The Complete Foam Buyer's Guide

This comprehensive guide to foam protective packaging is the easiest way to get the right industrial packaging protection for your equipment or product

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Why foam is an effective packaging material

Foam is lightweight and relatively cost-effective to manufacture, it can protect a shipment during transit without adding substantial weight and cost.

That makes it an effective cushioning and vibration dampening medium for one-off and reusable packaging for many products — especially sensitive and/or fragile ones. It's also often used for blocking and bracing and shock and vibration protection in crates and cases.

Expanded foam was invented during World War II — its original application was for floatation devices for the military. Shortly after its invention, it became obvious that polyethylene foam (PE) was also an excellent packaging material. Because most early foam applications were for the military, standards were developed that provided industry-wide consistency of sizes and foam properties.

Foam is made from different chemical polymers that are then expanded or blown by other chemicals, gasses, or processes to create an expanded foam material with tiny air bubbles inside. These air bubbles, surrounded by the plastic or rubber structure around it, provide cushioning and protection from shock and vibration.

The primary characteristics of foam that make it ideal for packaging and material handling are:

- Elastic and resilient (Like a spring it returns to its original shape)
- Weighs very little
- Widely available
- Cost-effective to manufacture
- Durable and resists tearing
- Easy to fabricate into shapes
- Provides shock absorption on impact

Common foams

There are many different types of foams used in packaging because they are relatively easy and cost-effective to fabricate into useful shapes and designs.

Some of the most common foams are:

Polyethylene

Crosslinked polyethylene

Polyurethane

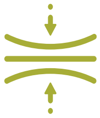
Polypropylene

Rubber and other speciality materials

Each type of foam can come in a wide range of:

Densities

Stiffnesses



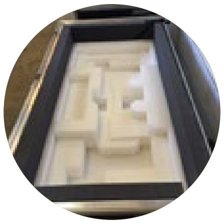
Resilience and responsiveness (IFD-indentation force deflection)

Chemical, anti-static and other physical properties

The geometry, amount, and type of foam are important decisions to:

- Manage stability
- Protect from shock (during drops or impacts)
- Protect from vibration (during transportation)
- Prevent abrasion and other functional, physical, or cosmetic damage
- Organize parts or tools (making them easier to use)

