Thermovacuum forming plastics for artistic endeavors

Rose E. Corcoran

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Thermovacuum Forming Plastics
For Artistic Endeavors

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WHAT IS THERMOVACUUM FORMING?

Plastic thermovacuum forming is a method of shaping plastic with the use of heat and a vacuum. Plastic is heated so it will soften and form over a mold with the assistance of a vacuum. Frames are used to hold the plastic in place during forming. (See figure 1)

![Figure 1](image)

Industry considers thermoforming a low technology process because of the simplicity of technology needed to produce a vacuum form. This simplicity is one reason why vacuum forming is an accessible method of working plastics for the artist. Most of the techniques described in this paper involve the use of a temporary studio vacuum forming set up or a small, thermoforming machine. Commercial use of thermoforming can be found in blister type of packaging, disposable cups and saucers, three dimensional plastic letters for signs, and most thin walled food containers, such as the ones used for cottage cheese containers.
Low cost, high availability, and workability are three things that attracted me to plastics. With a background in metalsmithing, I found that plastics worked much like metal. Metal has been used by man for centuries and its technology is well developed. Plastic is a comparatively new material, approximately one half of a century old. It made sense to me to approach plastic as if it were metal. The technology developed for plastics is different but comparable to metal. For example, metal is cast, while plastic is injected; sheet metal is soldered together, while sheet plastic is welded with a glue. Metal is raised for containers; plastic is vacuum formed. I feel that plastic, being man made material, was fashioned after metal. Currently, plastics technology is beginning to influence metal technology. For example, an aluminum alloy was developed specifically for vacuum forming. A technology developed for the forming of plastic is now influencing metal technology.
Not all sheet plastics are suitable for vacuum forming. Stretching the plastic over a mold requires elasticity in the plastic. Some materials are more rigid than others and thus more suitable for construction after the forming process. Acetate, styrene, butyrate, Uvex, and vinyl are good thermoplastics that I used in vacuum forming.

Acetate is the most expensive compared to styrene, Uvex, and vinyl. There are several advantages to using acetate. It can be purchased in many translucent colors and in clear, and can be found in most art supply stores. The acetate found here is usually .035" to .030".

Oftentimes thin colored acetate is attractive as additions of color sandwiched between an object and clear vacuum formed plastic. Overlays of colored acetate will blend and create a different translucent color.

On the other hand, because it is usually found in thin widths, the control of this plastic during heating is lessened. The thin sheets tend to soften quickly and not stretch too far without bursting. If the plastic punctures during forming, it will cancel the vacuum action. Airtightness for the creation of a vacuum is important to this process. Furthermore, acetate is brittle. It crumples and crushes easily.

Styrene is a good, inexpensive forming material that is almost always opaque. Styrene is rubbery when heated and will
form better because it will stretch further than acetate.

Styrene also has a memory after it has been formed. This means that it will snap back into almost its original sheet form when it is reheated. Scraps can be saved and recycled into new plastic, or ground up and used as a slurry for gluing plastics. Therefore, costwise styrene is good for industrial usage. In addition, it is rigid enough to be scored with an X-acto knife along a straight edge and snapped into squares by bending the plastic over a straight table edge along the score lines. Styrene can be purchased at a plastic supply company. The thickness available varies from paper thin to .100". I usually form with .060" to .080" thick styrene.

Uvex is an inexpensive clear plastic that is easy to use for vacuum forming. It is a butyrate type of plastic made by several companies, chiefly Kodak. It can also be purchased in plastic supply companies and is most economical to buy in large sheets. The consistency is gummy and flexible, so Uvex will not snap at score lines and must be cut by a band saw. The elasticity makes Uvex a good forming material, but the gumminess makes it difficult to sand and finish. Uvex also gives off a bad odor when it is heated or sanded. Furthermore, it sometimes turns whitish in the areas where it has cooled and been stretched more. Despite these negative qualities, I found it to be my most often used thermoplastic.

Rigid vinyl is an expensive material. It is rigid because few plasticisers have been added to the vinyl. It is usually clear and resembles clear acetate, except that it has a grey-blue
color. Rigid vinyl is very brittle especially after vacuum forming. It can be scored and broken up into individual square sheets if the breaking is done in small widths. Rigid vinyl will tend to break apart and crack at other places besides score lines. I usually buy rigid vinyl at the plastic supply companies in .030-.035" widths. The material gives me an impression of cheapness. This is probably because I see it most often used in blister type packaging and thin walled product displays.

