IN·TOUCH

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Flexible Polyurethane Foam: a Primer

Flexible polyurethane foam 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.

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

Flexible polyurethane foam is one of the most versatile materials ever created. It's used in hundreds of consumer products to provide comfort.

This remarkable versatility allows foam to provide the support needed for long-term medical confinement, or the comfort of pillowy furniture cushioning.

Flexible polyurethane foam appears to be a simple product, but it is actually very complex. It can be produced to have an almost infinite variety of properties. Even though two foams may look exactly alike, they may feel and perform entirely differently.

However, the properties of foam can be identified and specified very precisely. The foam industry utilized 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.

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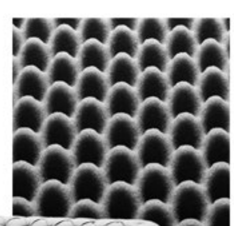
Auto

Bedding

Carpet Underlay



Packaging

Furniture

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

Although a number of different measurements and tests may be used to choose a foam to use in a given product, almost any selection task has any or all of the following three elements at its final goal:

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 losing its original properties. 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.

Flexible Polyurethane Foam is all about comfort, support and durability.

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 and hold up through use, but the camera cares nothing about comfort.

Foam Production

To better understand why foam properties can vary so much, it's a good idea to know something about how foam 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 vigorously in high intensity mixers 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.

SUPPORT

COMFORT

DURABILITY

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 then cut, stored, and allowed to cure for up to 72 hours. 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 Effects

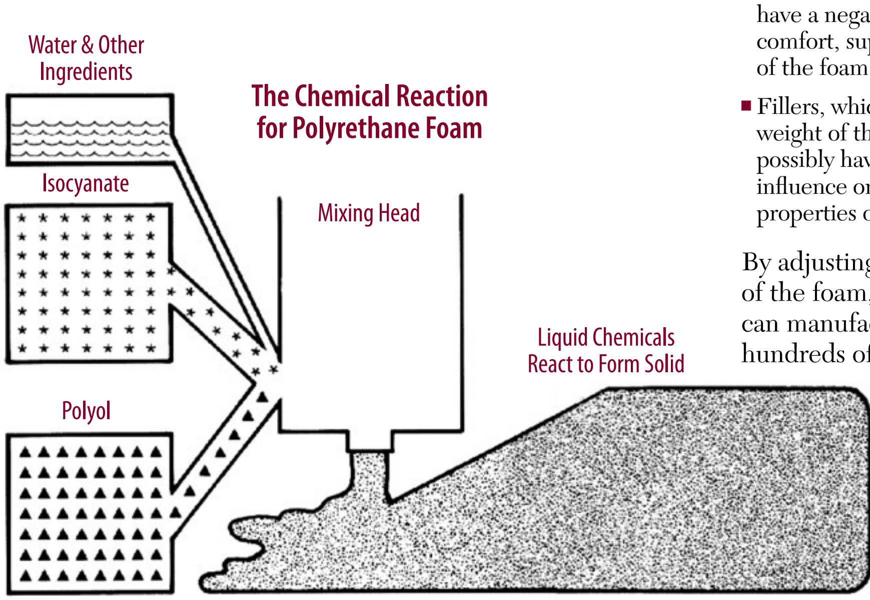
The foam production process can be controlled through changes in the foam raw material mix. In addition to the polyol, isocyanate and water used to produce foam, a variety of other chemicals and additives may be included based on customer specifications to change the final properties of the foam. These include:

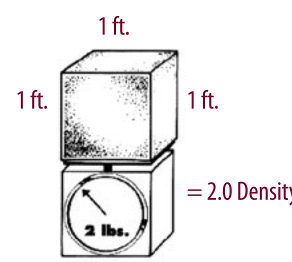
- Auxiliary blowing agents, which augment the primary blowing agent (carbon dioxide), can be used to make foam softer or lighter.
- Catalysts, which speed up the reaction to improve productivity or change foam properties.
- Surfactants, which aid in the formation of foam cells.
- Flame retardant additives, 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.

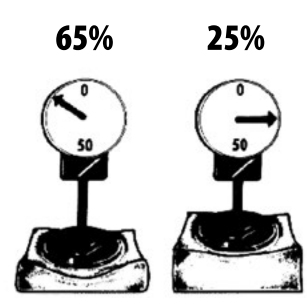
By adjusting the chemical mix of the foam, foam producers can manufacture literally hundreds of different types of foam, each with its own performance properties.

IFD Measurement

IFD is measured by indenting (compressing) a foam sample 25 percent of its original height. The amount of force (in pounds) required to indent the foam is its 25 percent IFD measurement. The more force required, the firmer the foam. Flexible foam IFD measurements range from about 5 pounds (supersoft) to about 80 pounds (very firm).







65% IFD ÷ 25% IFD = Support Fac

Properties that Affect Foam Performance

There are a number of physical properties of flexible polyurethane foam that can be used when selecting foam cushioning 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 under closely controlled conditions of humidity and temperature. Care must be taken to reproduce those conditions when testing samples of foam 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. For specification purposes, it is advisable to use the polymer density of the foam, or the density of the material made up strictly by the foam chemistry without fillers or reinforcements included.

