Fundamentals of Thermoforming KYDEX® Thermoplastic Sheet

THERMOFORMING PROCESSES

The process of forming a thermoplastic sheet into a three dimensional shape by clamping the sheet in a frame, heating it to render it soft, then applying differential pressure to make the sheet conform to the shape of a mold or die positioned below the frame.
Three basic methods of thermoforming:

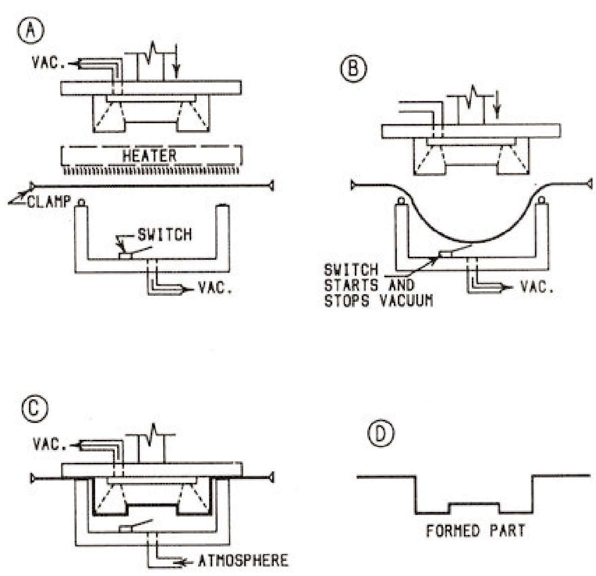
1. Vacuum Forming
2. Pressure (compressed air) Forming
3. Mechanical (plug assist) Forming

VACUUM FORMING AND METHODS

- The most popular method of thermoforming
- The forming process is accomplished solely with vacuum
- A male or female mold is pressed into the hot sheet to create a seal
- Vacuum is applied, drawing the hot material into or around the mold
- The vacuum is held until the material is cooled to prevent shrinkage

Snap-Back Vacuum Forming - Male

- A vacuum box seals the heated plastic sheet to the clamping frame.
- Vacuum applied through this box pre-stretches the material into a bubble.
- The mold enters the pre-stretched plastic sheet and seal to the clamping frame.
- Vacuum is applied through the mold, and the vacuum box is allowed to vent to the atmosphere.
- Very deep draws can be obtained with this system, and undesirable material thinning can be greatly minimized.



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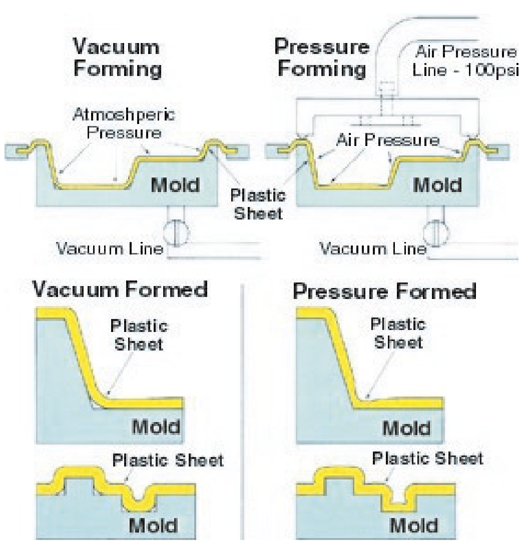
PRESSURE FORMING

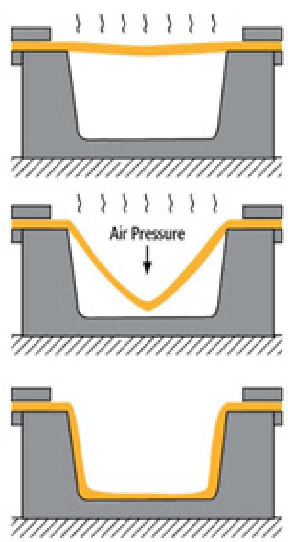
The main difference between these two processes is that vacuum forming utilizes only vacuum, while pressure forming utilizes vacuum to draw the material onto the mold and pressure to force the heated material into tight radii, crevices, and textures.

- Female tooling
- Material pressed into textured tool
- Less wall thinning allows for use of thinner materials, reducing weight
- Consistency from part to part
- Undercuts possible with plug assist and articulated tools

This technique is normally accomplished by forcing a hot plastic sheet against a mold, usually female, by introducing compressed air to the backside of the heated sheet.

