Vol. 6 No. 11 SPRING 1986

NEWSLETTER

THERMOFORMING DIVISION

SOCIETY OF PLASTICS ENGINEERS, INC.

CHAIRMAN'S COMMENTS

We are still having some difficulty in putting together our Thermoforming Exhibition. The project is still very much alive, but there seem to be more and more questions that have to be answered. We'll keep you posted. The Board of Directors is committed to a venture of this type.

The Thermoforming Technical Program looks like it is going to be the finest ever presented at an ANTEC. The papers are of very high quality and the sessions should be very well attended. In addition to our usual Session, for the first time ever, there will be a joint session sponsored by the Thermoforming and Extrusion Divisions. It is hoped that some of the difficulties encountered by thermoformers and extruders can be discussed in a common forum, and we all can benefit from the dialogue.

The continuing discussions between the Thermoforming and Extrusion Divisions has been most gratifying to me because they have culminated in this joint session at ANTEC. It seems that for too long each group has been operating "in the blind" and not sitting down to discuss the things that give each group trouble. Now we have a beginning. This is a project that Pete Hughes initiated, and through his perseverance in the face of many objections, he has been able to put this joint session together.

We again will be awarding the Thermoforming Man of the Year award at ANTEC, along with a Best Thermoform of the Year. These awards will be given at our Technical Session at an intermission.

Hope to see you at ANTEC! You better not miss the best one ever! !

John T. Kelly, Chairman
Thermoforming Division

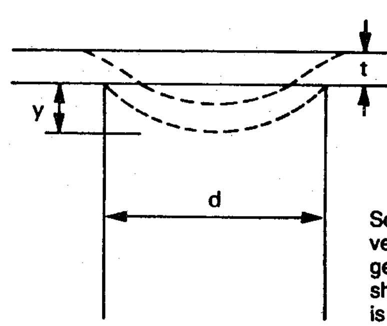
SIZING VENTS

Jim Throne
Engineering Consultant
Naperville IL 60540

(Material Extracted from "Design of Thermoform Molds", Ad. Poly. Tech., 4, (1985), 225-239 and from Chapter 6, Thermoforming, Hanser-McMillan, 1986

As hot plastic sheet is drawn into the mold, air trapped between must be evacuated. Normally small holes are provided in the mold surface at the point(s) where the last portion of drawing sheet contacts. The number and diameter of these vent)or vacuum) holes should be determined prior to mold design. If the vent hole diameter is too large, hot plastic will be drawn into it, producing an unsightly bump (known as a nipple) on the finished part. If the drawing is excessive, the sheet can actually rupture at this point. If too few vent holes are provided (or more correctly, if the vent area is too small), the rate of drawdown will be controlled by the rate of air flowing from the entrapped bubble. If this rate is too slow, rapid heat removal from the sheet may then prevent full mold shape replication. The plastic material covering the entrapped air bubble may cool to the point where it can no longer be stretched.

Mold vent hole diameter depends upon several factors, including modulus of the hot plastic sheet, sheet thickness over the hole and allowable draw depth into the hole. Consider the schematic.



Schematic of vent–hole geometry. t is initial sheet thickness, y is deflection, and d is hole diameter.

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It can be shown that the maximum deflection of the sheet, y, is given as

$$y = \alpha t = (3qd^4/16Et^3)(5 + \nu)(1 - \nu) \quad (1)$$

Where t is the local sheet thickness, q is the applied pressure, d is the vent hole diameter, ν is Poisson's ratio for the polymer and E is the polymer Young's modulus of elasticity. Now y is assumed to be proportional to local sheet thickness, with α being the proportionality. For many plastics, the value of ν is between 0.35 and 0.5. As an example, allow $\nu = 0.5$. Then

$$\alpha = 0.516(q/E)(d/t)^4 \quad (2)$$

The parts designer usually determines the maximum acceptable nipple height, thus setting α. Thus this equation can be rearranged to read:

$$(d/t) = 1.18\,(\alpha E/q)^{1/4} \quad (3)$$

This equation is shown below. As an example, if the temperature-dependent sheet modulus is 10 Mpa (1450psi), and the applied pressure is0.1 MPa (14.5 psi), a vent hole diameter 3.73 times the local sheet thickness will draw a nipple in length to the local sheet thickness. Note that this equation illustrates the high sensitivity of nipple length to vent hole diameter and sheet thickness. If, for example, the vent hole diameter is actually 4.44 times the local sheet thickness (or if the local sheet thickness is actually only 86% of the predicted, design thickness), the nipple length will be *twice* the local sheet thickness. A similar (but less dramatic) effect is seen if the sheet is hotter than originally predicted. Hotter sheet implies lower elastic modulus and longer nipple length.

