IN•TOUCH

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Viscoelastic (Memory) Foam

Viscoelastic foam, also known as memory or temper foam, was first commercialized during the mid 60's as a result of NASA's AMES Research technology transfer program.

This open-cell variety of flexible polyurethane foam (FPF) is distinguished by properties allowing it to redistribute the G-Force suffered by astronauts during take-off and re-entry, and providing commercial pilots a more comfortable seating surface during long flights.

Viscoelastic pressure distribution performance represents one of the most significant comfort innovations from the FPF industry.

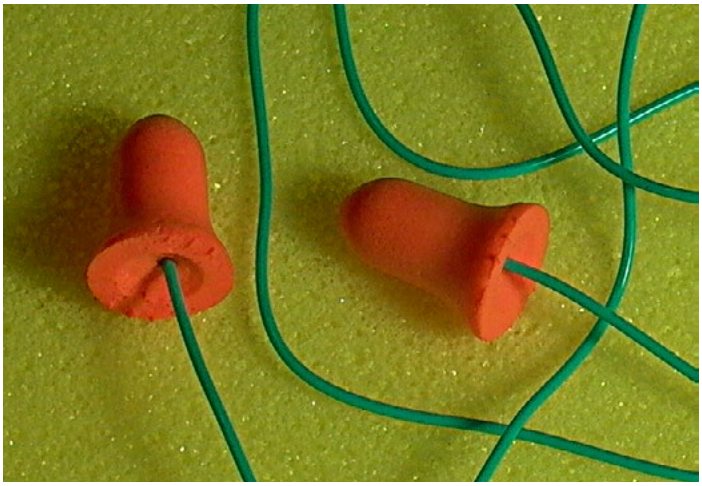
Characteristics

Viscoelastic foam is typified by its slow recovery after compression. When a weighted object (for example, the human body) is positioned on viscoelastic foam, the foam progressively conforms to the shape of the object, and after the weight is removed, the foam slowly reassumes its initial shape. Due to this gradual recovery, viscoelastic foam also can be described as "slow recovery" foam.

Other characteristics include viscoelastic foam's ability to dampen vibration as well as absorb shock. This latter performance characteristic is confirmed in the laboratory using ball rebound tests. Ball rebound of less than 20% (compared to 50% – 60% with other varieties of FPF) supports the description of viscoelastic polyurethane foam as "dead" or "low-resilience" foam, in that it lacks the surface "springiness" of other FPF products. In fact, certain viscoelastic foam products claim to absorb up to 90% of impact. While lack of resilience may appear to be a disadvantage, as discussed later, a "dead" foam can be highly desirable in some applications.

In addition to these key advantages, many viscoelastic products also react to body temperature and ambient temperatures, softening with heat and more easily adjusting to body contours.

Viscoelastic (memory) foam is characterized by slow recovery after compression. Its ability to closely contour to shapes allows surface pressure to be distributed over a wide area.



Moldable viscoelastic ear plugs are examples of how viscoelastic foam provides high-value performance with attractive economics.

Benefits & Applications

Viscoelastic foam's unique physical characteristics have led to its popularity in the bedding and medical industries. Due to its conforming aspect, viscoelastic material makes for a comfortable yet supportive mattress or mattress pad, and its low resilience works well in bed pillows. People with impaired mobility, confined to wheelchairs or hospital beds (especially burn victims) can benefit from the foam's capacity to redistribute weight and surface pressure, potentially reducing decubitus ulcers (bed sores) caused by aggravated pressure between the skin and bony areas of the body such as beneath heels, hips, elbows and the back of the head. If pressure is not relieved through body movement or technology, such as a viscoelastic foam surface, blood vessels may compress, inhibiting circulation and possibly irritating the skin tissue.

Aside from bedding and medical purposes, viscoelastic material can be used in standard household furniture (stationary or motion), office furniture, and in vehicle seating applications. It can cushion sports equipment, power tools, and footwear. Viscoelastic foam has also found utility in ergonomic applications such as neck, back and leg pads, as well as in arm and wrist rests for computers.

It can act as shock protection within electronics equipment and in industrial applications and has been used in specialty packaging, military and commercial aircraft seating, and weaponry (for recoil suppression).

