

IN•TOUCH

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Flexible Polyurethane Foam: A Primer

Flexible polyurethane foam (FPF) is one of the most versatile materials ever created. We are literally surrounded by it in our lives.

It's in our cars and under our carpet. It's used as packaging material to protect delicate instruments. And it's the cushioning material of choice in almost all furniture and bedding. In all, over 1.3 billion pounds of foam are produced and used every year in the U.S.

FPF has become such a widely used material because it provides a unique combination of form and function. It's light, quiet, resists

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mildew, and won't aggravate common allergies. Foam can easily be cut or molded to almost any shape. At the same time, foam can be made to provide very supple or very firm cushioning for any given application.

This remarkable versatility allows foam to provide the support needed for long-term medical confinement or the comfort of pillow-like furniture cushioning. Even though two foams may look exactly alike, they may feel and perform entirely differently.

The properties of foam can be identified and specified very precisely. The flexible polyurethane foam



Transportation



Carpet Cushion



Furniture



Packaging



Mattresses

industry utilizes a number of measurements and tests to accomplish this. And by using these measurements, it's possible to pinpoint the right foam for the right application.

Comfort, Support and Durability: Key Ingredients to all Foam Applications

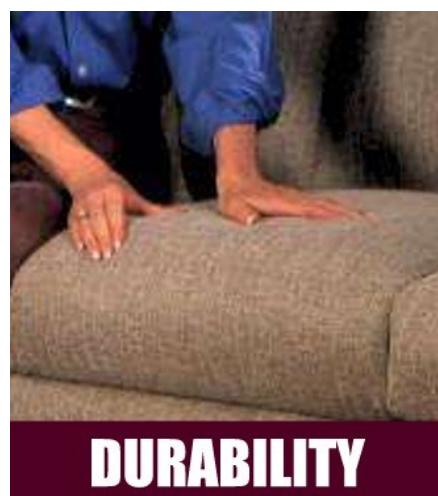
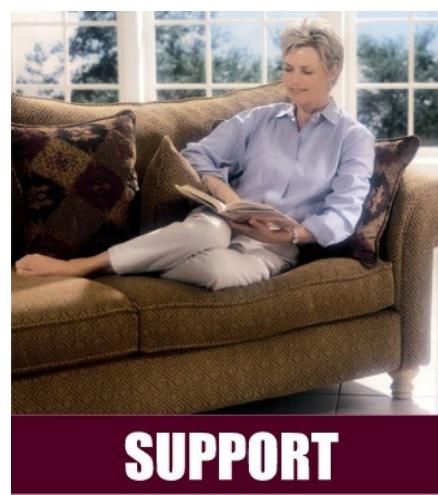
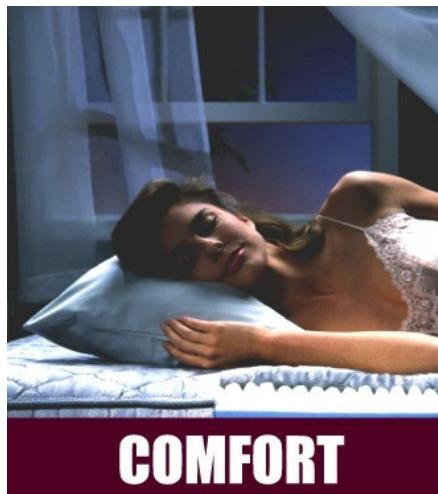
Although a number of different measurements and tests may be used to choose an FPF grade to use in a given product, the selection criteria often depend upon three performance attributes.

- **Comfort:** Foam cushioning has to feel good to the user and provide not just cushioning but also comfort.
- **Support:** The foam has to be able to support the proper amount of weight to properly cushion an object or person.
- **Durability:** The foam has to hold up through use without changes in performance.

These are the basic benefits that foam cushioning provides, and if the needs in each of these three areas are evaluated first, selecting the proper foam for a given use becomes fairly simple.

A sofa seat cushion has to have good support, comfort and durability, while the arm and back cushions for the same sofa need to last and be comfortable, but won't necessarily be required to support much weight.

