

IN•TOUCH®

INFORMATION ON

FLEXIBLE POLYURETHANE FOAM

IN-TOUCH® is a regular publication of the Polyurethane Foam Association (PFA). It covers topics of interest to users of flexible polyurethane foam and is designed as a quick reference for background information on key issues. To get more detailed information about a particular topic, consult a PFA member.

Flexible Polyurethane Foam In Packaging

This issue of IN-TOUCH® addresses many of the physical characteristics of polyurethane foam in packaging. This bulletin's goal is to help those who design and engineer packaging to obtain maximum performance and protection for their products.

The capability to control the physical performance characteristics of flexible polyurethane foam makes it the preferred cushioning product for many applications within the furniture, bedding and carpet cushion industries. This same controllable performance also provides important benefits for creation of protective packaging.

By understanding the physical issues and the basic terminology related to polyurethane foam, you can specify the appropriate protective flexible foam product for your individual packaging application.

Some concepts discussed are dealt with in greater depth in prior IN-TOUCH issues. These references are shown in the text with parentheses (X) and are noted below. Back issues can be obtained through the Polyurethane Foam Association.

#	Subject	Issue	Title
(1)	Basic Properties	Vol. 1, No. 1	"Flexible Polyurethane Foam: A Primer"
(2)	Density	Vol. 1, No. 2	"Importance of Density"
(3)	Recycling	Vol. 4, No. 1	"Efficient Solid Waste Management"
(4)	Performance Tests	Vol. 4, No. 2	"Laboratory Tests of Foam Performance"
(5)	Firmness	Vol. 4, No. 3	"How Foam Firmness Affects Performance"



Flexible polyurethane foam can provide outstanding protection in packaging fragile, lightweight items.

Engineering Foam For Packaging

The purpose of flexible polyurethane foam in packaging is to act as a shock absorber, protecting a moving packaged object from damage as it meets resistance, slows and finally comes to rest. Whether you need to protect a moderately heavy piece of equipment, or a delicate electronic component — the physical performance of polyurethane foam can be fine-tuned to meet most packaging needs.

Industry sources suggest that flexible polyurethane foam that can absorb impacts efficiently and recover its physical shape quickly, and repeatedly, is appropriate for packaging fragile items within a wide range of weights and sizes. In addition, flexible foam can be cut and shaped easily for bracing, supporting and wrapping objects. Two basic properties of flexible polyurethane foam are keys to packaging performance. **Firmness** ⁽¹⁾⁽⁵⁾ is expressed numerically as IFD, and

density ⁽¹⁾⁽²⁾. IFD, or indentation force deflection, is a measurement of foam firmness at 25% height deflection. So, for most packaging applications, IFD is a good indicator of the foam surface flexibility. High IFD numbers indicate a firm surface that will be less conforming to surface details. A lower IFD value, indicating a foam with more conforming facial texture, may be more appropriate for use in protecting delicate surface configurations such as found in many assembled electronic components and fragile glass and ceramic pieces.

Density is the weight of a cubic foot of foam and is an indication of the amount of material available to absorb energy. **Density is independent of firmness.** In addition a high density foam will be better able to stand up to repeated impacts without its cushioning characteristics being affected. A high density foam with high energy absorption capability can be specified to have a very soft and conforming surface, or it can be produced to be very firm and not so conforming. Density adds an important aspect to foam specification. Foam thickness is not the only energy absorbing consideration. For heavier objects or with shipping conditions where great shocks are anticipated, higher density and/or thicker polyurethane foam materials may be appropriate. Since higher density flexible foam absorbs energy efficiently, there may be opportunities to optimize packaging space and reduce overall shipping size. Your foam supplier can help you select a good thickness and foam density to serve your objectives.

