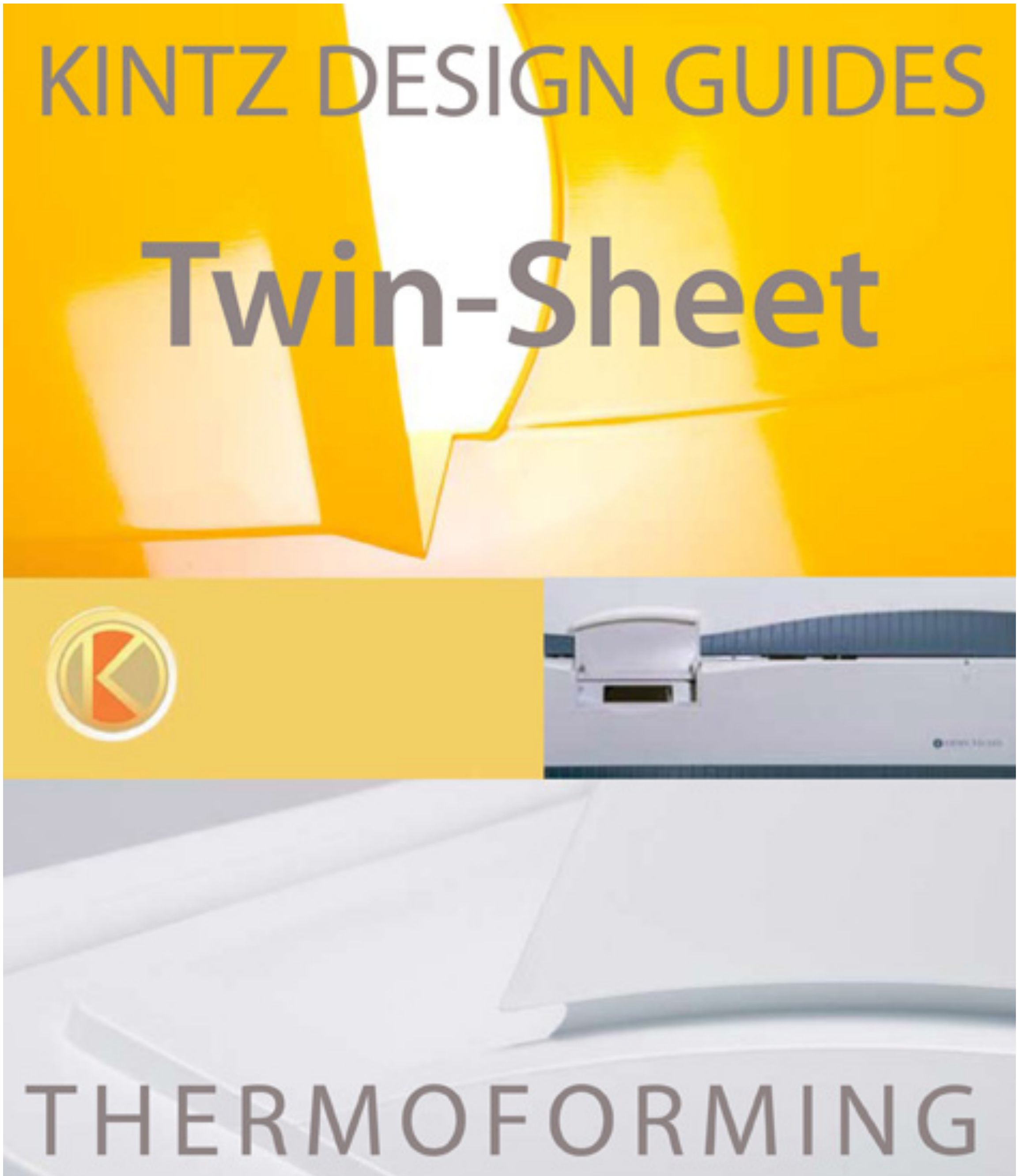

KINTZ TWIN-SHEET DESIGN GUIDE

Twin-sheet thermoforming produces double-walled parts, panels and components. Rather than producing two vacuum formed parts, and then attaching them to each other, twin-sheet thermoforming produces both sides and joins them as one seamless unit during the forming process.

