

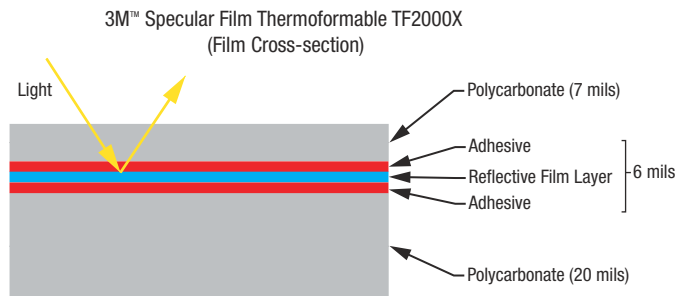


Product Description

3M™ Specular Thermoform TF2000X (the “Product”) increases the optical efficiency of a light fixture by using precise reflection optics to raise the lumen output. Reflectors can be custom designed to your specifications for a variety of light control options including directing the light exactly where you want it. Made of a lightweight polymeric, multilayer optical mirror film, 3M™ Specular Thermoform TF2000X provides up to 98% reflectivity with greater than 97.5% average surface reflectivity in most applications¹. This novel film can contribute to reduced costs for LED, lens, and tooling costs, and energy consumption.

The intent of this instruction bulletin is to provide guidelines that an optical, mechanical and/or application engineer should take into consideration when designing products to take full advantage of the performance enhancements 3M™ Specular Thermoform TF2000X can provide.

¹Parts with aspect ratios < 0.5 and areal draw ratio < 2.0. Parts with higher draw requirements (thus wall thinning) can be lower. Wall thinning is determined by part shape and depth of draw.



TF2000X is a laminated construction of polycarbonate and specular film. Total thickness of all three layers plus adhesive is approximately 33 mils. For best reflectance/optical performance, light should be reflected thru the thinnest layer of polycarbonate.

The thinnest side can be determined by viewing the edge of the material. The thicker side of the material will appear darker than the thinner side.

Figure 1. TF2000X Film Cross-section

WARNING

To reduce the risks associated with fire hazards, which if not avoided could result in serious injury and/or property damage, do not use this material in lighting applications where temperatures might exceed 176 °F (80°C).

CAUTION

Always provide adequate ventilation and/or personal protective equipment (PPE) in thermoforming production areas to reduce the risks associated with exposure to thermal decomposition products. Failure to provide adequate ventilation and/or PPE may result in serious injury or exposure to potentially harmful vapors.

An experienced industrial ventilation engineer and/or a certified industrial hygienist can evaluate your ventilation and PPE requirements based on your on-site process conditions and help to ensure that worker exposure is kept below occupational exposure limits. Always refer to the manufacturer's literature or Safety Data Sheet for additional details and recommendations.

Introduction

When designing reflectors for lighting using 3M™ Specular Thermoform TF2000X technology, consideration should be made concerning a number of key attributes, including shape, trimming options, operating environment and production considerations. In the design cycle of a new lighting product, the optical/mechanical engineer is encouraged to follow these reflector design guidelines to create an optimized reflector for the intended purpose of the application.



Figure 2. Thermoform parts examples

Forming

The forming process transforms flat polymeric sheets into 3D shapes by first heating the material, then forming it over a tool. Various process controls are employed to aid in part conformance to the desired shape. An important note to consider is that the material must stretch to some degree to achieve conformance to the tool. Optical dimensions are maintained, while wall thickness can vary. As discussed below, the degree of stretching is a function of a number of variables.

Shape

Based on standard forming techniques, almost any shape imagined can be formed using 3M Specular Thermoform TF2000X Film. There are limitations, however, in regards to available sizes, depth of draw, radius considerations, etc. For example, if a sample is too deeply drawn, wall thinning will reduce reflectivity. Wall thinning is a function of part shape and process conditions/technique. Please refer to the following table highlighting basic shape considerations.

