INTRODUCTION TO THERMOFORMING- Vacuum Forming

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INTRODUCTION

Vacuum forming involves pushing a mould into a heated TP sheet and evacuating the air from between mould and sheet, so that atmospheric pressure pushes the sheet onto the mould, making the forming.

There are many different kinds of vacuum forming machine available from small, manually operated units to fully automatic, in-line production machines, but no matter what the differences between units might be, they are all variations on the same theme, ie:

1 The sheet is clamped in place on a heat proof air-tight seal.

2 The heater system moves under or over the sheet, or vice versa, and begins heating.

3 Once the sheet has reached it's thermoforming temperature the vacuum pump is energised.

4 The heater moves back to it's resting position (or the sheet moves from the heating position to the moulding position).

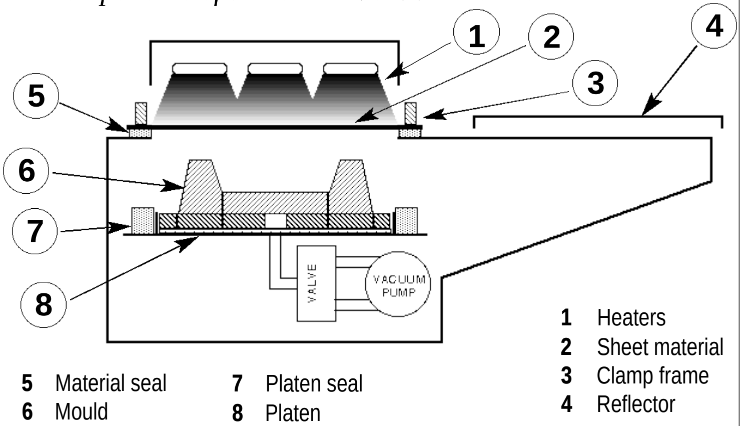
5 The mould, mounted on a moving platen, moves up into the sheet which drapes over it.

6 Once the platen reaches the top of it's stroke, the space between the underside of the sheet and the upper surface of the mould forms an air-tight pocket connected to the vacuum pump, which then pumps air from between the two. This removes air which is preventing atmospheric pressure from pushing the sheet down over the mould.

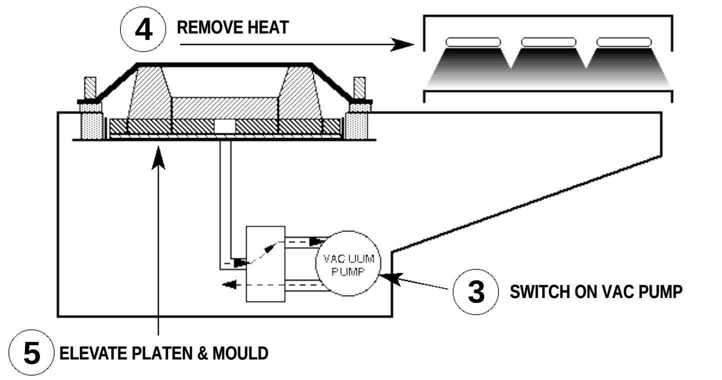
7 As the sheet cools it contracts, gripping the mould. Hence the next step is to reverse the airflow, using air pressure to force the forming off the mould and prevent it sticking, this step has become known as the 'blow cycle'. Blow cycles are short - just long enough for the forming to release from the mould - and immediately followed by another vacuum cycle.

8 Vacuum / blow cycling continues until the sheet is rigid once more. At this time, the vacuum is switched off or the mould lowered and the forming is released from the clamp.

