified.

The advent of regulations such as California TB 133, Boston Fire Code, NY Port Authority, FAA etc all of which required much greater resistance to ignition for finished items used in potentially hazardous situations were the driving force for developing improved performance foam types by use of much larger amounts of combustion modifiers (Penta) and other additives.

All in all the choices of CM materials suitable for use in flexible polyurethane foams have been small due to the combined requirements of combustion modifying performance, compatibility with the foaming process and effect on physical properties and aging performance of the foam. Although many materials have been tested over the years the major technology still involves use of halogenated (chlorine or bromine containing) compounds in conjunction with organic phosphorus compounds such as phosphate esters. Other materials that have been evaluated individually are generally not able to provide the combustibility performance provided by the halogenated and phosphorus compounds when used by themselves. These alternatives include such additives as melamine and aluminum hydrate which are used in combination with the above systems. Some special high performance FPF products include use of a special graphite or large amounts of melamine or hydrated alumina in combination with halogenated and phosphorus compounds. Other additives known to be used in other types of plastics such as borates have so far not been found effective in flexible foams. Nanotechnologies have been evaluated and found completely unsuitable in the FPF production process. The high performance FPF products generally require high levels of additives and higher than usual densities both of which result in substantially higher than normal costs as well as reduced physical properties. These penalties are accepted because of the need for the higher resistance to ignition that some specific end uses require.

We do not have data on the amounts of various combustion modifiers by different producers or by product type, because this information is proprietary to the foam producers and not available to the PFA.

The qualification process for a new additive is extremely complex. Once flammability performance under one or more requirements is established in small scale experimentation the development process begins on a larger (and more expensive) scale. Performance in full scale production runs are needed to obtain data on resistance to scorch formation and effect on physical properties, particularly any tendency to soften the foam or to affect aging and potential degradation during intended use. The latter two are

particularly problematical because a particular grade of foam may be used in many different end uses.

The question probably most often asked is for alternative methods of achieving the desired results of flammability performance for the end use consumer item. Such approaches as use of special fabrics and/or interliners have utility and drawbacks and are limited to the areas of furniture and possibly bedding, which involve combinations of fabric and foam. In those cases it is important to distinguish between the requirements of the filling material (foam) and the composite finished product (foam and fabric). There are many problems in this area including unpredictable synergistic effects (two “good” materials when combined may have bad performance characteristics). It has also to be remembered that some existing regulations require testing performance of both the individual components and the final composite (for example Cal TB 117, MVSS 302), thus still requiring the use of additives in the foam component.

The question of how a combustion modifying additive work also needs to be addressed. In this discussion we can only address the performance of the foam component and not the much more complex issue of the composite systems. There are basically two mechanisms involved. One involves the decomposition of the additive(s) by the heat of the ignition source and beginning of the burning of the product. The decomposition fragments in turn quench flame propagation in the vapor phase above the product. In addition coadditives such as melamine produce a molten mixture of partially degraded foam and melamine which is difficult to ignite or burn.

The other major approach uses additives such as inorganic phosphates, hydrated alumina or specially prepared graphite flake which produce a solid carbon foam char which prevents further decomposition of the underlying foam. It has to be remembered that these two approaches to the problem are incompatible and cannot be used in a single system. For example a foam containing Penta and melamine will lose its flammability performance and burn well if a charforming additive such as hydrated alumina is added. In the limited application case of foam and fabric it is generally ineffective to combine a melting foam with a melting fabric or a charforming foam with a nonmelting or charforming fabric.

The choice of approach to CM formulations is dictated mostly by the required FPF product performance, always remembering that the foam is only one component of the whole composite system – such as a piece of furniture. In general, foam producers prefer liquid CM additives because of the greater ease of processing on standard foaming equipment. Where needed solid additives can be used but processing is more difficult and these additives give lower strength properties and are most often used only in high performance products.