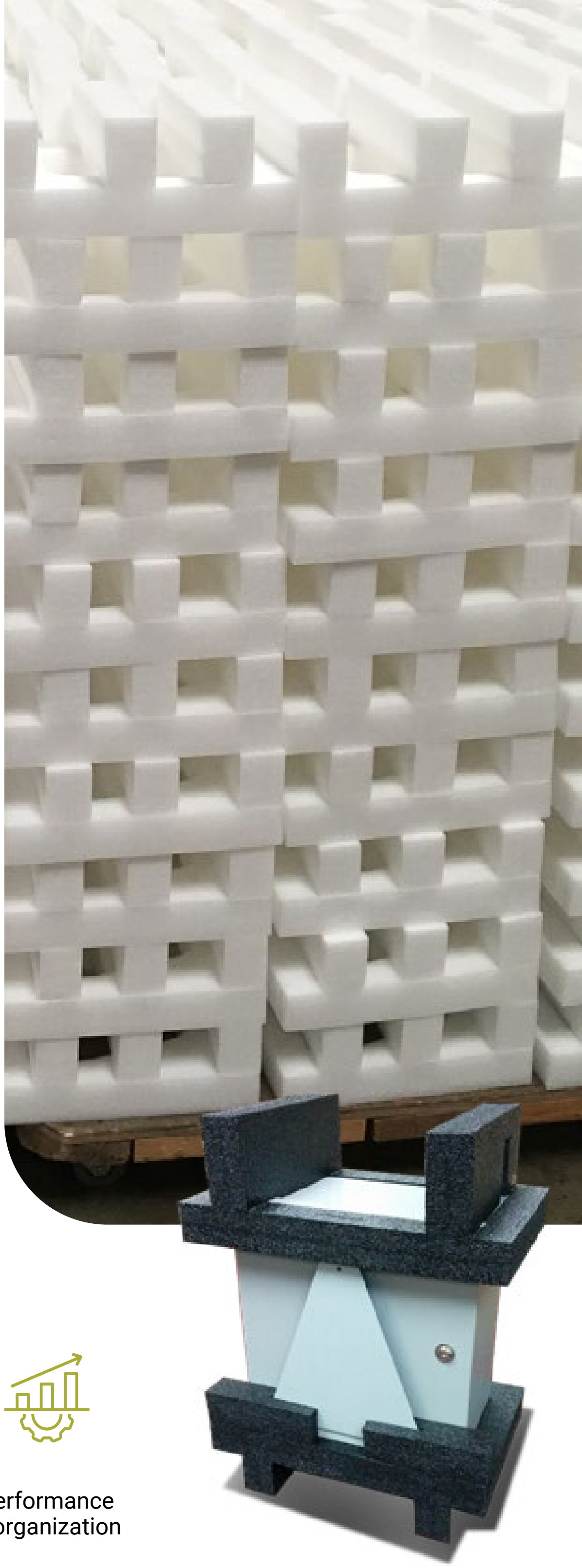




Every foam application is unique

Foam can be designed, cut, and fabricated to hold almost any shape. Many products have protrusions like flanges, brackets and buttons that change the overall surface of the product or have varying degrees of fragility or ability to bear weight all of which can be accommodated with a foam packaging design.

Foam is easily adapted with grooves, notches and curves to suit a product's uniqueness. A good packaging design will contain and protect your product at an optimal price while meeting your branding or presentation goals. The choice of a particular foam is made by considering the application or problem to be solved.



- Weight & fragility
- Positioning & cushioning
- Abrasion
- Appearance (color & texture)
- Accessories
- Others factors such as off-gassing
- Performance & organization

Foam constructs such as trays and inserts can have other benefits such as isolating and organizing separate components or sub-assemblies. Once the needs of the application are determined, a packaging designer will need to determine and specify:

1. Foam type
2. Density and performance characteristics
3. Bearing area, static loading and cushion thickness

Common industrial protective packaging foams

1 Polyurethane

Polyurethane (PU) is a common polymer used to make foam, particularly for furniture, but also for packaging. It has an elastic open-cell structure, and is relatively soft, which provides a wide range of performance especially useful for delicate and lightweight items, or those very sensitive to vibration.

2 Polyethylene

Polyethylene (PE) is a closed-cell, non-absorbent foam that is impervious to mildew, mold, rot, and bacteria. It is also highly resistant to chemicals. A medium-weight polyethylene foam provides excellent protection for products that have average to low fragility.

With the right design it can also protect lighter and more fragile products. It is great foam for positioning and cushioning. PE is available in extruded planks, or laminated sheets. PE is available in a wide range of thicknesses, densities and colors. Recycled PE is one of the most used foam packaging materials.

3 Cross-linked polyethylene

Cross-linked polyethylene (XLPE) foam is a high density, closed-cell foam that has a compact feel and resists water and chemicals. The cross-linking of polyethylene is a chemical or irradiation process that ties all the polymer molecules together with a strong chemical bond.

XLPE has many of the same properties as polyethylene foam, and can protect class “A” surfaces (will not affect any exposed or visible part of an automobile interior or exterior — it can be placed directly in contact with and will not scratch or mar high finish surfaces). XLPE is used extensively in the packaging of medical products and equipment, and many multi-part presentation kits.

Most PU and PE and some XLPE foams are available in anti-static formulations.

4 Expanded polyethylene and polypropylene

Expanded polyethylene (EPE) and expanded polypropylene (EPP) — also referred to as beaded foam — are produced by “popping” or expanding and fusing with temperature and pressure, small beads of polymer in a mold. EPE is safe for Class A surfaces. Both EPE and EPP are used extensively in automotive and packaging applications where durability, multiple impact resistance and other demanding performance challenges must be met.

