THERMOFORMING QUARTERLY®

A JOURNAL OF THE THERMOFORMING DIVISION OF THE SOCIETY OF PLASTICS ENGINEERS

P. O. Box 471
Lindale, Georgia 30147

CHANGE SERVICE REQUESTED

Thermo Forming Division

Our mission is to facilitate the advancement of thermoforming technologies through education, application, promotion and research.

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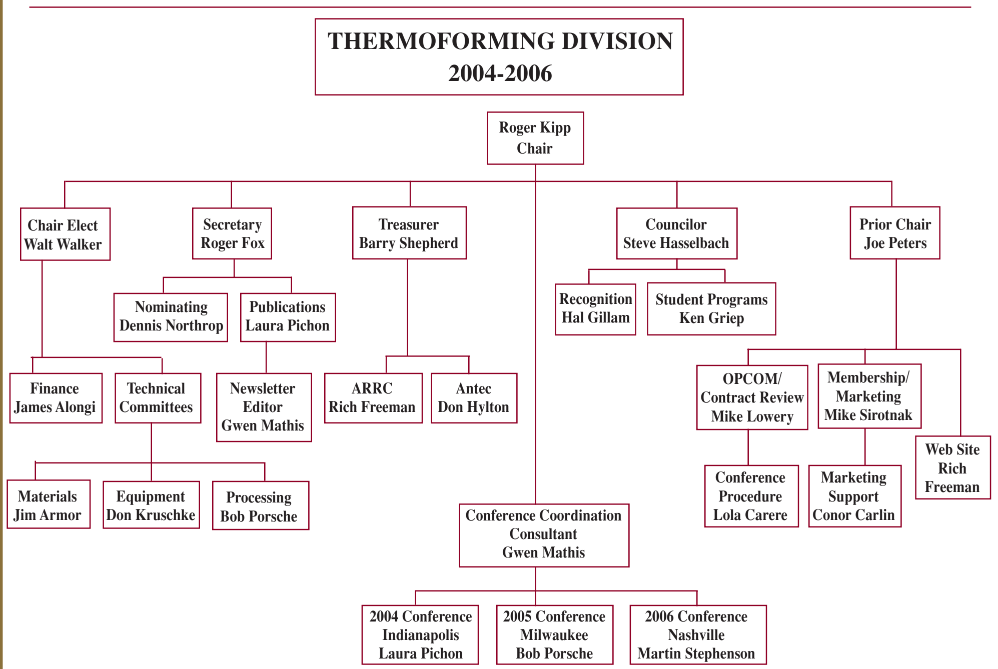
THERMOFORMING DIVISION ORGANIZATIONAL CHART



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THERMOFORMING QUARTERLY®

A JOURNAL OF THE THERMOFORMING DIVISION OF THE SOCIETY OF PLASTICS ENGINEERS
"WINNER 2003 & 2004 AWARD OF EXCELLENCE"

Special Conference Pull-Out Section

The success of this conference is attributable in a large part to the generosity of our 2005 Conference Sponsors.

PRE-CONFERENCE EDITION

LEAD TECH ARTICLE

"AUTOMOTIVE PLASTIC FUEL TANK SYSTEMS"
BY K. W. ALBAUGH, BIELOMATIK – see page 11

Web Site: www.thermoformingdivision.com

CHAIRMAN'S CORNER

BY ROGER KIPP, CHAIR

STRATEGY … POSITIONING FOR SUCCESS

The Thermoforming Division, like all successful business organizations, needs to operate with long-range goals and objectives. The goals and objectives provide the basis for our strategy and planning. Our Executive Committee has provided this long-range planning to our National Society as part of the 2005 Pride Compliance Report, submitted in February.

Long-term we see the need to continue to develop and refine strategic planning that provides **continuity, consistency and a cohesive vision** within our Board and from our Board. This is vital as each Chairman only has two years (six Board meetings) at the helm. In order to continue to meet the mission of facilitating the advancement of Thermoforming Technology through education, application, promotion and research this strategy is imperative. The primary goals supporting this challenge are:

1) We must maintain sufficient resources to meet the obligations we have committed to. This will involve growing and maintaining membership and membership values.

2) Provide continuing maintenance of operating procedures to assure consistency within our efforts.

3) Provide ongoing evaluation of the succession within the Executive Committee in order to assure continuity.

4) Maintain an open forum for new ideas. Encourage and promote fresh participation to assure cohesive growth. This is a goal that will need the involvement of all of our plastics' associates.

The short-term goals developed through committee communication and achieved through committee work position us for successful completion of our long-term goals. Please note the roster of Board Members on the inside of the last page of the Thermoforming Quarterly. We have added the Technical Committee affiliation of each Board Member. We invite you to communicate with the Board your ideas for achieving our missions.

The assimilation of new ideas and participation needs to be generated from outside our Board activity.

Alliance – The forum for creative thinking and energy.

Our Industry, Society, Division and Members need to look outside for added development input. The Thermoforming Division and Society have initiated formal alliances with "competing" organizations to set a path of knowledge sharing that will open opportunities for all participants.

- The Society of Plastics Engineers has announced an alliance with the American Management Association (AMA). As an SPE Member, we will receive significant savings and invaluable educational resources. The AMA can support workforce development through practical business training seminars, conferences, and online information. It is up to each of us to make use of this valuable asset.
- The Thermoforming Division has an alliance with the Decorating and Assembly Divisions involving conference participation. Please plan to attend and support these workshops at our Milwaukee Conference.
- A plan for developing an alliance with other Divisions is in place with our "Exactly What is Thermoforming" DVD providing an introduction. "It's About Plastics," an expansion of multi process knowledge and understanding can only strengthen the plastics industry and our individual growth.
- The alliance with the European Thermoforming Division is growing with plans for mutually beneficial programs and program support currently in the planning stage between your Chairman and Ken Braney, Chairman of the European Division.

It is my hope that our alliance feedback will provide thoughts and energy for business and personal growth to our members and members' companies.

Please provide your thoughts on the strategy of alliance for success.

Sincerely,

Roger C. Kipp, Chairman

Ken Braney, Chairman, European Thermoforming Division, and Roger Kipp, Chairman, Thermoforming Division in U.S., growing PARTNERSHIP.

Contents

THERMOFORMING QUARTERLY®

TECHNICAL SECTION

DIVISION ACTIVITIES

A NOTE TO PROSPECTIVE AUTHORS

TFQ is an "equal opportunity" publisher! You will note that we have several categories of technical articles, ranging from the super-high tech (sometimes with equations!), to industry practice articles, to book reviews, how to articles, tutorial articles, and so on. Got an article that doesn't seem to fit in these categories? Send it to Jim Throne, Technical Editor, anyway. He'll fit it in! He promises. [By the way, if you are submitting an article, Jim would appreciate it on CD-ROM in DOC format. All graphs and photos should be black and white and of sufficient size and contrast to be scannable. Thanks.]

THERMOFORMING QUARTERLY®

A JOURNAL PUBLISHED EACH CALENDAR QUARTER BY THE THERMOFORMING DIVISION OF THE SOCIETY OF PLASTICS ENGINEERS

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Membership is an HONOR!

BY MIKE SIROTNAK, MEMBERSHIP CHAIRMAN

By now, all of you have received the DVD "What Exactly is Thermoforming?" By now, some of you may have even watched it. I urge each and every one of you to watch this outstanding, short synopsis of our industry. Due to its enormous popularity, we just ordered its second printing. Additional copies can be requested from any Board member. The DVD is available by downloading it from our web site, www.thermoformingdivision.com. We have received requests for additional copies from material manufacturers, processors, professors and even recruiters. We encourage you to spread the news. Your feedback is always welcome.

Our division continues to be the trendsetter of the Society of Plastic Engineers. The focus of the division continues to be educating our industry through scholarships, matching grants for scholastic equipment, DVD's, *Thermoforming Quarterly*, technical conferences, trade shows to name a few. We are a division of action not just talk. And that is something to be proud of. I urge each and every one of you to actively recruit new members. My goal is to have our membership numbers challenge those of the more high profile industries. We offer so much more than the other divisions; we should have better membership numbers.

Now is the time to start planning for Milwaukee. This year's technical program and trade show should be very interesting. Bob Porsche and Gwen Mathis have put together a first-rate conference. The technical program is focusing on recent advancements in our industry. Walt Walker and Ed Probst are doing an outstanding job.

MEMBERSHIP REPORT
as of 3/1/05

Primary Paid	1,230
Secondary Paid	449
Total Membership	1,679
Goal as of 6/30/2005	2,000

Please remember to support the Parts Competition; it takes a lot of effort to set up and coordinate and the awards look awesome in your lobby. Joe Peters will be handling the competition for the first time, so there is even for reason to be concerned. As always, please support the exhibit floor. We cannot have a conference like we do without all those great, loyal exhibitors.

I look forward to seeing all of you in Milwaukee and appreciate all of your support.

God Bless America! ■

To Our New Members

Shawn Aldana
General Plastics
Milwaukee, WI

Adam W. Barton
Cincinnati, OH

Kelly Bennett
Southern Plastics
New Bern, NC

Brian A. Bentley
Livonia, MI

Adam Bishop
Spray Control Systems
Blooming Prairie, MN

David A. Branscomb
John Deere Co.
Molina, IL

Hector C. Cabezas
Moverol CA
Valencia, Venezuela

Brian T. Carvill
Pactiv Corp.
Lake Forest, IL

Lam Chuan Lim
Parade Mfg/
Federal Terrioto, Malaysia

Alfonso Diez-Gutierrez
Tapones Y Articulos De Distribution
Jiutepec, Morelos
Mexico

Joan Dorsey
Don's Specialities
Goodlettsville, TN

Daniel Drzik
Walton Plastics
Walton Hills, OH

Kenneth H. Franklin
Packaging Machinery Services
Cleveland, OH

Cress Hanenkratt
Poly Hi Solidur
Fort Wayne, IN

Robert D. Hirsch
Solvay Advanced Polymers
Alpharetta, GA

Sarah J. Holthaus
Trompealeau, WI

James Hunnicutt
CorStone Industries
Greenville, AL

Kenny Jensen
Spray Control Systems
Blooming Prairie, MN

Andre K. Johnson
Sicklerville, NJ

John R. Kennedy
Jaco Plastics
Plainfield, NJ

Daniel P. Ketchpel
Industrial Forming
Goleta, CA

Scott Koetje
Solo Cup Corp.
Wheeling, IL

Dick Kruckegerg
Spray Control Systems
Blooming Prairie, MN

Babu Kuruvilla
Duni Corp.
Thomaston, GA

Chuck Marion
Velux-Greenwood, Inc.
Greenwood, SC

Donald C. McCarthy
Georgia Pacific Corp.
Neenah, WI

Doug McGinnis
Howell Packaging
Elmira, NY

Tricia McKnight
Society of Plastics Engineers
Brookfield, CT

Jim Meyer
Flaxpak Corp.
Phoenix, AZ

Bill J. Moore
Alltrista Industrial Plastics
Fort Smith, AK

Mark Nothnagel
Visy Industrial Packaging
Melbourne, Victoria Australia

John D. O'Keefe
Walpole, MA

Dhavel N. Parikh
GE Plastics
Mt. Vernon, IN

Randy Paul
Plastics Ingenuity
Cross Plains, WI

Carlos Pineda
Flexpak Corp.
Phoenix, AZ

Dean Poelman
PSI
Olive Branch, MS

Ron Read
Plastics Unlimited
Preston, IO

Gary J. Rief
Fox Valley Tool & Die
Kaukauna, WI

Jaime Eduardo Salinas
Nikolau Alayon
Brazil

Matt M. Shade
GS Engineering
Sylvania, OH

David M. Smith
Conyers, GA

Anil Shah
Solo Cup Co.
Highland Park, IL

Jeremy J. Simkowski
Reynolds Food Packaging
Visalia, CA

Merie R. Snyder
Plastics Machinery & Auxiliaries
Denver, CO

Laurynas Straukas
AB Snalge
Lithuonia

Douglas Van Eeuwen
Lorco LLC
Sterling Heights, MI

Nicole F. Whiteman
Cargile Dow LLC
Minneapolis, MN

Robert J. Whitish
Plastics Ingenuity
Cross Plains, WI

WHY JOIN?