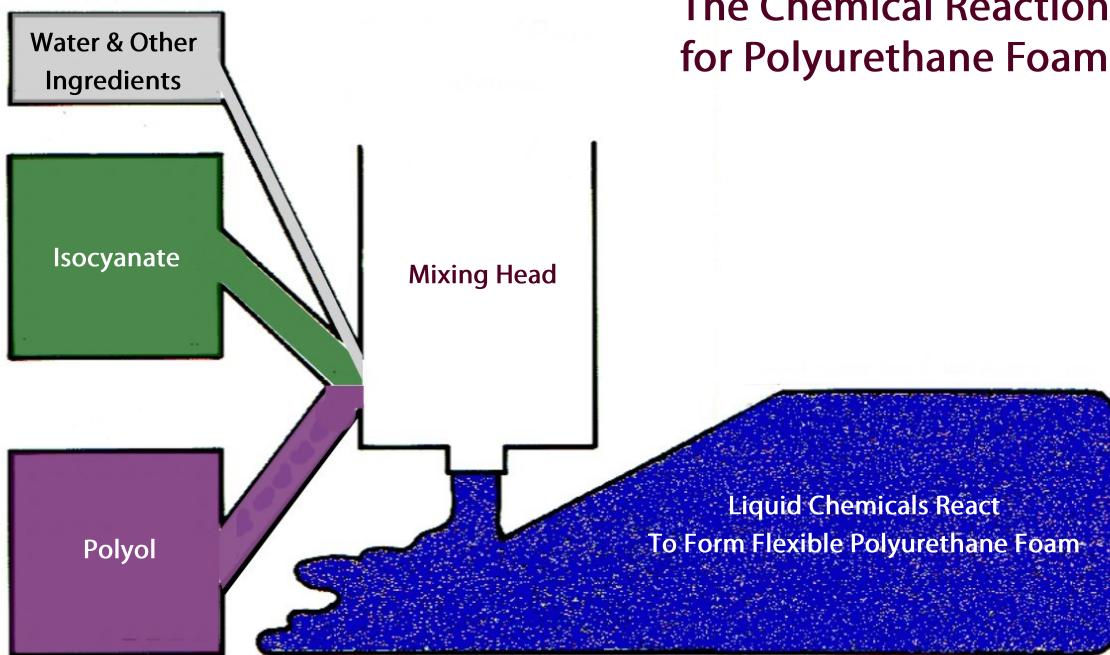
The foam used to line the case for photo equipment needs to support the weight of the camera, absorb shock, and hold up through use, but the camera cares nothing about comfort.



Foam Production

Foam properties can be better understood with a little background in how FPF is made. Flexible polyurethane foam is produced from a reaction of two key chemicals, a polyol and an isocyanate with water. These are mixed together in

specific amounts with other ingredients, and the foam reaction begins almost immediately. Bubbles are formed, and the mixture expands. It's been compared to bread rising. In a matter of minutes, the reaction is complete.



Slabstock Foam Process



To manufacture foam for cushioning, two basic procedures are used. In one, the chemical mix is poured onto a moving conveyor, where it is allowed to react and expand. Sides on the conveyor allow the foam to rise into a bun or slab anywhere from two to four feet high. The continuous slab is allowed to cure for typically 24 hours (longer for specialty grades). This manufacturing procedure is the **slabstock production process**. The cured foam is subsequently fabricated into useful shapes. Most foams for use in furniture and bedding are produced this way.

Molded Foam Process



A second method, **foam molding**, is a process where individual items are produced by pouring chemicals into specially shaped molds and allowing the foam reaction to take place. Examples of uses include automotive seating, contract furniture, and pillows.

Raw Material Mixture



The foam production process can be controlled through changes in the foam raw material mix. In addition to the polyol, isocyanate and water used to produce foam, a variety of other chemicals and additives may be included based on customer specifications to change the final properties of the foam. These include: **Auxiliary blowing agents**, which augment the primary blowing agent (carbon dioxide), can be used to make foam softer or lighter; **Catalysts**, which control the speed of the reaction to improve productivity or change foam properties; **Surfactants**, which aid in the formation of foam cells; **Flame retardant additives**, used to improve a foam's resistance to ignition or burning. (Unfortunately, these tend to have a negative influence on the comfort, support, and durability of the foam.); **Fillers**, which increase the weight of the foam, but can possibly have a negative influence on the physical properties of the foam. By adjusting the chemical mix of the foam, foam producers can manufacture literally hundreds of different grades of foam, each with its own performance properties. Learn more with our video instruction, [An Introduction to Flexible Polyurethane Foam](#).