Reduced Labor Costs: Producing two sides of a double-walled panel separately—then bolting, gluing or screwing them together—is reduced to a single process, eliminating an entire task from the assembly stream.

Faster Turnaround: Twin-sheet thermoforming a double-walled panel is a single process that replaces three conventional processes—producing one side of the panel, producing the second side of the panel, then joining the two sides together.
Stronger Unity: Since twin-sheet thermoforming joins the two halves of a part together at multiple points, the finished part is stronger and tighter than two vacuum formed sheets that have been bolted or glued together.
Stronger and Lighter than a Reinforced Single Sheet: Designing geometric strength into each half of the twin-sheet thermoformed panel creates a very strong—yet relatively lightweight—panel that does not require structural supports.
Less Expensive Tooling Than Other Processes: Tooling for twin-sheet thermoforming can be as much as 90% cheaper than tooling for other plastic molding processes such as rotational or blow molding!
Quicker to Market than Other Molding Processes: Because tooling for twin-sheet thermoformed parts is simpler than tooling for other molding processes, twin-sheet parts can be put into production much faster, getting the finished product to market that much sooner.
Product Redesigns and Updates Are Easier: When parts produced through other processes need to be modified when a product is updated or redesigned, a significant investment in new tooling is required. When a twin-sheet thermoformed part needs to be modified, the existing tooling can often be modified quickly and affordably to implement the change.
Flexibility to Offer Variations of a Base Design: The tooling used in twin-sheet thermoforming can quickly and economically be modified to produce different configurations of a basic product or different models within a product line. Replaceable inserts within either mold enable changes to be made in styling features, model designations, logos or openings in the twin-sheet thermoformed part.
Parts, panels, enclosures that will be seen from both sides, need considerable strength, or will house insulation, mechanical parts, or electrical or electronic components, are all ideal applications for twin-sheet thermoforming.
Two-Sided Parts: If both sides of the part will be seen by users and the public—for example, a door or hatch that opens so the inside is visible to users of the product—twin-sheet thermoforming can be used to create a double sided door with detail on both sides.
Four, Five and Six-Sided Enclosures: Enclosures that need some combination of a front, a top, a bottom and one or two sides can affordably be produced using twin-sheet technology.
Strong, but Lightweight, Panels: When a panel must have considerable strength and durability, but weight is also a consideration, building geometric strength into a twin-sheet thermoformed part results in an incredibly strong, yet surprisingly lightweight, part.
Panels that House Hardware and/or Components: Panels that need to support, protect and/or hide latches, locks, wiring, cables, switches, and/or electrical or electronic components are also ideal applications for twin-sheet thermoforming.
Pockets or Enclosures: The added capabilities twin-sheet thermoforming can be used to create value-added panels or housings that have pockets or enclosures. These can serve a variety of purposes, such holding manuals or operating instructions, or for the storage of tools, spare parts, accessories and/or supplies.
Panels that Need Thermal or Acoustic Insulation: Thermal or acoustic insulation can be pumped into the cavity between the two sides of the twin-sheet
thermoformed part.
Wide Range of Resins, Colors and Finishes: There is no limit to the combination of base materials, colors, exterior details and finishes that can be incorporated into a twin-sheet thermoformed part. The part can be produced with an inherent color in the resin, so no painting is required, or the part can be painted and/or screen printed, and the surface can be hot stamped or given other finishes.
EMI/RFI Shielding: For electrical or electronic equipment that require housings with EMI and/or RFI shielding, twin-sheet thermoforming is an affordable option. Shielding can be applied to required specifications in a secondary operation
Resins classified as thermoplastic can be used in twin-sheet forming. All thermoplastics can be thermoformed, but it is not always practical because special equipment and forming techniques are required.
Resins to Consider: These are the plastics used in thermoforming.
HIPS (High-Impact Polystyrene)