- Pressure forming is a sophisticated version of the vacuum forming process.
- This process closes the appearance gap with traditional molding techniques.
- It uses air pressure as a forming aid to increase the detail on the mold side.
  - The pressure applied is approximately five times higher than with vacuum forming.
  - Makes it possible to obtain highly detailed parts and textured finishes.
  - Air pressure above the heated sheet gives a higher quality finish with sharp edges, undercuts, and other closer tolerance details.
  - Features that could not be achieved by vacuum alone can be obtained with pressure forming.
- The result to the customer is a product that achieves the look and feel of an injection or structural foam molded part.
- For smaller volume runs, pressure forming offers injection-molded quality and details.





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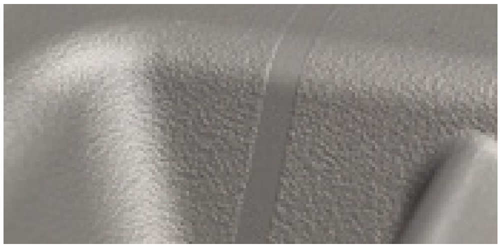
PRESSURE FORMING BENEFITS

In pressure forming the texture and gloss of the final part is dictated by the texture on the tooling. Because of this designers can selectively texture different areas of a single part, as shown in the image at right. This allows for much more design options compared to the traditional vacuum forming method, which relies solely upon the texture of the extruded sheet, which can introduce inconsistencies in parts as the material is stretched or distorted.



Another benefit to pressure forming is the very high detail that can be achieved. The detail from pressure forming can be comparable to that which is achieved in the injection molding process, without the high tooling costs of injection molding

The higher pressures also allow for tighter dimensional tolerances due to the lower mold shrinkage values. Typical mold shrinkage values for a female tool and conventional vacuum forming can range from 0.5 – 0.7%, while pressure forming mold shrinkage will be around 0.3 – 0.5%. Higher detail and tighter dimensional tolerances allow for mating parts to match up very well.

Overall aesthetics are superior when using pressure forming because of the gloss and texture control, as well as the ability to form precise details and intricate undercut and reverse angles. Other design advantages include molded in vents and ribs, textured surface, and various part sizes. Very large parts and parts with excellent dimension control are also well-suited to pressure thermoforming. This process is able to use heavier sheets, ranging in thickness from 0.080 inches to 0.375 inches and volumes are typically in the hundreds to high thousands.

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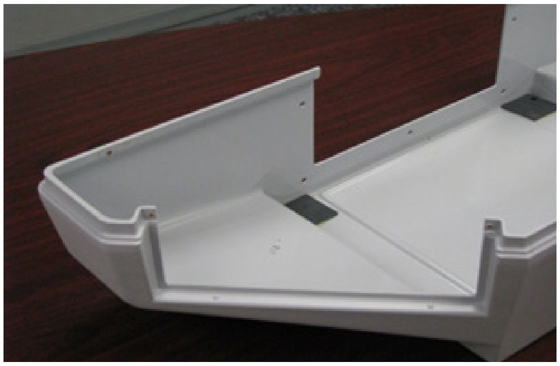
PRESSURE FORMING BENEFITS

Undercuts

Undercuts are possible with the use of plug assist and articulated tooling. Undercuts allow for better fit and finish when mating parts. Undercuts can be designed with a reveal or with flanges for hidden attachment. The image at right show two parts, the parts on the left were vacuum formed while the parts on the right were pressure formed. The parts on the have a much tighter fit when mating the parts.



PRESSURE FORMING SUMMARY

Pressure forming allows designers more freedom in designing parts with their own textures and logos. Manufacturers are to produce more consistent parts with tighter dimensional tolerances with less variation from lot to lot, allowing for mating parts to match closely.

Pressure forming provides nearly the same level of detail as injection molding, but at a lower cost and shorter lead time for tooling.

The following image shows the detail of a pressure formed part that would not be possible with traditional vacuum forming.

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TOOLS AND MOLDS USED FOR FORMING KYDEX® SHEET

In determining what type of mold to use, consider the following:

Type of Production:

- Prototype
- Parts with close tolerances
- Quantity of parts
- Pressure-formed parts
- Parts requiring break-away tool

HEATING ELEMENTS

All heating elements are suitable for thermoforming KYDEX® sheet.

- Calrods Elements
- IR Ceramic Elements
- Halogen Element Heaters
- Quartz Element Heaters
- Gas Catalytic Heater