These foams also have very low compressive creep, and will return to their original shape after continuous loading. Both EPP and EPE offer superior cushioning ability at half the density compared to other materials. It can be a great material for many packaging applications because less of it can be used than traditional PE or cross-linked polyethylene (XLPE) and it is also recyclable (XLPE is not).

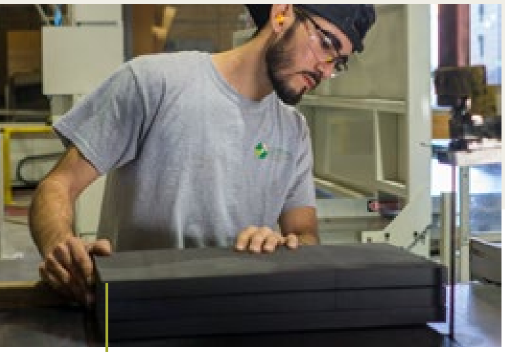
EPE beaded foam is also available in an anti-static version black at 1.9 # density.

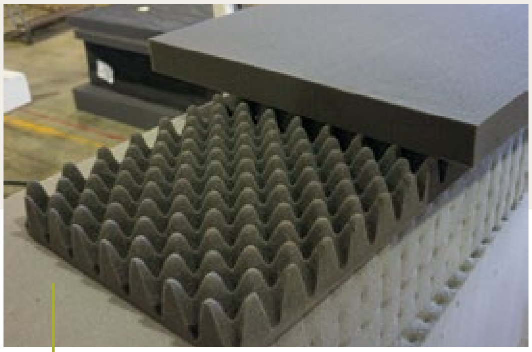
Typical foam packaging production methods

Foam is manufactured in buns (large blocks) or planks and may have to be cut or skived (trimmed or split to exact thicknesses) into sheets before it can be further processed.

A foam packaging product must then be custom cut and manufactured into smaller parts and often requires some assembly. There are many different fabrication technologies available depending on the shape, quantity, and quality that is required for the application, need for precision, and budget.

Most foam manufacturing is provided locally to customers because the creation of a foam packaging product is often a creative, iterative process between the customer, design, and manufacturing — and it is costly to ship as a non-value-added raw material.





Blocking, band saw and slitter

Bandsaws of different types are used to break down PU buns, cut sheets to specifications, and cut parts such as bars in crates.

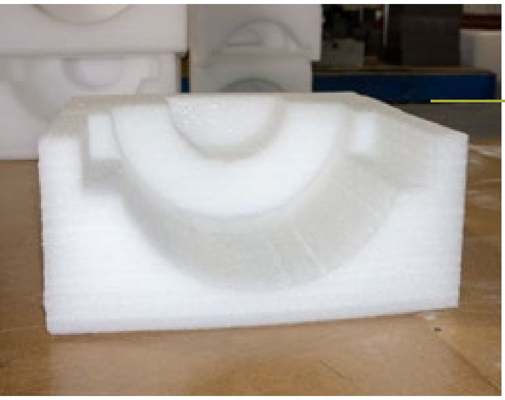
Convoluter

Convoluted foam sheets, also known as “egg crate” are made by splitting a mechanically deformed foam sheet into two sheets that have peaks and valleys and nest together. The convoluter pushes the foam through rotating rollers with fingered pins, stretching and distorting the foam.

When the blade passes through the distorted material it cuts a straight path, and when the foam rebounds back to its original sheet size, the egg crate pattern is the result

Skiver

Foam comes in sheets or planks of a standard thickness. Skiving is the process of cutting foam to a specific thickness required by our customers. At Larson Packaging Company, we are able to skive virtually any material to a precise thickness.