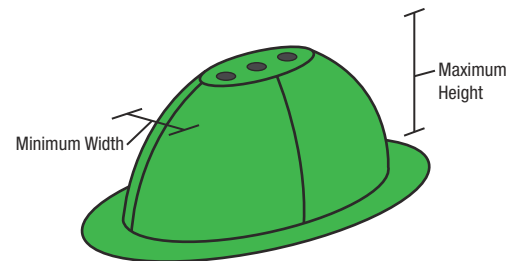


Figure 3. Basic part shape considerations

Effect of Aspect Ratio and Draw Ratio on Localized Thinning

| Ease of Forming (Guideline Only) | Aspect Ratio (Max Height/Min Width) | Areal Draw Ratio (Surface Area/Cavity Open Area) |
|---|-------------------------------------|--|
| Easy to form | < 0.5 | < 2.0 |
| Moderate forming challenges | 0.5 - 0.8 | 2.0 - 2.5 |
| Difficult forming challenges (Degraded optical/mechanical performance) | > 0.8 | > 2.5 |

Aspect Ratio is determined by finding the Maximum Height (tallest or deepest portion of the part) and dividing that by the Minimum Width (the narrowest portion orthogonal to the Max Height direction). See Figure 3. The smaller this number is (refer to above guidelines), the easier the part will be to form in regards to part fidelity and optical performance.

Areal Draw Ratio is determined by taking the part's total Surface Area and dividing that by the Cavity Open Area (aperture or opening cross-sectional area). This number will give a general indication of part thinning as it is formed along the part opening plane (in most designs). The smaller this number is (see chart above) the easier the part will be to build.

NOTE: If a part tends to fall in one or more of the difficult regions highlighted in the guidelines above, it doesn't mean that the part cannot be made. With these more difficult high Aspect Ratio parts, the designer is encouraged to work closely with 3M in addressing specific optical and/or mechanical challenges which could occur.

Part Size (Maximum Width)

| | |
|---|-----------|
| Minimum Part Size | 0.5 in. |
| Typical Part Size | 2 - 6 in. |
| Maximum Part Size (Aspect Ratios < 0.5) | 20 in. |
| Maximum Part Size (Aspect Ratios > 0.5) | 16 in. |

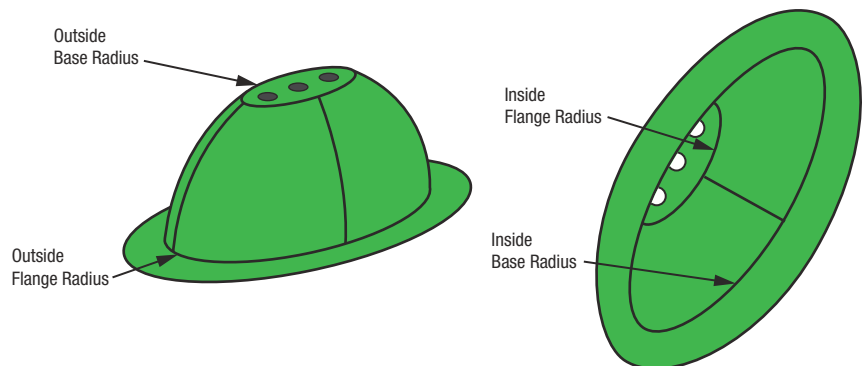


Figure 4. Inside/outside flange radius and base radius

Radius and Draft Angle Considerations

| | |
|------------------------------|-------------------------|
| Base Radius Inside | > 0.020 in. |
| Base Radius Outside | > 0.030 in. |
| Flange Radius Inside | > 0.060 in. |
| Flange Radius Outside | > 0.040 in. |
| Draft Angle | > 8 degree is preferred |

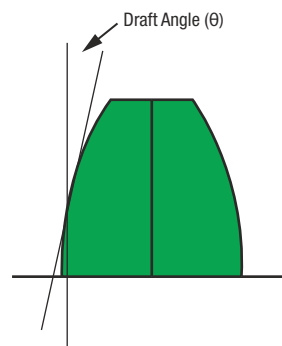


Figure 5. Draft angle

Material Thickness

Specular Thermoform TF2000X film is available as 0.034 in. thick film and is intended for use as a rigid standalone reflector.