ASA (Acrylic Styrene Acrylonitrile)
ABS (Acrylonitrile-Butadiene-Styrene) and ABS blends
Acrylic
PC (Polycarbonate)
HDPE (High-Density Polyethylene)
FIMWPE (High Molecular Weight Polyethylene)
TPO (Thermoplastic Poly-Olefin)
PVC Alloys (Flame Rated Polyvinyl Chloride)
Conductive Plastics
PETG (Polyester Terephthalate Glycol)
Mixing Resins: The same resin does not have to be used for both sides of the part. Compatible resins can be used if different characteristics are needed on each half of the twin-sheet part.
ABS and PETG
High Temperature ABS and Fire Retardant ABS
Acrylic and PETG

Thickness: These resins come in sheets as thin as .060-inch and as thick as .500- inch. Most thermoformed parts are made from stock in the 0.062 to .375 gauge range.
Selecting a Resin: Each plastic has physical characteristics that make it suitable for specific applications. The Kintz engineering staff can recommend a base material after considering several factors.
Painted or Unfinished: Will the part be painted? How important is finish and appearance? Newer resins have come to market that have very attractive finishes in a range of colors and do not require painting!
Durability: Will the part need to withstand a harsh environment? Will it be exposed to heat, humidity, chemicals, solvents or detergents?
Post-Thermoforming: Will the part need to be screen printed or hot stamped? Will hardware or secondary components be attached to or enclosed within the part?
Location: Will the part be internal or the exterior of the product?
Rigidity: Should the finished part be stiff and rigid, or is some flexibility desirable? This will be a factor of both the resin and the geometry of the twin-sheet structure.
Insulation and/or Shielding: Will insulation be pumped into the cavity of the twin-sheet part, or will EMVRFI shielding be applied?
Twin-sheet thermoforming is similar to conventional vacuum forming in that thermoplastic material is formed against a contoured surface using a vacuum to draw the material against the mold, with normal atmospheric pushing against the backside of the material. In twin-sheet thermoforming, however, two sheets of plastic are heated simultaneously, drawn simultaneously into two separate molds, then pressed together to form a double-walled part, panel or enclosure.
Two Sheets **of Plastic Are Heated:** The process begins when sheets of plastic are clamped into two horizontal, parallel frames (Figure 1) and heated to the forming temperature of the resin.
The Heated Sheets Are Drawn into Their Respective Molds: When both sheets reach their optimal temperature, each is drawn into its mold (Figure 2). Vacuum holes in each mold draw the heated plastic sheet into the recesses of the mold
The Vacuum Formed Sheets Are Then Pressed Together: Once both sheets have accepted the silhouette of their molds, the upper and lower molds are pressed tightly together by the clamp frames (Figure 3), joining the top and bottom sheets at pre-determined points. No adhesives are used, since the two heated sheets—once they are squeezed together under pressure—create a permanent thermal bond.
The Molds Are Released: Once the two sheets have permanently accepted the contours of their molds and have been pressed together into a single structure and cooled, the molds are released (Figure 4), and the new twin-sheet thermoformed panel is removed from the clamp frames.

Twin-Sheet Forming	Injection Molding

Tooling Investment	•	**Up to 90% less than tooling for injection molding!**	•	Five to ten times more expensive than tooling for twin-sheet thermoforming
Re-Tooling Investment	•	**Also up to 9096 less than cost of injection molding re-tooling**	•	**Also five to ten times more expensive than tooling for twin-sheet thermoforming**
Time to Market	•	Tooling can be developed in just six to ten weeks	•	Development of tooling can run three to six months, or more!
Part Characteristics	•	Features on both sides	•	Sharp, crisp features on both sides
Strength-to- Weight Ratio	•	**Part is strong, yet lightweight**	•	Part can be very strong, but relatively heavy!
Durability of Part	.	Equal to injection molded part	•	Equal to twin-sheet part, but heavier
Available Resins	.	Wider selection to choose from with more finish options	4	Fairly wide selection, but limited finishes
Adaptability of Tooling	•	Tooling can be modified quickly and affordably	•	Entire tooling has to be re-designed and built anew!