It has never been more important to be a member of your professional society than now, in the current climate of change and volatility in the plastics industry. Now, more than ever, the information you access and the personal networks you create can and will directly impact your future and your career.

Active membership in SPE:

- *keeps you current*
- *keeps you informed*
- *keeps you connected*

The question really isn't "why join?" but …

WHY NOT?

Manfred Jacob, Founder

Jacob Kunststofftechnik GmbH, Wilhelmsdorf, Germany

Manfred Jacob was born in Furth, Bavaria, Germany in 1942.

His first contact with plastics came in the family kitchen as his father experimented with expanded polystyrene and started the first of many Jacob plastic enterprises business in the late 40s. Manfred went on to become a world class gymnast but a back injury forced him off the German Olympic team. Unable to launch his own body into space, he joined the German Air Force to make the moves in a plane that he could no longer make in the gym.

When Manfred was mustered out of the air force he made an attempt to buy a well established thermoforming business but could not come to terms with the owner. On his way home an almost chance encounter with a friend's widow left with a small packaging business led to his purchasing the equipment and Jacob Kunststofftechnik was born 1st January 1973. Manfred's goal: To be an expert in his chosen field.

The equipment consisted of two Illig UA 100 thermoforming machines, two horizontal band saws and one roller trim press. Total employment for this new company was 2.5 people with the main thermoforming machine operator being Manfred. So he set out to learn his chosen craft. I

don't know about the band saws but the original Illig Thermoformer is still in Manfred's plant to this day.

Driven by this vision of becoming an expert, Manfred Jacob Kunststofftechnik has become one of the largest thermoforming companies in Europe. The Jacob Group's capabilities now include:

- High pressure formed technical components
- Highly demanding Twin Sheet formed technical parts
- Thermoforming of continuous fiber advanced composite materials and the cutting technology associated with this process
- Traditional custom thermoforming business in producing quality thin gauge and large area thick gauge parts
- Decorative Insert Molded foils and parts with particularly complex trimming associated with this process

A short list of cars using Jacob Dash and Interior Trim components include:

Ford Mondeo, Ford Focus, Mercedes SLK, PT Cruiser, Renault Clio, Rover 45, and Toyota Agenesis.

Manfred's inventions are many. One is cavity floor which uses thermoformed parts and self leveling cement to create a solid floor with multiple track ways below for air conditioning, electrical wiring and plumbing. This development would allow the services to run anywhere on an entire floor plan and had become a standard in Europe. Currently, over one million square meters of Cavity Flooring are used in German office buildings alone. Cavity Floor is also used in buildings in Tokyo, London and in South America.

His twin sheet baking pan has replaced wooden trays dating back to the dark ages, and his Thermoformed composite auto bumper is on its way to being the standard for all of BMW cars. To list all his inventions and innovations in thermoforming would take more time and kill more trees than is ecologically responsible, but it's safe to say if you buy German thermoforming equipment, or are in the packaging industry, Manfred's ideas and enhancements are all around you. His parts regularly win awards in the annual thermoforming parts competition.

Manfred is unquestionably a visionary of some standing. He also has the unique ability and willingness to transmit the message and his inbred enthusiasm to all those around him, as any visitor to his plant can testify. He was also responsible for forming the consortium that supplied forming data in relationship to simulation programs on thousands of parts enabling T-Sim to refine their software and make it more accurate.

One of his visions was in approaching a number of local small, but highly technical design, tooling and plastics companies, and all experts in their fields, to consider a form of amalgamating together under one roof. This has had a dramatic effect on all involved. Not only has it formed a tremendously successful and professional group, but each individual company has profited by this close association, an example of synergy in its purest form. This organization was known as QIC and was established in 1995. Much in the way of new technology and product ideas have come out of this collaboration.

This philosophy of becoming stronger through association with other thermoformers and a willingness to share his knowledge also played a major part in Manfred's long involvement with the Thermoforming Division of the SPE and the ultimate birth of the highly successful European Thermoforming Division. How did this come about?

Manfred became closely associated with two like minded companies, one in Holland and another in the United Kingdom. Personal relationships flourished and they started to meet regularly to share ideas and set standards for processing within their companies. They also would regularly visit the U.S. for the annual thermoforming conferences.

Since those early days, Manfred has been an active participant in the annual thermoforming conferences. Many of us remember his presentation of the "State of the Thermoforming in Europe," given at the 1995 conference in Independence, Ohio where he made many of us aware of some very interesting alternatives to the way things were done in the U.S.

Knowing that most European producers would never make it to the U.S. for conferences, the idea of a European thermoforming conference began to take shape. With help from the thermoforming division, a European "trial" conference was held in the spring of 1997 at the Manfred Jacob Kunststofftechnik facility, Wilhelmsdorf, Germany. It was here that the term "Spirit of Thermoforming" was first used.

Spurred on by the success of the event in Germany, a group of six European Thermoformers visited Chicago for a meeting with the SPE and the Thermoforming Division to discuss forming the European thermoforming division. The decision was made not only to form the division, but also to attempt to hold an International thermoforming conference in March 1998 in Ghent, Belgium. since then four more highly successful European conferences have been held and in the first SPE Division outside of the U.S. "The European Thermoforming Division of SPE" was founded.

At the last conference in Viareggio, Italy, Manfred was honored as the father of that division. He was awarded for his services to the ETD and to the European thermoforming industry in general.

Now semi retired, Manfred still spends time inventing, teaching his grandchildren English, as well as golfing, skiing and driving as close to mach speed as the autobahn allows. ■

THERMOFORMER OF THE YEAR CRITERIA FOR 2006

Every year The SPE Thermoforming Division selects a individual who has made a outstanding contribution to our industry and awards them the Thermoformer of the Year award.

The award in the past has gone to industry pioneers like Bo Stratton and Sam Shapiro, who were among the first to found thermoforming companies and develop our industry. We have included machine designers and builders Gaylord Brown and Robert Butzko and toolmaker John Greip, individuals who helped develop the equipment and mold ideas we all use today. We have also honored engineers like Lew Blanchard and Stephen Sweig, who developed and patented new methods of thermoforming. Additionally, we have featured educators like Bill McConnell, Jim Throne and Herman R. Osmers, who have both spread the word and were key figures in founding the Thermoforming Division.

We're looking for more individuals like these and we're turning to the Thermoforming community to find them. Requirements would include several of the following:

- Founder or Owner of a Thermoforming Company
- Patents Developed
- Is currently active in or recently retired from the Thermoforming Industry
- Is a Processor – or capable of processing
- Someone who developed new markets for or started a new trend or style of Thermoforming
- Significant contributions to the work of the Thermoforming Division Board of Directors
- Has made a significant educational contribution to the Thermoforming Industry.

If you would like to bring someone who meets some or all of these requirements to the attention of the Thermoforming Division, please fill out a nomination form and a one- to two-page biography and forward it to:

Thermoforming Division Awards Committee
% Productive Plastics, Inc.
Hal Gilham
103 West Park Drive
Mt. Laurel, NJ 08045
Tel: 856-778-4300
Fax: 856-234-3310
Email:
halg@productiveplastics.com

You can also find the form and see all the past winners at www.thermoformingdivision.com in the Thermoformer of the Year section.

You can submit nominations and bios at any time but please keep in mind our deadline for submissions is no later than December 1st of each year, so nominations received after that time will go forward to the next year.

Thermoformers of the Year ...

1982
William K. McConnell, Jr.
McConnell Company

1983
E. Bowman Stratton, Jr.
Auto-Vac Corp.

1984
Gaylord Brown
Brown Machine

1985
Robert L. Butzko
Thermtrol Corp.

1986
George Wiss
Plastofilm Industries

1987
Dr. Herman R. Osmers
Educator & Consultant

1988
Robert Kittridge
Fabri-Kal Corporation

1989
Jack Pregont
Prent Corporation

1990
Ripley W. Gage
Gage Industries

1991
Stanley Rosen
Mold Systems Corp.

1992
Samuel Shapiro
Maryland Cup
Sweetheart Plastics

1993
John Grundy
Profile Plastics

1994
R. Lewis Blanchard
Dow Chemical

1995
James L. Blin
Triangle Plastics

1996
John Griep
Portage Casting & Mold

1997
John S. Hopple, Hopple Plastics

1998
Lyle Shuert, Shuert Industries

1999
Art Buckel
McConnell Company

2000
Dr. James Throne
Sherwood Technologies

2001
Joseph Pregont, Prent Corp.

2002
Stephen Sweig, Profile Plastics

2003
William Benjamin,
Benjamin Mfg.

2004
Steve Hasselbach, CMI Plastics

THERMOFORMER OF THE YEAR 2006

Presented at the September 2006 Thermoforming Conference in Nashville, Tennessee

The Awards Committee is now accepting nominations for the 2006 THERMOFORMER OF THE YEAR. Please help us by identifying worthy candidates. This prestigious honor will be awarded to a member of our industry that has made a significant contribution to the Thermoforming Industry in a Technical, Educational, or Management aspect of Thermoforming. Nominees will be evaluated and voted on by the Thermoforming Board of Directors at the Winter 2006 meeting. The deadline for submitting nominations is December 1st, 2005. Please complete the form below and include all biographical information.

Person Nominated: ____________________ Title: ____________

Firm or Institution: ______________________________

Street Address: ______________ City, State, Zip: ____________

Telephone: __________ Fax: ____________ E-mail: __________

Biographical Information:

- Nominee's Experience in the Thermoforming Industry.
- Nominee's Education (include degrees, year granted, name and location of university)
- Prior corporate or academic affiliations (include company and/or institutions, title, and approximate dates of affiliations)
- Professional society affiliations
- Professional honors and awards.
- Publications and patents (please attach list).
- Evaluation of the effect of this individual's achievement on technology and progress of the plastics industry. (To support nomination, attach substantial documentation of these achievements.)
- Other significant accomplishments in the field of plastics.
- Professional achievements in plastics (summarize specific achievements upon which this nomination is based on a separate sheet).