Visco Applications

While viscoelastic foams are widely used in bedding products today, why isn't it used in more comfort cushioning applications? Unfortunately, production economics often restrict end-use applications.

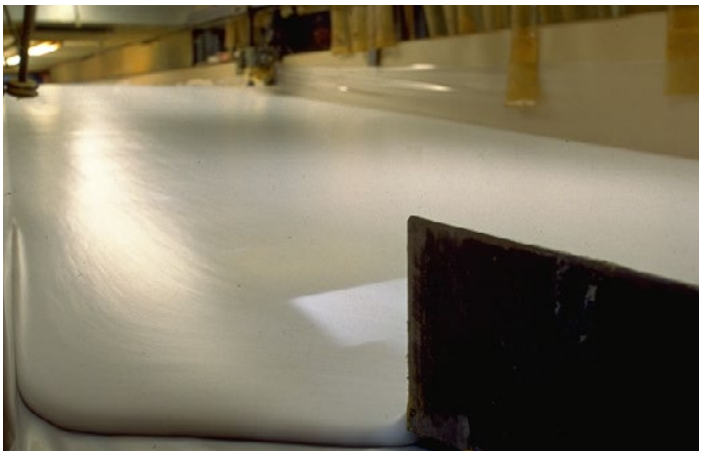
Unlike traditional foam processing, viscoelastic formulation flexibility is more restrictive. Raw materials must be carefully altered to generate foam with varying properties. Cutting, profiling and other fabrication techniques may also require more care due to the slow recovery aspect of the foam. These considerations certainly affect product economics.

Production

Formulating and Processing

While formulating and processing can be challenging, foam manufacturers and chemical suppliers have worked together to develop a range of successful viscoelastic products. For instance, certain formulations can alter the foam's recovery, elasticity, and firmness, giving it the ability to meet a diverse set of end-use needs. Because viscoelastic foam is hypersensitive to formulation, the challenge focuses on maintaining product performance consistency. This requires a close working relationship between FPF manufacturers and their raw materials suppliers. With careful attention to quality control procedures, end products can meet or exceed application performance requirements.

Viscoelastic foam can be manufactured using conventional flexible polyurethane foam slabstock or molding processing equipment.



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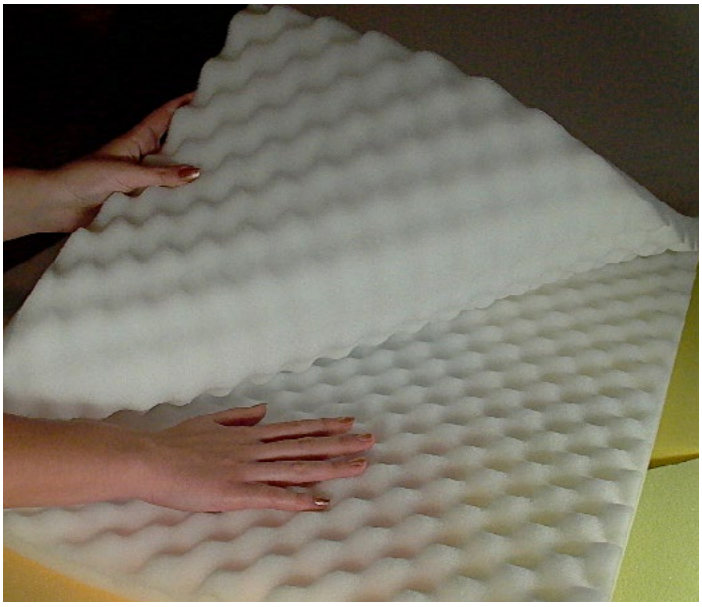


Although fabrication speed for viscoelastic foam may be slower than with conventional FPF, a wide range of product designs can be produced.

Fabricating Considerations

Commercial slitters and saws can be used to fabricate viscoelastic foam. However, in most cases viscoelastic foam must be cut at a much slower rate than conventional foam due to its slow recovery characteristic. Cutting machines are capable of processing conventional FPF products at up to 150 feet per minute, but with viscoelastic foam, table speeds are commonly slowed depending on the softness of the material. Of course, slower fabrication reduces output and can affect product economics.