Lexan and acrylic are two plastics that can be used for thermoforming if they are dried out beforehand. The moisture in Lexan and acrylic causes air bubbles in the surface. Therefore, sheets of Lexan and acrylic should be dried out in a kiln at 150-200°F Farhenheit for six to eight hours and then slowly cooled. Extruded sheets will have less moisture than cast sheets.

The following is a forming temperature chart provided by the AAA Plastic Equipment Company.
<table>
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<th>SET TEMPERATURE</th>
<th>LOWER PROCESSING LIMIT</th>
<th>NORMAL FORMING TEMPERATURE</th>
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<tr>
<td>Acrylic</td>
<td>185°F</td>
<td>300°F</td>
<td>350°F</td>
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<tr>
<td>Styrene</td>
<td>185°F</td>
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<tr>
<td>Rigid PVC</td>
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<tr>
<td>Acetate</td>
<td>160°F</td>
<td>260°F</td>
<td>310°F</td>
<td>360°F</td>
</tr>
<tr>
<td>Acrylic/PVC</td>
<td>175°F</td>
<td>325°F</td>
<td>370°F</td>
<td>400°F</td>
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1. **Set Temperature**: the temperature at which the part may be removed from the mold without warpage. Sometimes parts can be removed at higher temperatures if cooling fixtures are used.

2. **Lower Processing Limit**: this represents the lowest temperature that the material can be formed without creating undue stresses. This means that the sheet material should touch every corner of the mold before it reaches this lower limit. Material processed below the lower limit will have stresses and strains that later could cause warpage, brittleness or other physical changes in the finished item.

3. **Normal Forming Temperature**: temperature at which the sheet should be formed under normal operation. This temperature should be reached throughout the sheet. Shallow draw projects with fast vacuum and/or pressure forming will allow somewhat lower sheet temperature and thus a faster cycle. Higher temperatures are required for deep draws, pre-stretching operations, detailed molds, etc.

4. **Upper Limit**: the temperature point where the thermoplastic sheet begins to degrade or where the sheet becomes too fluid and pliable to thermoform. These temperatures normally can be exceeded only with an impairment of the material's physical properties. Injection molding and extruding do use much higher temperatures but only for short durations.
THE TEMPORARY VACUUM FORMING SYSTEM

A metalsmith can set up a temporary and flexible system in a studio equipped with a vacuum pump used in investment casting. A heat gun, approximately two square feet of tempered 1/4" masonite, duct tape, and empty coffee cans are needed to set up a forming system. The following is a step-by-step method of how to set up one type of temporary system:

**STEP 1** Cut out both ends of a coffee can or a large, 46-114 oz. institutional size food can.

```
coffee can
```

**STEP 2** Cut two identical frames from the masonite. The opening in the center should not be wider than the diameter of the coffee can. These frames are to fit on top of the can. They will hold the plastic in place and dictate the outer shape of the formed plastic. Drill at least two holes through the frames for registration the same diameter as the screws to be used. The screws will hold the two frames together and the plastic sheet in place.

```
drill holes
```
STEP 3 Duct tape one of the frames to the coffee can. Then tape the other end of the can to the vacuum table. It is very important that the seal is airtight or the plastic will not form evenly.

STEP 4 Cut the plastic the same size as the outside dimension of the frames and drill registration holes in the same place as on the frames. Thinner plastic is best for this type of set up because it will heat faster and more evenly. Use .030-.035" thickness.

STEP 5 Using two wing nuts, clamp the plastic tightly between the frames. For additional airtightness use two C clamps at the corners.
STEP 6 Using the heat gun, heat the plastic until it is pliable and rubbery. (Overheating or uneven heating will melt a hole in the plastic. Getting the correct softness of the plastic takes much trial and error.) Touch the plastic. If it burns your finger it is too hot to form. (Even paper thin acetate can be formed this way if you are careful.) Turn on the vacuum to draw the plastic into the can. Do not heat the plastic while the vacuum is on. The depth of the form is controlled by the heat, vacuum, and the thickness of the plastic. The amount of vacuum can be controlled by the on/off switch or the pressure dial. Keep the vacuum on until the plastic cools.
STEP 7 Remove the plastic from the frames. The shape of the opening in the frames will be the same as the outer shape of the bubble.