Individual Submitting Nomination: ____________ Title: ____________

Firm or Institution: ______________________________

Address: ____________________ City, State, Zip: ____________

Phone: __________ Fax: ____________ E-mail: __________

Signature: ____________________ Date: ____________
(ALL NOMINATIONS MUST BE SIGNED)

Please submit all nominations to: Hal Gilham,
Productive Plastics, 103 West Park Drive
Mt. Laurel, New Jersey 08045

THERMOFORMING DIVISION SPRING 2005 BOARD MEETING SCHEDULE

May 4 – 8, 2005

National Plastics Museum
Sheraton Four Points Hotel
Leominster, Massachusetts

RESERVATIONS:
CALL 978-534-9000

REQUEST SPE ROOM RATE OF $95.00
(Deadline for reservations April 4, 2005)
35 miles from Boston Logan Airport

Wednesday, May 4, 2005
Executive Committee Arrive

Thursday, May 5, 2005
Sheraton Four Points
Boardroom
9:30 am - 5:00 pm - Executive Committee - Boardroom

Friday, May 6, 2005
Sheraton Four Points
8:00 am - 9:30 a.m. - Technical Chairs meet with Executive Committee - Boardroom

9:00 a.m. - 11:00 a.m. - Machinery Committee Meeting - Gershwin Room

9:00 a.m. - 11:00 a.m. - Materials Committee Meeting - Cole Porter Room

9:00 a.m. - 11:00 a.m. - Processing Committee Meeting - Irving Berlin Room

8:00 a.m. - 3:00 pm - Other Committee Meetings - Rodgers & Hammerstein Room

3:30 pm - 5:00 pm - Tour National Plastics Museum

Lunch & Dinner on Your Own

Saturday, May 7, 2005
7:30 am - 8:30 am - Breakfast - National Plastics Museum

8:30 am - Noon - Board of Directors Meeting - National Plastics Museum

12:00 pm - 1:00 pm - Tour Plastics Museum

1:30 pm - Board Bus at National Plastics Museum - Box Lunch on Bus - travel to Universal Plastics for Plant Tour

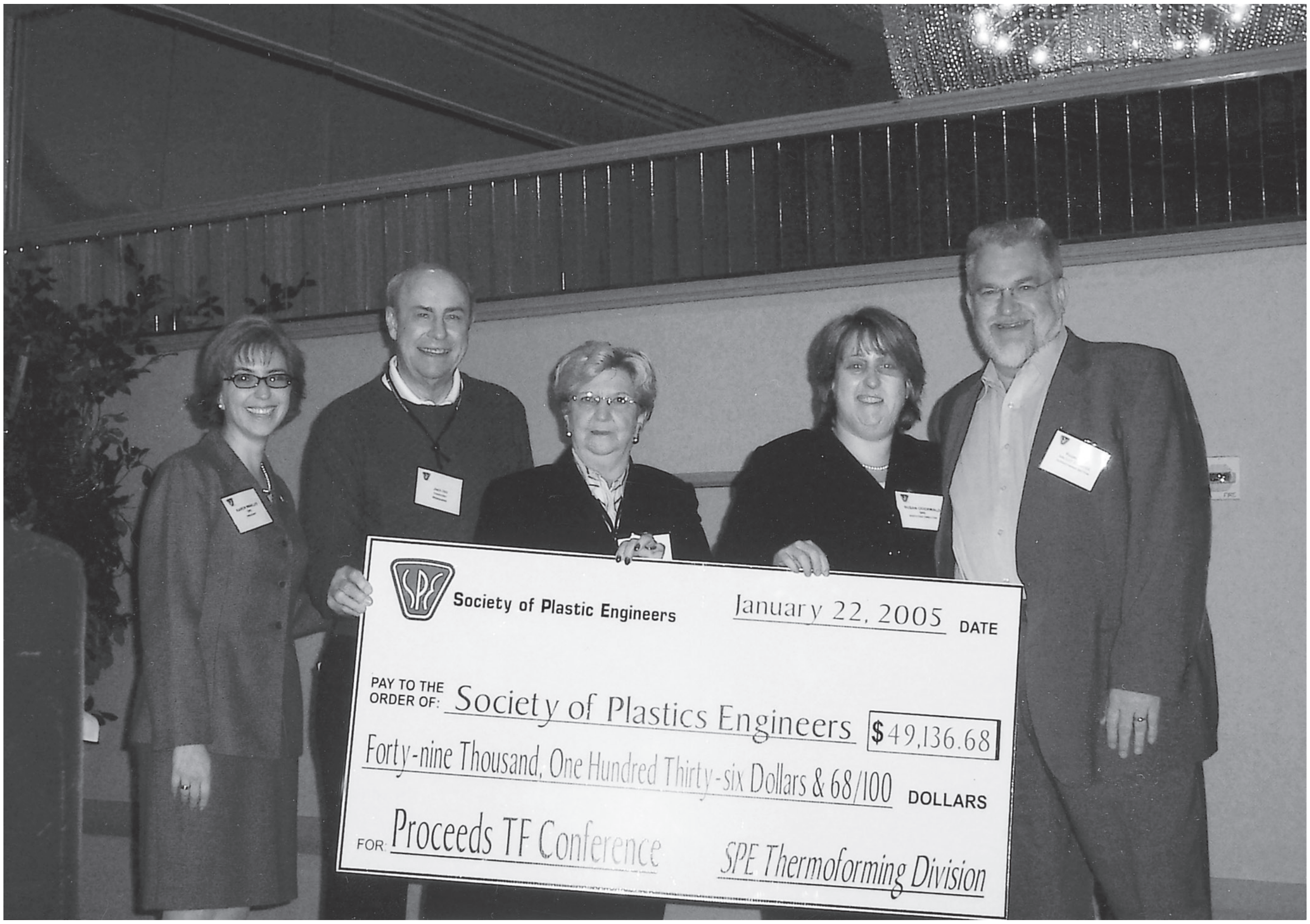
4:00 pm - 5:00 pm - Hosted Cocktail Reception at Colony Club - DRESS CODE: JACKET & TIE

5:00 pm - 6:30 pm - Dinner - Colony Club

7:00 pm - Bus Trip back to Sheraton Four Points in Leominster

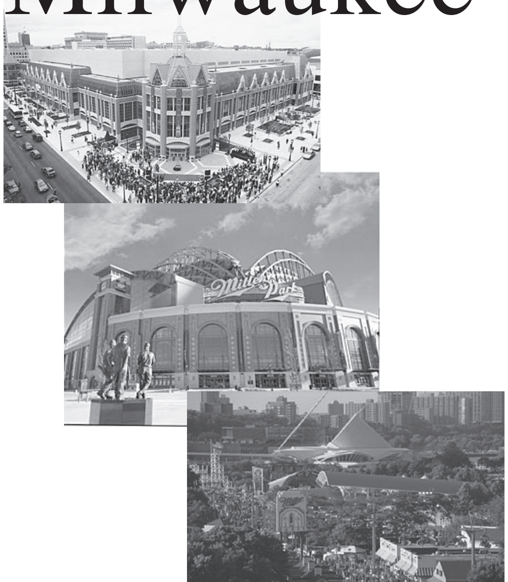
Sunday, May 8, 2005
Depart

THERMOFORMING DIVISION PRESENTS CHECK TO SPE



The SPE Thermoforming Division is shown presenting the proceeds from a 50/50 split from the net proceeds of the 2004 Thermoforming Conference in Indianapolis. The check was in the amount of $49,136.68. Shown, left to right, are: Karen Winkler, International SPE President; Jack Hill, Thermoforming Board Member; Gwen Mathis, Conference Coordinator; Susan Oderwald, SPE Executive Director; and Roger Kipp, Thermoforming Division Chairman.

Milwaukee



LEAD TECHNICAL ARTICLE

Automotive Plastic Fuel Tank Systems[1]

BY KENNETH W. ALBAUGH, BIELOMATIK, INC., NEW HUDSON, MI

Abstract

The manufacturing of Plastic Fuel Systems [PFS] is an ever-changing and technology-driven field. The field is influenced by governmental emission standards that are becoming tougher to meet with plastic fuel tanks. Several new technologies have been developed to accommodate the environmental legislative changes.

Introduction

PFS have evolved over many years. The first plastic tank was produced in Germany in the mid 1970s. Fuel systems are a tightly regulated product falling under local, state and federal standards for safety and emissions. Today automotive plastic fuel tanks are produced in North America only by a handful of large Tier I suppliers. The manufacturing of PFS is a very large financial undertaking and is burdened with a tremendous amount of liability. Products are required to meet or exceed regulations up to 15 years and/or 150,000 miles from the date of the auto sale.

Most automotive gasoline applications that use a PFS call for a six-layer COEX material construction. This is currently configured with outer and inner layers of high-density polyethylene (HDPE). Two layers of linear low-density PE (adhesive) sandwich an ethylene vinyl alcohol (EVOH) core. The material code[2] for the tank is <PE-HD,E/VAL,PE-LLD>. Figure 1 illustrates the typical layer configuration.

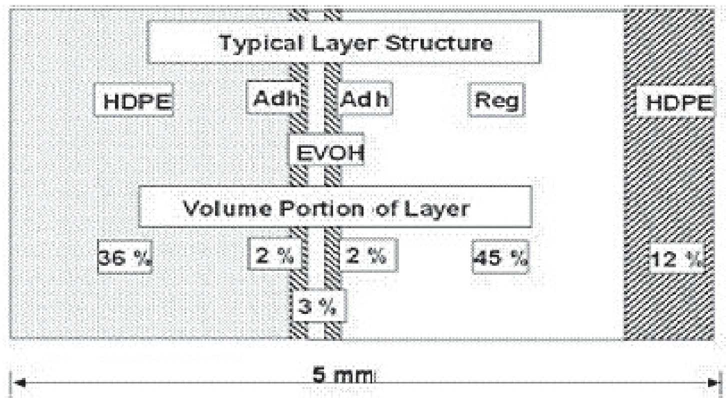


Figure 1. Typical COEX layer configuration.

Process Methods and Equipment

The following paragraphs will provide a very brief description on manufacturing of PFS. Each company has its own very unique way of producing PFS and thus only very basic information can be discussed.

The product begins in the molding phase. This is accomplished today by two basic processes. The first is traditional continuous extrusion blow molding. The other are the newly developed thermoforming processes. The blow molding process uses a six-layer continuous extrusion head and creates a circular parison. The parison is transferred from the extrusion head to the mold via two methods. The most common method is parison transfer via industrial robot with a specialized end of arm tooling. The shuttle machine style, illustrated in Figure 2, is also used.