Profiles or contour cut

Profiles or contour cuts are specific shapes other than a square or rectangle, usually on a thick piece of foam (not suitable for die-cutting). Any rectangle with a slot, notch, or curve, cylinders, large diameter or wavy cuts, odd geometric shapes or any shape cut within another long block are all profiles. Profiles can be made with a manual fast-wire saw or horizontal or vertical CNC cutters using fast wire or thin saw blades.

Die cut and die press

After the final shape has been prototyped, tested, and finalized, a steel-ruled die on a hydraulic die-press is often used to produce higher volumes of parts. A die press uses a ram and a steel rule die (the tool) in order to cut the proper shapes.

A die is a special shaped blade like a cookie-cutter specially designed to cut shapes and maximize yield. The press uses high pressure (many tons) to push the blade through the foam to produce the shape just like pushing a cookie cutter through dough.

Die-cutting is one of the most efficient ways to create a foam shape or cavity. Multiple shapes and parts can be grouped together on an individual die. This way each "hit" creates a multiple piece set, which can be produced every few seconds, making the die cutter the work horse of foam fabrication. This process requires tooling (the "die") which can be produced in a matter of days.

Die-less

Die-less cutting is traditionally used for low-volume runs and prototyping where the cost of a steel rule die cutting tool is not justified. Die-less cutting uses a CNC (computer numerically controlled) table equipped with an oscillating knife — a programmable machine capable of making precision cuts. The resulting walls are precise and straight at full depth. Die-less cutting can be used to cut a wide variety of foams as well as corrugated fiberboard and plastic corrugated material.

At Larson Packaging Company, we have the capabilities to die-less cut a wide variety of foams as well as corrugated fiberboard and plastic corrugated material on our CNC and Kongsberg machines.

Watch in-action >

Waterjet

Water only waterjet cutters use a high-pressure fine stream of water to cleanly and precisely cut foams, plastics and other soft materials with incredible precision. Waterjet cutting is excellent for both prototyping or short production runs as well as large volume production.

Unlike CNC machines that are slower and use knives that have both kerf and produce lateral force on the material being cut, the waterjet cutters use a non-contact form of cutting that creates minimal lateral force on the material and virtually no kerf (lost material due to the cutting tool). There's simply no risk of compressing, deforming, or melting the material. And, because of these features, the machine can cut complex shapes, radii and very thin walls consistently, precisely and fast. This makes waterjet cutting perfect for high-end upmarket case interiors that need a perfect presentation.

The most advanced waterjet cutters like our new WARDjet J106 cutters can also use multiple heads including a 5-Axis cutting head that enables chamfers, bevels and complex three-dimensional shapes to be cut in one pass. Or multiple layers of material and versions of each profile. This delivers in excess of 50% improvement in processing speed and a corresponding reduction in manual labor for cost savings and turnaround times.

Our WARDJet J-106 waterjet cutter can cleanly cut foams as thick as 8 inches in a single pass. Plus, it will cut up to 1⁄2" thicknesses of ABS, PVC, PVC foam, HDPE and plywood. A conveyer belt table and sensor-based controls automate material loading and can manage either large rolls or flat sheets for greater efficiency and faster turnaround times.

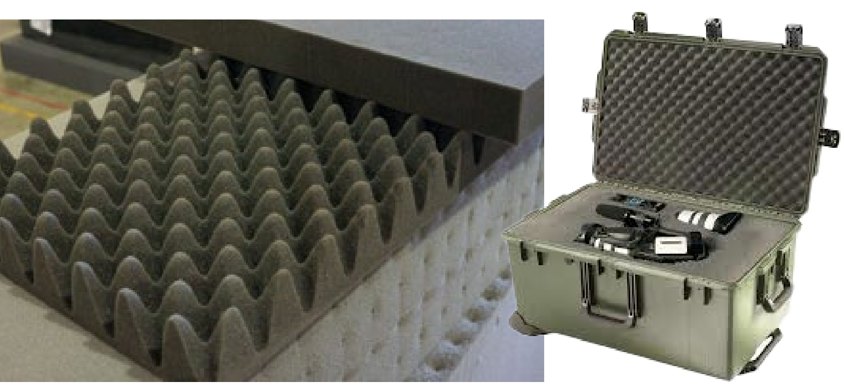
The most common form factors of foam for packaging applications