Properties that Affect Foam Performance

There are a number of physical properties of flexible polyurethane foam that guide the selection of FPF for different applications. Following is a brief description of key physical properties of foam, and the importance of each. Physical properties of foam are measured in a laboratory under closely controlled conditions of humidity and temperature. Care must be taken to reproduce those conditions when testing samples for physical properties.

Density

Density is a measurement of the mass per unit volume. Measured and expressed in pounds per cubic foot (pcf) or kilograms per cubic meter (kg/m³), density is one of the most important of all foam properties. Density is a function of the chemistry used to produce the foam and additives included with the foam chemistry. (Additives are sometimes used to give foam specialized properties. For example, gel additives to viscoelastic, or “memory” foam used in mattresses may be used to help users sleep cooler.)

Density affects foam durability and support. Typically, the higher the density, the better the foam will retain its original properties and provide the support and comfort it was originally designed to produce. [See our InTouch issue on Density.](#)

IFD

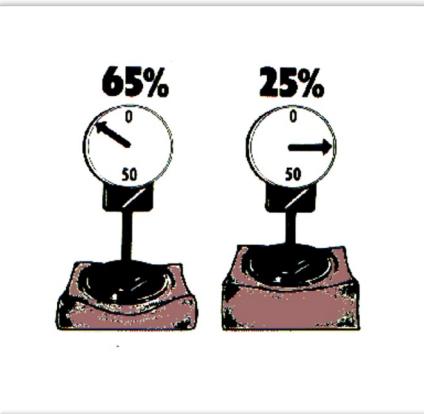
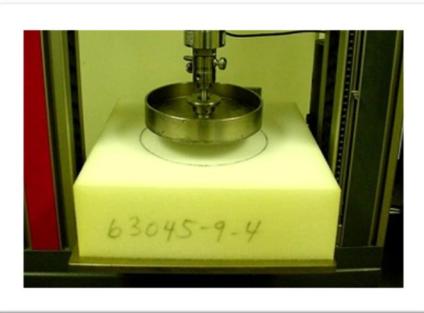
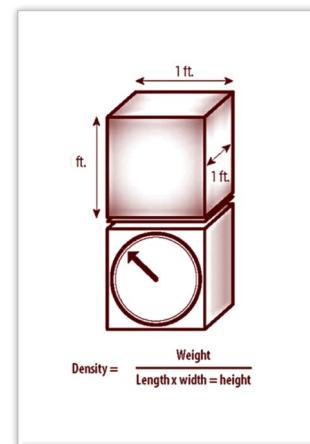
Indentation Force Deflection (IFD) is a measurement of foam firmness. Firmness is independent of foam density, although it is often thought that higher density foams are firmer. It is possible to have high density foams that are soft—or low density foams that are firm, depending on the IFD. IFD specification relates to comfort. It is a measurement of the surface feel of the foam. It is measured by indenting the foam 25% of its original height. Foams are typically offered in IFD ranges of $\pm 10\%$.

Support Factor

A second IFD measurement is sometimes taken by indenting the foam 65 percent of its original height. This second IFD measurement is used to help determine the ability of the foam to provide deep down support.

Typically, the more difference between the 25 percent IFD and the 65 percent IFD, the more ability the foam has to support weight. The ratio of the 65 percent IFD divided by the 25 percent IFD is called the foam's **support factor**. Support factors for foam range from about 1.5 to 2.6. The higher the number, the better the ability of the foam to provide support.

Foams with high support factors offer a number of advantages. A low 25 percent IFD on a foam with a high support factor to create extra surface softness without causing the foam to “bottom out” when weight is applied. Typically, the higher the foam density, the better the support factor. ([See our InTouch issue Vol.3, No. 1.](#))



Dynamic Fatigue

There are several tests that are used to determine foam durability, or how well foam retains its original firmness properties and height. Some are standard laboratory tests; others are customized tests developed by different manufacturers. But virtually all of them are based on flexing or compressing the foam a specific number of times to a set deflection or weight load, and measuring foam firmness and height before and after testing. Differences are called fatigue.

In **fatigue testing**, foam samples may be compressed a few thousand times, or many thousands of times. The percentage of IFD loss is then measured. Shorter tests provide an idea of how much firmness a foam may lose through initial use, while longer tests provide data on overall foam durability.



