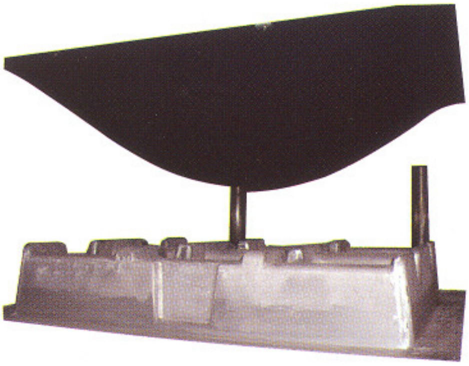
BO-MER PLASTICS, LLC

Design Guide for Thermoforming and Pressure Forming

Bo-Mer's early involvement in YOUR design will pay off for YOU

At the onset of an idea for a plastic part, the method of manufacture must be determined. To do this, evaluations of the size of the part, volume, time restraints, and tooling costs must be made.

Why Thermoforming/ Pressure Forming over other plastic production methods?



Part Size: A wide range of part sizes can be manufactured using the Thermoforming/ Pressure Forming process. Smaller parts will generally be formed on single station machines, or if volume and starting gage (less than .062) dictates, on "in line" roll fed equipment. Larger parts with gages of .062 and up will be formed on single station or multi-station "rotary" machines. For large parts the primary limitation will be in the size of the forming equipment.

Volume: Annual or Life of Project volumes will be a major factor in determining the viability of the process chosen. Low volume parts will generally show a positive ROI (return on investment) when considering total cost of the project when using the Thermoforming/Pressure Forming method of manufacture. As the volume of the product increases into several thousands annually, the ROI will tend towards alternate methods of manufacture due to lower piece price. Thermoforming/Pressure Forming tooling will still provide an overall cost saving.

Time to Market Place: Bo-Mer's quick turnaround using advanced CAD/CAM systems, early design involvement and the use of temporary tooling can bring prototypes and product to market in a fraction of the time as alternate methods of manufacture.

Tooling Cost: Thermoforming/Pressure Forming tooling costs provide an advantage at any level, but as part size increases, the advantage over alternate methods of manufacture becomes even more apparent. Tooling for Thermoforming/Pressure Forming can save as much as 80%- 90% over alternate processing methods and is easily modified when necessary.

What is Thermoforming/ Pressure Forming?

Thermoforming – (Vacuum Forming - Drape Forming) are all synonymous with the heating of thermoplastic sheet to a forming temperature, lowering the sheet on to a mold/or plunging the mold in to the sheet. A seal is created between the sheet and the mold, a vacuum is applied and entrapped air between the sheet and the mold is removed. The atmospheric pressure (14.7 lbs psi) will then force the sheet against the mold while cooling. After cooling, the formed part is removed from the mold, trimmed, and finished.

Pressure Forming follows the same basic steps through the application of the vacuum. However, a pressure box is added to the process. The pressure box forms a seal on the off-mold side of the sheet and air pressure (20 lbs psi or greater) is introduced to force the hot sheet against the mold surface. This additional pressure allows the textured surface of the mold to be transferred to the part, and forms undercuts, ribs or louvers, molded recess, etc.

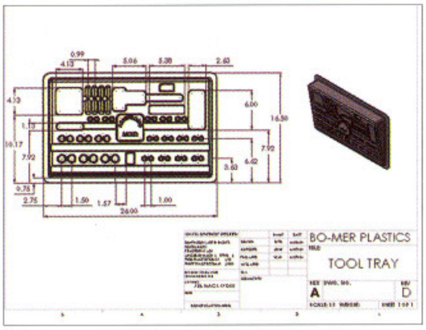
Now that we have decided that the Thermoforming/Pressure Forming method of manufacture is viable, lets look at design parameters that Bo-Mer's design/ engineering personnel must consider in the design and manufacture of your part.

Part Design Parameters:

Length, Width, and **Height** of the part must be evaluated to determine mold size, number of cavities to be considered (in conjunction with order quantity volume and type of material), and size of sheet.

13 Pulaski Street • Auburn, New York 13021 • Phone: 800/221-6563 or 315/252-7216 • www.bo-mer.com

Part Design Parameters: continued



Finished Wall Thickness of the part must be determined to establish the **Starting Gage** of the sheet. Unlike the injection molding process in which the finished wall thickness is determined by the opening between the two surfaces within the mold, in the Thermoforming/Pressure Forming process, the starting gage of the sheet will determine the average finished wall thickness. As part height increases, the starting gage of the sheet also increase.

To determine the **Starting Gage**, the **Draw Ratio** must be established.
The **surface area** of the part is divided by the **foot print** of the part to establish draw ratio.