It is recommended that the vent hole diameter chosen be based on the first common drill size below the calculated value and, further, that the vent holes br drilled perpendicular to the plane of the mold and that a 6mm (0.25 in.) diameter hole be counterbored from the reverse side for each vent hole to within 6mm (0.25 in.) of the primary mold surface.

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COUNCILMAN'S REPORT

The fall Council Meeting was held in Toronto, Canada on October 25, 1985. The major item on the agenda was a discussion concerning a proposal to increase dues in 1986-87 by $10.00 to $55.00, a 22% increase. Prior Past President Bob Schaffhauser and Marketing Division Councilor Bo Chinners presented extensive information on a variety of aspects affecting the rate of dues. The subject will again be discussed at the February 21st Council meeting in Hollywood Beach, Fla.

Two new Student Chapters were chartered at the University of Maine at Orono and at Auburn University. Appointments of two Committee Chairmen were confirmed; Donald V. Rosato (Technical Volumes) and George C. Bennett (Sections).

The next Council Meeting will be February 21, 1986 in Hollywood Beach, Fla.

NOTE: Make plans to attend ANTEC '86 in Boston, MA on April 28th thru May 1st.

Frank Palmer,
Councilman

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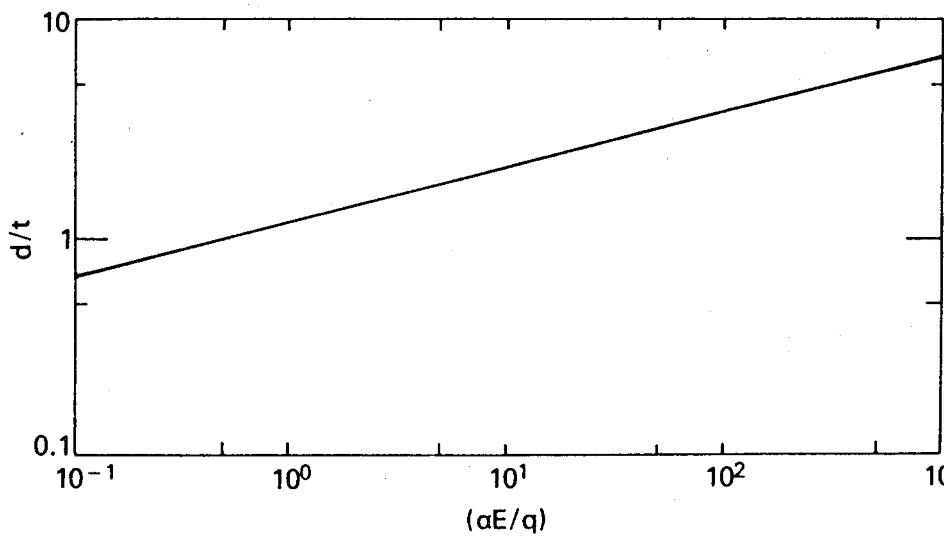
Specific vent hole design diameter (d/t) as a function of material modulus E and applied pressure q. α is the allowable specific sheet deformation (y/t). t is sheet thickness.



Number of Vent Holes

Once the size of the vent hole is established, the number can easily be detemined. From very simple measurements the volume of air captured in the mold cavity the instant the heated sheet is sealed against the mold rim can be determined. Thus volume, V, must be removed from the cavity in a reasonably short period of time, say, θ. Thus the volumetric flow rate of air through the vent holes should equal (or exceed) the value, V/θ. When the ratio of internal to external to external (vacuum side) pressure exceeds about 0.52, evacuating air speed reaches a maximum value, the sonic velocity C about 33500 cm/s (1100 ft/s). The vent hole surface area is given as:

$\pi ND^2/4$, where N is the number of holes and D the hole diameter. So

$$CN\pi D^2/4 = \beta V/\theta \qquad (4)$$

Where β is a proportionality, acting as a safety factor tc prevent air escape velocity from limiting drawdown rate Since the number of holes is to be determined, this expression can be rewritten:

$$N = 4\beta V/\alpha C\pi D^2 \qquad (5)$$

As an example, if $V = 1000\ cm^3$, $\theta = 0.1$ s, $D = 1.59$ mm (0.0625 in.), and $\beta = 10$, $N = 150$ holes.

These holes must, of course, be placed in the region(s where the last drawdown occurs. Experienced moldmakers note that inexperienced shops provide far too few vent holes of diameters that are far too large. Thus, although the volume of entrapped air is usually exhausted in reasonable time, objectionable nipples result. This forces the fabricato to use lower sheet temperatures and if stretching forces are limited, this results in poorer part replication of the mold shape.