- Cut-to-size pads or bars
- Convoluted foam
- Foam end caps, or top and bottom frames
- Cut to shape or cavity cut—Die-cut, dieless cut (flash/CNC knife), water jet, profile/contour cut, or routed
- Heat-welded foam assemblies
- Corner protectors/corner blocks
- Adhesive-bonded foam assemblies
- Trays and inserts
- Foam and corrugated combo assemblies
- Floater base/shock pallet cushioning systems

Common foam packaging form factors and assemblies

Plain pads and bars

Plain pads and bars can be used as a single layer inside a rectangular cavity (such as a box, crate or molded case). In addition to protection, they can provide organization, blocking and bracing, and other properties such as thermal insulation. Pads and bars are also used in many crates and crating applications.



Convoluted foam

A single sheet of convoluted foam is effective for packaging several items of different sizes together. A sheet of convoluted foam may be used on the lid of an enclosure such as a hard case because it will put positive pressure and hold down force on the item, yet will give when it is closed and not put too much pressure on the item or seal.

End caps, side caps and top and bottom frames

Many products are packed in corrugated or other boxes and suspended by a foam set comprising end or side caps, or a top and bottom frame depending on how it will be loaded. In addition, these types of assemblies can comprise cutouts to hold accessories, documentation, other items etc.

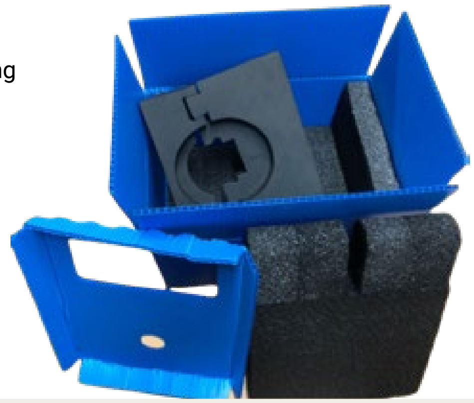
Multiple foam parts can be assembled to create protective foam packaging shapes of many different designs. Most parts are easily glued together by using a hot-melt adhesive. Hot melt is also effective in gluing different foam types and/or to different materials, such as corrugated. Spray glue or contact cement can also be an effective adhesive.

Multiple PE parts are typically heat sealed or welded together. This leaves no adhesive residue and provides a stronger bond for the joined union. Complex or compound parts can include foam and corrugated assemblies, case inserts, and trays.

Foam packs and trays for corrugated and hard cases

Many components or subassemblies will frequently need to be packaged in a single enclosure. A foam pack may consist of several layers of foam shapes and trays designed to isolate each component. When cost is an issue, standard foams work well and are easy to fabricate. If appearance and durability or cleanliness are more important, specialty foams can be used because they last longer, have better performance, and have a better look and feel.

The foam pack can also be designed to protect different products or models having some similar dimensions with the use of perforations, removable inserts and the like. When several packaging goals are important such as to provide separate protection, organization, and aesthetic presentation, it is crucial to work with an experienced designer.



Foam for crating such as blocking and bracing, shock-mount bases, etc

Foam is used in crating for blocking and bracing to prevent movement of products/equipment within the crate. Simple blocks are easily cut with a bandsaw and glued to the walls or corners of a crate to provide increased stability of the contents. Most crate contents are relatively heavy and can often weigh thousands of pounds.

Also, abrasion can damage the surface of the contents through constant rubbing against the foam during transit. Foam is a critical component in shock-mount systems, also commonly known as floater pallets, floater decks or floater bases. Selecting the right foam for the job is critical.