Density affects foam durability and support. Typically, the higher the polymer density, the better the foam will retain its original properties and provide the support and comfort it was originally designed to produce.

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 specification. 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.

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 higher support factors offer a number of advantages. It is possible to specify 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.

FLEX FATIGUE

(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 and measuring foam firmness and height before and after testing.

In flex 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 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 or shredding. 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. These additives can increase the tendency of foams to tear or shred. When specifying foams which contain additives, it is suggested that tensile strength, tear and elongation tests be reviewed to see if the foam may require special handling.

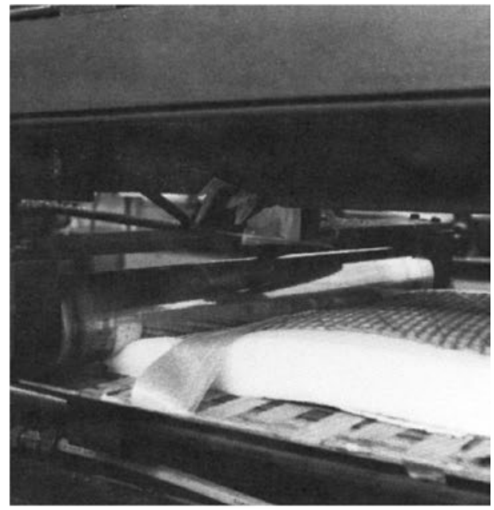
RESILIENCE

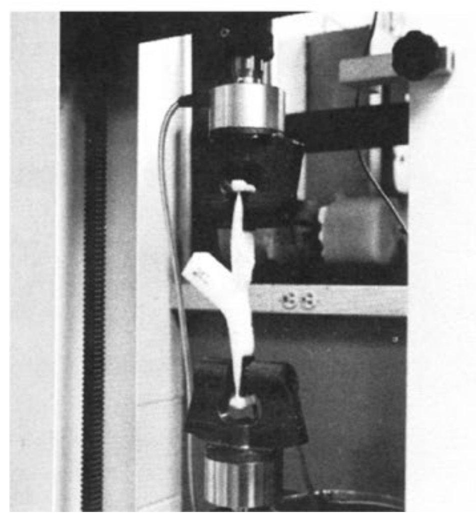
Resilience is an indicator of the surface elasticity or "springiness" of foam. Resilience can relate to comfort. Resilience is typically measured by dropping a steel ball onto the foam cushion and measuring how high the ball rebounds. Foam resilience ranges from about 20 percent ball rebound to as high 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. Viscoelastic 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 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.

Roller shear is a particularly tough test of foam durability.





Tests for tear strength analyze both long term durability and the foam's ability to be handled during product assembly.

A good Hysteresis rating also contributes to how easy it is to get out of a sofa or other furniture piece that is designed for people to sit deeply into the seat.

AIR FLOW

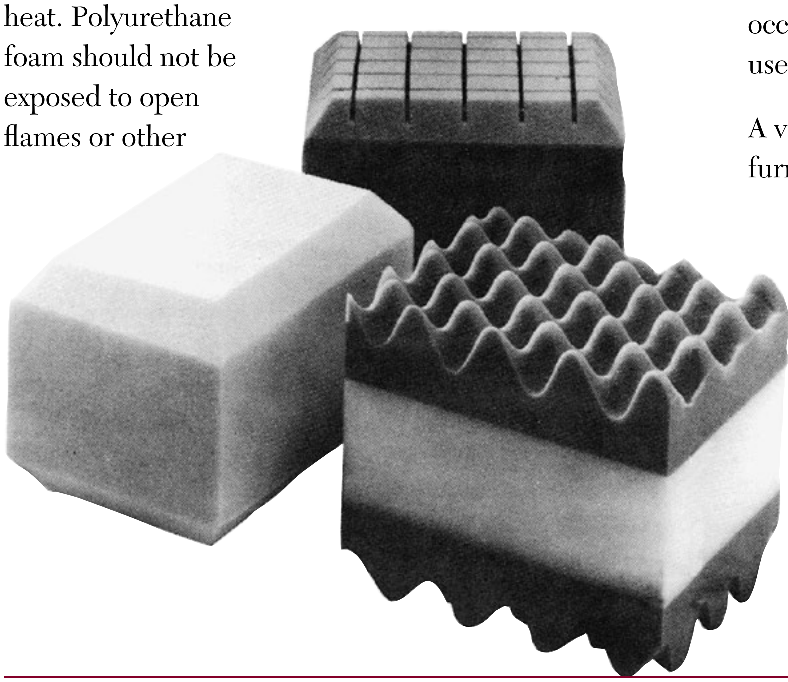
Air flow is an important diagnostic test. Foam performance is optimized when air flow is maximized. This indicates that cells are open and as flexible as they should be. A good rule of thumb for air flow in flexible polyurethane foams is a minimum of 2.0 cubic feet per minute (cfm).