Check the bubble for a good even form. This will indicate even or uneven suction. If the bubble is uneven or not drawing down very far into the can, look for air leaks in the duct tape. Sometimes the leaks can be heard if another flat sheet of plastic is clamped in and the vacuum is turned on.

The bubble surface can be altered by using a smaller can as an inner jig. Take the smaller can (V-8 or 4oz. juice can), cut out the top and bottom, and drill air vents all over the surface. Set the can over the vacuum source inside the larger coffee can but do not obstruct the vacuum. (see figure 2)

A piece of wood can be glued to the top of the juice can, so that objects or small molds can be set on top of the wood. (See figure 3) Be careful to
estimate the distance between the objects and the plastic (probably one inch to one and one-half inches) so the objects will make a good impression. More wood blocks can be added to adjust the height of the inner jig. Avoid overheating of the plastic for it will result in undercuts and trap the mold and frame inside the plastic (see figure 4).

figure 3

[Diagram of objects and wood]

figure 4

[Diagram of undercutting and no undercutting]

and result upside down.
USING A THERMOFORMING MACHINE

A thermoformer is a machine made specifically for vacuum forming plastic. The thermoformer has three basic parts: the heat source for bringing the plastic up to temperature, framing bars to hold the plastic in place, and the platen - a sealed box which is the vacuum source. There are several advantages to using the thermoforming machine. First of all, the heat source is built into the equipment rather than hand held. The heat source is usually a broiler type or an enclosed oven. Broilers and ovens are attached to slide mechanisms so they can slide over the plastic. (see figure 5) Oftentimes, an oven will be stationary and the plastic will slide into it. The broiler type brings the temperature up by heating one side of the plastic. An enclosed oven will radiate heat from all sides therefore bringing the plastic up to temperature more quickly and evenly. The
faster plastic is heated and reaches temperature, the less likely it will form surface bubbles or chemically break down. Thicknesses no greater than 1/8" should be used with a broiler because it cannot heat thick plastic evenly. An oven can efficiently heat plastic up to 3/4".

The second basic part of the thermoformer, the framing bars, hold the plastic in place. (see figure 6) The plastic is cut to fit the frames and platen. A small machine will form 12 to 24 square inches, and a large industrial one can form up to 10 square feet. On a small thermoformer the plastic is sandwiched between the frames which are held down by rubber tipped handles. (see figure 7)
The third part, the platen, is the base upon which the mold sits and where the vacuum is connected. During vacuum forming, the platen is designed to move up to the plastic sheet, or to be stable and have the bars drop down over the platen. On the small thermoformer shown here (see figure 8), the vacuum is connected to two perfectly sealed boxes. One box is constructed of an aluminum plate that has evenly spaced small air vents drilled into it. When the platen makes contact with the heated plastic and the vacuum is turned on, the platen and plastic make a seal. The platen must be able to fit within the dimensions of the bars in order to obtain a seal. Some machines have adjustable framing bars to hold larger sheets of plastic and corresponding sizes of
box platens. The other sealed box is connected between the platen and the pump to build up pressure for a good draw. The vacuum pump is connected to the box by a hose and a clamp system. (see figure 9)

A thermoformer will have a switch to turn on the vacuum pump, one to turn on the heating elements, and one to draw a vacuum through the platen. The vacuum pump must first be turned on so it can build up pressure to at least 25 inches of mercury on the dial gauge. This is a good time to warm up the heating elements. On the thermoformer shown in figure 8 the broiler is slid over the plastic. (This particular machine was made by AAA Plastics Equipment Inc.) The plastic will then buckle and sag down. At this point it has reached temperature. The broiler is slid back, the foot pedal is depressed to push the platen up to the plastic, and the button is pressed to draw the vacuum. This button is held down until the plastic has cooled. The pump is turned off and then the vacuum is released. The heating elements are turned off after use.

There are many types of machine designs that change the horizontal and vertical positions of the three basic parts.
Variations are made with each machine. The illustrations shown here are of a very basic manual thermovacuumforming machine. Some more sophisticated machines will have oven radiated heat, electronic or computerized controls, and a cooling system. Figure 10 shows thermoformers made by the Zamec Corporation division of Faro Industries, Rochester, NY.
DESIGNING MOLDS FOR VACUUM FORMING

Practically anything can be used to vacuum form over as long as it can withstand the vacuum pressure, heat up to $350^\circ$ F, and it is the appropriate height and width in relation to the size sheet of plastic used. If the object is too high, the plastic will stretch and pop open. If the object is too wide, the edges of the object will not form. Found objects, sawed out jigs, wood, plaster, and metal make good molds.