		Twin-Sheet Forming		Rotational Molding
Tooling Investment	•	**UP to 90% less than tooling for rotational molding!**	•	Five to ten times more expensive than tooling for twin-sheet thermoforming
Re-Tooling Investment	•	**Also up** to 9096 less than cost of rotational **molding re-tooling**	•	Also five to ten times **more expensive than tooling for twin-sheet thermoforming**
Time to Market	*	Tooling can be developed in just six to ten weeks	•	Development of tooling can run three to six months, maybe longer!
Part Characteristics	•	Features on both sides	•	Features on just one side
Strength-to- Weight Ratio	•	**Part is strong, yet lightweight**	•	Part can be strong, but it can be relatively heavy! **-**
Durability of Part	•	Greater than rotational- molded part	4	Can be equal to twin-sheet part, but part will be heavier
Available Resins	4	Wide selection to choose from with many finish options	4	Limited selection with limited finish options

Adaptability of Tooling	• Tooling can be modified quickly and affordably	• Entire tooling has to be re-designed and built anew!
	Twin-Sheet Forming	**Blow Molding**
Tooling Investment	• **Up to 90% less than tooling for blow molding!**	• **Five to ten times** more **expensive than tooling for twin-sheet thermoforming**
Re-Tooling Investment	* **Also up to 90% less than cost of injection molding re-tooling**	• **Also five to ten times more expensive than tooling for twin-sheet thermoforming**
Time to Market	**4** **Tooling can be developed in just six to ten weeks**	• **Development of tooling can run three to six months, or more!**
Part Characteristics	• **Features on both sides**	• **Features only on the outside**
Strength-to- Weight Ratio	• **Part is strong, but also lightweight**	• **Part can be strong, but probably heavier than a twin-sheet part**
Durability of Part	* **Equal to blow-molded part**	• **Equal to twin-sheet thermoformed**

Available Resins	• **Wide selection to choose from with many finish options**	• **Limited selection and finishes**
Adaptability of Tooling	• **Tooling can be modified quickly and affordably**	• **Entire tooling has to be re-designed and built anew!**

In twin-sheet thermoforming, as well as conventional vacuum forming and pressure forming, addressing two related issues—draw ratios (sometimes referred to as stretch ratios) and material distribution is very important.

What Is a Draw Ratio? Whenever a flat sheet is drawn over a contoured surface, the material is going to stretch. A contoured part has **a surface area greater than that of a flat sheet of the same length and width. This difference in surface area is known as the "draw ratio".**

There are a number of formulae to express the draw ratios of different shaped objects, and the mathematical formulations for each of these are available from a number of sources. Here are the three most common shapes.

Part Dimension

2H (L+W)

LW Available

where D = Nominal draw ratio Plastic

H = Height of box or rectangle

L = Length of box or rectangle

W = Width of box or rectangle

Therefore, a formed box with the dimensions 6" height by 10" length by 10" width would have a draw ratio of

2 (6) (10+10)

= + =

(1 (bop)

Hemisphere: D = 2 TT R 2

Where D = Nominal draw ratio

R = Radius of the cylinder

TrR2+TrDH

Cylinder: D

Where

Tr R^z

D= Nominal Draw ratio R= Radius of the cylinder

D= Diameter of the cylinder H= Height of the cylinder

The first considerations when engineering a part to be twin-sheet thermoformed are surface details and surface texture.

Grain Pattern: Only grain patterns that have connecting channels between peaks should be selected as this allows air trapped in between the sheet and the mold to escape through vacuum holes, enhancing the detail of the surface. There are a myriad of grain textures available, and Kintz can provide samples of each. Avoid quick fixes such as "shot peening" for this process.

Vacuum Holes: The positioning, size and number of vacuum holes are important, too. On flat areas, they should not exceed the size of any pattern mark in the texture. The more vacuum holes the better, because they will evacuate air from the mold quickly, and there will be less of a tendency to show shiny areas on flat surfaces of the part.