COMBUSTIBILITY

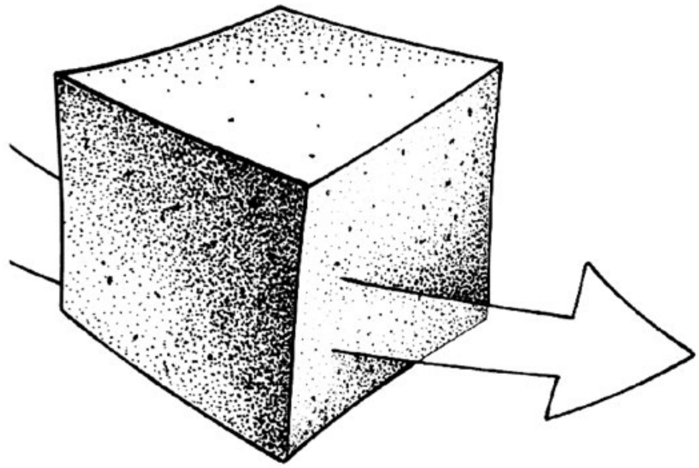
When selecting a polyurethane foam or a product containing polyurethane foam, consideration should be given to the anticipated ultimate end use of the foam or product, the type of occupancy or vehicle in which its use is anticipated, the flammability characteristics of available polyurethane foams, and the fact that burning polyurethane foam, like all organic materials, emits toxins.

Foam is an organic material and is combustible like all organic materials. Organic materials include a wide range of substances like wood, wool, paper, cotton, nylon, polyester, and polyethylene.

Polyurethane foam, once ignited, can burn rapidly, consuming oxygen at a high rate and generating great heat. Polyurethane foam should not be exposed to open flames or other



Air flow through foam should be a minimum of 2.0 cfm.



Flex fatigue tests vary but are designed to see how well foam retains its original firmness properties and original height.

direct or indirect high temperature ignition sources such as burning cigarettes, matches, fireplaces, space heaters, or naked lights. Like any other organic material, when it is ignited and burns, polyurethane foam liberates smoke containing toxic gases, the primary one being carbon monoxide. Oxygen depletion in an enclosed space can present a danger of suffocation.

Since polyurethane foams are made from different formulations and exhibit varying flammability characteristics, some formulations may not be safe for certain uses. In fact, there may be some uses or occupancies for which polyurethane foam should not be used regardless of the formulation.

A variety of combustion resistance requirements for furnishings, transportation, and other uses have evolved.

Requirements range from moderate to very stringent. Most require that the finished items or components be tested and approved before they can be used in applications requiring compliance with a standard. Compliance with such standards or regulations does not necessarily insure that a product made with polyurethane foam is safe for all end uses or occupancies. Following is a list of major combustion resistance standards and their applications:

Standard	Application
California Technical Bulletin 117-2013	Residential furniture and certain block foams sold at retail in California
California Technical Bulletin 133	Commercial furniture sold for use in public occupancies in California (versions are being used or considered in other states)
California Technical Bulletins 121 and 129	Mattresses used in high-risk occupancies and public buildings in California
Boston Fire Code	Commercial furniture sold for use in the City of Boston (also used as a standard for specifiying some commercial furniture)

Standard	Application
Port Authority of New York and New Jersey	Commercial furniture sold in NY/NJ area
Consumer Product Safety Commission FF 1-70, part 1630	Carpet Cushion
Consumer Product Safety Commission FF 4-72, part 1632, and part 1633	Residential Mattresses
Upholstered Furniture Action Council (UFAC)	Residential Furniture (voluntary guidelines used by furniture mfrs.)
Federal Motor Vehicle Safety Standard 302	Passenger Compartments of Motor Vehicles
Federal Aviation Regulations FAR 25.863, 25.853c, 25.853 (a-1)	Seat Cushions and Compartment Interiors-commercial aircraft

These standards are illustrative only and are not intended to be all inclusive.

Additives used to enhance the combustion resistance properties of foam have an effect on foam performance. The flammability of an end product can be reduced in some cases by use of interliners and other devices. The type of fabric or covering, design and construction of the product and other factors can also affect the flammability and resultant toxicity of products using polyurethane foam.

The storage and handling of polyurethane foam in bulk requires fire safety considerations. See InTouch Bulletin Vol. 15, No. 1 on Storage and Handling for more information. Fire insurance underwriters are good sources for advice on the storage and handling of polyurethane foams.

This information is provided as a service of the Polyurethane Foam Association to improve the understanding of key issues that affect flexible polyurethane foam cushioning. To learn more about specific foams, contact your foam supplier.

A complete library of PFA IN•TOUCH issues can be found at www.pfa.org.

Polyurethane Foam Association
334 Lakeside Plaza, Loudon, TN 37774
Phone (865) 657-9840 | Fax (865) 381-1292
www.pfa.org