



GE Structured Products

Thermoforming LEXAN[®] Sheet: General Guidelines

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Easily Thermoformed with Sharp Detail

LEXAN sheet is easily thermoformed with sharp detail on any conventional forming equipment capable of quickly transferring the sheet from the heating station to the mold or forming table. Rapid transfer is necessary because the sheet cools quickly and becomes form-stable at a higher temperature than most other sign materials. Although double-oven automatic or semi-automatic forming equipment is recommended for LEXAN sheet, single-sided heating canopy-type equipment can be used. Avoid using separate heating and forming devices, such as are often used to form acrylic.

Always dry LEXAN sheet prior to vacuum forming.

Small amounts of moisture absorbed in storage or shipment can cause moisture bubbles, loss of forming detail and visually unattractive surfaces.

Drying

For drying, use a vented, air circulating oven at 250°F. Place the sheets vertically in the oven, or in racks that provide a minimum separation of 1" between sheets. When a sheet has been dried, it can be used for up to 12 hours without re-drying. When using automatic equipment, cool the sheet to room temperature to maintain uniform cycles. Remove protective masking before predrying.

Drying Recommendations

Thickness	Drying Time
.093"	4 Hours
.118	4
.150	8
.177	12
.236	24

Clamping Frames

Place pre-dried sheet in machine clamping frames capable of exerting sufficient force to prevent the sheet from pulling out during forming. The frame should also provide some stripping action as the formed part is removed from the tool.

The mass of the metal clamp frames can cause a substantial difference in sheet temperature between the relatively cool edges of the sheet and the heated center. Therefore, design clamping frames to allow maximum temperature build-up in the sheet under the clamp and always pre-heat the clamp frame.

Allow 1/2" – 1-1/4" between the clamp frame and the mold vacuum box to permit a positive seal. Also, shading is sometimes used on the center portion of the sheet to allow faster heating of the clamp and sheet edges.

Controlling Sagging

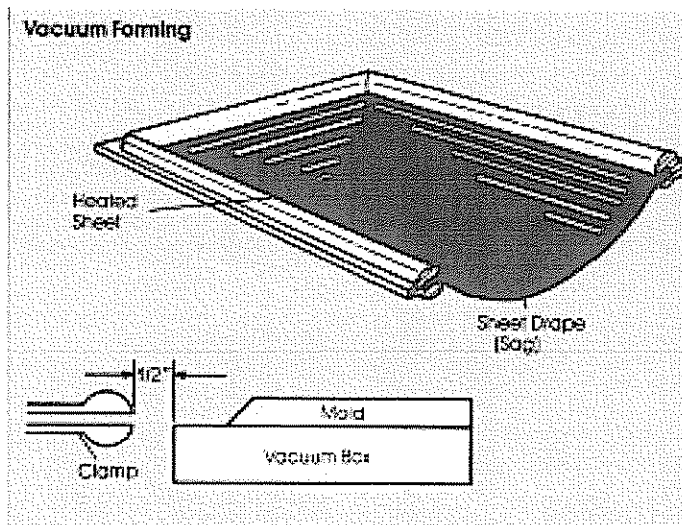
As the LEXAN sheet approaches forming temperature (350°–400°F range), it will begin to sag. The edges and corners of the sheet along the metal clamp frames must be softened sufficiently to provide a vacuum seal when the sheet is pulled over the vacuum box and mold. The sag is predictable, and is a reliable method of determining the heating cycle.

Uniform sag and consistent forming cycles are necessary for good part detail and proper registration of pre-decorated sign faces. To determine sag automatically, install an "electric eye" on the equipment. Determine the proper sag using a manual cycles, then set the electric eye to trip the forming sequence thereafter.

Heating/Cooling Cycle

When LEXAN sheet reaches forming temperature, bring it down over the tooling and apply vacuum. LEXAN sheet sets up very quickly, permitting a much shorter cycle than is possible with most other materials. Remove the formed part from the mold as soon as the material is form-stable and still hot to the touch. If possible, perform the trimming operation while the part is still warm to minimize flange warpage.