The foam creates a cushioning layer between the material handling pallet and the support surface on which it "rides". Many shock-mount systems support very heavy products. The foam can be constantly under pressure and wear, degradation, and compressive creep (see design considerations) can affect the performance of the system over time.

Significant compressive creep will degrade foam performance and may make loading or unloading difficult. It is important to select a foam that performs for floater bases and side blocking.

Engineering cushioning systems for protective packaging

Many components or sub-assemblies will frequently need to be packaged in a single enclosure. A foam pack may consist of several layers of foam shapes and trays designed to isolate each component.

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Packaging design is an important consideration that affects performance during transit, cost due to damage caused during shipping, and presentation of your product. Often, a company is trying to optimize between three parameters: performance, cost, and presentation, based on its specific needs.

The primary purpose of packaging is to protect the product/equipment during transit to its destination.

No matter the exterior of the package, whether it be a corrugated box, crate, some sort of hard case, or something else, the interior foam cushioning system protects your product from damage due to shock and vibration. Often the nature of the product will dictate the kind of foam used in a cushioning system, but the specific type, density, thickness and overall amount of foam should be a combination of judgement, experience, and calculations by an experienced packaging engineer.

How g-forces and drop height affect cushioning requirements

A cushioning system is designed based on a detailed understanding of the product to be packaged and the environment that the package will be shipped in. Supply chains can be very abusive. And once your product ships, it is out of your control. The first thing to consider is product "fragility" and can be found during bare product testing.

As a reference, Table 1 lists some typical products, their fragility category, and the amount of force that they can generally withstand as a multiple of the force of gravity (typically abbreviated to g) (applied as a deceleration, such as a drop).

TABLE 1: Product g-Sensitivity

CATEGORY	FRAGILITY	g'S
Laser optics, aligned optics and mirrors, telescopes, unique laboratory devices.	**Critically Fragile**	**<15**
Aircraft altimeters, gyroscopes, items with delicate mechanical alignments. Biomedical electronic gear, medical.	**Extremely Fragile**	**15-25** **40-50**
Diagnostic apparatus, X-ray equipment, microwave tubes. Navigational equipment. Electromechanical –equipment, printers copiers, display terminals, printers, test instruments, hard disk drives.	**Very Delicate**	**25-40**
Stereos and television-receivers, floppy disk drivers. Computer processors, TVs, monitors, electronic-games, calculators, solid state electronic devices.	**Moderately Delicate**	**0-85** **70-100** **or 150**
Major appliances, furniture table saws, sewing machines, machine tools.	**Moderately Rugged**	**85-115**
Raw egg.	**Rugged**	**115+ 200+**

A product's g-force sensitivity is the maximum force that the product can withstand without damage, and can be either estimated, or determined by testing. The shipping environment comprises different modes of material handling and transportation such as:

- Forklift
- Truck (LTL, FTL)
- Airplane
- Ship
- Rail and other

The entire transit path should be examined to profile and maximum shock and vibration to which your package will be subjected. The various handoffs and handlers include:

- Common carriers
- Local delivery
- Warehouses
- Third parties/3PLs
- Multiple shipping/ receiving departments

Shock is determined by the potential drop heights and product weight. The weight of the product will limit the drop height.

For example, boxes weighing less than 50lbs can be manually unloaded off the back of a truck, so a drop height of 30-48" (the approximate height of the back of a trailer) might be appropriate. Whereas, anything 100lbs or more will normally only be 6-8" off the ground for handling with a pallet jack or forklift.

Table 2 illustrates some typical drop heights based on a weight and the mode of transportation.