Vacuum forming is one way to encase objects within a plastic skin. If the object has undercuts, the plastic will seal under and around the object. Therefore, this method can be used as a type of cold connection. (see figure 11)

![Diagram](image)

figure 11

An object cannot have any undercuts if it is to be used for only the impression and if it is to be removed after the forming. It is difficult to find things without undercuts so packing the
objects with clay is usually necessary. The hot plastic will soften clay ("Play Dough" type) and cause it to stick to the formed plastic, therefore, an object will probably need to be repacked each time it is formed. (see figure 12)

Wood is an easily workable material for mold making. Mahogany and birch are best but pine and poplar work well too. The grain lines will mark off on the formed plastic. (Mark off is the unwanted textures from the wood grain.) However, the grain texture will not be seen if an opaque plastic is used. Some type of mold release must be used with wood or any mold. Talc will fill in wood grain crevices, reduce mark off and also serve as a mold release.

Design wood molds with no undercuts and a 3 degree positive draft. The draft is the degree of taper on the side walls. For example, a 0 degree draft would be perpendicular to the table surface. If the plastic is forming into a concavity the walls may be cut straight up and down. While cooling the plastic will shrink in toward the exterior walls and away from the walls inside a concavity.

Wood molds have a tendency to dry out and crack. Pick out
top grade, quarter sawn wood to prevent drying and shrinking. (Naturally, a cheaper wood would be used if the mold were only to be used a few times.) After the mold is finished, cast the mold with a polyurethane satin finish or Zipatone shellac, and then paste wax. A well made mold will run up to 500 vacuum forms before breaking down.

A more efficient mold includes its own sealed unit that will connect to the vacuum pump and takes the place of the platen box. (see figure 13) In this way, vacuum holes can be drilled where they are needed for a good draw. Holes can be as small as a size 60 drill and still give adequate draw. Larger holes will cause mark off. On female molds, drill holes in the corners of concavities so the vacuum will draw plastic into them. Vacuum vents should surround the exterior walls evenly.

When designing molds that are to be placed on a platen with predrilled vents, the mold should obstruct as few vents as possible. In addition to the mold a short base should be made which outlines the mold with a 1/4" ledge and whose walls have a positive 10 degree draft. (see figure '4) This base will ease
the break away of the plastic from the mold and the cutting of
the form from the surrounding plastic. The base will come out
easily or can be pried out. When it is out there is an air space
left below the mold. This space gives the mold room to fall out
of the form if the vacuum form is set on a table and the top of
the form is hit with a leather mallet. A female mold must have a
cavity routed out underneath and holes drilled through so the
vacuum will draw the plastic into the concavity. Likewise a
circle in the base for the female mold must be pierced out so the
base will not obstruct air vents. (see figure 15)
Another method of removing the plastic from the mold is to separate them using compressed air. A hole is drilled 3/4 of the way through the bottom of a mold. A smaller hole the size of violin wire is drilled through the rest of the way. The violin wire is inserted in the small hole. After forming compressed air can be shot into the larger hole. The air will push the wire up against the formed plastic and separate the mold with only a small pin hole mark.

The plastic will sometimes crease and fold up on itself at the corners of molds. This can be a desirable effect. There are ways to avoid folding if it is not wanted. Rounding the edges of molds will reduce the chance of creasing to some degree. The plastic creases and folds because there is not equal stretching due to the mold configuration. To prevent this, dummy blocks must be set around the mold near high sharp corners. (See figure 16) These will help to evenly distribute the degree of stretching in the plastic over the entire surface.

Jigs or frames can be used to make a specific outline of a shape. Jigs are necessary in a temporary set up, but they can also be used on a thermovacuumforming machine. A very strong
1/4" masonite can be used if only a few runs of the pattern are needed. A sturdier material is a plastic pressboard found at plastic supply companies. It is a combination of sawdust, fiberglass, and plastic. The color is similar to masonite, but the addition of plastic make the material more durable.