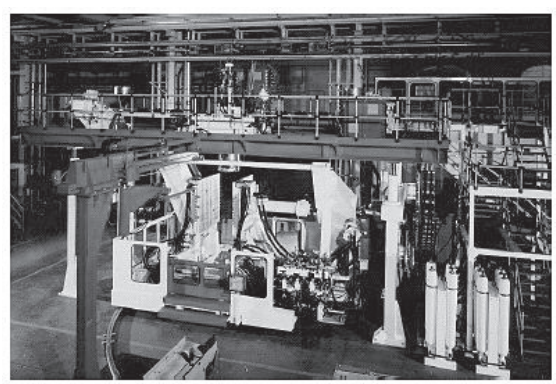


Figure 2. Typical blow molding machine.

(continued on next page)

[1] This paper was presented at 2004 SPE ANTEC. Twin-sheet thermoforming is currently being touted as a method for making automotive gas tanks. This paper provides an overview of the current status of and the standards that must be met by automotive plastic fuel tanks. The paper has been edited by the technical editor, who accepts all responsibility of any errors or omissions.

[2] Ed. Note: This is the European standard notation. The typical U.S. notation for this material combination is <HDPE/LLDPE/EVOH/LLDPE/HDPE>.

(continued from previous page)

Thermoforming uses two pre-extruded six-layer sheets. The sheets are loaded into a machine and sent through a reheating oven. When hot, they are transferred to vacuum tools and formed into final molded shapes.

Blow molding has the ability to control wall thickness more accurately during the molding process. Also a blow-molded part has only a pinch edge on the parison ends, whereas a thermoformed part has a pinch edge on the entire circumference of the part.

The key area in the molding process is the pinch edge, Figure 3, which is the area where the parison or sheets are welded together under pressure of the molding machine. The pinch area must have the correct compression to allow for all layers to flow evenly to the edge of the part to create proper adhesion and thus withstand all the vehicle level requirements for burst and environmental testing.

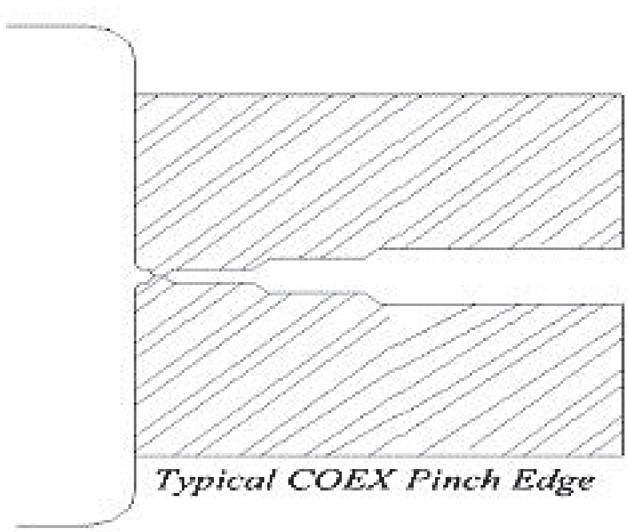


Figure 3. Typical COEX pinch edge.

Deflashing is the next phase in the process. Here the excess material is removed from the molded tank. This phase can be accomplished by automation, Figure 4. Some companies still do this manually. Regardless of the method, the trimming operation is very important to insure that no material is removed that should not be. This area is key to the future success or failure of the product. The structural integrity of this area of the tank is required to insure that the tank will withstand all tests and specifications and function correctly in the field.

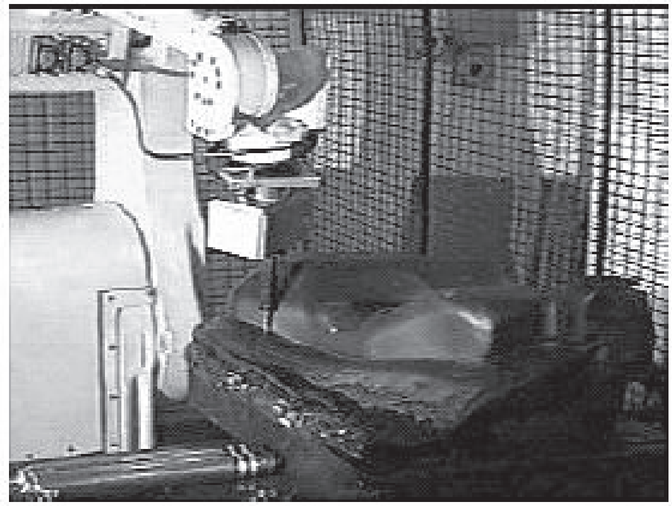


Figure 4. Deflashing System.

Cooling is also important. The cooling process is required to ensure that the tank is cooled in a manner that will produce repeatable and predictable dimensions for the finished product and then proper fit and function at the OEM. Care must be taken to remove the excess heat from the product in a controlled manner. This is done today using air-cooled fixtures, water-cooled fixtures, and/or ambient air. As a rule, the product is cooled from 100/110°C to 50/40°C, but some companies cool parts to room temperature, 21°C.

The finishing and welding phase of the manufacturing process is when all the needed openings are machined or bored and all external mounted valves, fittings and clips are welded to the tank. With ever-tightening requirements for emissions, all Tier I companies are trying to keep the number of openings to a minimum.

Typical weldments are valves. The valves welded to fuel tanks consist of inlet or fill spuds and vapor management devices. The majority of valves welded to the tank are called grade vent valves or fuel limit level vent valves. These valves are used to control vapor levels in the tank and to allow vapors to escape to filtering systems or even to the engine vapor management system. Fill or inlet valves are designed to allow the tank to be filled and yet keep the tank isolated in no-fill conditions or crash situations.

The finishing operations are completed using several styles of devices. Chipless boring is the most popular method and includes fixed mounted bor-

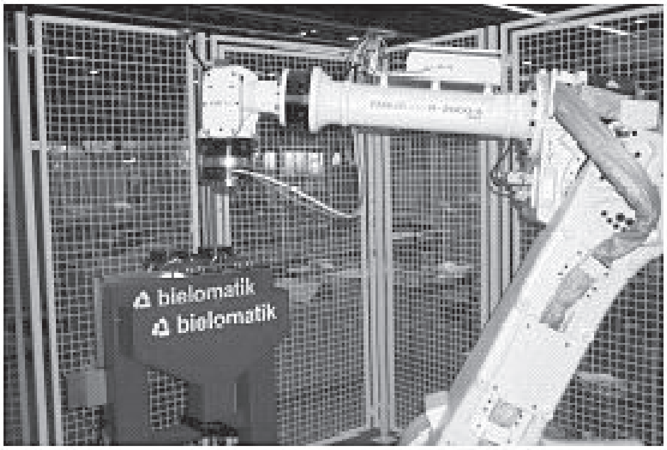


Figure 5. Typical robotic boring method.

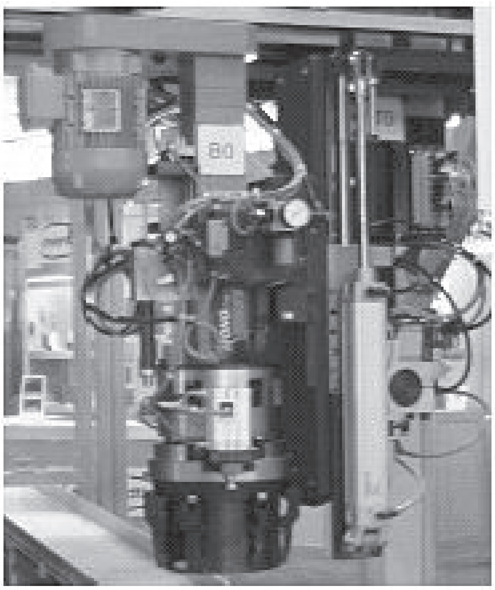


Figure 6. Typical boring head.

ing heads to robotically mounted six-axis cutting systems. Figures 5 and 6 show typical boring methods. In the chipless method, a cutting knife is inserted into the plastic and rotated using low revolution speeds and high torque. Cutting scrap material is retained on the boring head and deposited in a recycle receptacle. Other types of surfacing and peeling operations can also be done, but these usually produce cutting debris.

After the openings are machined, the required valves are welded to the tank. Today this is done using hotplate welding. Alternative techniques such as spin welding, vibration, infrared, laser and ultrasonic welding techniques have all failed to meet the tough validation requirements and process constraints. Over many years of fuel tank production, hotplate welding has proved capable of producing welds having strengths that are 90%-95% of parent material strength. The hotplate welding process is also compliant with all sections of the Federal Vehicle Motor Safety Standards (FVMSS) Section 301 for Crashworthiness.

Hotplate welding is defined in DIN Standard 1910. The standard states, "Plastic welding is pressure welding with the application of heat and force with or without filler material. The energies introduced are thermal conduction, radiation, friction (internal and external friction), convection and electrical energy." Hotplate welding uses three distinct phases, Figure 7. Phase one is heating during which the highest force is applied to the part to remove any surface imperfections and increase thermal conductivity. Changeover time is next. This is the time from the point when the hot plates are removed from between the component and tank and the component and tank move together. The seal phase is when the two components are homogenized and cooled under pressure.

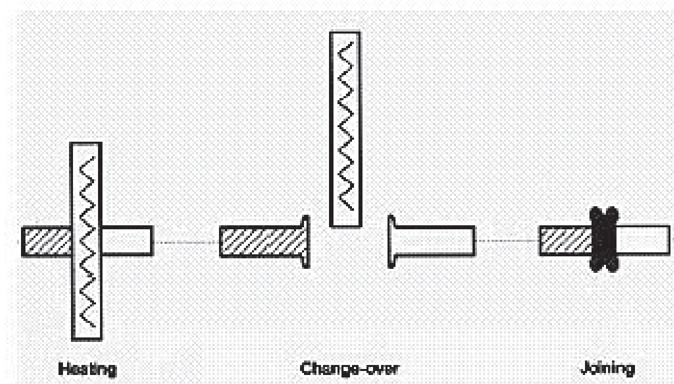


Figure 7. Hotplate welding process diagram.

The typical welding process includes process parameters that are adjusted. The main parameters are melt time, temperature, and applied pressure. The melt time for a typical fuel tank weld of 50 mm diameter is 20-25 seconds. The changeover time is 3-5 seconds and the seal time is 15-20 seconds. The total process time is 38-50 seconds. The factor that influences this time is part-to-part flatness. Part temperature and part wall thickness are also major contributors to this time. Most welding plates are aluminum bronze at 250-270°C.

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Most hotplate weld testing is destructive testing. Tensile pull or push testing and microtome analysis are usually done. OEMs have different requirements. The main test requirement for hotplate welding is 2000N removal force on a penetrating weld. Approximately 1.0 mm of homogenized materials and 1.0-1.25 mm heat emersion is required and determined by microtome. All customers use the "double bead" criterion for operational speed inspection. This is a very subjective criterion but it is the industry standard for non-destructive visual inspection. Figures 7-9 illustrate the hotplate welding process, tool, and cross-sections of completed welds.