TABLE 2: Typical Drop Heights by Weight

WEIGHT RANGE (LBS)	HANDLING TYPE	PROBABLE DROP HEIGHT (IN)
0-10	**1 person throwing**	**42**
10-20	**1 person throwing**	**36**
20-50	**1 person throwing**	**30**
50-100	**2 person carrying**	**24**
100-250	**Light equipment**	**6-8**
>250	**Heavy/Forklift**	**6-8**

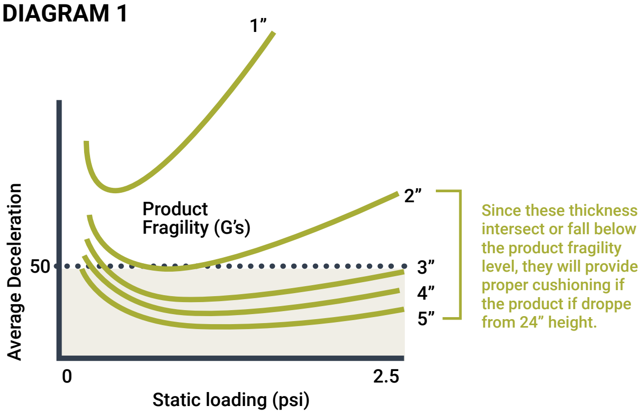
The g-force and the drop height determine the requirements for the cushioning system.

Other factors such as creep, buckling, and change in material behavior due to temperature may affect the performance of a cushioning system to different degrees and should be considered.

Material requirements

When product fragility (g-force) and handling environment (drop height) have been determined, the packaging engineer can calculate the amount of functional cushioning material which will provide adequate protection for the packaged item.

DIAGRAM 1

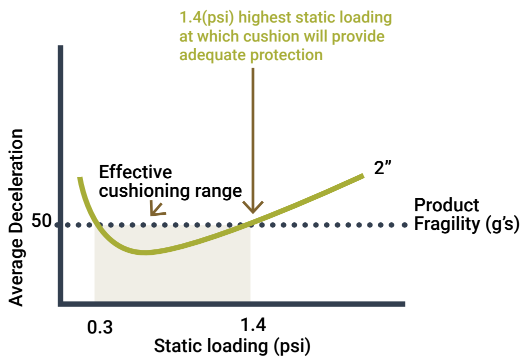


Using dynamic cushion curves

Cushion curves are provided by manufacturers for each type, and density of foam. The curves for different thicknesses of foam represents performance for a given combination of thickness, drop height, and number of drops (foam can lose performance over multiple drops). In Diagram 1, a 1" thick piece of foam will NOT provide ample cushioning for a product that has a product fragility of 50g and is dropped from a height of 24".

However, a 2", 3", 4", 5" thick foam will provide cushioning for a wide range of static loading.

DIAGRAM 2



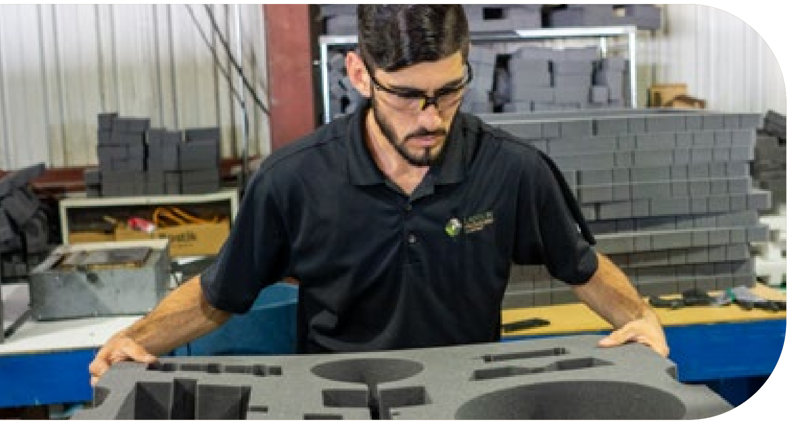
0.3(psi) Lowest static loading at which cushion will provide adequate protection

Notice that a 2” thick foam will provide adequate cushioning only in a range of static loading from 0.3 to 1.4 psi (see Diagram 2). This tells us that, with a 2-inch cushion, we can apply a static loading anywhere within this “cushioning range” and still protect to 50g or lower. The highest static loading value within the cushioning range will result in the most economical design because it will use less cushioning material to provide adequate protection, thus lowering materials cost, weight, volume, etc. If too little foam Is used the product may bottom out with a shock.