Fabrication of viscoelastic products mostly relies on horizontal and vertical cutting. Slow recovery products also can be convoluted and profiled, but there are limitations. Viscoelastic foam usually does not recover before it hits the blade; therefore the "dimples" are not as pronounced as with conventional convoluted or profiled FPF products.

Physical Properties

Density

As with all FPF, the density for viscoelastic foam is the weight of one cubic foot of material measured in pounds. With conventional FPF formulations, a higher foam density generally equates to increased foam durability (retention of performance properties). The same is true of viscoelastic products. Density enhances durability and the ability of viscoelastic foam to maintain its physical performance. Viscoelastic foam found in most household and healthcare product applications typically ranges in density from 2 to 6 pounds per cubic foot (pcf).

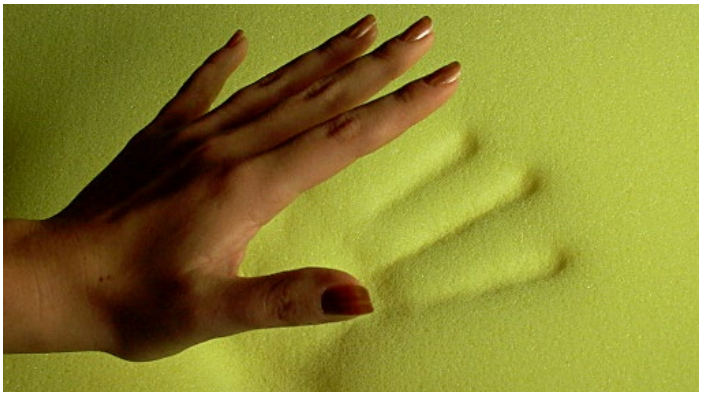
Firmness

Normally, firmnesses of viscoelastic foams can range from supersoft (less than 10 lbs. @ 25% IFD) to semi-rigid (as high as 120 lbs. @ 25% IFD). The potential for surface pressure reduction is closely associated with firmness. Desired firmness is achieved through custom formulation. Viscoelastic products with a lower IFD tend to exhibit increased conformance and can distribute body weight more efficiently to alleviate pressure. However, if the IFD is very low, and there is not sufficient foam density or thickness to provide support, the product may "bottom out," negating the benefits of pressure reduction. When performing IFD tests, firmness measurements of viscoelastic products can be significantly affected by some of the foam's key characteristics: rate sensitivity (the foam's rate of recovery after compression), sensitivity to temperature, and sensitivity to humidity. Conditioning the foam sample prior to testing is extremely important.

Rate Sensitivity

Viscoelastic foam rate sensitivity, observed as the speed that a foam sample recovers after compression, affects the way firmness (IFD) can be determined in laboratory tests. Because of rate sensitivity, when testing viscoelastic foam under load,

The potential for surface pressure reduction is affected by foam firmness and recovery speed.



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as in IFD measurement, the speed at which the weight force is applied can alter firmness readings. In other words, if the indentation plate used in the test descends quickly, the foam may respond with stiffness, whereas slower speeds may result in different IFD measurements. With viscoelastic products, IFD tests should show notation of the process speed (rate of deflection) being used so that valid and fair comparisons among foam grades and between laboratories can be consistently made.

Sensitivity to Temperature

The physical properties of viscoelastic foam can be greatly influenced by temperature. Even slight changes in room temperature can affect measured firmness and recovery rates. Recovery rate has been positively correlated to heat, so that as the foam increases in temperature, pliability and compression and recovery rates increase. In colder conditions, viscoelastic products tend to become firmer or even stiff. Depending on formulation, some viscoelastic products can maintain "memory" performance as low as 30°F, but the optimum range for best "memory" action is typically between 55°F and 85°F. Research continues to investigate ways to moderate pliability and allow viscoelastic products to perform within a broader spectrum of temperatures, especially below freezing. This is especially important in vehicle seating and other applications where ambient temperature cannot be controlled in use.

In testing viscoelastic foam performance characteristics, it is also important to make notation of the ambient temperature and be certain that all comparison testing be performed under like conditions. Foam samples must be conditioned prior to testing.

