

Fundamentals of Thermoforming KYDEX® Sheet

For information applicable to KYDEX® FST please refer to 300 series technical briefs.

TB - 140-A

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:

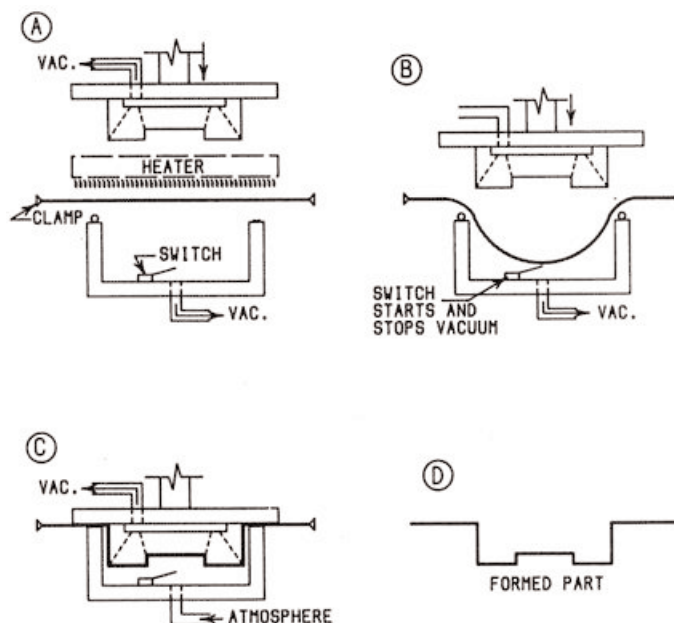
- 1) Vacuum Forming
- 2) Pressure (compressed air) Forming
- 3) Mechanical (plug assist) Forming

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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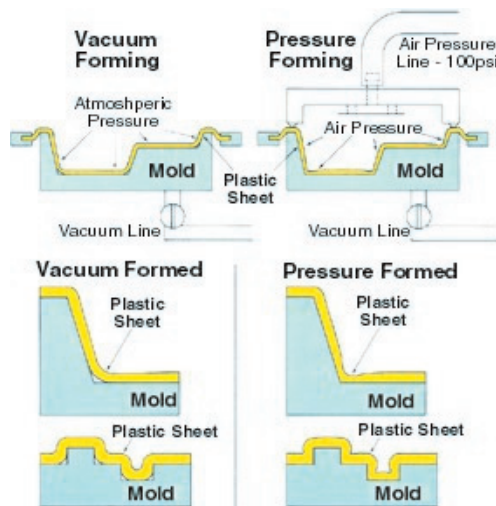
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Pressure Forming

- 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.



Tools and Molds Used for Forming KYDEX® Sheet

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

Type of Production:

1. Prototype
2. Parts with close tolerances
3. Quantity of parts
4. Pressure-formed parts
5. Parts requiring break-away tool

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Heating Elements Used in Thermoforming

All heating elements are suitable for thermoforming KYDEX® sheet.

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

Calrods

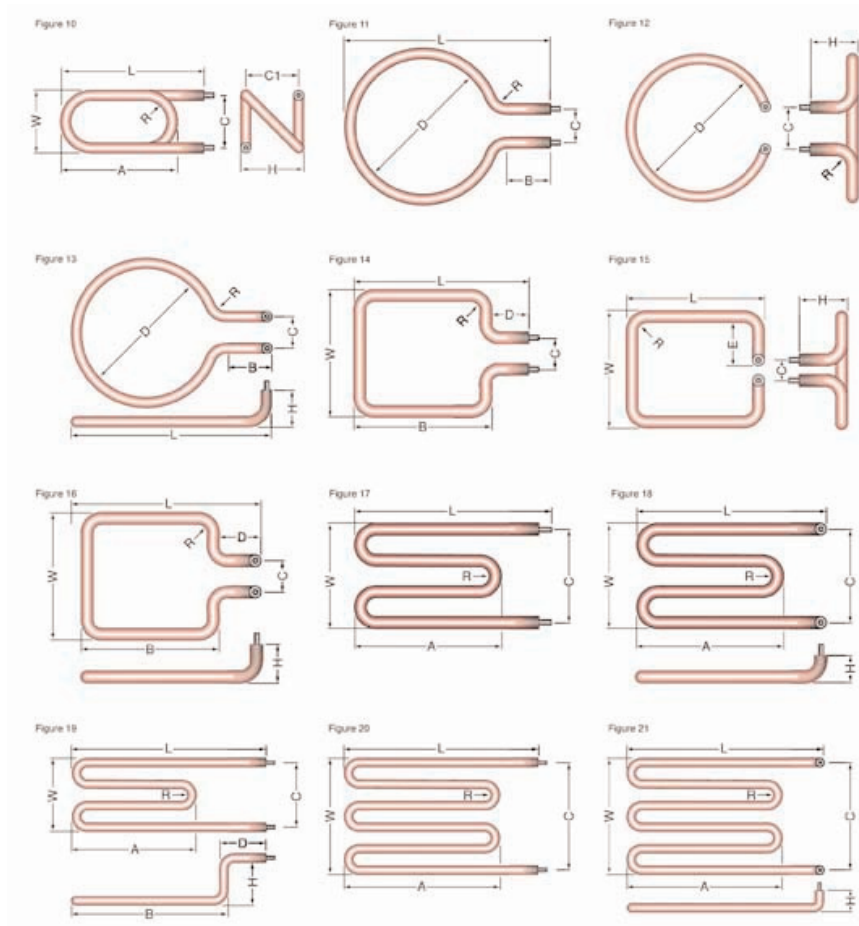
Metal tubular heaters were popular in the 90's. They are still in use in some of the older thermoformers.