There are some significant differences in CM additive use between the US and European countries. Use of additives in the USA has historically been much larger (particularly in furniture) because of regulatory requirements. In Europe use varies widely between countries, with Great Britain having a strict furniture requirement, some other EU

countries requiring a lesser degree of performance and others such as Germany preferring that no additives be used in any plastic product. For any country that does not demand flammability resistance for their consumer end use items there still is a need for treated products for export to the US (such as for example in passenger automobiles or for furniture for export to California). A further difference between the USA and Europe is the greater use of “polymeric MDI” (a different isocyanate) in Europe. MDI is little used in the USA for slabstock FPF. These approaches are practical only for higher density foams and also produce foams of lower tensile strength and elongation and therefore have only found limited use.

FOAM RECYCLING

There are two major sources of scrap foam which have to be considered separately. The first is scrap foam produced during foam production and fabrication. The second one is foam from products at the end of their useful life.

Production scrap comes from startup and shutdown of the production line and from blocks of foam produced during on the run formulation changes during the production day. More scrap results from fabrication as the foam blocks are cut or shaped into desired end products. All of these foams are good materials but cannot be used for regular production orders.

Historically in the US all of this type of scrap has been recycled by shredding the foam into small pieces and rebonding the shredded mass into molded large blocks. These are then converted to long rolls of foam laminated with a film and used as carpet padding. Some shredded foam is also used as filler for pillows or as soft filling for furniture backs. The use as carpet padding is mostly limited to the USA for the major market of wall to wall carpeting. In addition to utilizing the production scrap originating in the USA this end use has also consumed large amounts of imported production scrap originating in Europe and elsewhere. Over the last few years post consumer scrap has become available in significant amounts mainly from used carpet padding. These materials are also recycled into new carpet padding. Shredding and rebonding is done by a number of foam producers.

More recently the feasibility of grinding FPF to produce a very fine powder which can be added as a filler to new foam has been established and commercialized but it is still in the early growth stages. Such fillers can be incorporated into new foam at a level of up to 15 %.

Chemical degradation schemes for scrap foams to recover some or most of the raw materials have been investigated intensively but so far have not been established as a significant commercial process.

Energy recovery by incineration is eminently appealing but has not made a significant impact for the same reasons it is not a preferred approach for other materials.

In all cases of foam recycling the end products must be checked for manufacturing and end product performance including flammability. No major problems have been found.

The major problem with expanding use of recyclable materials is the process of collecting it and separating it from contaminants and transporting it to the scrap utilizing facilities in an economic manner. Greater availability of recovered scrap in the automotive industry is expected over the next few years as pending requirements in Europe take effect.

As far as BFRs such as Penta are concerned it should be remembered that the major end use in furniture is only about 20 years old and considering the average life cycle of furniture to be 15 – 25 years little foam scrap containing this material would be expected to be in landfills at this time.

BFR ALTERNATIVES

The major question is – what are they and how do they perform ? One option is to go back to the older technology of using chlorinated phosphate esters. These are effective as combustion modifiers but have the problem of producing scorch in low-density foam formulations. Since they are more volatile and somewhat less stable than such products as Penta, they pose developing problems in automotive end uses because of restrictions on volatile emissions (“fogging”) and in noise deadening applications (office equipment, large computers etc) because of potential corrosion.

Other CM products under evaluation include non halogen (chlorine or bromine) containing phosphorus additives and some reactive bromine compounds. None of these have reached large scale applications trials. In all cases the effect on finished FPF product performance, including aging, has to be established for each consumer end use item for which it is intended. In the development of new additives, preference is still for liquid high boiling products. Because of the many performance requirements and large number of end uses the choice of potential new CM additives is limited and becomes even more restricted if the choice has to be a non halogen containing compound. Of course it will also be necessary for each possible alternative to establish that it does not present an environmental problem equal to or worse than the current situation. There are no expected major problems affecting recyclability if they meet the other requirements. Cost, which is a major consideration for most applications, is unknown at this time.

It may also be worthwhile to continue investigation of barrier fabric technology for upholstered furniture and bedding as a possible alternative to the use of CM additives. This, of course, would require additional revision of California TB 117 and the pending AB 603.

Thank you for the opportunity to make this presentation.