Roller Shear

A particularly severe flex fatigue test is roller shear, where a rolling weight is run over a foam sample from two directions, typically for about 25,000 cycles. This **roller shear** test provides a combination of compression and abrasion, and helps identify how the foam would stand up to particularly difficult applications, such as commercial furnishings or as carpet cushion. Again, IFD loss is measured, and multiple measurements may be taken, at different time periods after the foam has had a chance to “recover.”



Tear Strength

Flexible polyurethane foams are also measured for their ability to resist tearing, breaking, or stretching. This is important in applications where foams must be handled frequently, such as in upholstering. The tests to determine these properties are tensile strength, tear resistance, and elongation. They determine the foam’s ability to be stretched or flexed without tearing. These durability measurements are particularly important for foams which contain large amounts of fillers (such as combustion modified foams), because these additives may increase the tendency of foams to tear or shred. When specifying foams that contain additives, **tensile strength, tear and elongation** tests should be reviewed to see if the foam may require special handling.



Resilience (Ball Rebound)

Resilience is an indicator of the surface elasticity or “springiness” of foam. Resilience can relate to comfort. Resilience is typically measured by dropping a steel ball onto the foam cushion and measuring how high the ball rebounds. Foam resilience ranges from about 20 percent ball rebound to as high as 80 percent rebound. Higher resilience in a foam often means that sofa seat cushions, for example, have a better “hand” or surface feel.

Foams can also be made to have very low resilience for certain applications. For example, viscoelastic (memory foam) products typically exhibit very low resilience.

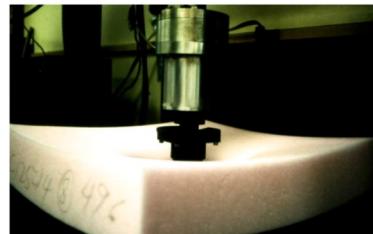


Hysteresis

Hysteresis is another laboratory test used to determine a foam's ability to retain its original firmness properties.

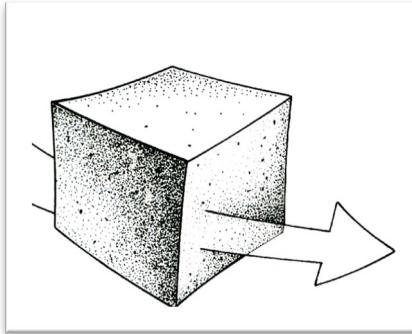
Hysteresis is measured by first indenting the foam sample 25 percent and measuring firmness, then indenting it 65 percent and again measuring firmness, and finally releasing indentation to the 25 percent level without allowing the foam to completely relax. Without fully releasing indentation, foam won't immediately recover all of its original 25 percent firmness, but the percentage of firmness it does recover is believed to be a good indicator of overall cushion durability.

Unlike other durability tests, Hysteresis can be performed quickly on a variety of foam samples.



Air Flow

Air flow is an important diagnostic test. Foam performance is optimized when air flow is maximized. This indicates that cells are open and as flexible as they should be. A good rule of thumb for air flow in flexible polyurethane foams is a minimum of 2.0 cubic feet per minute (cfm). (Note: Viscoelastic or memory foams have lower air flow because of their chemistry, but still perform as intended.)



Testing Methods

To learn more about testing flexible polyurethane foam, refer to ASTM International's test method, *D3574, Standard Test Methods for Flexible Cellular Materials—Slab, Bonded, and Molded Urethane Foams*, which details test procedures and terminology. Also, [see our “Testing” video segment in “An Introduction To The Flexible Polyurethane Foam Industry.”](#)



Examples Of Flammability Standards

Standard	Application	Standard	Application
Safer Occupancy Furniture Flammability Act (SOFFA)* (Based on California Technical Bulletin 117-2013 Test Method)	National Standard For Residential Furniture Residential Furniture And Certain Block Foam Sold at Retail In California	Upholstered Furniture Action Council (UFAC)	Residential Furniture (Voluntary Industry Standard)
California Technical Bulletin 117-2013	Residential Furniture And Certain Block Foam Sold at Retail In California	Consumer Product Safety Commission FF 1-70, Part 1630	Carpet Cushion
California Technical Bulletins 121 and 129	Mattresses Used in High Occupancies and Public Buildings in California	Consumer Product Safety Commission FF 4-72 16 CFR Part 1632 And Part 1633	Residential Mattresses
Boston Fire Code	Commercial Furniture Sold For Use In The City Of Boston (Also Used As A Standard For Specifying Some Commercial Furniture)	Federal Motor Vehicle Safety Standard 302	Passenger Compartments Of Motor Vehicles
		Federal Aviation Regulations FAR 25.853a, 25.853(a-1)	Seat Cushions And Compartment Interiors

Flammability

Like any organic material—including wool, cotton, nylon and polyester—FPF is flammable. It should be kept away from open flames and heat sources such as burning cigarettes, lighters, matches, space heaters or any other potential ignition source, because if ignited, FPF can burn rapidly.