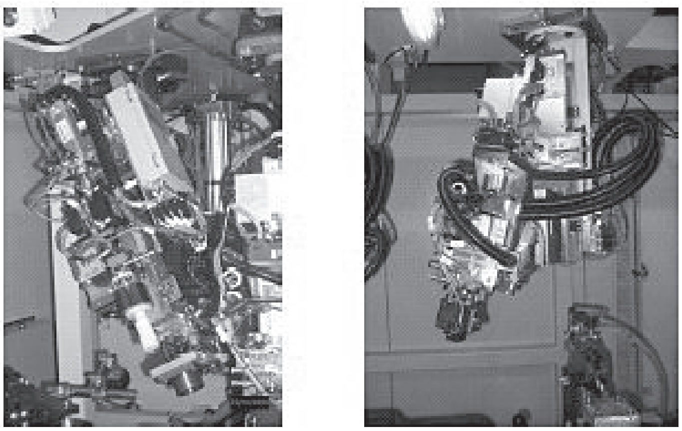

Figure 8. Typical hotplate tank-welding units.

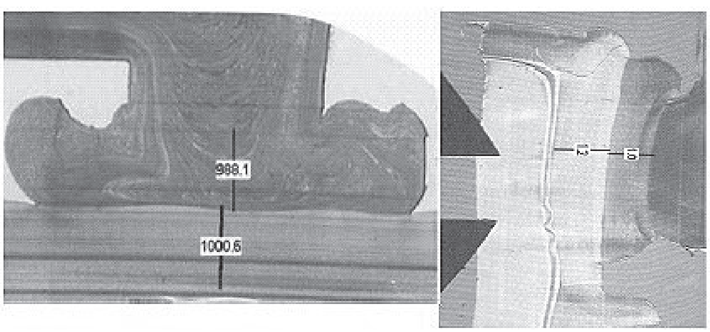

Figure 9. Typical layer configurations.

Assembly and testing is done using various types of OEM equipment and are very part specific as to design and content. OEMs often require specific leak testing methods to find OEM-specific leak rates. Hard vacuum leak testing is the most widely used technology. It is capable of detecting leak rates of 5×10^{-4} std cc/sec at 13.5 kPa pressure differential. Another popular method is ultrasonic bubble detection. This method is capable of determining leak rates of 5×10^{-3} std cc/sec at 13.5 kPa applied pressure.

New Technology and Requirements

As federal emissions standards change from LEV I (Low Emission Vehicle) requirements to LEV II and now to PZEV (Partially Zero Emission Vehicle) over the next few years, new testing methods and standards are being developed to insure full compliance to regulations. Tier I suppliers are transitioning to new technologies for producing these lower emission fuel systems. Many companies are exploring alternative processing methods to push the current processing limits to meet the new standards. These include but are not limited to internalization of all valves and components. Another solution is that all external mounted components have some form of post-welding treatment.

The suppliers of plastic tanks must keep apprised of the steel industry, which is making good progress on steels and coatings that can meet the 15-year, 150,000-mile requirement. The steel industry is already able to meet zero permeation requirements.

Summary

All tier suppliers are working hard to meet federal standards and are coming up with very innovative solutions that will carry plastic fuel systems for the next 30 years.

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Design Features of a Multi-Cavity Mold Used for High-Cyclic Thermoforming

BY STANLEY R. ROSEN, PLASTIMACH CORPORATION, LAS VEGAS, NV[1]

All mold systems are designed for a specific model of roll fed continuous thermoforming machines and incorporate its specifications within the tooling layout. Parameters for the mold system dimensions are available within the machinery operating manuals.

Essential data includes stroke for each platen, maximum and minimum open and shut height dimensions for both of the moving platens as well as the footprint of the mold area. A complete mold system comprises much more than just the forming cavities; it includes all of the tooling components that make up a complete system. New mold projects often must be held within tight budgetary constraints, as cost is always an important consideration that dictates final mold features.

A mold system consists of two major stand-alone sub-assemblies

The *mold base assembly* is composed of cavities (either male or female), temperature-controlled mold base, front and rear sheet clamps (occasionally four sided clamps) and spacer bars (Fig. 1).

The *opposite mating half* comprises either a pressure box or a vacuum seal off box, plugs for female cavities or assists for male cavities, and spacer bars (Fig. 2).

The mold base, pressure and vacuum seal off boxes are available in both adjustable or fixed length configurations. Adjustable tooling has the advantage of multiple usages for a variety of cavities that are less than 2 inches high. Conducting heat from the top surface of a cavity to the temperature-controlled mold base becomes less effective as its height increases. All-purpose tools are less thermally efficient when compared to a properly designed dedicated mold. Variable length tooling may offer only an approximate fit for the most economical cavity layout, thereby creating additional scrap areas within the formed shot. A simple cost comparison of the combination of slower production output and the additional scrap versus the cost of new dedicated tooling will determine which path to follow.

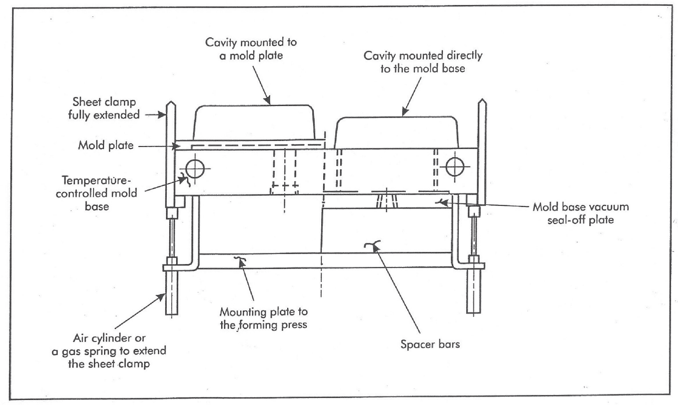

Figure 1. Mold base assembly.

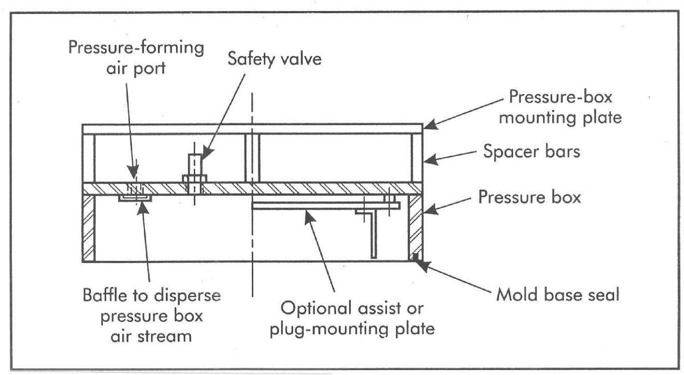

Figure 2. Pressure box assembly.

Compromise in the selection of some of the following mold features may be necessary to meet a specified mold budget

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[1] Stan Rosen is 1991 Thermoformer of the Year and author of **Thermoforming: Improving Process Performance**, Society of Manufacturing Engineers, Dearborn MI. The material presented here is taken from his book, available at www.sme.org.

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1. Choice of male or female cavities is often based on what is the best thermoforming option for a high quality part. However, in many cases, either type of cavity would suit the process and a male cavity is often half the cost of a female cavity; male cavities do not require a plug for proper function and it is less expensive to machine the exterior of a cavity than its interior (Fig.3).

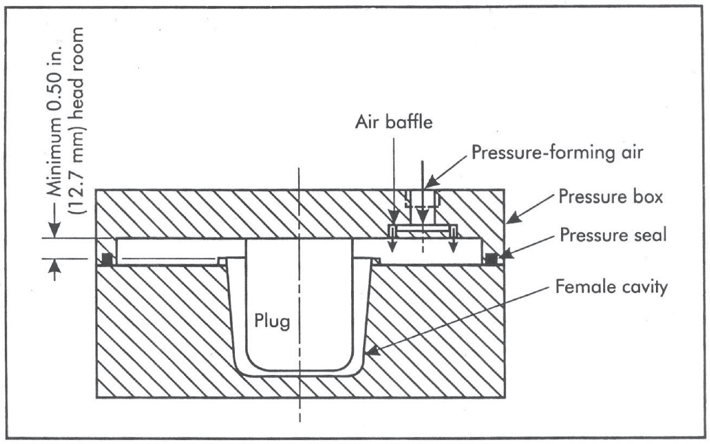

Figure 3. Female cavity plug and the pressure box.

2. The number of cavities specified determines the number of usable components formed with any given machine cycle. Each additional cavity increases the incremental cost of the mold. Therefore, the total quantity of formed parts ordered is the major determinant used when deciding on the number of cavities per mold.
3. Utilizing existing tooling components for a new project can result in considerable savings. This option should be weighed against possible increased plastic waste and inefficient cavity cooling if the existing mold base is too large.
4. Maximizing thermal efficiency of a cavity may necessitate cooling passages within or around the cavity, requiring fluid inlet ports flowing from the mold base. The additional plumbing can be costly, leaving the option of specifying a less effective cooling mode, which can reduce production output per hour.
5. An ejection method for difficult or undercut parts formed on a multi-cavity mold requires accurate information based on experimental evidence gleaned from a prototype cavity. Air blow off ejection is the simplest procedure and has a zero cost if it can effectively accomplish the task. The most direct and certain method of ejection is a mechanically activated knockout, which entails considerable expense and must be initially designed into the mold. Other solutions might include modifying a continuous undercut segment into one which is interrupted or Teflon® coating the cavity to ease ejection and still allow the formed part to be functional. Teflon® coating acts as a release medium but adds an additional thermal barrier to part cooling, further reducing productivity. It is important to note that Teflon® is difficult and dangerous to remove from a cavity once it is baked on metal. Always consider this coating to be permanent once it has been applied.
6. It is foolhardy to build a multi-cavity mold without first forming a sample part from a prototype cavity. A drawing of the formed part may be geometrically correct, but it does not tell us anything about its rigidity. The "squish" test of a sample in the buyer's hands provides the last word on the subject.

Details to be developed for the design of mold layout

1. *Choice of resin* determines the plastic shrinkage coefficient that will be used to increase the dimensions of a mold cavity. The cooled plastic formed part then will shrink to its specified size. Any change in thermoforming resin after a cavity is fabricated can cause serious size alteration of the finished product.
2. *Computing the minimum cavity center-to-center dimensions* will provide the most effective use of the available cavity area.
   a) Female cavities may be grouped as tightly as is mechanically practical.
   b) Male cavities need to achieve a compromise for the most desirable center-to-center dimensions. Details shown on Fig. 4 are an attempt to provide a guide to the most efficient layout. If the cavities are grouped too closely together, webs can

form and the sidewalls may thin out unacceptably. When cavities are set too far apart, they waste mold space and create unnecessary plastic scrap.

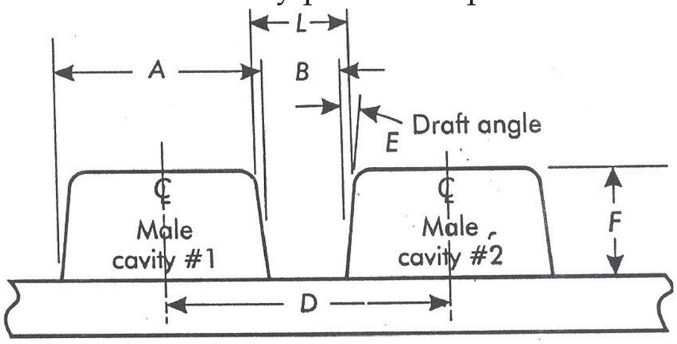

Figure 4. Male mold standard cavity separation.