Another satisfactory, but less accurate method of controlling total heat input is to control the heating time. During production runs, electrical power fluctuations can cause variations in heat output. Air drafts, which affect the rate of heat absorption or oven temperature build-up, can also cause changes in the heating rate of the sheet. Since variation is often small, this type of heating control can be used for regulating sheet temperature. However, for the most critical type forming (prescreened sheets), more precise control, such as electric eye drape control, may be required.



Another concern when heating LEXAN sheet, especially in thicker gauges, is getting the proper amount of heat in the flange area. To ensure a flat flange, preheat frames to 250°F and maintain them at that temperature. This can be accomplished by shading the center of the sheet or by adding heaters immediately above the clamps or in the clamps themselves.

Shading or Screening

Shading, a technique used to balance out hot spots in an oven for temperature uniformity, can also be used to control the sag of LEXAN sheet when heated.

In addition to preheating the metal clamp, cold edges and corners, can be overcome by using ordinary metal window screening to shade all of the sheet except several inches along the edges.

The window screen can be positioned on a support rack between the heaters and the LEXAN sheet. The number of layers and position of the screen depends on the desired location and shape of the sag.

When using shading, heat slowly. This is especially important with heavier gauges of LEXAN sheet, to prevent gradient heating and to provide more opportunity for heat to be conducted to the center of the sheet. Reduce the heating rate by using a lower intensity or by moving the sheet away from the heaters.

Mold Design

One of the advantages of sheet forming is the variety of mold materials you can use – wood filled and unfilled polyesters, epoxies, Formica* laminate and metal – since vacuum-forming molds need only withstand 14 psi. The minimal flow of the plastic against the mold's surfaces results in very little tool wear.

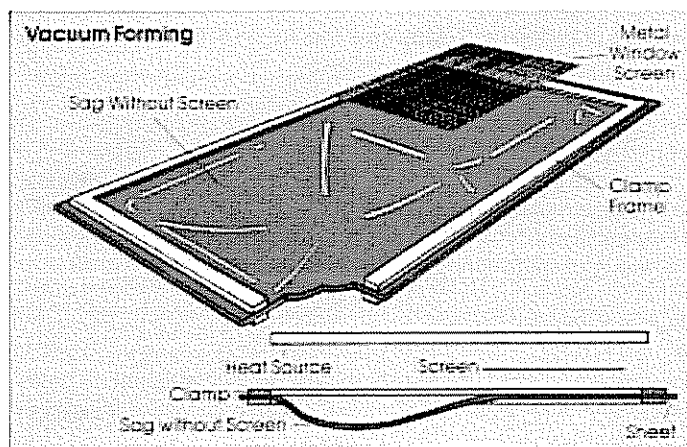
In general, follow standard practices in mold design and selection of mold materials. The following recommendations are a further refinement of these practices as they relate to LEXAN sheet.

- Materials – use non-heat-conductive mold materials to avoid thermal shocking the LEXAN sheet since it has a high heat distortion temperature. Preheated metal tooling, may also be used. Formica laminate tooling is acceptable, but caution is advised because blistering and separation of the tool facing may result if continually exposed to heat source.
- Draft angles – make them as generous as possible . . . minimum desired 5° –7°.
- Radii and fillets – use generous radii – at least equal to the sheet thickness wherever possible for more uniform walls and greater rigidity. Female tooling should have permanent corner fillets.
- Shrinkage – allow 1/16" per foot of sign dimension for mold shrinkage.
- Vacuum holes – provide sufficient holes for fast removal of all air between the sheet and mold to allow the sheet to form as rapidly as possible. In female molds, provide air evacuation holes at all deep areas, especially the perimeter of the mold – where the sheet will be drawn last.

Keep the diameter of the holes small to avoid marking the sheet. In general, holes .030"–.050" in diameter are adequate. Molds can also be made with long slots instead of holes to remove air. Slots are most commonly used in female tooling with a loose bottom insert.

Mold Surface Finish

The finish on thermoforming tooling can be too smooth. When this condition exists, small pockets of air may be trapped during forming and produce marking on the finished part. To prevent air entrapment, hand-sand the surfaces with medium grit paper to provide minute



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channels for air evacuation. Repeat this procedure on long production runs.