Since the 1960s, PFA members have been researching and improving FPF cushion components to help reduce the ignition and combustion properties of furniture and mattresses. Over many decades, PFA has contributed accurate industry knowledge to the development of both private sector standards and government regulations governing the flammability of products containing FPF.

Mattresses

In 2006 and 2007, the U.S. Consumer Product Safety Commission (CPSC) approved new regulations (16 CFR Parts 1632 and 1633) setting mandatory national fire performance criteria for most mattresses. PFA actively supported the new standards and worked with the CPSC, the International Sleep Products Association (ISPA), the Sleep Products Safety Council (SPSC) and other industry groups in its development. Compliance is largely accomplished using fire barrier materials that limit the involvement of internal cushioning materials in mattress fires.

Upholstered Furniture

In 2013, the California Bureau of Household Goods and Services (BHGS) approved a new version of California Technical Bulletin 117. The revised CA TB-117-2013 responds to concerns that the earlier standard drove increased use of flame retardants (FR) chemicals in foam and furniture.

PFA again worked closely with the Bureau and stakeholders including the American Home Furnishings Alliance (AHFA) to develop the updated standard. TB-117-2013 focuses on ignition of furniture by smoldering sources such as cigarettes, which account for approximately 90% of furniture fires.

In late 2020, the U.S. Congress adopted California TB-117-2013 as a national standard for upholstered furniture sold in the U.S.

The National Fire Protection Association (NFPA), ASTM, and the model building code authorities have also considered standards for the flammability performance of upholstered furniture. Commercial interests that stand to benefit from changes in furniture construction and testing requirements have proposed an array of measures that would add cost and complexity to the production of furniture and its components. PFA and its industry and public interest allies actively engage in standards development to ensure that proposed flammability requirements are scientifically based and repeatable.

Motor Vehicles and Aircraft

In North America, FPF used in motor vehicle applications must meet the Federal Motor Vehicle Safety Standard MVSS-302, administered by the U.S. Department of Transportation. This regulation, which applies to both slabstock and molded foam, typically requires FR treatment of the foam.

Aircraft seating is regulated by the Department of Transportation under Federal Aviation Regulation Section 25.853(a) and FAR 25.853(c) Appendix F. This standard is met through a combination of FR treatment and fire-blocking barrier materials. [Click here for InTouch Vol. 6, No.1, Foam In Transportation.](#)

*Included in the COVID-19 Regulatory Relief and Work from Home Safety Act

Summary

- Flexible polyurethane foam (FPF) is one of the most versatile products ever created.
- FPF applications include furniture, mattresses, carpet cushion, transportation, and packaging.
- Flexible polyurethane foam provides benefits for many consumer products. These include comfort, support, and durability.
- FPF is manufactured by combining a polyol with an isocyanate (plus additives to control the properties of the finished product) and water. Foam can be produced as slabstock (a large foam bun that is fabricated into other products) or molded into individual components.
- Foam density is the most important specification for determining performance. Foam density is independent of foam firmness. You can specify a high density foam to be very soft.
- A number of other characteristics, such as support factor, flex fatigue, air flow, and resilience, should be considered when specifying foam for different applications.
- Your foam supplier can work with you to help determine the best foam performance characteristics for your applications.
- An organic material—like wool, cotton, nylon and polyester—FPF is flammable. It should be kept away from open flames and other potential ignition source, because if ignited, FPF can burn rapidly. Over many decades, PFA has contributed accurate industry knowledge to the development of private sector standards and government regulations governing the flammability of products containing FPF.

This bulletin is intended to serve as a reference regarding the general properties and uses of polyurethane foam and has been developed as a service for the Polyurethane Foam Association's (PFA) members and their customers. The information contained in this bulletin is offered in good faith, developed from sources deemed to be reliable, and believed to be accurate when prepared, but is offered without warranty, express or implied, as to merchantability, fitness for a particular purpose, or any other matter.

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