D = A + {L – 2 (F x tan E)}
where:
D = center-to-center of cavities (A + B), in. (mm)
A = base dimension of the cavity, in. (mm)
B = separation of cavities measured at the base of cavity, in. (mm)
L = F for small draft angles less than 5°
or
L = F x 0.75 for draft angles greater than 5° (maximum angle used is 10° for this calculation)
F = cavity height, in. (mm)
E = draft angle of cavity, °

3. *Good layout procedures* for most polygon or round cavities, both male and female, are best aligned in straight rows to simplify later trimming operations. Triangular parts can be nested to make best use of available mold area. Alternating high and low profile mold section aids in distributing the part wall thickness (Fig. 5).

4. *Cavities closest to the chain index rail* have two factors affecting their placement. This area may have a different sheet-heating pattern than the rest of the web due to the heat loss to the metal chain rail and may require an increase of edge distance to maintain part quality. The pressure box wall thickness dimension should be added to the cavity edge distance allowance (Fig. 6).

5. The maximum overall length of the mold in the index direction cannot be greater than the maximum index stroke of the chain. Overall length of the mold includes the thickness of the front and rear sheet clamps. A rear sheet clamp prevents webs from forming in the back row of the cavities. The previously formed shot retains enough residual heat to become distorted when the mold is closed if not protected by the action of the front sheet clamp gripping the web.

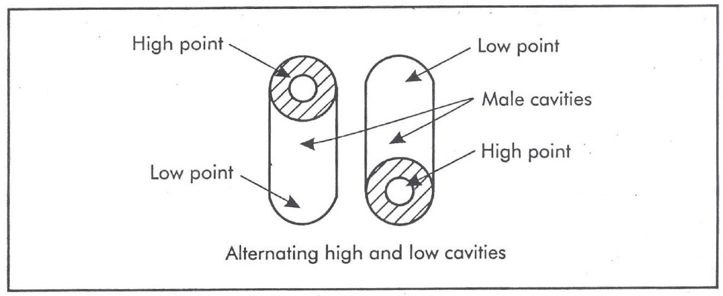

Figure 5. Alternating high and low profile male cavity sections.

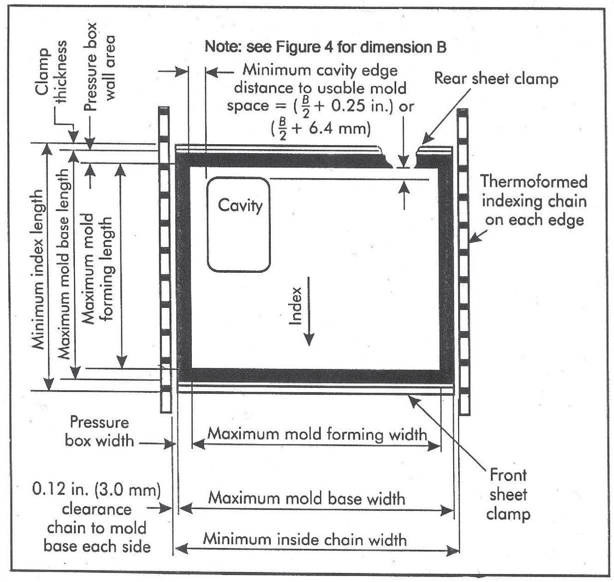

Figure 6. Fixed mold base space requirements.

Properties of male or female cavities

The natural thermoformed wall thickness distributions of male and female cavities are 180° opposite to each other when not aided by plugs or assists. A part formed on a male cavity is thicker in its top plane and a female cavity is thinnest at its base. This type of distribution results as the hot plastic chills when it contacts the first metallic mold face it touches during thermoforming.

A fairly uniform wall thickness can be achieved by utilizing a mechanical aid (plug or assist) mounted in the pressure box to pre-stretch the hot plastic just before vacuum or pressure is activated. Timing is important to prevent the mechanical aids from chilling the sheet and disturbing the distribution within the cavity. By prestretching the hot sheet, these devices help to discourage the formation of webs and result in a more uniform wall thickness distribution.

Plugs which tend to remain in intimate contact with the sheet for a relatively long time can be fabricated from either temperature controlled

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aluminum or insulated syntactic foam to minimize heat transfer from sheet to plug. Large corner radii and smooth surface finish are used to reduce the plug's coefficient of friction, which helps the hot plastic slip smoothly over the plug. A new prototype plug often is altered during development of a thermoformed prototype sample to avoid costly modification after a multicavity mold is completed.

Cavity materials and fabricating techniques

Many sorts of materials have been used to fabricate a thermoforming cavity – wood, plaster, epoxy, silicone rubber, and even concrete. All of the materials named are very poor conductors of heat and may find occasional use in forming a few prototype parts or for slowly producing small quantities of parts. Continuous production thermoforming machines require rapid heat transfer to achieve economic speeds in the range of 10-30 cycles per minute. Only aluminum, copper and silver have a high enough heat conductivity coefficient to meet the cyclic conditions. Aluminum meets the low weight and cost criteria as a practical all-around mold material. Aluminum mold cavities from the earliest days of thermoforming have been cast in fine sand using a carved wooden pattern as the model for the cavity. However, since the advent of computer-aided machining, the majority of molds are now machined from aluminum plate or bar, with each cavity an accurate twin to the others.

Aluminum-filled epoxy cavities can be operated economically on continuous forming equipment (3-8 cycles per minute) if they are relatively thin 0.38 to 0.63 inches (9.7 to 16 mm) high and mounted directly on a temperature-controlled mold base. These cavities can be fabricated to reproduce complicated detail from a model and are far less costly than a machined aluminum mold for this purpose.

Methods for quickly venting male and female cavities during the thermoforming process

Venting of cavities can be accomplished using small drilled holes, thin slots or porous non-metallic mold materials (Fig. 7). Female cavities often require a low pre-vacuum 3-5 inches of mercury (21 to 35 kPa) to evacuate the majority of residual air volume when plug forming. All of these methods attempt to purge the air between the hot sheet and the cavity in the shortest possible time so that thermoforming can take place as rapidly as possibly. If any air remains entrapped, pimples and fisheye blemishes will appear on the flat planes of the shot.

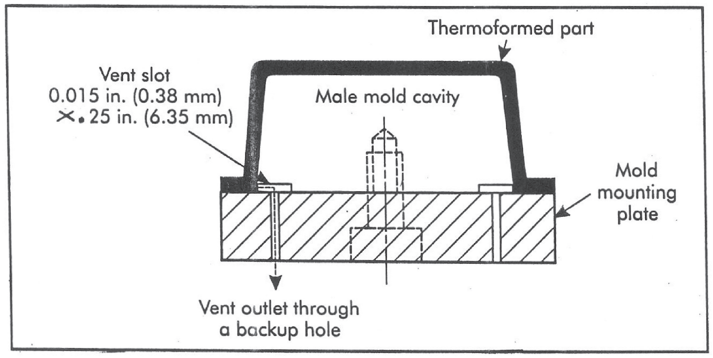

Figure 7. Male cavity base vent slot is exhausted through a large diameter backup hole.

Commonly used drilled vent holes of #76-.020 inches (0.5 mm) in diameter leave only a small cosmetic blemish which is generally acceptable but its vent area is quite tiny .0003 sq. in. (0.196 sq. mm). A venting slot .015 in. (0.4 mm) wide x 1.00 in. (25.4 mm) long has an area 50 times as great and will increase air evacuation by that multiplier. Porous mold materials can be used on flat faces to successfully vent all the residual air but may cause low clarity on transparent plastics and excessive wear problems on fine detail surfaces.

A female cavity requiring a plug increases the internal cavity air pressure as the plug's rapid movement displaces the cavity air volume. The internal cavity pressure can be lowered by judicious use of a low vacuum. A high vacuum can cause the sheet to lose contact with the plug and thin out both part bottom and walls. A very weak vacuum may cause air pressure to build up, resulting in bursting the sheet and ruining the shot.

When very large quantities of shots are to be thermoformed, the tooling cost per unit part becomes negligible and the mold can be designed to incorporate every desired production feature. When lesser quantities are to be produced, the mold budget decides which features will be selected, to the detriment of efficient output. Design engineering of all products is a compromise of what a customer is willing to pay versus what he is willing to accept. ■

Thermoforming: Growth and Evolution[1] Part II

BY JAMES L. THRONE, SHERWOOD TECHNOLOGIES, INC., DUNEDIN, FL 34698 AND PETER J. MOONEY, PLASTICS CUSTOM RESEARCH SERVICES, ADVANCE, NC 27006

Abstract

Thermoforming is the process of heating and shaping plastic sheet into rigid containers, components of final assemblies, and stand-alone end-use parts. The value of all thermoformed parts produced in North America in 2003 exceeded U.S. $10 billion. Traditionally, about 3/4 of all thermoformed products are produced from sheet of 1.5 mm or less in thickness and are primarily rigid disposable packaging products. Most of the rest is produced from sheet of 3 mm or more in thickness and are primarily durable structural goods.

Thermoforming has benefited by its ability to fabricate thin-walled parts having large areas, using relatively inexpensive, single-sided aluminum tooling. Its deficiencies – variable wall thickness, the added cost of sheet and trim regrind, and extensive trimming and additional cost to reprocess the trim – are offset by the ability to economically produce low-volume, thick-walled parts or high-volume thin-walled parts.

The advances in thermoforming technology in the past decade have allowed the industry to grow at a rate that exceeded the growth rate of the plastics industry in general. However, this pattern has changed in the past few years. Newer advances in plastic materials, tooling, forming machinery, and auxiliary equipment are needed to regain earlier growth rate momentum.

This paper considers several emerging technologies such as forming composite sheet materials, surface decoration, and new material development. It also considers the effect of globalization on both thin-gauge and heavy-gauge domestic thermoformers.

[1] The authors were invited to present this paper in a special session at 2005 SPE ANTEC, but the abstract was not accepted. It is in two parts. The first part was published in TFQ 24:1, 1Q05.

"New" Technologies to Advance the Industry

As pontificated in Part I, many extant technologies have not been fully exploited. This section highlights some of those technologies that appear to provide thermoformers with future market advantage.

Forming Composite/Laminated Structures

Heavy-gauge thermoforming has very thoroughly mined the "pretty part" or "easy" applications, where the part is made of unreinforced plastic and is designed to be incorporated into or fastened onto a supporting structure. Formers now need to go beyond their current comfort zones to new materials and processing variants. There are two general types of formed structures – single-layer composite materials that are formed into non-appearance parts, and thermoformed "skins" or "shells" that are thermoformed, then backed with composite materials.

Single-Layer Composites. A military drone structure made of matched-mold glass-reinforced nylon composite was an early commercial application of a non-appearance single-layer structural product. The composite bumper structure for the recent BMW 5 vehicle is another single-layer composite application. The reinforcing medium is usually either woven or non-woven continuous glass mat. In general, matched tooling is required and the sheet must slip or slide into the mold to avoid substantial fiber breakage (1). Furthermore, the force needed to bend the composite into even gentle shapes is usually quite high. As a result, forming presses for such applications are more akin to compression molding presses than conventional thermoforming presses.