Styling Lines: Additional cosmetic considerations include using styling lines to add detail and depth to the part. As long as they do not create a lock-on situation during molding, they can be used to aesthetically improve and increase the rigidity of the part, but there may be some draft and design guidelines to consider. On inverted styling lines, the distance between depressions should be at least twice the distance of the starting thickness of the forming sheet (Figures 6 and 7). The depth or height of the slots should not create secondary draw ratios that excessively thin the material. Generally, a secondary draw should never exceed a 3-to-1 depth-to-draw ration. These parameters also hold true for molded-in slots, which are aesthetically superior to routed slots.

Corner Radii: The thicker the material formed into a radius corner, the larger the radius corner will have to be. If the finished gauge of a right angle is .150", the radius should be a minimum of around .500-inch. If the finished gauge is .050", the radius should be approximately .020inch. This is roughly a straight-line function, but at some point in the draw ratio—when the material thins to about .015-inch very close to the right angle—the material will simply become too weak to pull through (Figure 8).

The radii of corners and draft angles is a key consideration in any type of vacuum forming, especially twin-sheet thermoforming.

Tight angles should be avoided, as they can create weak areas where the finished part may crack. On female cavities, however, the radii should vary with depth.

2-Inch Depth: Approximate radii = .030" minimum
6-Inch Depth: Approximate radii = .075" minimum
12-Inch Depth: Approximate radii = .150" minimum

Other Values May Be Interpolated

Variations in Part Thickness: This occurs for many of the reasons just given. Variations in thickness are most often caused by multiple or secondary draw ratios within the part (Figure 9). It may be necessary to design around theses problems, but if forming techniques alone do not solve them, secondary assembly measures may be necessary. To accommodate load-bearing requirements or stiffening needs, it is possible to bond spacer blocks, fastening bosses with inserts, or reinforcing blocks to the backside of the part. Design some latitude into the part, and discuss with Kinti's engineering staff if gluing secondary pieces to the backside of the part is practical and makes sense.

Twin-Sheet Thermoforming Limitations: While it offers major benefits, twin-sheet thermoforming does have limitations:

No Plug Assist: When material has to be pushed into a tight or sharp corner, or there is significant depth of draw, a plug assist can be used to move more material. This is not an option with twin-sheet thermoforming because the plug assist would be caught between the two sides of the twin-sheet component.

Limited Pressure Forming: Pressure forming—an advanced form of thermoforming that uses both vacuum pressure to pull plastic into the mold and positive air pressure to push material more tightly against the mold—can be done in twin-sheet thermoforming, but it is limited by the amount of air pressure that can be applied.

Undercuts: Edges that turn under or inward must be limited in twin-sheet thermoforming. Severe undercuts can only be accomplished with pressure forming

SECONDARY DRAW

***Variations in wall thickness are* most often *caused by a secondary draw in the design* of the part.**

A critical factor in producing quality twin-sheet thermoformed components is the tooling used to form the two halves. The high pressures used with this process require aluminum molds.

Aluminum Tooling: To make consistent, cosmetically appealing parts, there is no substitute for machined or cast aluminum temperature-controlled tooling. They both produce parts with minimal warpage, and aluminum tooling-produced parts are dimensionally more consistent and stable,

Cast Aluminum: This alternative can be less expensive than fabricated molds if multiple-up molds are being produced. However, the tendency towards porosity limits the texture choices.

Machined Aluminum: A temperature-controlled mold machined from a block of aluminum is clearly the superior alternative for quality thermoforming. Tolerances can be held to industry standards, and plates can often be milled and laid up with .005- inch vacuum openings along a detail area to evacuate air. More detail can be achieved and texture definition can be improved because porosity is eliminated.