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.

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.
- Both elements give the ability to incorporate heat levels or heat steps in within a cycle.
- Ideal for fast cycling times.
- High radiant efficiency.

Cons:

- The only drawback is longevity.
- Elements are made of glass tubes, which makes them more fragile and easily damaged.
- They are typically more expensive.



Quartz and Halogen Elements

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Gas Catalytic

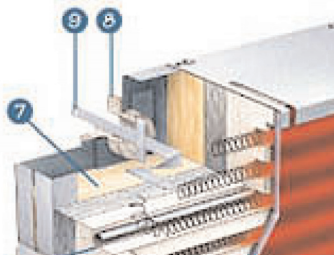
A diffusion type heater, that operates on chemical oxidation reduction process that reduces the methane or propane gas in the presence of platinum and oxygen, into moisture, carbon dioxide, and produces infrared energy from this reaction.

Pros:

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

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.

Thermoforming KYDEX® Sheet Product

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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 corners.
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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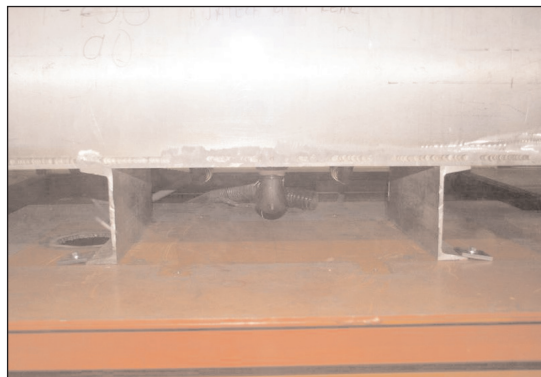
New Technologies in Cut Sheet Thermoforming

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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Thermoforming and Mold Shrinkage

- Most thermoformed parts shrink on forming
- Shrinkage must be considered during mold construction
- Shrinkage varies with:
 - The amount and type of material orientation during forming
 - Mold temperature (hotter the mold temperature, the more mold shrinkage), length of time the part remains on the mold, and whether it is a male or female mold
 - The recommended mold shrinkage for KYDEX® thermoplastic sheet for a male mold is 0.4% - 0.6% and for a female mold is 0.5% - 0.7%
- 0.080" and thicker gauge sheets require two-sided (sandwich) heaters.
- Heating (dwell) time varies with the heat source, oven conditions, dimensions, and age of the oven.
- An indication of overheating is a shiny part surface.
 - Reduce the percentage of heat delivered and increase the heating time to maintain crisp part definition.
- Recommended heater settings: 30-50% of top heat, 50-70% of bottom heat capacities.
 - Bottom heat is maintained higher as the distance between the heating elements and the sheet is greater than the top distance.
 - Heat rises and is trapped under the sheet allowing it to absorb faster to the core of the sheet.
- Optimum forming temperature range for KYDEX® sheets is 365-400°F (depending on the thickness of material).

Heating KYDEX® Thermoplastic Sheet

Sheet Thickness Range	Approximate Dwell Time	Forming Temperature Range
0.028"-0.080"	15-80 seconds	330-350°F
0.080"-0.125"	80-140 seconds	350-385°F
0.125"-0.500"	140-up seconds	385-400°F

The following are guidelines for thermoforming KYDEX® sheet products.

A good rule of thumb is:

- Up to 0.125" thickness, every millimeter in thickness = 1 second in dwell time
- > 0.156" thickness, every millimeter in thickness = add 1.25 seconds in dwell
- This provides an approximation of the required forming temperature range

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