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Most applications have focused on forming thick composite sheet (2). However, composite sheets having thicknesses less than 1.5 mm (0.060 inches) are now commercially available (3,4). Glass levels are typically 10% to 20% by weight, but they can be less, depending on the applications. The focus will be on structural applications where the parts must have large surface areas but must be thin-walled.

Laminated Structures. The plastics industry has had success commercializing multilayer structures where one of the layers is a high-performance composite and another layer is a cosmetic shell. The best example is found in the sanitaryware industry where spas, shower stalls, and tub surrounds are fabricated of thermoformed ABS sheet that are backed with spray-up chopped fiberglass-reinforced polyester resin (FRP). Automotive innovators such as DeLorean and Bricklin adopted similar techniques in the 1980s to produce exterior car parts. Today some models of the SMART car in Europe boast of laminated parts.

The resurgence of this technology is due in part to automated methods of handling the reinforcing layer. Robots apply the fiberglass- or filler-impregnated resin (often polyurethane) to the formed "skin" residing in the lower half of a matched mold press. Then the press is closed, expressing air and compressing, shaping, and fully reacting the reinforcing layer. Although the automotive industry was apparently the first to adopt this technology, the marine and farm equipment industries are actively pursuing it (5,6).

In-Mold Decoration

In-mold decoration is not a new concept. Paper labels with pressure-sensitive adhesive layers were developed for thin-gauge containers in the 1980s. And rotational molders have been pre-applying heat-activated decoration to mold surfaces for a decade or more. Recently the automotive industry has been considering paint film technology as a way of minimizing the economic cost and environmental hazards of conventional "wet" exterior surface painting (7).

Paint film can be either single-layered or multi-layered. Polycarbonate is the preferred single-layer paint film (8). Multi-layer films are usually structures on the order of 0.5 mm (0.020 inches) in thickness. The film consists of at least a high-gloss, weatherable and durable clear outer layer (e.g., a fluoropolymer), a pigmented color layer, and a supporting substrate (9). This film is laminated to a structural sheet. To maintain surface gloss, the laminated sheet is very carefully heated and formed, usually against a male mold. To prevent color wash, care must be taken to ensure that the film is not stretched. Although there have been a few successful applications, the high current film cost, the concern with reprocessing regrind, and the degree of difficulty forming the part are mitigating against rapid non-automotive market penetration.

Nanofillers and Nanofibers

Nanomaterials are substances having dimensions in the range of 1 to 100 nanometers (0.001 to 0.1 mm). There are at least three general categories of nanoparticles – carbon nanotubes, intercalcated platelet particles of clay, and near-spherical particles of silica. Carbon-based nanotubes and larger-diameter nanofibers are apparently destined for reinforcement of specialty plastics (10). Nanoclays, primarily intercalated montmorillonite clays, are touted for their reinforcing effects at very low weight fractions of 10% by weight or less (11). Nanosilicas are touted for their ability to increase polymer strength and stiffness without dramatically decreasing impact strength, because the particle sizes are below the Griffin crack initiation size (12). Polymer viscosities are not greatly affected even at loadings in excess of 40 wt-%.

It appears that nanoclay-filled polymers offer opportunities in thin-gauge part thermoforming where stiffness is now achieved only with increased thickness. Polyolefins have good chemical and high temperature resistance but they tend to be weak at elevated temperatures. They appear to be prime candidates for nanoclay fillers.

Nanosilicas are being considered for heavy-gauge part forming applications. To date, nanosilicas are best dispersed in prepolymers that are then polymerized. Cast PMMA is one example. Because the filler particles are so small, forming forces should be substantially more modest than those for equivalently loaded glass-fiber reinforced sheet. Improved mechanical strength can lead to substantial reduction in formed part wall thickness in many industrial parts. Moreover, down-gauging usually leads to improved cycle time and lower production cost. And because nanoparticle sizes [about 20 nm] are far below the wavelength of light [400-700 nm], highly filled cast acrylic sheet remains transparent.

Nanofillers are finding early application in low-viscosity thermosetting prepolymers. Although addition to higher-viscosity thermoplastic polymers is being intensely researched today, uniformity in particle dispersion and distribution through the polymer matrix, and production cost remain major concerns. Nevertheless, the unique property improvements that might be achieved indicate that the thermoforming industry must continue to monitor this new technology.

Others

In this section, we simply highlight some other technologies that might influence future thermoforming developments.

Porous mold materials. There are now two commercial types of porous mold materials – porous aluminum and porous ceramic. Porous aluminum is best used when vacuum or vent hole mark-offs are not acceptable on the formed parts. Open areas and pore sizes range from 8% and 5 µm (13) to 20% and 100 µm (14,15).

Porous ceramics, used for years as liquid and gas filters and high-temperature diffusion plates, can now be fabricated directly into mold structures. Open areas and pore sizes can be tailored to essentially the same characteristics as porous metal. As with porous metal, the ceramic is mixed with a volatile material such as a polymer. The slip is formed against the pattern and dried. It is then fired to vitrify the ceramic and volatilize the pore-forming material. Shrinkage is about 30% or about the same shrinkage level as porcelain. Although the porous ceramics tend to be fragile, they are usually tough enough to be used for a few hundred parts (16).

Newer Polymers. The earliest polymers – camphorated cellulose nitrate and viscose rayon – were based on biological materials. Today, oil-based polymers dominate the thermoforming material palette. However, biopolymers are finding new interest, particularly in rigid packaging applications where compostability and biodegradability are desired. Polylactic acid or PLA, invented by Wallace Carothers in 1932, patented by Dupont in 1954, and available today primarily from Cargill Dow, is the leading polymer in this area (17,18). PLA processes as a "stiff polystyrene." Although it is currently more expensive than current packaging materials, its "earth friendliness" often outweighs the additional cost.

Biopolymers based on polyhydroxybutyrate (PHB) may also offer thermoforming opportunities. PHB is reported to be a rather brittle highly crystalline polymer with properties similar to those of polystyrene. When copolymerized with polyhydroxyvalerate (PHV), the polymer degradation rate at elevated temperature is greatly reduced (19). It is thought that these polymers are best suited for medical applications.

Polymers based on norbornene are now commercial (20). These cycloolefins are produced by reacting ethylene or propylene with cyclopentadiene. The polymers are amorphous with glass transition temperatures that can be increased from 30°C to 230°C by increasing the norbornene content. Commercial grades have norbornene concentrations of 40 to 60 mol-% and T_gs from 70°C to 170°C. They are FDA food contact-approved and steam-sterilizable. It is reported that cycloolefins process more like PVCs than polyolefins.

Although these materials are not yet major players in thermoforming, there appear to be many future packaging applications.

"Moldless" prototyping. Since the 1930s, heat has been used to produce generous bends in plastics (21). Strip heating was introduced during WWII and again the allowable bends were generous. Cut sheet was fabricated into sharp-edged shapes by gluing. The objective of making sharp bends without excessive gluing has always required accurate machining techniques. Computer-driven three-axis

(continued on next page)

(continued from previous page)

machines are now being used in conjunction with precise bending protocols and exacting gluing procedures to produce very elaborate structures directly from sheet (22). These allow designs to be very quickly reduced to prototypes or commercially functional products.

Summary

Thermoforming, being the art and engineering of fabricating functional plastic parts from sheet, is maturing into a viable, competitive technology in packaging and structural parts. The future of thermoforming depends on quickly adapting advances in composites, nanofillers, and other commercialized technologies. The global scene will undoubtedly dictate future business decisions regarding offshore production, consolidation, and diversification.

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***Correction:* In Part I, we stated that the earliest roll-fed transformers were developed in Germany in the 1930s. Stan Rosen correctly pointed out that Clauss B. Strauch Co. of Milwaukee, WI developed the first machine in 1930.**

Comparing Concept to Reality[1]

BY JIM THRONE, SHERWOOD TECHNOLOGIES, INC., DUNEDIN, FL

THERMOFORMING 101

We began our discussion of part design by reviewing why we might not want to quote on a job. If we are serious about fabricating the customer's concept, we need to understand the methodology in reducing a concept to reality.

Naiveté v. Experience

Before we consider developing a hard cost for a given project, we need to ascertain the technical level the customer brings to the design. Most of us have dealt with customers of at least one of the following levels:

- ***Expert Customer.*** Fully cognizant of the advantages and limitations of thermoforming in general, conversant of the plastics characteristics, and having a complete understanding in the myriad ways of fabricating his design, in particular.
- ***Experienced Customer.*** Has designed certain parts in thermoforming in the past but is not up-to-date, vis-a vis[2], newer processing techniques, mold materials, polymers, and so on.
- ***A Non-Thermoforming Technical Customer.*** Has extensive experience in blow molding, rotational molding, or injection molding, but has no knowledge of the differences between these techniques and thermoforming.
- ***A Technically Naïve Customer.*** Knows little about plastics and nothing about thermoforming. Has always purchased his plastic products to either mate with or package his non-plastic products.
- ***The Totally Naïve Customer.*** Has a great idea worked out on the back of a Burger King napkin, has no funding, no customer, and no idea how to reduce his idea to reality.

We all agree that it is very difficult to treat each of these in the same fashion. In other words, a checklist of things necessary to reconcile prior to quotation might be too technical for the naïve customer and an insult to the experienced one. Nevertheless, we should all keep in mind before every take-off and landing, the pilot and copilot are required to complete an extensive checklist, regardless of their years of experience and the number of times they had flown the specific airplane. So let's take a look at a typical design checklist.

General Advantages and Limitations of Thermoforming

We all know the advantages and limitations of our skills. But the customer may not. So tell him/her. Some advantages:

- Lower tooling costs
- Quicker design-to-prototype time
- Quicker prototype-to-production time
- Relatively wide selection of polymers, grades
- Large surface area per unit thickness
- Economic production of a few pieces (heavy gauge) or many, many pieces (thin gauge)

Some limitations:

- Non-uniform wall thickness
- Single-surface molds
- Hollow parts difficult
- Sheet cost
- Extensive trimming, recycling needed

[1] This is the second in a series that focuses on part design

[2] vis-à-vis, French for face-to-face, with the usual meaning being "as compared with" or "in relation to."

- Mostly neat plastics (few reinforced and highly filled plastics)
- Wide forming windows desired (needed)

The Material Issue

We, along with the astute customer, need to discuss material choices in some detail. It is not enough for the customer to specify "general purpose polystyrene." He/she needs to work with us to develop a list of property requirements. In other words, what are the elements of the environment in which the product must perform? Some examples are:

* Environmental temperatures (high and low)
* Corrosive/erosive conditions
* Static/dynamic loading conditions
* Impact conditions
* Surface quality
* Product lifetime
* Assembly restrictions (if any)

And we must all be aware that some of these conditions are compound. For example, the product may need to withstand dynamic loading at high temperature in a corrosive environment. And the customer must understand that not all grades of plastics that meet the desired criteria are available in sheet form.