And if too much foam is used it leads to wasted foam, but mostly may not perform as a spring and become like a “brick.” Designing to the minimal foam volume required is usually the baseline, but in practice, the optimal solution may include some additional thickness or volume based on performance (especially vibration) and cost trade-offs.

An experienced packaging engineer will consider many factors when designing a foam construct such as:

- Eliminating damage
- The geometry and load bearing area
- Final package size
- Manufacturing yield
- Cost and more



Vibration control

Many products, however, are more susceptible to damage from vibration during transportation than shock. Vibration can become the single biggest problem customers and their products face.

Sensitive equipment like medical devices packaged in crates are especially vulnerable to damage from vibration. Bigger products are often more vibration sensitive. Every mode of transport subjects the packages being shipped to some amount of vibration at various frequencies. In order to protect products which are prone to vibration damage against such effects, it is essential to determine the natural frequency of any component which is sensitive to vibration damage and compare it against the vibration characteristics of your package design.

For most vibration-sensitive products, making sure that the package design does not excessively amplify vibration in the product’s natural frequency is enough to prevent vibrational damage from occurring during shipment. For severely vibration-sensitive products, however, it may be necessary for the package design to attenuate the frequencies of concern.

That is the goal around the resonant frequency.

TABLE 3: Forcing Frequencies of Carries

MODE	FREQUENCY	SOURCE OF VIBRATION
Railroad	2-7 Hz (suspension) 50-70 hz (structural)	Moving freight car
Truck	2-7 Hz (suspension) 15-20 Hz (tires) 50-70 Hz (structural)	Normal highway travel
Aircraft	2-10 Hz (propeller) 100-200 Hz (jet)	On aircraft floor during flight
Ships	11 Hz(on deck) 100 Hz(bulkheads)	Vibrations caused by interference to the flow of water by the ship,and from imbalance and misalignment of the propeller shaft system.

Design packaging to keep vibration ideally one octave below the resonant frequency that destroys the bare product. Urethane and Polypropylene foams are excellent for vibration but have very different physical and dynamic properties.

As with shock, there is no substitute for testing the vibration characteristics of your design. However, in some cases, vibration performance may be estimated from some knowledge of the vibrational characteristics of the foam product used.

Design and creep, buckling & extreme temperature

In most cases, the design approach above results in economical designs which adequately protect your packaged product.

There are three constraints that must be checked, however, to be sure this loading and design will not create other problems:

Compressive Creep

Compressive creep is the gradual loss of thickness a material may experience if placed under a constant load for an extended period. Higher temperature, more creep potential. Significant compressive creep will result in the packaged product loosening in the cushion and becoming vulnerable to excessive movement inside the package during shipment.

Excessive creep can result in significant loss of cushion performance. For example, once a floater base exhibits creep, it will become difficult to handle the crate with a pallet jack or remove the product from the crate, (particularly if the creep causes alignment problems with a ramp). Creep can also be affected by temperature (sometimes crate designs can be adjustable to account for this if products are stored for an extended time.

Other strategies for alleviating creep are:

- Use a lower static-loading
- Spreading the loading over a larger area
- Use a different foam

Beaded foams and XLPE exhibit less creep.

Cushion Buckling

Buckling is the non-uniform compression of a cushion. When buckling occurs, the energy of the impact is not transferred evenly throughout the cushion and more shock is transferred to the package contents. Buckling usually occurs when the cushions become too tall and thin.

Extreme Temperature Effects

When foams are exposed to extremely high or low temperatures over a considerable length of time, they may be affected. The materials become stiffer at low temperatures and increasingly softer at higher temperatures, which could also affect adhesives. In extreme cases, it may become necessary to compensate for these effects when designing.

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