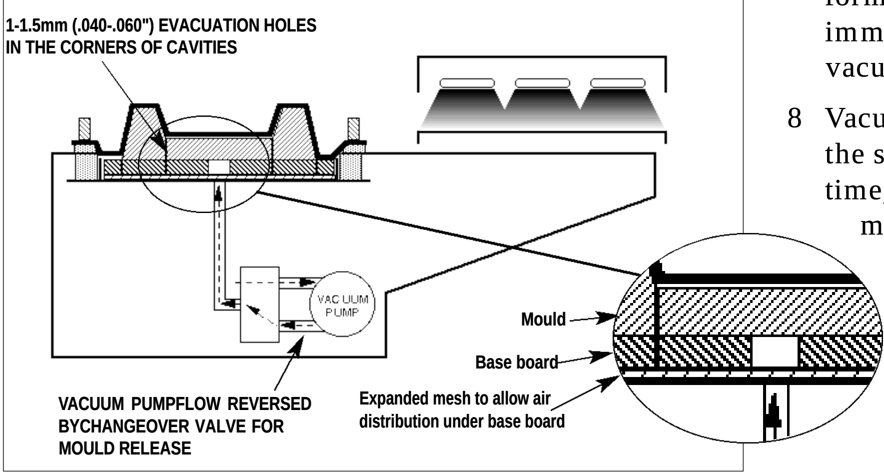
The components of a 725FLB Vacuum Former



Steps 3-5 on a 725FLB



Steps 7 & 8 on a 725FLB

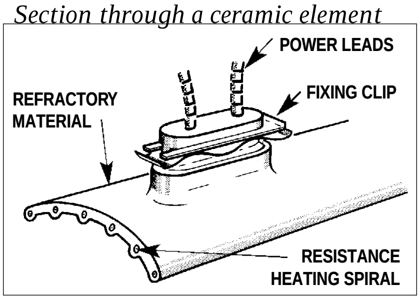


THE HEATER SYSTEM

Ceramic heaters are possibly the most common amongst vacuum forming machines. They consist of coiled resistance wire elements set in moulded china clay. Available in round, square or rectangular shapes, they can be flat (for maximum proximity) or curved (to provide a parabolic reflector which radiates more effectively).

The main advantage of ceramics is that they radiate long wavelength heat which is readily absorbed by TP's.

Section through a ceramic element



They can run at very high power outputs but the normal level for high performance vacuum forming is around 22.25 kw / sqm (2 kw / sqft).

Their only drawback is their high thermal mass, which means they take some time (10 - 15 minutes) to warm up and are slow to respond to energy regulation adjustments.

Quartz emitters are also used in vacuum forming and like ceramics, they have a coiled resistance wire element but housed in a quartz glass tube, rather like a bathroom heater. With much less thermal mass there is hardly any warming up time and the medium wavelength heat is more responsive to reflectors so that a greater percentage of heat can be projected downward.

The drawback of quartz emitters is that medium wavelength heat is not so easily absorbed by TP's as the long wavelength heat of ceramics.

HEAT ZONES

Heaters are arranged in a reflective hood in groups or clusters which can be controlled independently. This allows the operator to control the distribution of heat over the sheet which is useful, particularly for complex moulds (eg. fridge linings).

To determine what each individual heat setting should be, a grid is drawn on a sheet corresponding to the pattern of heat zones. A forming is taken and where there is excess thinning, heat output is reduced. Equally, heat output is increased in zones where definition is poor.

DOUBLE SIDED HEATING

For material thicknesses over 5 or 6 mm, single sided heating is usually too slow, and a double sided system is used. In such a system the sheet will normally move to the heating station, which is pressurised, so that the sheet can be supported by air as it sags to prevent it from sticking to the lower heaters.

THE PLATEN SYSTEM

Lifting the platen is an important part of the process as it needs to be done promptly and as quickly as possible so that forming takes place before the sheet begins to cool and go rigid.

On smaller machines it is done manually with a lever. Bigger machines need pneumatic, hydraulic or other mechanical systems because they have bigger, heavier moulds and bigger, thicker sheets which offer more resistance.

