IN•TOUCH

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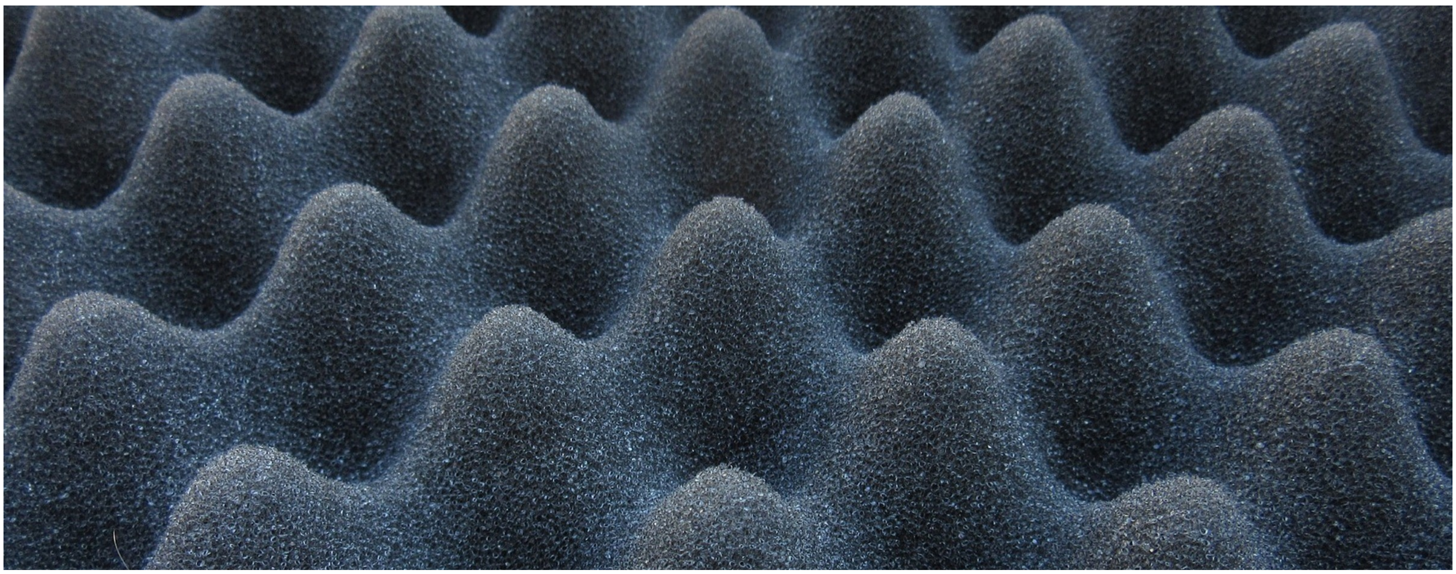


Flexible Polyurethane Foam In Packaging

This issue of INTOUCH® addresses many of the physical characteristics of flexible polyurethane foam (FPF) in packaging. This bulletin's goal is to help those who design, engineer and specify packaging to obtain maximum performance and protection for the products packaged.

The capability to control the physical performance characteristics of flexible polyurethane foam makes it a preferred cushioning material for furniture, bedding and carpet cushion. This same controllable performance also provides important benefits for protective packaging. In addition, flexible foam can be molded or fabricated into custom shapes easily for bracing, supporting and wrapping objects. It can be contour cut using modern CNC machines to precisely match the shape of an object to be protected. Foam can also be convoluted (dimpled) for lighter packaging solutions and better protection.

FPF Is Effective In Packaging Because Of its Light Weight, Shock Absorption, and Ease of Fabrication.

Understanding physical characteristics and the basic terminology related to polyurethane foam can assist you in meeting packaging needs.

Some concepts are dealt with in greater depth in other INTOUCH bulletins. Follow the links in this document to view these other INTOUCH editions.

Engineering Foam For Packaging

Flexible polyurethane foam in packaging acts as a shock absorber, protecting a moving (falling) 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.

Packaging foam is specified for its ability to absorb shock. This is determined through testing known as **dynamic cushioning testing**, or more commonly called, **cushion drop testing**.

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 Figure 1.

A cushioning product's packaging characteristics are fully identified with additional testing using different sample thicknesses and drop heights.

Shipped Object Characteristics

Two additional 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). The fragility index is the maximum G force that an item to be packaged can withstand without sustaining damage. G Force is the force of gravity or acceleration on a body, about 32.19 feet/second^2 (9.8 m/s^2).