A jig is like a stencil. Negative shapes are cut out of a sheet of 1/4" masonite or plastic pressboard with a jeweler's saw. (see figure 17) Any pattern or shape can be used. The jig can be set in a built frame or on top of blocks of wood with clay packed around it. (see figure 18)
(Remember that the clay will soften under heat and have to be repacked after each forming. Masonite will also break apart at the edges and lose sharp detail as more runs are made.)

Constructing a frame for the jig to set into and using plastic pressboard will result in faster, more consistent outlines. The frame should be at least one inch high, but not high enough to let the plastic move under the jig and trap it in the plastic. A large opening in a jig will tend to allow undercuts more often than a series of small patterned openings.

An extremely efficient jig would be one cut out of metal. It can replace the pressboard jig and use the same framing system. Again, the shapes must be sawed out with a jeweler's saw. The shapes can be transferred by using carbon paper, by rubber cementing the pattern to the surface, or by first photoetching the pattern and then sawing out the shapes.

Plaster also makes excellent molding material because of its easy workability as a liquid and a solid. Plaster can be poured into disposable plastic containers and duplicate their glasslike surface exactly. When pouring plaster, avoid removing the set-up plaster from the mold until it has completely dried. Plastic tends to break away from plaster easier than wood. Nevertheless, a mold release should always be used to ease break away. Plaster will not, however, take as much abuse as wood. Protruding thin lines will break off the mold after one or two runs, but they can be reattached with Elmer's glue. Since it breaks down more easily, plaster allows one-of-a-kind pieces from a process that lends itself to mass production.
Metal molds or "tools" form efficiently and are generally used in high production industrial situations. Cast aluminum is most often used because it is an excellent conductor of heat. It allows the plastic to cool faster, is a low cost metal, and it casts and finishes well. The aluminum tool can be made more efficient by casting heating and cooling tubes into it. However, the tool must be designed so the tubes will not run through the areas where vacuum air vents are to be drilled. After casting, the tool is sanded to a 600 sandpaper grit finish because the plastic will pick up any finishing marks on the tool.

During vacuum forming, the plastic reaches a temperature between 300° and 350° F. If it makes contact with a mold, which is at room temperature, the plastic cools. At that point of contact the plastic keeps the same wall thickness and thins out as it forms downward. Therefore, the top of the molded plastic is thicker at the top and thin walled to the base. A metal mold, however, can be heated to near the temperature of the soft plastic and yield a more even walled container. That means the optimum temperature was reached and sustained during the forming over the tool. The use of metal molds produces more accurate and controlled vacuum forms.

One may become limited with smoothly designed contoured shapes and slightly angled walls, and want to make a mold that undercuts. A break apart mold is a complex design problem and can best be handled in wood. Wood allows greater manipulation because it can be cut, gouged, milled, and additional shims can be glued on to account for the subtraction of material in
The break apart mold works like a puzzle. A key piece is removed to allow enough space for the other pieces to shift and fall out. The following are step-by-step instructions showing how to construct one type of male break apart mold to set on a predrilled platen.

**STEP 1** Construct and finish a male mold with an undercut plus a base for the mold.

**STEP 2** Drill holes and saw out the core on a scroll saw. The holes are located at the corners of the cut for the insertion of the blade and ease in turning.

**STEP 3** Remove core and cut out a handle at base for grasping.

**STEP 4** Route out fairly deep channels for pegs that will hold the pieces in place. Cut the remaining mold into parts through those peg channels.
**STEP 5** Glue shims onto the quarters and the core to make up for material lost in cutting and sanding.

The tighter the pieces fit together the smoother the surface of the form will be. The plastic will pick up any lines or indentations on the mold. Finished mold should fit together like this:

**STEP 6** After forming, pull out the base and the core from the mold. The other pieces can now be shifted and removed from the form.
The following is a step-by-step method of how a female break apart mold is constructed. End result is shown in figure 19.

**figure 19**

![plastic form]

**STEP 1** Cut out the centers of five one inch pieces of plywood in the shape of circles. Cut a square out of a 2" base and drill a large hole for the vacuum hose to attach. Glue the five 1" pieces of plywood to a solid piece of 1" plywood and the hollow 2" base. Smooth out the interior and sand to a 400 grit sandpaper finish.

```
  plywood with cut out circles

  solid piece

  2" hollow base for vacuum
```

**STEP 2** Drill registration holes for pegs at least three-quarters
of the way through the mold.

**STEP 3** Cut 1" off of the top. Cut out a circle from another piece of 1" plywood with a diameter approximately 2" smaller than the other, and glue it to the base of the cut off piece.