THE VACUUM SYSTEM

Vacuum pumps, appropriate to the size of sheet being formed and the volume of air being evacuated (approximately -0.83 bar [25 inHg]) should be an integral part of the machine.

The type of pump is important because most TP's give off vapours when they are heated which can corrode the delicate components found in some pump units, leading to reduced performance and ultimately failure.

THE BLOW CYCLE

When vacuum forming manually, it is best to make the first blow cycle as soon as the material has been drawn completely over the mould - it will still be soft over much of it's area but, if a short blow cycle, to break the material's grip, is followed by another vacuum cycle, the material will draw back down onto the mould and subsequent blow cycles can be shorter. It's important to keep the blow cycles as short as possible because they will put stress into the corners of a mould if they are done for too long once the material is rigid.

COOLING AND THINNING

As soon as the heated sheet makes contact with the mould, it will start giving up it's heat to the mould and becoming rigid again. This is why it is common to find vacuum formings with deeper material thickness at the top than the base; the material at the top cools first and stops stretching because it makes contact with the mould before any other part of the sheet. The material at the bottom of the mould is the last to cool so it's stretching for longer than other parts (see Heat Zones earlier).

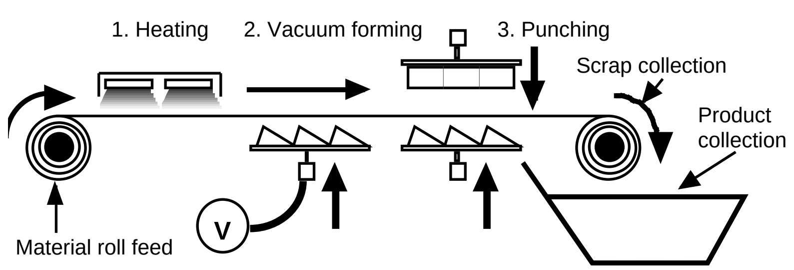
THERMOFORMING MACHINE OPTIONS

AUTOMATION

Any or all of the vacuum forming functions can be automated and indeed they are for most commercial production purposes along with some others, such as automatic cutting, stacking or counting.

For example, vacuum formed pvc sandwich packets are made 24 or so at a time on a large thermoformer. The material is fed from one roller, over the machine and onto a scrap collecting roller. The fixed heater heats an area of sheet at the same time as one batch of packets are being vacuum formed and the previous batch are being punched out ready for stacking and collection. Each cycle takes only seconds to complete and one machine produces thousands of packets each day. The heaters may not be set to work at their full capacity - to allow enough time for the thermoforming to be completed.

Schematic of a sandwich packet thermoformer



VACUUM / PRESSURE FORMING

The pressure exerted by ordinary vacuum forming is limited to atmospheric pressure which, for some applications does not produce enough definition. In such cases vacuum / pressure forming may be used. This technique involves a machine with a sealed pressure chamber over the top of the forming into which compressed air is pumped during forming thus increasing the pressure drawing the material down onto the mould.

PLUG ASSIST VACUUM FORMING

The depth of a forming is limited by the ability of the material to stretch into a long deep shape, such as a cup. Ordinary vacuum formers can only really vacuum form a depth of about half the diameter of a cup - any deeper and the material at the bottom becomes so thin as to be unusable. So cups and yogurt pots are made with machines that have a male mould which pushes the heated material into a female mould before vacuuming commences. This distributes the material more evenly over the mould thus achieving deeper draws.

PRE-DRYING

As we've already mentioned TP's absorb moisture which can lead to problems when vacuum forming -particularly Extruded Acrylic, ABS and Polycarbonate; these materials must be pre-dried before heating.