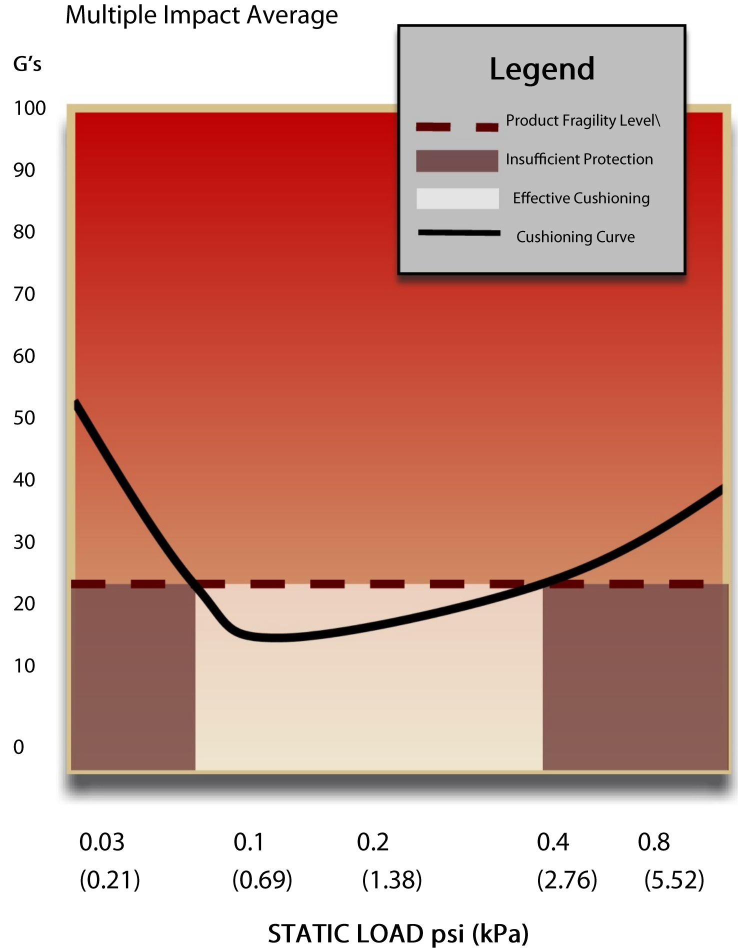
This is determined by dropping test objects from increasing heights and recording the G force sustained by the item when damage first occurs. (This is similar to, but not to be confused with, the dynamic cushion drop test.)

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 typical handling and shipping procedures. Once the maximum drop height and fragility index are determined, dynamic cushioning curves can be developed to design a protective package.

Figure 1: Deceleration-Cushioning Curve

Flexible Polyurethane Foam Slabstock

Thickness: 3″ (7.6 cm)
Drop Height: 24″ (61.0 cm)
Multiple Impact Average



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

A packaging engineer takes the separate elements of maximum drop height, object size, object fragility index and dynamic cushioning curves to design a package and create packaging material specifications. The goal is to minimize cost and volume/bulkiness while maximizing protection.

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 must be used.

Packaging manufacturers and/or foam suppliers may be responsible for testing, depending on the relationship between a company and a foam supplier. With modern computer simulation technology, drop test and dynamic cushioning data may be generated through computer modeling, once there has been sufficient physical testing to establish baseline data for products or situations.

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 or CFD), 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 an effort to standardize testing and specification of foams used in packaging. The United States Defense Logistics Agency (www.dla.mil) has established test protocols and specifications for government use of foam in packaging. These procedures and product selection guidelines are widely used in industry as well.

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 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 (psi or lbf/in^2) loading capability in order to yield reasonable impact absorption values. Higher loadbearing (firmer) foams (produced with graft polyols) extend the limit, but use of flexible polyurethane foam in packaging is still confined primarily to reasonably lightweight items. New technologies extend this range into the region historically dominated by polyethylene foams. Not only do these new products perform well at higher static stress loading levels, but also at an extended range. They also continue to have the fabrication benefits customarily associated with flexible polyurethanes.

The use of **viscoelastic foam** technology (also known as “memory foam”), has more than doubled load limit for flexible polyurethane foam. Viscoelastic foam is most useful for protection of heavy, delicate objects. Composite packaging (combining flexible polyurethane foam with other packaging material) is also a preferred approach. (Note: viscoelastic foams can be sensitive to temperature changes, so these must be taken into account. In order to be effective, viscoelastic foams must be used just around their *glass transition temperature*. If used at lower than the glass transition, the material will be stiff, and above it will become bouncy.)

Foam Properties Affecting Performance

There are several properties of flexible polyurethane foam to consider when evaluating packaging performance. Here are summaries:

Firmness

Firmness is quantified by [Indentation Force Deflection (IFD)](), 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 of the shipped object. 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 those found in fragile glass and ceramic pieces. For thinner and firmer foams, Compression Force Deflection (CFD) is also commonly used instead of IFD.