Tooling Design Considerations: Such factors as drafts, undercuts, corner radii, cutouts, holes and slots need to be considered when designing tooling. Female molds do not theoretically need any draft other than for cast removal in producing the mold. In actuality, however, enough draft is needed to prevent the texturing from abrading when the thermoformed part is removed from the mold. The amount of draft needed is determined by the depth of texture. For example, if the texture of the tool has a depth of .003-inch, the amount of draft needs to be 1.5 degrees for each .001-inch of depth. (3 x 1.5 = 4.5 degrees of draft per side). This allows for proper part removal from the tooling.

Corners: To avoid thinning of material in corners, sharp corners should avoided whenever possible (Figure 8). If two distinct radii exist going into a corner, they should be blended in. Radii in corners should be about 1-1/2 times the minimum allowed radii for various depth female cavities.

Holes, Slots and Cutouts: These should be designed into the tooling to take advantage of the thermoforming process and also minimize secondary trimming. However, if distances between holes and cutouts are critical, some tolerances need to be designed in, as variations in mold shrinkage from run to run, and differences in coefficients of thermal expansion of unlike materials, may cause parts to not fit, and thus, cause stress cracks.

Dimensioning Parts: On parts requiring female tooling — which is normally the case in twin-sheet forming — the tooling should be dimensioned from the outside. On male areas, dimension the tooling from the inside. Only the surface of the part against the mold can be controlled. This will enable both Kintz and the user of the part to more accurately predict the functionality of the part.

Joining the Two Sides Together: The design of each half of the twin-sheet structure must take into consideration the points at which the two halves will be squeezed together. Remember that no adhesives or mechanical connections are used. The two sheets of heated resin are squeezed and bonded together to form a single, seamless part.

Venting of Hot Air: Holes must be built into the design so the hot air trapped between the two sides of the twin-sheet structure can be vented during the cooling process. They can be placed so they will not negatively impact the appearance or performance of the part.

Shadowing at Joined Areas: The compression of the two sheets of plastic will cause some shadowing of the plastic at the compression points, so the design of the part should compensate for this. If the part is being painted, this is not an issue. If the part is not being painted, the compression points must be engineered so they are invisible or at less visible locations.

Twin-sheet thermoforming requires some of the most sophisticated and highest precision equipment in the entire plastics industry.

Many factors need to be considered when selecting the equipment that will configure into an efficient and effective twin-sheet thermoforming system.

Platen Clamping Pressure: These should have clamping pressures of 10,000 pounds or more so the two halves of the finished part are truly joined together to form a single, seamless unit.

Platen Alignment: It is also critical that the alignment of the upper and lower platen be precise so the two halves of the twin-sheet part are joined at the precisely the desired points, and done so consistently from part to part, product run to product run.

Top Screening Heating Elements: These should have zone control or a way of screening heat locally.

Air Flow System: Only the correct amount of airflow will cool the thermoformed part at the optimal rate, and airflow has to be adjustable based on the ambient temperature and humidity.

Cycling Systems: These must be able to repeat each step in the thermoforming process with accuracy to -I- a few seconds.

Secondary Operations: The machinery used in secondary operations is just as important as the tooling and thermoforming equipment. The quality and precision of trimming and routing fixtures will have a direct impact on quality and consistency. With good planning, however, secondary operations can be minimized or even totally eliminated. The use of robotics can further enhance consistency on parts with close tolerances.

Post-Thermoforming Operations: Once the part has been formed and trimmed and/or routed, numerous other procedures may be needed to prepare it for integration into the final product.