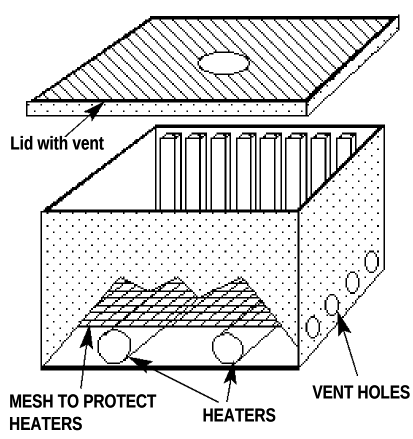
OVEN

Materials can be dried by placing them in a fan assisted oven at 40˚C (70˚F) below the start of their thermoforming temperature range for about 1-2 hours per mm of thickness. Polycarbonate generally takes longer than ABS or Extruded Acrylic and times will vary from batch to batch - depending on how much moisture has been absorbed due to the conditions that the material has been stored in.

HOT BOX

Alternatively, you can construct a simple hot box using plywood and a low power heater such as a greenhouse heater or even light bulbs. If sheets are stored in the hot box then (as long as they've been in there for more than a day or so) they will always be ready to use.

Simple Hot Box construction



! SAFETY NOTE !
For safe operation ensure that heater power will not exceed 60°C (140°F)

MATERIAL REFERENCE CHART

Material	Pre-drying	Definition	Forming temp. ˚C(˚F)
Polystyrene	NO	Good	120 (250)
Extruded acrylic	YES	Good	160 (329)
PVC	NO	Fair	130 (265)
ABS	YES	Good	159 (300)
Polycarbonate	YES	Good	200 (400)
Polypropylene	NO	Very good	180 (350)
Polyethylene	NO	Fair	120 (250)
PETG	NO	Good	120 (250)

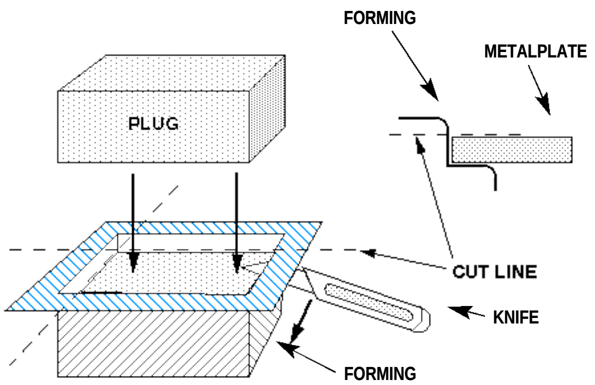
TRIMMING

LOW VOLUMES

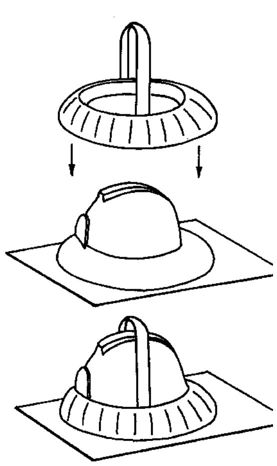
Special machines are available that are designed specifically for cutting out vacuum formings.

Our Profile Router 145, suitable for material up to 3mm thick, comprises a slot drill mounted in a work table with a guard/fence that allows you to follow the profile of a forming accurately whilst protecting against injury from the cutting tool.

Using a plug to help cutting out



Using a trimming guide



The whole table pivots so that you can cut into the corners of a forming or cut leaving a flange which is useful for gluing.

Thinner materials, up to 1mm can be cut with an art knife and this process itself can be made somewhat easier if some form of cutting guide or plug is used.

HIGH VOLUMES

Many mass production thermoformers are designed with an integral trimming or cutting device.

Small, lightweight items such as packaging are simply punched out by a die mounted immediately after the vacuum press.

Yogurt cups or tubs designed to take lids are treated specially with a rolling device as they are cut which turns over the top to form the lip.

Heavy gauge products can be cut out using hand held routers, hole saws, band saws or guillotine. A five axis CNC router is probably the fastest and most efficient form of trimming and finishing. These routers not only cut out the basic shape but can also cut out windows from cars or boats and engrave features, lettering or details.

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