Density

Density is the weight of a cubic foot of foam and is an indication of the amount of material available to absorb energy. Lower density foams may be used for cushioning lightweight materials or in one-time shipments to reduce shipping weight. For packaging used multiple times, a higher density foam may be better able to stand up to repeated impacts without its cushioning characteristics being affected.

Flexible polyurethane foam is a popular choice for protecting electronics because of its antistatic features.

Thickness

Foam thickness should be considered in concert with foam firmness and density, as they all may influence energy absorption. If space is a consideration, a higher density foam may allow the use of a thinner foam profile, for example.

Foam suppliers can help shippers select foam with optimum thickness and density to serve packaging objectives.

Air Flow

Beyond foam thickness, firmness and density, lesser known characteristics affect specifications for cushioning material. 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). Foams with the greatest porosity (highest airflow values) are generally better suited to the protection of lightweight, 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. For example, polyester polyurethane foams with very low air flow have very high shock absorption capabilities, and are commonly used in cases for cameras, guns, binoculars, and other items.

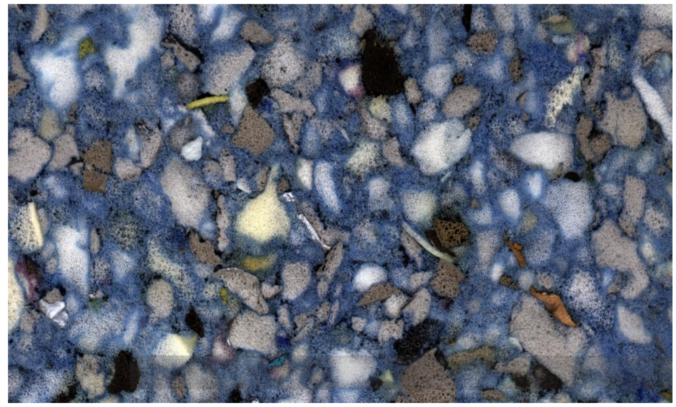
Since foam cells are ellipsoidal and not spherical, how cells are oriented can also affect packaging performance. Foam samples cut parallel to the bunstock base may display slightly different dynamic cushioning properties to samples cut perpendicular to the base. In the determination of a foam product's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

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 during the manufacturing process, but can also be added as a post treatment (roll coating or spray). 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.

Recyclability

Flexible polyurethane foam can be readily recycled. For decades, the flexible polyurethane foam industry has been a leader in manufactured waste recovery and recycling. Currently, about 90% of manufactured foam waste is recovered for alternative processing. Recovered scrap foam is shredded and used mainly in the manufacture of bonded carpet cushion. So, the choice of flexible polyurethane foam packaging material can also be a good environmental choice.



Bonded polyurethane foam carpet cushion

Foam Packaging Terminology

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 feet/second^2 or 9.8 m/s^2).

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.

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 graphic 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 ore depicted. The x axis represents the static loading level. The y axis is measured in Gs. (See Figure 1, Page 2)

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.

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	
Desktop PCs, medical diagnostic equipment	**40-80 Gs**
Moderately Rugged	
Televisions, stereos, lap-top computers, VCRs and keyboards	**80-100 Gs**
Rugged	
Furniture, machine tools, white goods	**115 Gs**

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

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.

Summary

1. Engineering protective packaging is a complex process. Foam suppliers can provide valuable assistance by sharing physical performance information on the many foam products that may serve specific packaging needs.
2. The controllable physical characteristics of flexible polyurethane foam provide a range of possible performance capabilities for packaging.
3. Firmness, density and air flow all can affect a foam's ability to dissipate the energy of impact.
4. Testing foams for packaging applications involves item size, weight, fragility and maximum expected drop height. Once basic properties are known, computer modeling may take the place of some physical testing.
5. Military Specifications (www.dla.mil) are widely used in conjunction with ASTM procedures for physical testing of packaging and flexible foam components.
6. Technologies like viscoelastic foams and low air flow polyester polyurethane foams serve to increase the static load capacity for flexible polyurethane packaging and broaden possible applications.
7. Flexible polyurethane foam is recyclable. The majority of foam scrap from manufacturing is now recovered and processed into bonded carpet cushion.

Additional Issues Of InTouch To Review:

Vol. 1, No. 1: Flexible Polyurethane Foam, A Primer
Vol. 2, No. 1: The Importance Of Density
Vol. 4, No. 2: Laboratory Tests of Foam Performance
Vol. 4, No. 3: How Firmness Affects Performance
Vol. 11, No. 1: Viscoelastic Foam

You may also want to view our "Introduction To Flexible Polyurethane Foam" video series, which contains detailed information about foam chemistry, testing, production, and applications.

Visit the literature section at **www.pfa.org** for a complete, downloadable library of IN•TOUCH Bulletins. For video training and to learn about entry-level jobs in the FPF industry, visit **www.flexfoamjobs.com.**

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