Like all plastics which go through the forming process, final caliper will vary depending on shape geometry and process conditions (see earlier shape section). Care should be taken to ensure that the most critical dimensions are maintained, however one can expect wall thickness to vary between 100% of nominal to as thin 60% in extreme cases. Sharp localized features should be avoided as well as high aspect ratio parts.

Most low aspect ratio parts experience thinning of less than 20%, thus they maintain high reflectivity and color uniformity.

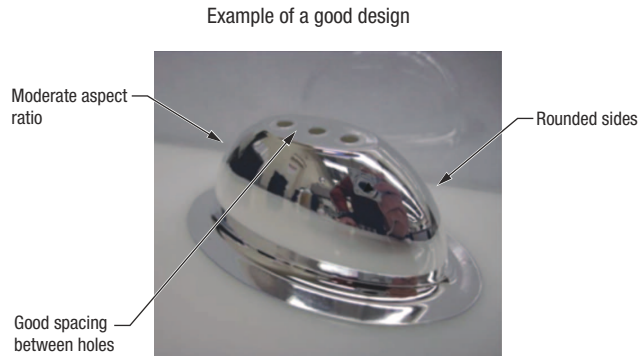


Figure 6. Example of a good design

Effect of part thinning in high aspect ratio parts



Figure 7. Effect of thinning in high aspect ratio part

Effect of part thinning in high aspect ratio parts

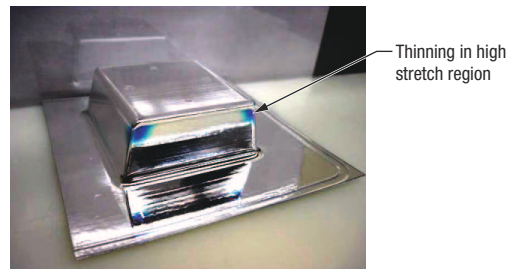


Figure 8. Effect of thinning along sharp corners/features

Trimming

After forming, most parts need to be trimmed to their final dimensions, including cutouts. Consideration should be made during the design phase as to how the part is to be trimmed in order to minimize tool costs and meet tolerance specifications.

Steel rule die punching is the most economical method of trimming. Low up front tooling costs and multi-punch capability make this the first choice in trimming methods. In order to use this method, all cut outs should be simple in form and be on a similar cutting plane.

Matched metal die punching is the most economical and precise method of trimming more difficult cut patterns at high volumes. Typically, up front tooling charges are highest for this technique.

Laser and/or high speed routers can be used for difficult cut patterns, with low up front tooling charges. However, piece part trimming costs are high compared to match metal die as part volumes increase. This technique is most useful during the prototype stage where tooling charges are minimized and a fast turnaround time is desired.

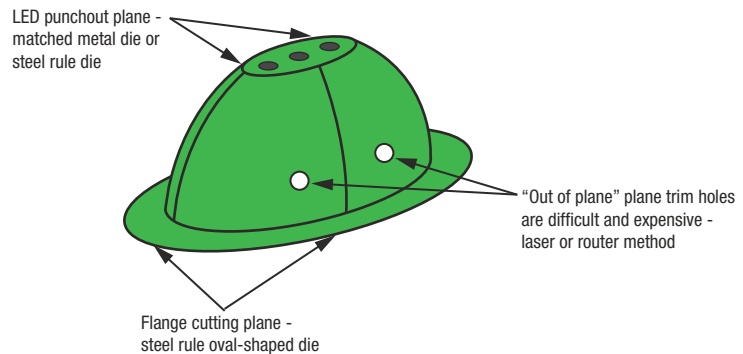


Figure 9. Trimming examples

| Trimming Attribute | Typical Value |
|---|------------------|
| Punched circular hole diameter | ≥ 0.125 in. |
| Corner radius on square cut | ≥ 0.030 in. |
| Distance Between Holes | ≥ 0.080 in. |
| Trimming Tolerance Parts < 6 in. in width | ± 0.005 in. |
| Trimming Tolerance Parts 6 in. to 12 in. in width | ± 0.007 in. |