Example: A part is 20 in. long by 10 in. wide by 4 in. high (20″l x 10″w x 4″h)

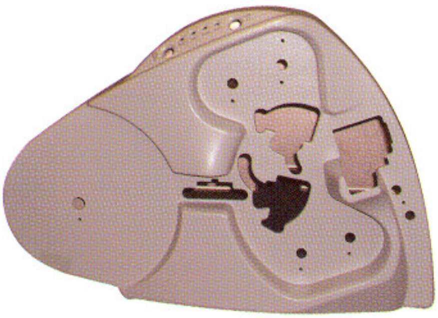
Surface area is: (20″ l x 4″ h) 2 + (10″ w x 4″ h) 2 + (20″ l x 10″ w)
or 160 + 80 + 200 = **440** sq. inches

Foot print is: (20″ l x10″ w) = **200** square inches

Draw Ratio: **440** (surface area) / **200** (foot print) = **2.2**

Starting Gage: multiply the **Finished Wall Thickness** (assume .100) of part by the **draw ratio** of 2.2, then **Starting Gage of sheet** is **.220** thick.

Be realistic when establishing the finished wall thickness as the starting gage of the sheet heavily impacts the cost of the product!



Side Wall Draft is ideally at 1-1/2 degrees or greater. This amount of draft is typically required in the release of the mold from the pattern in the initial casting process as well as allowing the proper release of the part from the mold during the molding process. When Pressure Forming is used, draft can be critical in the release of a textured surface from the mold.

Minimum Allowable Radius has to be considered from the mold side and whether they are an inside or outside radius. An inside radius should not be smaller than 75% of the connecting vertical walls thickness. An outside radius of .015 can be obtained if using Pressure Forming, but larger Radii are preferred for greater strength and integrity of the part.

In a female mold or at the sheet line of a male mold, as the depth of draw (height of part) increases the Radius must increase and at the convergence of corners, the Radius has to increase substantially to prevent excessive thinning.

Undercuts are achievable through the Pressure Forming process (to a much lesser degree in the Thermoforming process), with an ideal undercut no greater than .375 deep. Localized undercuts can be greater than .375 but the material thickness thins out accordingly. Undercuts at corners will typically reduce part strength and corrective action such as 1) increasing the sheet starting thickness; 2) backfilling the corners with epoxy; 3) adding features to the mold such as cams or draws; or 4) a combination of these actions.

Ribs/Louvers are accomplished through the use of the Pressure Forming process. A basic rule of thumb is to have the distance between the Ribs/Louvers equal to or greater than the height (or depth), respectively.

Molded Openings will follow the general guidelines as Ribs/Louvers.

Tolerances for the formed part should be within these parameters.

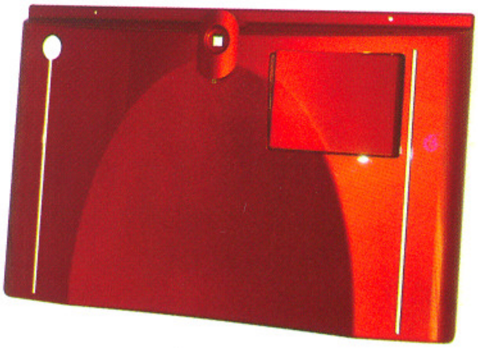
Styrenics: +/- .030 up to 12 inches, each additional inch = +/- .001

Olefins: +/- .030 up to 1 inch, each additional inch = +/- .001

Texture: "Most" sheet stock will come with a type of texturing on one surface. Textured sheet is used primarily with male molds and will be sufficient in many applications. If a specific textured surface is required, the molds will typically be female, textured to a "Mold Tech" or similar specification, and the Pressure Forming process will be used. Textures available on the molds are generally the same as available for injection molds. Textured molds will have a different type of casting process used so that the surface finish of the mold will accept the etched texture finish.

Dimensioning of Part Drawings/CAD Files: All dimensioning for drawings or files should be from the mold surface. (This is why Bo-Mer's design engineers should be brought in to the process during the development of the program).

Material Selection:



The selection of the material to be used is every bit as important as the physical design of the part. Considerations for the type of material will be dependent upon the environment that the product will typically be subjected. These considerations must include the impact resistance, dimensional stability, heat/cold extremes, exposure to ultra violet light (UV), flame resistance (FR), surface texture, etc.

Styrenics will provide impact resistance (in the higher rubber content materials), dimensional stability, heat resistance, flame resistance, and surface texture.

Styrenics are commonly used for OEM applications such as Computer Housings, "Cabinetry" electronic housings, and Enclosures. Materials such as GP - ABS (Acrylonitrile Butadiene Styrene) in Low, Medium or High Impact, FR - ABS (Fire Retardant having a PVC or Bromide additive), also including UVI (Ultra Violet Inhibitor additive) or application of a Cap to the sheet and/or AS (Anti Static additives) will meet these needs. Other materials such as HIPS (High Impact Styrene), FR - Acrylic/PVC (Kydex), PET, PETG, Acrylic, SAN, Polycarbonate, etc. can also be considered. These materials can also be Co- extruded/Laminated and have Preprinted materials applied to the sheet surface.

Polyolefin's will provide for impact resistance, cold extremes and UV. Both types can obviously overlap with similar properties.