Forming Equipment

LEXAN sheet can be formed using conventional vacuum forming equipment: canopy, shuttle or rotary.

When using the shuttle type, the ovens either move over the sheet or the sheet moves in and out from between the ovens. The double oven shuttle balances the intensity of the heat, facilitating the forming of undried thin gauge material. Thick material also forms more easily and quickly on double oven type machines.

Normally, heavier gauge materials form more easily on rotary machines because of their longer cooling cycles. Prescreened faces in thin gauges may cool too much if there is excessive delay from the time the material leaves the oven until it is vacuum formed. Also, there may be too much movement in the sheet on large faces for accurate registration.

In recent years, the use of canopy-type heaters – utilizing either electric or gas heaters with movable vacuum tables and automatic or manual clamping systems – have become very popular. This type of equipment has some distinct advantages for vacuum forming. The tool spends most of the time beneath the heat. The travel distance of

the heated sheet to the tool is relatively short and takes place under the heat source. There is also virtually no limit to the size of the machine. In fact, because of LEXAN sheet's unique physical properties, large sheets can be handled without fear of fracturing. Sheets up to 30 feet long have been successfully formed on canopy-type machines.

Using separate ovens and forming tables for transfer vacuum forming is not recommended because of LEXAN sheet's quick cooling cycle.

General Electric has developed a successful forming method utilizing male tools and canopy-type overhead heaters. The method is as follows:

Fabricate a vacuum box of 1" x 8" boards, ensuring that it is cross-braced sufficiently to prevent collapse. On top of this, place 3/4" plywood, chipboard or similar material, then the male tool.

The deep vacuum box is recommended when forming large sign faces. This allows the operator to stretch out the excess sag in the material and prevent wrinkling in the formed sign face.

The following table provides suggested distances between clamping frames and vacuum box.

Distances Between Clamping Frames and Vacuum Box

LEXAN sheet thicknesses	.060"	1/2"	1/2"	1/2"	3/4"	3/4"		
	.080"	1/2	1/2	1/2	3/4	3/4		
	.093"	1/2	1/2	1/2	3/4	3/4		
	.118"	3/4	3/4	3/4	3/4	1		
	.177"	3/4	3/4	3/4	3/4	1	1-1/2"	1-1/4"
	.236"	3/4	3/4	3/4	3/4	1	1-1/4	1-1/4
		2'	3'	4'	5'	6'	7'	8'
		Short dimension in feet						

Key Thermoforming Points

- Predry LEXAN sheet before forming (remove protective maskign before predrying).
- Suggested heat sources – calrod, nichrome wire, gas, infrared, quartz, and ceramic.
- Preheat the clamp frames. Cold clamp frames will act as a heat-sink and draw the heat away from the edges of the LEXAN sheet. Ideal clamp frame temperature is between 200°–250°F.
- Preheat the molds.
- Heat metal molds to 200–250°F.
- Use electric eyes that sense the sheet sag when forming prescreened signs.
- Allow at least 1/2" between the clamp frames and the vacuum box to assure proper heating and to promote a good vacuum seal.
- Make draft angles as generous as possible for easy part removal: 1) Male molds should have a minimum draft angle of 5° to 7° degrees. 2) Female molds require less – 2° to 3° degrees is usually sufficient.
- Avoid sharp edges on molds. A minimum radius of 1x thickness is required for proper part performance.
- Allow at least 1/16" per foot of sign dimension for mold shrinkage.
- Control drape of sheet sag by shading the center of the sheet with metal window screen.
- Trim the flange immediately after forming to reduce part warpage.
- Provide sufficient vacuum holes for fast removal of air between the sheet and mold. In female molds, provide evacuation holes at all deep areas – especially the mold perimeter. Keep hole diameters small – .030"–.050". Long slots can be used instead of holes.