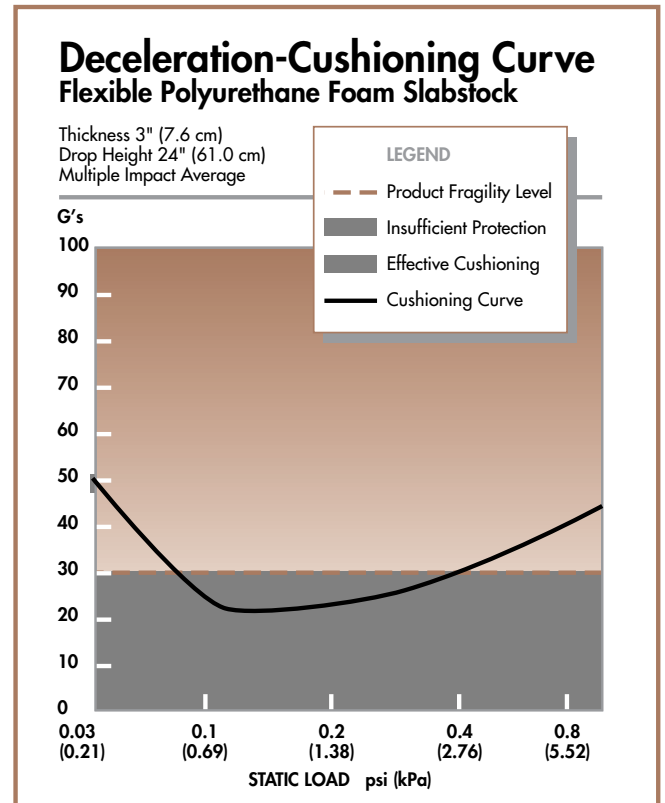
In specifying flexible foam for packaging, the foam supplier plays a vital role, helping to calculate the cushioning requirements for various products, and sharing information on foam properties including physical performance capabilities, anti-static characteristics, and recycling.

Important Background Information

When consulting a foam supplier, two pieces of information are key to engineering a proper packaging solution: the **fragility** of the product to be protected and the **maximum drop height**.

The fragility of an item is measured and reported numerically as its G factor Fragility Index (expressed in Gs). It provides a basic parameter for packaging engineers to use in the selection of cushioning materials. The fragility index is the maximum G force that an item to be packaged can withstand without sustaining damage. This is determined by actually dropping test objects from increasing heights and recording the G force sustained by the item when damage first occurs.

In addition to the fragility index the maximum drop height must also be determined for an item to be packaged. Maximum drop height is simply how far the packaged item is expected to be dropped during



A typical cushioning curve developed from cushion drop testing for an object with 30 Gs fragility and a maximum drop height of 24".

typical handling and shipping procedures. Once the maximum drop height and fragility index are determined, a packaging engineer uses dynamic cushioning curves for various packaging materials to design a protective package.

Foam packaging materials are classified for packaging by determining their ability to absorb shock. This is determined through testing known as dynamic cushioning testing or more commonly called cushion drop testing. Although similar in design, this should not be confused with the drop testing conducted to determine an item's fragility index. Dynamic cushioning tests consist of dropping platens of a specific size repeatedly from a specific height onto a foam sample. The maximum shock (expressed in Gs) sustained as the falling platen impacts the foam sample is measured and recorded. The test is repeated using different platen weights. The results are graphed as shown in the diagram above. A cushioning product's packaging characteristics are fully identified with additional testing using different sample thickness and drop heights.

A packaging engineer takes the separate elements of maximum drop height, object size, object fragility index and dynamic cushioning curves to create packaging material specifications.

Foam Packaging Terminology

You may want to copy this section and save it for future reference by attaching it to the inside back cover of your PFA *Flexible Polyurethane Foam Glossary*. You can obtain a free copy of the PFA Glossary by writing the Polyurethane Foam Association, PO Box 1459, Wayne, NJ 07474-1459, or calling 201/633-9044.

Fragility Index - the fragility of an item is measured and reported numerically as its Fragility Index (expressed in Gs). It provides a basic parameter for packaging engineers to use in the selection of cushioning materials. The fragility index is the maximum G force that an item to be packaged can withstand without sustaining damage.

G Force - the acceleration of gravity (32.19 ft/sec/sec)

Impact Dissipation - the ability of packaging material to provide deceleration, or absorb the force of impact across its available space, thus preventing damage to the product it protects. (See related article, this issue).

Drop Height - based on the probable handling environment of the package and its handling or delivery system, the distance it is likely to be dropped.

Cushioning Curve - a graphical representation of the dynamic cushioning properties of a packaging media. It is determined by dropping varying masses of a specific size from a defined height onto a specimen of the product to be tested. Defined for each curve is the drop height and the specimen thickness. Through the use of varying specimen thickness drop heights, a product's dynamic cushioning characteristics are depicted. The x axis represents the static loading level. The y axis is measured in Gs.

Static Loading - the weight of the product distributed over the foam surface area expressed in pounds per square inch (psi). Since a product may be dropped on any of its sides, there will be several static loads per product, depending on the number of sides, (including top and bottom) and their dimensions.

Loadbearing Area - calculated by dividing the highest static load into the weight of the product. Since several different types of polyurethane foam products may provide adequate protection, the packaging engineer should perform calculations to determine the optimum selection considering material cost and package size.

$$\frac{\text{Weight of Product (lbs.)}}{\text{Static Loading (psi)}} = \text{Required Loadbearing Area (sq. in.)}$$

Viscoelastic - the characteristic found in some polyurethane foam grades that allows a slow, gradual recovery from compression.