**STEP 4** Cut this top piece in half.

**STEP 5** Glue pegs in the base of the mold. Gouge channels to allow air to escape and insure good detail at the undercut. Drill holes inside the concavity until they reach the hollow 2" space at the bottom.

**STEP 6** After forming lift out the plastic. The top part of the mold will come up with the form and can then be slid off.
Any mold should be first tested with styrene. This gives an accurate view of what the form will look like at low cost and little waste.
PRINTING ON PLASTICS FOR THE VACUUM FORMING PROCESS

Thermoplastic can be painted, printed, or textured. The results yield an interesting meld between surface image and the object's form. Aesthetically this meld gives more opportunities to express color, line, texture, pattern, shape, and form.

As long as the paint can endure the optimum forming temperature of the plastic used, and does not contain a solvent that will melt the plastic, it can be used in thermoforming. Acrylic paint, plastic ink, and some spray enamels are sufficient for the process. Testing the paint is advisable.

Painting the surface with acrylic paint is a simple and direct method of coloring sheet thermoplastics. Acrylic products will not adhere to a smooth surface. Therefore, a tooth must be made on the plastic with steel wool so the paint will have a texture upon which to grasp. The paint will form better if it is applied in thin flat coats. If the plastic is opaque the painted side should be placed down facing the mold if the interior is to be a decorated surface. Place the painted side up in the forming bars if the exterior of the form is to be a decorated surface. Painting on a clear sheet of Uvex will give a different effect because the painting can be viewed from both sides. The painting looks richer through 1/16 inch clear Uvex than the flat color of acrylic paint on opaque plastic.

The surface of the plastic can be textured in ways such as raising stitches with an engraving tool, or scoring lines with a scribe. Stitches are small whisker-like burrs raised up with a V shaped engraving tool. After forming, the painting and stitches
will conform to the shape of the mold thus distorting them with the degree of stretching.

Another simple method of decorating the plastic surface is by the use of a transfer or decoupage'. Liquitex Acrylic Matte Medium, and magazine photographs that are printed on clay coated paper are needed. The clay coated paper can be recognized by its slick, shiny sheen and can generally be found in less expensive magazines. The clay coating in the paper allows the ink to separate from the paper surface.

Acrylic Matte Medium or Polymer Gloss are two products used to extend acrylic paint. They are white in the jar but they dry clear. Again, a tooth must be brought up on the plastic surface or the medium will not adhere to it. A thin coat of Matte Medium is applied to the plastic and also to the photograph. The photograph is then placed face down on the surface of the plastic, and all of the air bubbles are pushed out as quickly as possible before the paper starts to buckle up. Wipe off any excess medium with a towel and allow this to dry at least six hours, though overnight is best. The longer the medium dries the harder it is and the less likely it will resoften when the paper is soaked off. After drying, soak the plastic in cold water until the edges of the paper peel up and lift away. Check the other side to see if the polymer has turned white. The plastic should not soak too long or the medium will soften, turn white, wrinkle, and separate from the plastic. Do not rub the paper off too roughly. Try instead to peel the paper off. The print ink should adhere to the plastic.
Stencils are a fine way to obtain even patterns on plastic. A cut out jig can be used as a stencil for spray painting. A hard waxy paper called stencil paper is useful for printing with an ink roller. It can be used to hand print onto the plastic too. A thin mylar or acetate can be cut with an X-acto knife to make stencils for painting. Newsprint or Vellum bond are two good papers to use for screenprinting stencils if only a few prints are needed. Bond paper gives a cleaner and sharper edge.

Photoscreenprinting is an accurate way to produce a delicate pattern many times on plastic. The process is similar to photoetching in that a photostat, or dark color Xerox transparency of the image is needed. There is a special ink for silkscreening onto plastics to be vacuum formed called Vac-u-print. It will stretch with the plastic and retain its color. Vac-u-print ink will also dissolve any blockout or varnish used to correct the image on the screen.

Industrial vacuum forming companies usually screenprint onto their plastics. They use styrene to calculate the position of the image on the flat plastic so it will form in the right place over the mold. As mentioned before, styrene has a memory and will flow back into place when it is reheated. A one inch grid is scored on the styrene and it is then formed over the mold. The image is painted where and how it is supposed to appear on the vacuum form. The styrene is then reheated until it is flat again. The image is now in the place where it must be printed, and the grid system shows the proportion to print the image so it will stretch to the correct size. Many of the labels on vacuum
formed plastic containers are printed this way.