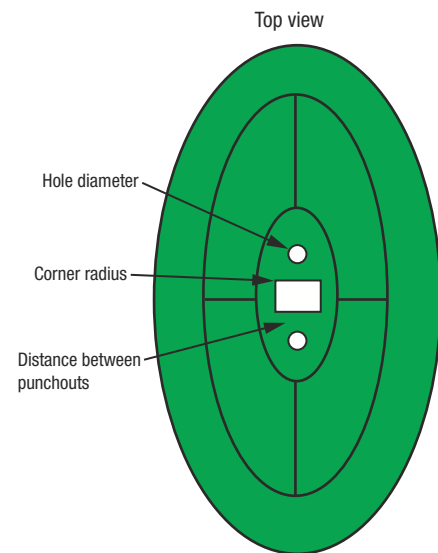


Figure 10. Trimming attributes

Environmental

3M Specular Thermoform TF2000X technology is based on an all polymeric material set. As such, reflectors exhibit no corrosion or electrical conductivity issues, which are typical in metal coated films and substrates. For outdoor LED applications, intense UV sources and/or exposure to sustained heat greater than 176°F (80°C) may cause damage to reflectors. Carefully evaluate potential outdoor applications.

In outdoor LED applications with the reflector exposed to indirect sunlight, use only with a UV absorbing glass or lens to protect the reflector.

NOTE: After accelerated testing², samples exhibit change in CIE b* of less than 4 units.

² Accelerated dosage at UV sensitive wavebands was equivalent to that which occurs after 10 years at the surface of a 32 Watt T8 fluorescent bulb. This assumes the light is on 24 hours per day. Testing temperature was maintained at 95 - 104° F (35 - 40° C).

High Intensity Radiant Flux

When using high intensity radiant light sources such as LED's, designs should be considered which minimize radiant flux density, time of exposure and heat. In high irradiance applications, 3M Specular thermoform TF2000x film can begin to yellow and brown in time. Initial models estimate that the first onset of yellowing will occur after a blue radiant exposure of 50kJ/mm² at 122° F (50° C). For example, a reflector made of 3M Specular Thermoform TF2000X film placed 5 mm from the edge, and perpendicular to the base, of a typical 100 lm (4000K) LED, is estimated to remain colorless for at least 115K hours at 122° F (50° C). Higher operating temperatures are expected to shorten this lifetime.

IMPORTANT NOTE

Do not use in incandescent applications due to temperature limitations.

Do not use exposed in outdoor applications.

The customer is solely responsible for evaluating and determining whether this 3M product is suitable and appropriate for any particular application or manufacturing process.

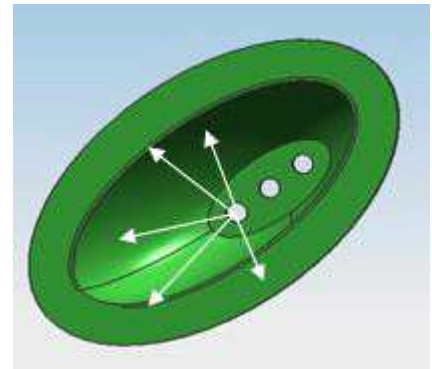


Figure 11. Best for indoor LED applications



Figure 12. Good for CFL and fluorescent applications

Storage Conditions

| Characteristic | Value |
|---------------------|---------------------------------|
| Storage Temperature | 40° F to 100° F (4° C to 38° C) |
| Storage Location | Out of sunlight |
| | Clean, dry area |
| | Keep in original container |
| Shelf Life | 1 year |

Technical Information

Technical information and data, recommendations, and other statements provided by 3M are based on information, tests, or experience which 3M believes to be reliable, but the accuracy or completeness of such information is not guaranteed. Such technical information and data are intended for persons with knowledge and technical skills sufficient to assess and apply their own informed judgment to the information. The typical values shown should not be used for the purpose of specification limits. If you have questions about this product, contact the Technical Service helpline at 1-888-650-3497.