Typical Drop Heights

Type of Handling	Weight of Item (pounds)	Drop Height (inches)
Heavy equipment handling	250+	12
Light equipment handling	100-250	18
2 people carrying	50-100	24
1 person carrying (arms down)	20-50	30
1 person carrying (arms extended)	10-20	36
1 person throwing	0-10	42

Approximate Fragility of Typical Packaged Articles

Very Delicate

Hydraulic disc drives, aircraft altimeter, figurines, weapons guidance systems **15-40 Gs**

Delicate

Floppy disc drives, networking hardware, PCs, medical diagnostic apparatus **40-80 Gs**

Moderately Rugged

Televisions, stereos, lap-top computers, VCRs and keyboards **80-100 Gs**

Rugged

Furniture, machine tools, white goods **115 Gs**

$$\frac{\text{Weight of Product (lbs.)}}{\text{Foam Loadbearing Area (sq. in.)}} = \text{Static Loading (psi)}$$



I N F O R M A T I O N

Sample Drop Tests

After a packaging system is designed on paper, full scale prototypes are constructed for performance testing with actual objects. For consistency of results and comparison purposes, if more than one company is performing sample drop tests, identical protocols⁽⁴⁾ must be used.

The Impact Of Fragility: Consider An Egg Toss

How flexible foam can help decelerate a falling object and provide impact dissipation is best demonstrated with the familiar egg toss game, in which two people repeatedly toss an egg back and forth. With each toss the distance the egg travels is increased, so the egg catcher's hands and arms must also travel farther to decelerate the flying egg without breaking the shell. And so it is with flexible foam packaging – with fragile objects, the distance provided for deceleration must increase with the maximum drop height. With more rugged objects, less distance is required and less responsive foams may be used. Foam responsiveness can be affected by openness (airflow), firmness (IFD), density and combinations of these properties.



As in handling a successful egg toss, foam can also provide efficient deceleration and impact dissipation.

Military Specs: A Guide To Testing And Specification

Since the early 1970s, there has been a widespread effort to standardize the format used to specify foams used in packaging. The United States Air Force Packaging Division has established test protocols and specifications for government use of foam in packaging. These procedures and product selection guidelines, known as **Military Specifications**, (identified in MIL-PRF-26514G) are widely used in industry as well. From time to time, the Military Specifications guide is updated to accommodate new packaging materials and foam technologies, so it is important to periodically confirm the version of the Military Specifications being used.

Military Specifications detail testing conditions and procedures, and provide performance requirements for each class of polyurethane foam used in military packaging. The government bulletin includes objectives for water absorption, creep, compression set, pliability, volume change, combustibility, compressive strength, dynamic cushioning properties, anti-static and corrosive characteristics. ASTM test procedures⁽⁴⁾ are often used in combination with Military Specifications to develop complete packaging specifications.

New Technologies Expand Packaging Options

Conventional flexible polyurethane foams typically feature a relatively low static stress (lbs./sq. in.) loading capability in order to yield reasonable impact absorption values. Higher loadbearing (firmer) foams (produced with reinforcing polyols) extend the limit, but use of flexible polyurethane foam in packaging is still confined primarily to reasonably lightweight items. New technologies being developed extend this range into the region historically dominated by polyethylene foams. Not only do these new products perform well at higher static stress loading level, but also at an extended range. They also continue to have the fabrication benefits customarily associated with flexible polyurethanes.

New technologies are being developed to help combine the desirable properties of flexible polyurethane with the static loading capability of thermoplastic foams based upon a viscoelastic model. With the new technology, the static load limit for flexible polyurethane foam can be more than doubled. At present, this viscoelastic technology is only available at relatively high densities and is produced in small quantities necessitating premium economics. Viscoelastic foam is most applicable for protection of heavy, delicate objects. Composite packaging (combining flexible polyurethane foam with other packaging material) is the current preferred approach.

Foam Properties Affecting Performance

There are a great number of foam properties⁽¹⁾ that can affect the cushioning curve, and ultimately the specifications for packaging to provide necessary product protection. Foam thickness, firmness and density have apparent implications, but there are other lesser known characteristics that can be very important. For example, foam openness or porosity may affect how well the cushioning can absorb shock (impact dissipation) and decelerate a very fragile object.

In the laboratory, **airflow** testing is used to measure foam porosity (the relative degree that air is able to pass through a foam sample). Airflow is the cubic feet per minute (cfm) of air that passes through a 1"x2"x2" sample when drawing a 1/2" of water differential pressure between the front and back side of the sample. Openness is primarily affected by a foam's cell structure. Very open foams are generally in the lower density ranges and have a minimum window content.