CALRODS

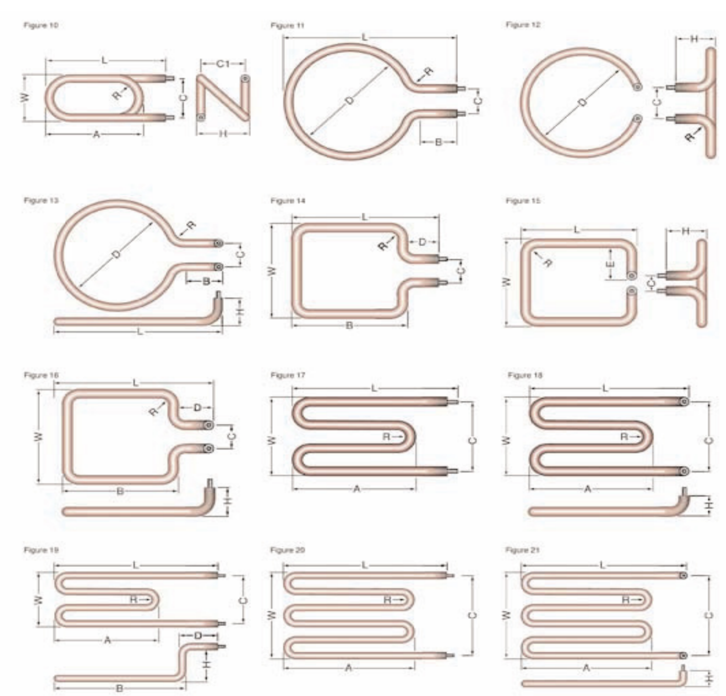
Metal tubular heaters were popular in the 90's. They are still in use in some of the older thermoformers.

Pros:

- They last a long time and are somewhat inexpensive to build into an oven.

Cons:

- They tend to age and degrade quickly, causing inefficient heating.
- Longer heat up time.
- Heat non-uniformly and limits the possibilities of multiple heating zones.



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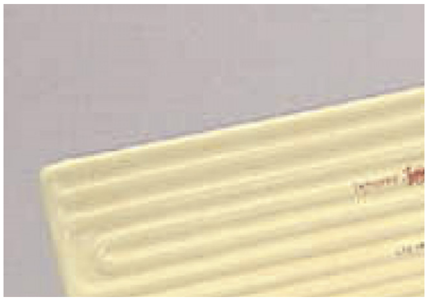
CERAMIC

Ceramic elements may still be the most widely used in today's thermoforming machines.

Pros:
- Very versatile
- Long lasting
- Easily zoned for balanced heating
- Favored for long production runs since they are durable and maintain excellent uniform heating
- Moderately priced

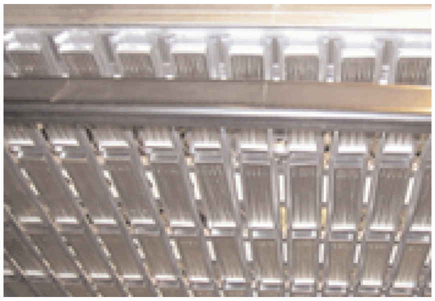
Cons:
- Only drawback are the moderate heat up times and slow response times when being compared to Quartz and Halogen heaters



Features:
1. Ceramic heaters are 96% infrared energy efficient, leading all other types of infrared emitters.
2. They are the best heaters on the market for zone control.
3. Watt density can be easily controlled to produce the most gentle heat on the market
4. Ceramic infrared heats objects not the air.

QUARTZ AND HALOGEN ELEMENTS

These elements are continually gaining a large share of new machinery sold today.
They tend to be best used in shuttle type machines.



Pros:
- Fast response times.
- Very versatile, have excellent temperature control.
- Rapid cool-down and heat-up times.
- Easy to zone like ceramics.
- Ideal for fast cycling times.
- High radiant efficiency.
- Both elements give the ability to incorporate heat levels or heat steps in within a cycle.

Cons:
- Lack of longevity.
- Elements are made of glass tubes, which makes them more fragile and easily damaged.
- They are typically more expensive.

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GAS CATALYTIC

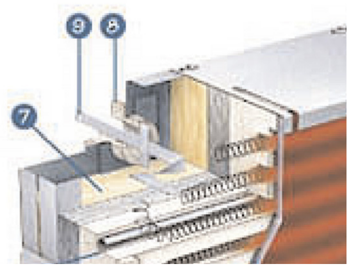
A diffusion type heater that operates on a chemical oxidation reduction process. In the presence of platinum and oxygen, the process reduces the methane or propane gas into moisture and carbon dioxide. The reaction produces energy.

Pros:

- Economical alternative to the high energy cost associated with electric resistance elements.
- Catalytic heaters will cost 50% - 80% less to operate then electric heaters.

Cons:

- Balancing of the temperature zones is more sensitive than other heating elements.



Features:

1. Glass, metal or kormic emitter surface material
2. Ceramic standoffs used to keep electrically conductive material separated from resistance wire
3. High temperature cement bond
4. Refractory board to hold resistance wire
5. Precision-resistance wire
6. Heavy gauge aluminum steel frame
7. Blanket insulation layer
8. Ceramic bushings to insulate terminals
9. Stainless steel terminals
10. Quartz thermowell tube (optional)

THERMOFORMING KYDEX® SHEET PRODUCT

Before thermoforming, the following issues should be addressed:

1. Are there doors opened around the machine?
   a. Close doors or use a welding curtain to block air flow.
2. Are there fans and/or vents operating around machine?
   a. Turn fans and vents off or redirect them.
3. Are the back and sides of the machine open to air flow?
   a. Close in the thermoformer heating area to block air flow. This makes it an enclosed heating chamber.