Another way to color plastic is with indelible ink markers. On clear plastic the light will refract the color throughout the plastic.
CUTTING, ASSEMBLING, AND FINISHING THE VACUUM FORM

After the plastic has been formed it will have a flat ledge where it was held by a frame. This ledge can be used in its entirety to provide a picture framing effect, thus giving the form a formal presentation.

An important design consideration for vacuum forming involves the combination of different forms. For example, the shape of the jig gives all the vacuum forms identical outlines. Also, plastic formed over a male mold can be inverted and presented as a concavity. A transparent vacuum form can be attached to a flat sheet of plastic and create a closed window environment. (see figure 20) A combination of a low relief vacuum form as a base and a high relief form will add extra dimension. (see figure 21) The addition of objects into this environment emphasizes window display enclosure. For exhibition, delicate objects can be protected by an outer clear plastic sheath. The addition of color transfers (which still allow light through), texturing of the surface, or patterning spots of color on the outer sheath emphasize the dimension that this outer sheath takes up.

Cutting and Assembling

Most often the form is cut out of the sheet on a band saw. This leaves an edge that will lie parallel to a surface. (see
Holes can be drilled through the ledge and the form riveted to a base. (see figure 23) Metal wire, screws, or plastic rod can be used for rivets. The form can also be cut away with a cut off wheel attachment on a flexible shaft for an edge that sits perpendicular to a surface. (see figure 24)

Edges can be filed and sanded to a fine finish, scraped, and then burnished so they reflect light.

Plastic forms can be welded together with a Weld-on #3 glue. This glue is a liquid form and adheres plastic by melting it chemically. A Weld-on #16 is a glue with more body that adheres to the plastic and bonds it with plastic filler.

Finishing

Paint and transfers can be protected on the surface by spraying the form with a clear acrylic Krylon spray. Masking tape and finger prints can be removed with rubbing alcohol. Static can be reduced by using a product called Kleenmaster
Brillianize. A simple paste wax will also remove some scratches temporarily and shine the plastic.

The glues and antistatic products or products similar to those mentioned above can be purchased in a plastic supply store.
THE VACUUM FORM AS A BOX

Since vacuum forms lend themselves to containers it seems as though they should have lids. A separate mold can be made for a lid that will fit to the base form, or the lid can be formed directly over the container to produce a snug fit. Forming directly over the container is a simple way to make a fitted lid. However, the container must not have any undercuts or it will be sealed inside the second forming. Here is a step-by-step method for making a box and a lid.

**STEP 1** Make a male mold without undercuts. Cut off the top one third of the box to function as a lid.

**STEP 2** Drill holes in the center of the base and cut out the center with a scroll saw. This makes the bottom of the box.

**STEP 3** Cut a base for the bottom of the box that has a 10 degree positive draft. Be sure to cut out the center of this base.

**STEP 4** Lay screen between the base and bottom of the box.
Elevate the screen with tiny blocks of wood. Form over this and trim off the excess plastic. Leave the parts inside the form. This is support for the plastic base shell. It will be withstanding pressure up to 30 inches of mercury plus the heat of the second forming. Without the box mold the plastic shell will collapse.

STEP 5 Set the lid mold on top off the vacuum formed base. Double stick tape will hold it in place. Form over this unit.

STEP 6 Remove base, molds, and trim the lid as desired.

A separate forming for the lid is needed if the base has undercuts. (see figure 25) The base is formed and then the width or diameter of the form is measured. The lid should be cut .060" bigger than this measure on at least a 3 degree draft. The 3 degree angle will assure a fit. (see figure 26)
figure 25

molded form

bowl

cross section

together

separate
SAFETY CONCERNS FOR THE ARTIST

One should be cautious when using plastics and avoid carcinogenic irritants. If the plastic gives off fumes, affects normal functioning of the lungs, or gives headaches, then precautions should be taken. Find out about the material being used. For example, Polyvinylchloride is a toxic plastic that should be used under a ventilation hood, especially when it is being heated. Also, gluing should be done with adequate ventilation. Wear an appropriate respirator and protect your eyes from fumes even during gluing. Always wear a surgical mask when finishing plastics. Particles from the finishing of plastics will accumulate in the lungs and eventually irritate them. Sometimes cold symptoms will result. Since plastic is a modern material it is wisest to take these precautions when working with it.
GLOSSARY

Acetate- a compound derived from acetic acid. A name commonly used for the cellulose group of plastics.