Polyolefin's are used for Material Handling Trays, Dunnage, Fabrication, and Retail Products. Materials that fall in to this category are HMWPE (High Molecular Weight Polyethylene), HDPE (High Density Polyethylene), LDPE (Low Density Polyethylene), and PP (Polypropylene). These basic grades can also be Filled (Talc or Calcium), have UVI (Ultra Violet Inhibitor), AS (Anti Static), and Conductive additives.

Less common materials are Cellulosics, TPO (Thermoplastic Elastomers), etc.

Other considerations for materials are the need for certification such as UL (Underwriters Lab), FDA (Federal Drug Adm.), ESD (Electro Static Discharge), FR (Flame Rating), MVSS (Motor Vehicle Safety Standards), etc.

Coloring of the sheet material falls in to two categories, standard or custom.

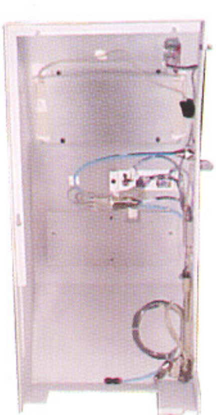
Standard colors are as supplied by the sheet manufacturer and are limited to basic colors such as black, white, beige, blue, etc. and are generally used in limited run applications.

Custom colors are matched to the customers needs using "Pantone Charts" as a common reference and offer a very broad range of color. Custom coloring does require minimum material buys of 500 to 2500 lbs. These minimum buys are determined by the type of material and the material suppliers.

Textured sheet is available, but is limited by the sheet suppler to style of texture and minimum buys required. If a specific textured surface is required, it will require going to a female mold, etching the mold surface, and using the Pressure Forming technique of molding.

The selection of material is an extremely important part of the process. Realistic specification of the product environment will determine the success of the project.

Finishing:



All products using the Thermoforming/Pressure Forming process will need to be finished in some manner. The simplest finishing will be the removal of the "web" surrounding the finished part area. This will normally be accomplished at the forming machine through the use of a steel rule/forged "die" or routing.

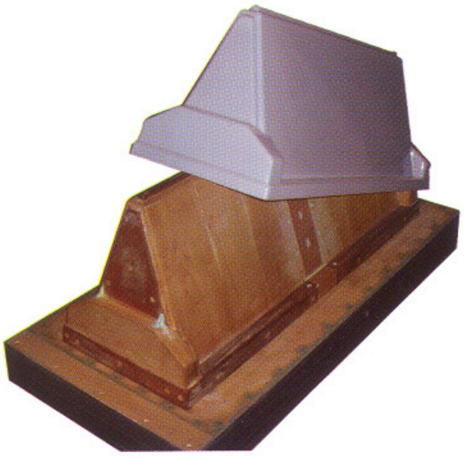
More intricate machining will be through the use of 3 or 5 axis CNC routing machines. This process will trim the perimeter and openings in the part to the dictates of the design. Typical standard tolerances on the machines will be +/- .020 inches up to 12 inches, and +/- .001 inch for each additional inch.

Mechanical assembly of plastic or metal components or electronics can be accomplished by means of bonding with adhesives or epoxy, sonic welding, and through mechanical means such as screws or pop rivets.

Painting of the part to provide a particular color scheme or to exactly match other components that are to be assembled together is standard practice. **Bo-Mer** uses a water based paint system that is environmentally acceptable. EMI/RFI shielding can also be painted on the inside surfaces of the molded part.

Other methods of finishing the part is by silk screening, ink transfer, hot stamping, or the addition of decals/graphics.

Prototyping:



Molded prototype parts taken from temporary tooling can be a cost effective alternative to determining material distribution and develop the fit and function of the production part. Prototype molds can be developed following a couple of basic paths. Prototype molds/patterns are usually made from wood, epoxy, or machined from a composite such as "REN" board. The type of material is determined by the part configuration, type of mold (male or female), availability of computer files, and type of prototype sample required.

Prototype molds from a **mold pattern** is the least expensive and has the shortest time line to production. However, the prototype will not be of finished size when sampled. The part will be oversize by .011 Inches/inch as the pattern will have double shrink (part plus mold) built into it. The pattern/ prototype mold can be altered and the production mold cast, after approval of the prototype sample.

Prototype molds that are **part size specific** will provide the molded prototype to a finished size as it has only the part material considered. This is a more expensive approach and can extend the production time line. Once prototype sampling has been approved, a master pattern for casting the aluminum mold still must be produced.

The development of a production part entails the melding of many different design criteria into a homogeneous mix to provide the best quality, the most cost effective, and the shortest time line to the market place.

EARLY INVOLVEMENT by the Bo-Mer Plastics Team is crucial to the design and development of your product.

At this point we have earned your confidence – now let us produce your product.

BO-MER PLASTICS, LLC

SPECIALISTS IN CUSTOM THERMOFORMING SINCE 1946

NSF-ISR ISO 9001:2000 REGISTERED

13 Pulaski Street • Auburn, New York 13021

Telephone: 800/221-6563 • 315/252-7216 • Fax: 315/252-7450

Email: bo-merplastics@bo-mer.com • www.bo-mer.com