Heat (even body heat) can soften viscoelastic materials and, in extreme situations, affect the foam's ability to provide support. This process is known as a phase change or relaxation. Rather than broadening the temperature range at which viscoelastic foam retains its slow recovery, foam formulation can be adjusted to narrow the temperature span at which phase change occurs, anticipating the influence of room temperature combined with body temperature. In other words, if the phase change occurs at lower temperatures, its reaction to added body heat could lessen its firmness to the point where support is lost. On the other hand, if the phase relaxation were to happen in warmer conditions, added body heat would not be enough to soften the foam, and the resulting foam rigidity would reduce the potential for pressure relief. Hence, careful control of the phase change characteristics is crucial for the foam to serve its pressure reduction purpose and to provide predictable support.

Sensitivity to Humidity

Similar to temperature effects, viscoelastic foams also react to humidity. Viscoelastic products tend to soften in more humid conditions. For example, very pliant foam may feel slick or "buttery" as opposed to coarse, depending on the humidity. Surface feel is generally not a critical factor in end-use applications, because in almost all cases, the foam is enclosed inside a covering material that provides its own surface feel.

Firmness that changes with ambient conditions can make accurate calculation of physical properties difficult.

Phase Change Additives Can Affect Thermal Performance

A phase-change material (PCM) is a substance with a high heat of fusion which, melting and solidifying at a certain temperature, is capable of storing and releasing large amounts of energy. Heat is absorbed or released when the material changes from solid to liquid and vice versa; thus, PCMs are classified as latent heat storage units.

There are roughly three kinds of PCM: eutectics, salt hydrates, and organic materials. Organic PCMs, such as waxes, oils, fatty acids and polyglycols, are most commonly used in viscoelastic foam. Because of the solid to liquid phase changing nature, PCM may be microencapsulated to assist processing in viscoelastic foam formulations.

PCM, as used in viscoelastic foam, absorbs heat when the temperature of the foam reaches the melting point of the PCM 28 with a melting point of 82.4°F (28° C) would be appropriate for use in foam bedding products. By absorbing the heat, PCM helps to maintain the temperature of the foam bedding products around 82.4°F until all the PCM potential is consumed. When the heat source (person) is removed, the PCM recovers back to the solid state, and is ready to absorb the heat again.

Modified formulations are needed to obtain the desired heat absorption while maintaining physical properties of the foam.

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Performance Testing

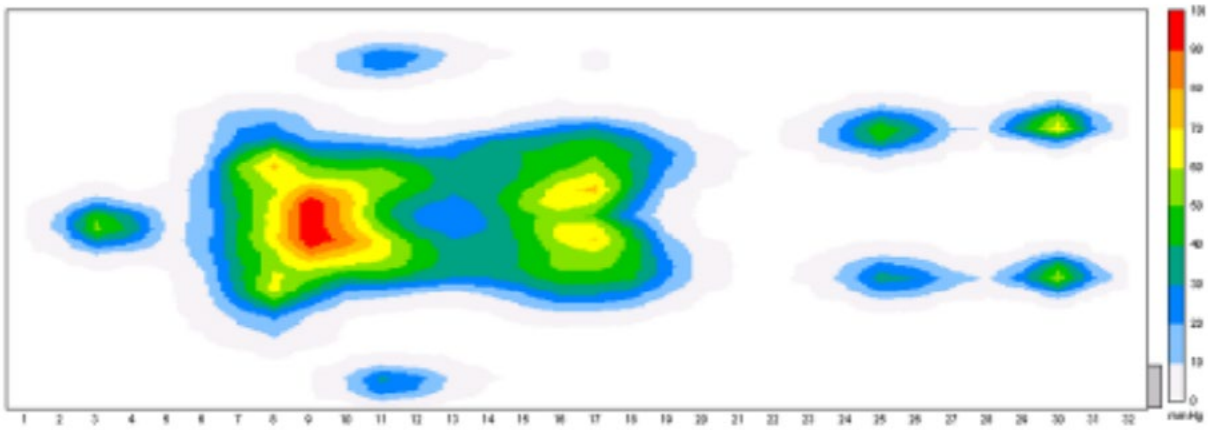
Pressure Reduction and Pressure Relief

Because viscoelastic foam can closely conform to the shape of the human body, it can efficiently distribute pressure over the whole surface. Pressure-mapping equipment is often used to calculate the degree of weight distribution. During the mapping procedure, computer programs monitor pressure. The body's impression is graphed to show which areas endure the most pressure (namely the shoulder blades, posterior region, head, heels, calves, and elbows).