For more information or to order samples, please visit 3M.com/AMD.

WARRANTY

Product

3M™ Specular Thermoform TF2000X (the “Product”).

3M Basic Product Warranty

The Product(s) specified in this document are warranted to be free of defects in materials and manufacture (“3M Basic Product Warranty”) at the time of shipment (“Warranty Period”) by 3M or its authorized distributor.

Limited Warranty

1. For the Products specified in this document, 3M makes the 3M Basic Product Warranty only.
2. EXCEPT TO THE EXTENT PROHIBITED BY APPLICABLE LAW, THE 3M BASIC PRODUCT WARRANTY IS MADE IN LIEU OF ALL OTHER WARRANTIES, RIGHTS OR CONDITIONS, EXPRESS OR IMPLIED, INCLUDING, BUT NOT LIMITED TO, ANY IMPLIED WARRANTY OF MERCHANTABILITY, SATISFACTORY QUALITY, FITNESS FOR A PARTICULAR PURPOSE AND THOSE ARISING FROM A COURSE OF DEALING, CUSTOM OR USAGE OF TRADE. THE BUYER IS RESPONSIBLE FOR DETERMINING IF A PRODUCT IS SUITABLE FOR ITS PARTICULAR PURPOSE AND APPLICATION METHODS.
3. For a buyer’s convenience, 3M may provide engineering or technical information, recommendations, installation instructions or guides, and other information or materials relating to a Product (“Other Product Information”), but 3M makes only the 3M Basic Product Warranty and does not warrant any Other Product Information.
4. 3M has no obligation under the 3M Basic Product Warranty as to Product that has been: (a) modified, altered or processed in any manner; (b) stored, applied, installed, or used in a manner other than that 3M recommends in this document and in all Other Product Information; (c) damaged through contact with a person or thing, misuse, accident, neglect, or other action by anyone other than 3M; (d) improperly installed, including, without limitation, installation after the expiration the Product’s shelf life or installation without proper surface preparation, or (e) exposed to excessive heat, humidity, dirt or UV light.
5. 3M must receive any 3M Basic Product Warranty claim in writing no later than 10 business days after (a) the end of the Warranty Period or (b) the discovery of the 3M Warranty claim, whichever is earlier.

Limited Remedy

IF ANY PRODUCT IS PROVEN NOT TO HAVE MET THE 3M BASIC PRODUCT WARRANTY DURING THE WARRANTY PERIOD, THEN THE BUYER’S EXCLUSIVE REMEDY, AND 3M’S SOLE OBLIGATION, WILL BE, AT 3M’S OPTION, TO REPLACE THE NONCONFORMING PRODUCT OR TO REFUND THE NONCONFORMING PRODUCT’S PURCHASE PRICE.

Limitation of Liability

3M WILL NOT UNDER ANY CIRCUMSTANCES BE LIABLE TO A BUYER FOR DIRECT (other than the Limited Remedy stated above), SPECIAL, INCIDENTAL, INDIRECT OR CONSEQUENTIAL DAMAGES (INCLUDING, WITHOUT LIMITATION, LOSS OF PROFITS) IN ANY WAY RELATED TO THE PRODUCT, THIS DOCUMENT OR OTHER PRODUCT INFORMATION, REGARDLESS OF THE LEGAL OR EQUITABLE THEORY ON WHICH SUCH DAMAGES ARE SOUGHT.