Painting: The part may need to be painted. Kintz can also paint the thermoformed part in-house, and that will reduce the overall part cost and take time out of the manufacturing process.
Screen Printing and Hot Stamping: As with painting, Kintz can screen print or hot stamp logos, company identification, model designations, warning labels of other indicia onto the part in its facility and both money and time will be saved.
Assembly and Fabrication: If latches, hinges, handles, brackets, supports, harnesses, other hardware or electronics are to be integrated into the twin-sheet thermoformed part, having Kintz perform these procedures reduces the number or vendors, minimizes trans-shipping of the part, reduces costs and saves time.
Fulfillment: Kintz can package and ship the part—or even the completed product—to a contract manufacturer, the final assembly point, a reseller or the actual end-user of the product!
An examination of the use and application of the part to be twin-sheet formed will result in better planning, and a better quality part.
Increased Tolerances: Thermoforming requires tolerancing that is different than machined dimensions of secondary operations performed after the molding process. Molded tolerances should be +.020 for the first inch, and +.001 for each additional inch. The shrink rate tolerance for thermoformed plastic is typically +.001/inch.
Design Limitations: Since twin-sheet thermoforming is a unique process, it offers advantages that are not available in conventional vacuum forming. An understanding of the design limitations can help both Kintz and the end user get greater satisfaction from the product.
'There are three major considerations when designing twin-sheet thermoformed parts.
Satisfying the End User: Will the finished part meet spec? Will it be a component that is affordable, attractive, durable and easy to integrate into the finished product?
Material to Be Used: Will the plastic come out of the thermoforming process with the right finish, texture, features, dimensions, rigidity and durability?
Tooling and Equipment Selection: Will the tooling and thermoforming equipment lead to a pressure-forming process that is efficient, repeatable, consistent, and labor and material-efficient?
Questions? Questions? What makes the product marketable? What alternative design features can accommodate the process? Will the part function? There are several end-use issues that need to be considered.
Heat Deflection: Does the material under consideration have a high enough heat deflection threshold for the operating temperature of the unit it will be used on?
Thermal Expansion: How might expansion of the part when exposed to heat affect the final assembly?
Cosmetics: How important are the aesthetics of the finished part?
Variations in Thickness: How thin or thick can different areas be?
Properties and Formability: How will the resin's characteristics change after it has been thermoformed?
Load-Bearing: Will the part be required to bear weight?
Agency Listings: Does it have to be UL, CSA, FDA, NSF approved?
Allow for Expansion: A resin's thermal expansion doesn't change after it's been thermoformed, but the degree of expansion varies from resin to resin.. Parts must be designed so they *can* expand, or flexural points must be built into them so they will not fatigue and they can accommodate expansion and contraction.
Purchasers of twin-sheet thermoformed components must be involved in the design and engineering of the part, as well as the tooling required to produce it. However, it is the thermoformer that is selected to form the part that is ultimately responsible for producing parts that are affordable and consistent, meet spec, and are delivered on time.

What to Look for in a Thermoformer: Several factors should be considered in the process of selecting a thermoformer.
In-House Engineering: Kintz has its own engineering staff and can provide relevant, practical, ongoing, on-site expertise to the design and engineering process.

In-Mouse Tooling: Kintz can design and produce tooling in-house and offers faster turnaround on tooling, lower costs for tooling, and complete quality control through the entire design, engineering, production and post-production continuum.

ISO Registration: Kintz is ISO registered. Quality is not just a buzzword in their advertising program.
UL-Listed Fabricator: Kintz is a UL-listed fabricator insures adherence to all UL standards and guidelines

Professional Affiliations and Recognition: Kintz is active in industry associations and societies such as the SPI and SPE, and has been recognized by the industry for its innovation and excellence?

In-House Post Thermoforming Capabilities: Kintz has in-house trimming, routing, painting, screen printing, assembly, fabrication and fulfillment capabilities and produces a quality thermoformed part more affordably and more quickly. While some thermoformers advertise they can paint parts, they really have subcontractors that do painting for them. Sending parts to a subcontractor adds overhead to the cost and time to the process.

Industry Experience: Kintz has produced parts for other manufacturers in many industries and has an understanding of the nuances and peculiarities of those industries that are invaluable.

Seek a Partnership: Kintz is far more than a supplier. Kintz is your partner, and the success of your finished product will be the result of the skill set, capabilities and dedication to quality of both companies.

Contacting Kintz Plastics: *The Engineering Department at Kintz Plastics is staffed from 7:00 a.m. to midnight, Monday through Friday, and any member of the department is available to answer any vacuum forming, pressure forming or twin-sheet thermoforming-related design or engineering questions, share his expertise and offer his advice.*