Butyrate- 1. a salt or ester of butyric acid. It is characterized by a particularly rancid odor. 2. term often used to describe any cellulose acetate butyrate plastic.

Decoupage'- the use of paper cut-cuts to form a new picture. Used for the decoration of table tops, etc. Oftentimes rather abstract images are made by collaging pictures. Varnish, Polymer Gloss, or Liquitex Matte Medium can be used to adhere the images to the surface.

Draft- the degree of taper on the side wall of a mold to facilitate removal of the molding. Also used as a measure of a molding, particularly in vacuum forming.

Draw- the process of stretching a thermoplastic to reduce its cross sectional area thus creating a more orderly arrangement of polymerer chains with respect to each other. The word draw is chiefly used in this manual to describe the pulling action of the vacuum on the plastic.

Female Mold- in molding practice, the indented half of a mold designed to receive the male half. In this manual the term female mold is used to describe any mold with a concavity.

Framing Bars- the part of a vacuum forming system which secures the plastic during forming. Framing bars are designed so that a variety of sizes of plastic sheet can be held.

Inches of Mercury- a method commonly used to determine the amount of vacuum in an atmosphere by measuring the inches of mercury on a gauge.

Jigs- a tool designed to hold or align component parts on other tools during fabrication or assembly. In this manual the term jig is used to describe a frame that holds plastic during vacuum forming to control the outer edge of the shape so it will be consistent.

Lexan- polycarbonate made by the General Electric Company. This product is especially used whenever the plastic needs to be shatter resistant.

Male Mold- in this manual a male mold is any mold that has no concavities.

Mark off- the finishing marks or wood grain picked up by the formed plastic from the mold.
Plasticisers - a material incorporated in a plastic to increase its workability and its flexibility, or its distensibility; normally used in thermoplastics. The addition of the plasticiser may lower the melt viscosity, the temperature of the glassy transition, or the elastic modules of the plastic.

Platen - the mounting plate of a thermoformer to which the entire mold assembly is bolted or set onto.

Plexiglas - a Rohm and Haas trademark product which is a type of acrylic plastic.

Rigid Vinyl - a vinyl that is more rigid because no plasticisers have been added.

Runs - the number of times a mold is formed over. Each forming is considered a run.

Slurry - a term used for a glue that contains ground up bits of the plastic to be used along with the glue. The bits of plastic give the glue more body, plus some plastics will not adhere to one another unless the glue is a slurry of its own type of plastic.

Styrene - polystyrene - a thermoplastic produced by the polymerisation of a chemical compound styrene (C₆H₅CHCH₃). Such material is classified as a general purpose type, but more recently the styrene monomer has been polymerised with other monomers and polymers to produce materials with specialized properties (toughness and heat resistance). Polystyrene materials which are fabricated by injection molding and extrusion techniques, have excellent electrical properties and produce lightweight moldings free from taste and odor. Such moldings may be produced crystal clear or in a wide range of colors. Among the vast number of applications for the material are refrigerator trays and boxes, housewares, display figures, light filaments, etc.

Thermoplastics - A material that will repeatedly soften when heated and harden when cooled.

Thermovacuum Forming - a method of forming plastic sheets or films into three-dimensional shapes, in which the plastic sheet is clamped in a frame suspended above a mold, heated until it becomes softened, drawn down into contact with the mold by means of vacuum, and cooled while in contact with the mold.

Undercut - an indentation or protuberance in a mold that tends to impede withdrawal of a molded part from the mold. Articles of soft materials such as flexible vinyls can be removed from molds with severe undercuts, but undercuts must be avoided in molds for rigid materials.
Uvex— a butyrate type clear plastic manufactured by the Eastman Kodak Company.
SOURCES CONSULTED

Books


Pamphlets


Interviews


Pullman Incorporated, 77 Commerce Street, Henrietta, NY, interview with Bob Huling and Alex Pasqualeni, 5/13/81.

RB Plastics, (division of Faro Industries) 40 Commerce Ave., Henrietta, NY, interview with Bill Bashford, 12/9/80.

Roson Plastics, 400 Avis St., Greece, NY, interview with Bruce Rasmusson, 4/29/81.