Some viscoelastic foam producers perform these tests as an indication of how well the foam might act to minimize pressure. In the healthcare area, to be labeled as providing "pressure relief," readings must be at 32mmHg or lower, whereas "pressure reduction" performance is agreed to occur between 32mmHg and 50mmHg. The following charts help illustrate the process and show some typical pressure readings for viscoelastic foam. When readings made on viscoelastic products are compared to those of conventional foam and other common cushioning surfaces, the pressure differences are notable.

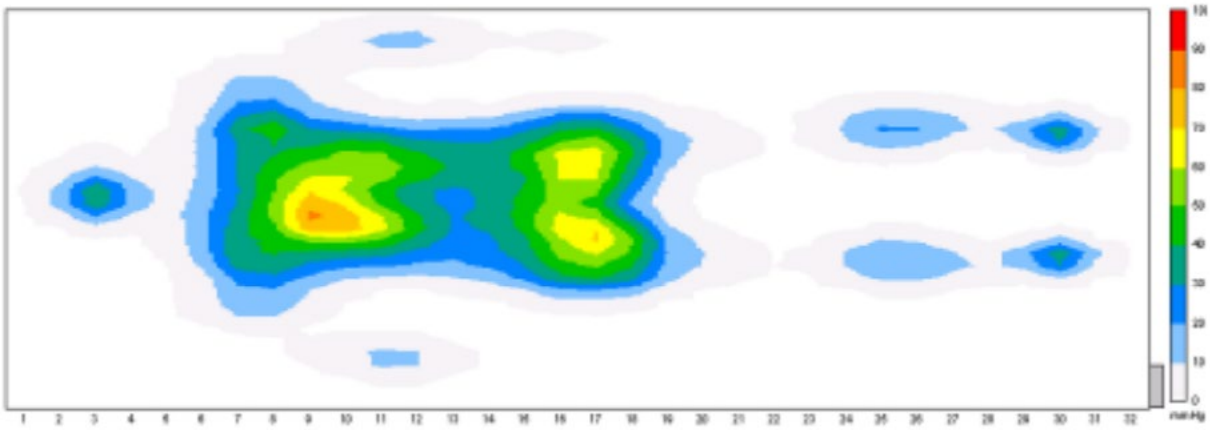
1.8 pcf Density
20 pcf IFD

Conventional Flexible Polyurethane Foam



3 pcf Density

Viscoelastic Polyurethane Foam



Pressure map comparison using 2" thick foam samples mounted on top of a rigid board covered with a 3" thick layer of 1.6 lbs density conventional foam with 40 IFD as a standard test foundation.

Test Samples: 2" thick slab of 1.8 pcf density conventional flexible polyurethane foam
2" thick slab of 3 pcf density viscoelastic polyurethane foam