Addressing the above issues will aid in repeatability in thermoformed parts.

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TOOLS AND MOLDS USED FOR FORMING KYDEX® SHEET

Type of mold (Male vs. Female):

1. Where on the part are the tolerances needed?
2. Which side of the parts needs the detail?
3. Male molds are cheaper to build than female molds.
4. Are parts to be fitted or bond together?
5. Closer tolerances can be held with a male mold.
6. Parts using a female mold will have greater thickness at the flange area of the part and thinning at the bottom. Pre-stretching can minimize the thinning.
7. Parts using a male mold will be thicker where the material first comes in contact with mold.

Multiple mold cavities:

1. Molds can be produced with multiple cavities incorporated into one tool.
2. Molds can be produced for various designed parts in one tool to maximize usage of sheets.
3. Rule of thumb used for spacing cavities in such molds is space at twice the height of the part. This allows for enough material to be distributed to the side walls of the molds.

ADJUSTABLE CLAMP FRAMES

These frames eliminate the need for storing and replacing different short frames for every sheet width. The system will handle your maximum sheet sizes down to 6” X 6” in 114” increments. The clamp frames can be arranged for either bottom or top loading. Clamp frames utilize standard clamp frame components with other off-the-shelf items enabling users to vary the length of the clamp frames. This system reduces clampframe set up time to under 5 minutes.

Advantages of Clamp Frames:

1. Standard MAAC clamp frame components: cylinders and extrusion can be interchanged with standard clamp frames.
2. The sheet is gripped on a single plane, there is no offset in the comers.
3. Position of the clamp frames can be noted and stored along with the part menu in the notes section and easily returned to the exact position the next time the product is run.
4. NO TOOLS are required for any part of the adjustment.
5. Large airflow passages insure quick even operation of the cylinders.
6. Requires approximately 112” of material to be clamped meaning less waste and trim.
7. No “old-style” steel pin bars. All aluminum, meaning better heat transfer.
8. Light-weight and cost effective when compared to competing systems.
9. No need to store all those different size clamp frames.

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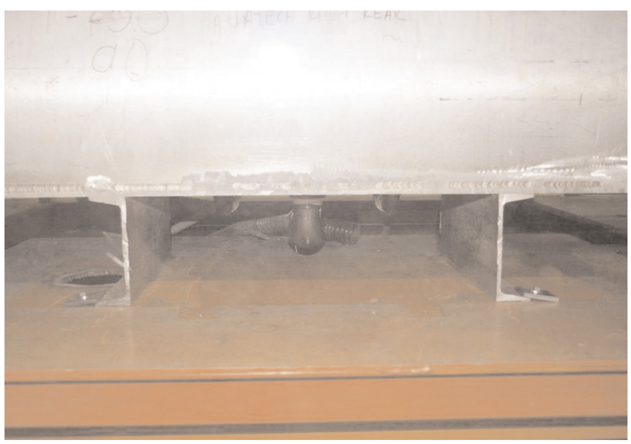
NEW TECHNOLOGIES IN CUT SHEET THERMOFORMING

Quicker clamp frame:

- Routine clamp frame change can take up to 4 hours depending on number of stations
- Typically consists of replacing the short clamp frame segments for every different sheet width
- Adjustable clamp frames offer the ability to vary the length of the clamp frames without having to add or remove clamp frame sections
- Changeovers takes only fewer than 5 minutes (per station)
- Ability to document the position of these clamp frames and easily return them to the exact position the next time the product is run
- Helps in reducing sheet sizes to minimize wastage

Mold Changeover:

- Mold changeovers are another one of the leading factors causing machine downtime.
- Most molds are unique, built by different suppliers and most thermoformers end up with a large quantity of different mold bases and mold configurations.
- The key to quick mold change is to make all design factors on each mold common to each other.
- For uncommon mold bases, the use of steel plates with precisely spaced bolt patterns or aluminum plates with T-slots have been most popular.
- Stand alone or common mold bases allows one mold (attached to the 1st mold base) to be run in production while another mold is being secured to the 2nd mold base outside the machine.
- This can even be taken a step further by having all of the utilities connected outside the machine.
- Scales, locating pins, locating cones or back stops can be consistently used to locate the mold base to the platen.
- Hand clamps/ automatic clamps controlled through the machine can be used to secure the base to the platen.



Mold Base Change System

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KYDEX THERMOPLASTICS

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INTRODUCTION

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