Thermoforming Troubleshooter

Problem	Possible Causes	Suggested Solutions
Voids or Bubbles in Formed Parts	Excessive moisture in sheet.	Dry as recommended – 250°F for specified time with minimum separation of one inch between sheets.
Crazed or Brittle Parts	- Mold design. - Part left on mold too long. - The use of incompatible mold lubricants.	- Mold radii should be at least the thickness of material. - Remove part from mold as soon as it becomes form stable. - Use compatible powdered mold release.
Part Warpage	- Mold too cold. - Clamp frames too cold. - Part left on mold too long.	- Preheat mold 200–260°F. - Preheat clamp frames. - Remove part from mold as soon as it becomes form stable.
Non-Uniform Drape	Uneven heating of sheet.	- Check heater section and adjust. Use selective screening if necessary. - Check for cold air drafts.
Difficult Part Removal	- Insufficient draft angle mold undercuts. - Mold finish perpendicular to direction of part removal. - Ejection pressure too low.	- Increase draft angle. Use strip rings or cam action mold. - Resurface mold. Sand mold sides vertically. - Add air holes, increase injection pressure. Use powdered mold release.
Poor Surface Finish	- Mold surface too rough. - Mold mark-off. - Draft angle.	- Draw-polish mold or use different mold material. - Use silicone or powdered mold lubricant sparingly. - Increase draft angle.
Insufficient Draw Down Poor Definition	- Improper sheet heating. - Insufficient vacuum. - Poor mold design.	- Increase heating time and temperature. - Check vacuum system for leakage. - Add more vacuum holes. Check for good seal between clamp frames and vacuum box.
Webbing or Bridging	- Improper mold layout. - Blank too large for mold. - Material overheated. - Improper mold design. - Vacuum rate too fast.	- Increase spacing between molds. Use grid or ring assist. - Leave minimum of material around mold. 2" is a good rule of thumb. - Shorten heat cycles. - Increase radii and draft angle. - Slow down vacuum rate (use smaller vacuum holes). Restrict main vacuum lines.
Chill Marks	- Mold too cold. - Insufficient draft angle and radii.	- Mold should be heated (250°–260°F). - Increase mold radii and draft angles.
Loss of Vacuum Seal	- Cold clamp frames. - Improper spacing between clamp frames and vacuum box.	- Preheat clamp frames (250°–260°F). - Minimum space between clamps and vacuum box 1/2" to 3/4".
Material Pulling Out of Frames	- Insufficient clamp area. - Inadequate clamp pressure. - Uneven heating.	- Adjust clamp points uniformly at sheet perimeter. - Increase clamp pressure to maximum. - Control sheet temperature. Use center screening to allow more heat at sheet perimeter.
Excess Thinning Severe Necking Poor Surface Finish	- Drape speed too fast. - Improper forming temperature. - Mold design. - Incorrect forming technique.	- Drape speed should be set between 4–9 inches per second. - Ideal forming temperature 375°F. - Increase upper radii. - Try snapback or billow-forming techniques.
Uneven Material Distribution	- Excess thickness variation. - Uneven heating. - Non-uniform clamp pressure. - Improper forming technique.	- Check gauge tolerances. - Check uniformity of heater output. Screen if necessary. - Maintain uniform clamp pressure to avoid pull-out. - Use billow or snapback forming method.
Wrinkles on Flat Horizontal Surfaces	- Uneven cooling due to slow drape speed. - Material too hot (too much sag or drape).	- Drape at higher speed 6–8 in/sec. - Screen center of sheet allowing edges to heat first. Use taller vacuum box to provide more pull by area.
Texture Washout and Excess Gloss	- Forming temperature too high. - Improper heating technique.	- Reduce heater inputs and cycle time. - Heat sheet from smooth side. Keep texture cool. - Precoat texture with strip-able mask such as TR4997 by Spraylat Corp.
Pinholing or Pimples	- Vacuum holes too large. - Dust on mold or sheet. - Mold too cold/too smooth surface finish. - Vacuum rate too high.	- Use 50-mil holes or smaller. - Clean mold and sheet with deionizing airgun. - Keep mold temperature at 250°F. Sand mold surface with medium grit paper. - Place small orifice over main vacuum holes.

This image shows a single sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

Notes

**For more information
call: (800) 451-3147.**

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