Test subject: Male 67" height 195 lbs weight

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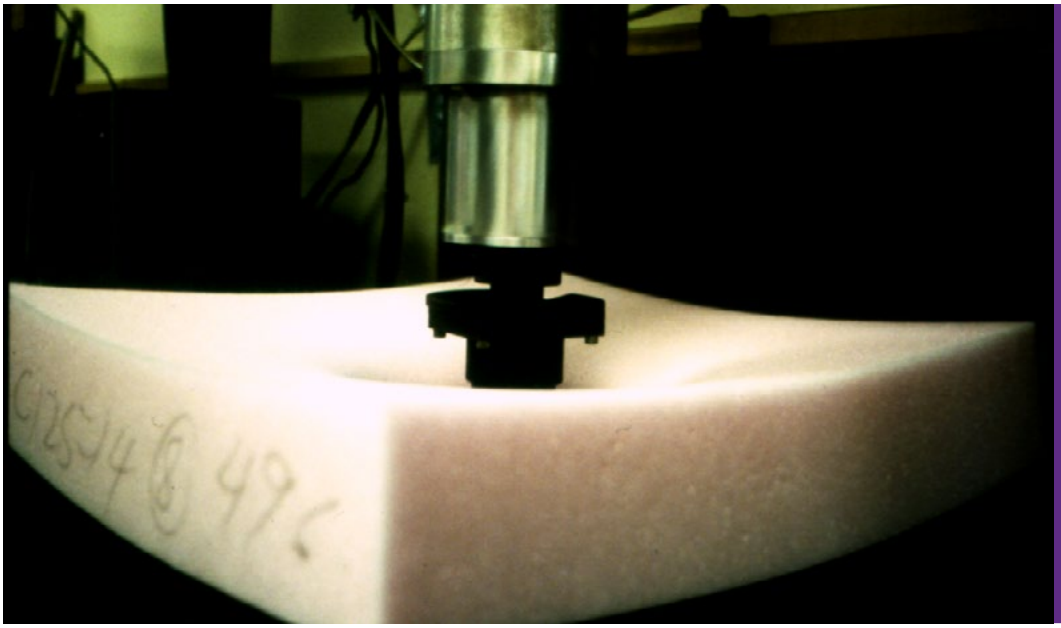

ASTM has developed D3574 Test M for testing viscoelastic foam where the indentor foot moves up at a very rapid rate compared to normal FPF testing.

Testing Procedures

With the unique nature of viscoelastic foam performance, some traditional FPF test methods do not produce consistent results. For example, measuring durability with the use of a Dynamic Pounding Fatigue Test procedure can be problematic. Due to the foam's slow recovery characteristic, pounding fatigue data loses validity because the foam has not fully recovered in between each cycle. Compression set testing may provide a better measurement of viscoelastic foam durability.

The foam industry uses IFD measurements to quantify FPF firmness. Unfortunately, IFD testing may not accurately evaluate viscoelastic foam firmness because the foam relaxes during the one-minute hold period before taking the IFD reading. Due to rate sensitivity and other factors, standard IFD testing procedures used throughout the industry are not completely understood and may not accurately measure the firmness characteristics of viscoelastic products.

ASTM has developed D3574 Test M for testing viscoelastic foam where the indentor foot moves up at a very rapid rate compared to normal FPF testing.

Environmental Considerations

As with any product, off-gassing naturally occurs. The formulation technologies used to produce viscoelastic foam products sometimes create the potential for more noticeable aromatic emissions than typically found in conventionally manufactured foam products. While not known to be harmful, residual odor may be bothersome to some consumers. Therefore, it is advisable to thoroughly ventilate viscoelastic foam products prior to final product assembly.

Flammability Considerations

Viscoelastic foam can be manufactured to perform with varying degrees of ignition and combustion resistance. Viscoelastic products can be combined with barrier materials in mattresses designed to comply with CPSC 16 CFR Part 1633 and other composite-type flammability specifications. Visco foams also can be formulated to meet the California Technical Bulletin (TB) 117-2013 smolder test standard and FMVSS (Federal Motor Vehicle Safety Standard) 302, as regulated by the National Highway Traffic Safety Administration (NHTSA). As is the case with all flexible polyurethane foams, great care should be taken to avoid contacting a viscoelastic product with an ignition source such as a lit match or candle, heating element, sparks, exposed electrical wires, an exposed light bulb or smoking materials. Once ignited, all flexible polyurethane foams have the potential to burn vigorously, emitting great heat and dense smoke.

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Summary

Viscoelastic (memory) foam technology represents an alternative to conventional and HR flexible polyurethane foams. It's performance in bedding has had a tremendous impact on share of market in the mattress industry and created a strong market for mattress toppers, specialty pillows, and more.

- Viscoelastic foam is a type of open cell, flexible polyurethane foam.
- Surface comfort and pressure distribution are closely related to the foam's ability to conform to body shape.
- Slow recovery adds comfort characteristics.
- Viscoelastic foam firmness, support and height recovery rate are often affected by temperature and humidity.
- Comparative laboratory testing must match ambient testing conditions for accurate comparisons and replicability of test results.
- Viscoelastic products should be thoroughly ventilated after production and during fabrication to reduce the possibility of bothersome aromatic emissions.

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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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