Like density and firmness **airflow is an independent foam property.**

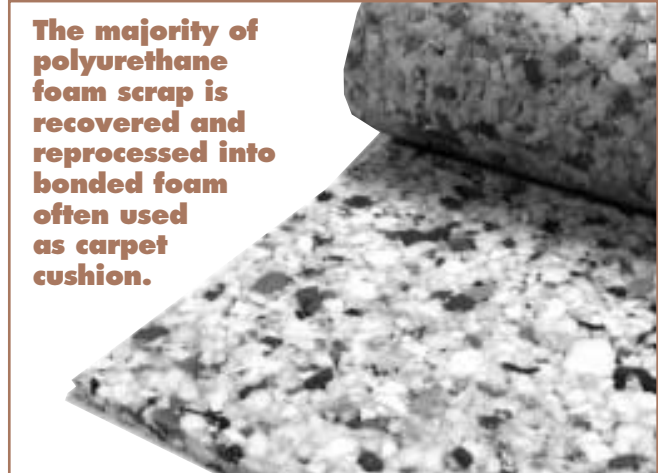
Foams with the greatest porosity (highest airflow values) are generally better suited to the protection of light weight, delicate objects with high fragility and/or lower maximum drop heights. Conversely, foams with lower airflow values may be more appropriate for heavier objects requiring greater energy absorption. Tight foams, having cells with a high degree of window content (lowest airflow values), may be ideal for items with moderate fragility and drop height.

Since foam cells are ellipsoidal and not spherical, how cells are oriented can also affect packaging performance. Foam samples cut parallel to the bunstock base may display slightly different dynamic cushioning properties to samples cut perpendicular to the base. In the determination of a foam product's dynamic cushioning properties it is important to recognize the potential effect of cell orientation.

Flexible Foam: The Recyclable Choice

Demand for recyclable packaging is increasing. For more than twenty years, the flexible polyurethane foam industry has been a leader in manufactured waste recovery and recycling⁽³⁾. Currently, about 90% of manufactured foam waste is recovered for alternative processing. Recovered scrap foam is shredded and used almost

The majority of polyurethane foam scrap is recovered and reprocessed into bonded foam often used as carpet cushion.



exclusively in the manufacture of bonded carpet cushion. Bonded foam may have packaging implications as well. The scrap recovery process is driven hard by the fact that bonded carpet cushion is now the leading underlayment used in residential carpet installation. So, the foam you have chosen for its performance and value may also be the best environmental choice, too.

Anti-static Performance

By the nature of its chemical composition and high surface area, flexible polyurethane foam is prone to the build-up of static charges. This characteristic is overcome with the addition of anti-static chemical additives. These additives are usually incorporated into the foam

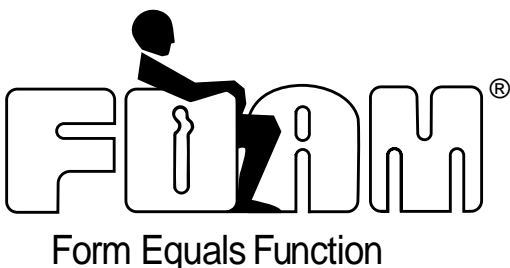


Polyurethane foam is the preferred packaging material for electronic parts sensitive to static discharge.

during the manufacturing process. This assures even distribution throughout the foam block for uniform anti-static protection. Anti-static flexible polyurethane foam has become a preferred packaging material for objects which may be harmed by static discharge such as computer hard drives, memory chips and electronic circuitry. Packaging a circuit board in a shielding bag with conventional packaging foam may not be adequate static protection. An anti-static treated polyurethane foam should also be incorporated into the packaging design.

Summary

- ▶ 1. The controllable physical characteristics of flexible polyurethane foam provide a range of possible performance capabilities for packaging.
- ▶ 2. Firmness, density and air flow are independent of one another and all can affect a foam's ability to dissipate the energy of impact.
- ▶ 3. When working with a foam supplier, it is important to share data on item size, weight, fragility and maximum expected drop height.
- ▶ 4. Military Specifications (MIL-PRF-26514G) are widely used in conjunction with ASTM procedures for physical testing of packaging and flexible foam components. Military Specifications also provide guidelines for expected foam performance.
- ▶ 5. New technologies in loadbearing and viscoelastic foams serve to increase the static load capacity for flexible polyurethane packaging and broaden possible applications.
- ▶ 6. Flexible polyurethane foam is recyclable. The majority of foam scrap from manufacturing is now recovered and processed into bonded carpet cushion.
- ▶ 7. Engineering protective packaging is a complex process. Your foam supplier can provide valuable assistance by sharing physical performance information on the many foam products that may serve your needs.



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.

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