Before we can discuss design concepts with our customer, we need to review them ourselves. We'll continue this litany after our review.

Keywords: advantages, limitations, material choice, experienced customer, naïve customer

■

BOOK REVIEW

Donald C. Hylton, ***Understanding Plastics Testing***, Hanser Gardner Publications, Cincinnati, 2004, 92 + XII pages, $39.95.

Over the years, Hanser Verlag, Munich and Hanser Gardner, Cinty, have been publishing introductory softback texts in their "Understanding …" series. Don Hylton, Fellow of the Society and a longstanding board member, recently published this excellent monograph.

Of course, this is not the first book devoted to plastics testing. My reference library includes Vishu Shah's **Handbook of Plastics Testing Technology**, Vincent Mathot's **Calorimetry and Thermal Analysis of Polymers**, Gunther Kampf's **Characterization of Plastics by Physical Methods**, and Nicholas Cheremisinoff's **Polymer-Plastics Test Methods**. In addition there are many other books that relate test results to polymer properties.

So, why do we need a new book in plastics testing? Simply put, nearly all books overwhelm the beginning reader. For example, Kampf details "Thermoanalytic Methods" in nearly 20 pages. If your objective is to determine the extent of crystallinity of your sample, Kampf provides you with detailed methodology and the equations. The same is true regarding reduction times for isothermal oxidation. But if you just need a clear explanation of the test to see if you can use it to determine a specific property, such as crystallinity, you'll be quickly overwhelmed by Kampf's detail. And that's where an introductory text is valuable. Don describes these tests in one page.

There are six chapters to the Hylton book – The Science of Testing, Understanding Polymers and Their Behavior, Mechanical Properties, Thermal Testing, Viscous Flow Properties, and Quality in the Testing Laboratory. He lists 22 general references, four Appendices, and 6-1/2 double-columned index pages. There are brief descriptions of nearly all the tests of significance to thermoformers, including DSC, orientation and shrinkage, melt index and intrinsic viscosity (for the PET people). The tests are usually identified through their ASTM and ISO numbers, where appropriate. The monograph does have some shortcomings, however. It does not describe environmental tests such as ESCR or UV degradation, or mechanical abrasion, or optical and color measurements, or electrical characterization, or flammability tests. This reviewer hopes that when Hylton revises this work, he will include at least brief descriptions of these tests. Ten or fifteen more pages, please, Don!

The chapter on Quality is particularly interesting, as it presents Hylton's philosophy on laboratory quality. As he points out, laboratory quality differs dramatically from production quality. Quality must be defined, properties must be measurable and controllable, documentation must be required, and these criteria must be universally accepted. By "universally," it means by the tester, the laboratory, production personnel, corporate management, and above all, by the customer. Hylton adds "continuous improvement" to the quality issue. I would also add "repeatability." If the lab cannot repeat the test and obtain the same result time after time, quality cannot be defined. To extend this further, if an independent lab cannot duplicate the in-house lab test results, quality is not defined. Replacing "real people" with robotic testers often does not improve data consistency for the simple reason that a "real person" needs to calibrate the mechanical critters and qualify the resulting data. Hylton concludes his monograph with a listing of accrediting and sanctioning agencies.

All in all, an excellent introductory text for beginners and a quick reference source for someone needing general information or just the ASTM number of a specific test. I give it four books out of five.

~ Jim Throne

UNIVERSITY HIGHLIGHT ... MILLERSVILLE UNIVERSITY

MILLERSVILLE UNIVERSITY GETS DIVISION GRANTS FOR THERMOFORMING MACHINE

During the 2004 academic year, I (George Kerekgyarto, on the right in the photo) was fortunate enough to have the time to research grant opportunities in the polymer industry. As part of my sabbatical leave I was trying to expand a polymers program for our Industry and Technology program that consisted primarily small bench top equipment, most of which was in disrepair. During the year we were able to refurbish much of the equipment. I discovered the Society of Plastic Engineers (SPE) had a Thermoforming Division that provided assistance to purchase new Thermoforming equipment through a unique grant opportunity. This equipment would significantly expand our capabilities in our polymer lab. A grant was provided and additional support was provided by Hoover, Inc., MAAC, the manufacturer of the machine, and Millersville University. Dr. James Laporte (on the left in the photo) worked with me on this program. The MAAC machine is behind us in the photo.

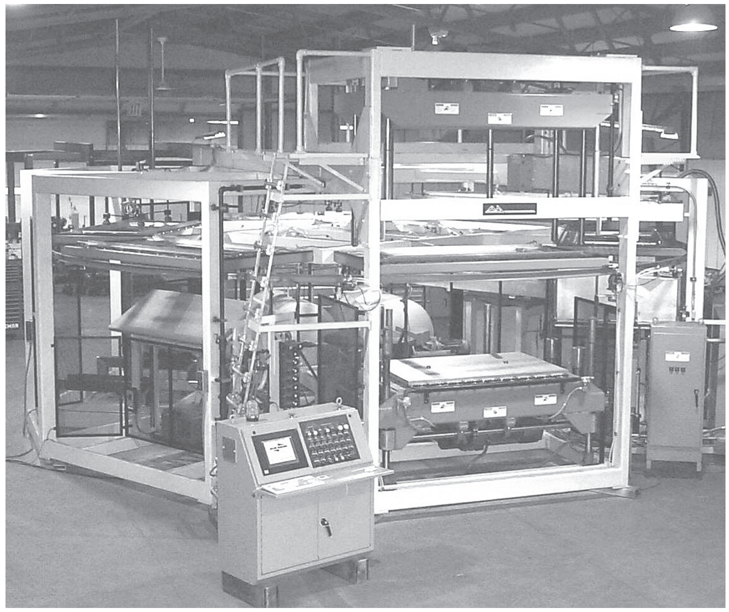
Our polymer classes focus on product development through the design and construction of patterns and molds. We begin by teaching our students how to replicate almost anything or create new molds. We use plaster and ceramic materials to teach basic mold development. The next step introduces RTV mold development. Students begin by replicating existing intricate objects, learning how to build a mold for this procedure, which is similar to plaster mold development. Blanket molds are introduced and students work with difficult patterns to gain the necessary experience. Students also experience the lost wax method of casting by developing original pieces and replicating them by using the RTV mold process. Multiple wax castings are produced from the RTV mold. A wax tree is developed for the investment casting process and multiple products are produced by the centrifugal casting method.

> *Adding thermoforming ... will allow our students to expand their abilities to produce molds.*

Adding thermoforming to this area will allow our students to expand their abilities to produce molds. Student work will begin with basic mold development of some basic thermoforming projects, emphasizing draft angles, and proper mold procedures. As students become familiar with the MAAC thermoformer they can then begin to develop more complex molds using CNC capabilities in aluminum and wood, using a production laboratory next door to the polymers lab. Many of the molds will be wood since the amount of large runs will be minimal. Most of the student and faculty work will be prototype development. We also will begin developing more packaging ideas for other production and manufacturing classes. Having the capability to do sophisticated thermoforming, plug assist, snap back etc. will allow our students to understand and develop ideas using state-of-the-art thermoforming equipment.

This endeavor of acquiring a MAAC thermoformer machine was truly a cooperative effort. Our thanks and gratitude to the wonderful people at SPE who were willing to support the Industry and Technology program at Millersville University with a generous grant to purchase the MAAC thermoformer. A special thanks to MAAC corporation for manufacturing the thermoformer and their financial contribution to the grant program. Also a special thank you to HDJ Corporation and Brown Transmissions for contributing to the shipping costs. ■

Millersville University is located in Millersville, PA, muweb.millersville.edu.
Dr. Kerekgyarto can be reached at George.Kerekgyarto@millersville.edu.
Dr. Laporte can be reached at james.laporte@millersville.edu.



The FoxMor Group, Inc. of Wheaton, IL, the #1 sales organization for thermoforming machines and auxiliaries, is now the sales arm for Advanced Ventures in Technology, Inc. (AVT) of Gladwin, MI. The firm designs and manufactures some of the world's largest and diverse rotary thermoforming systems like the one shown here.

Council Report ... Atlanta, Georgia

BY STEVE HASSELBACH, COUNCILOR

This summary is intended to help you review the highlights of the Council Meeting held in Atlanta, Georgia on January 22, 2005.

SPE President Karen Winkler called the meeting to order.

The Council weekend format was as follows:

• Council Orientation – this session was provided again as an orientation for the weekend.

• Council Committee of the Whole – there was a separate shortened version of the Council Committee of the Whole meeting.

• Council Meeting – the format had presentations followed by open discussion on the presentations, and ample time for general discussion.

Moment of Silence:

The Council recognized the passing of the following members:

Barry Huguenin, inaugural President of SPE New Zealand - on July 24, 2004 at the age of 53 after a short battle with cancer.

George Pickering, SPE's 1976 President and member since 1959 - on October 13, 2003.

The thousands of Tsunami victims who lost their lives this past December were also included in the Moment of Silence.

Elections:

Council elected the following people as Society Officers for the 2005-2006 term, which begins at ANTEC (May 1-5).

President-Elect – Tim Womer
Senior Vice President – Vicki Flaris
Vice President *(nominated by the International Committee)* ***– Hector Dilan***

In addition to these formal offices, each year Council also elects a ***Chair*** for the ***Council Committee of the Whole***. ***Barbara Arnold-Feret*** will hold this position for the 2005-2006 year.

Executive Director Update:

Susan Oderwald reviewed the financial outlook for 2005. SPE is beginning to stabilize revenues in some key areas but still continues to operate under financial pressure. With that in mind, staff and the Finance Committee have reviewed the 2005 approved budget and have already developed some revised expectations on revenue and made adjustments to some expense areas. A full reforecast for 2005 will be distributed to Council at the end of the first quarter and every quarter thereafter.

ANTEC remains SPE's largest "risk" in terms of overall financial performance. Educational products continue to be an area of concern. Susan was pleased to report that we ended the year with 20,106 members and are on track to see continued modest growth for the early part of 2005. SPE has grown membership (month by prior year month comparisons) every month since July of 2004.

Susan also reported on SPE's new alliance with the American Management Association (AMA) to provide SPE members with seminar and other educational access to AMA's resources. SPE members will be able to access these programs at AMA member pricing.

SPE is organizing a formal committee for the governance of Europe.

The SPE Foundation ended 2004 solidly in the black. Additional members have been added to the Foundation Executive Committee, and recruitment for a full Board of Trustees is in full swing.

A copy of the full Executive Director's Report is available on the website at http://www.4spe.org/communities/leadership/0501/materials.php.

Rebate Plan Proposal:

Bill O'Connell presented the recommendation of the Rebate Committee, the Finance Committee and the Executive Committee that the rebates for 2005 that will be payable in 2006 return to the plan and formulae that was in effect before Council voted to suspend rebates for the past two years.

Councilors participated in a group exercise to rank various options for a new rebate proposal for 2007 and beyond. That proposal will be voted on at the May Council meeting.

Other Business:

Presentations and discussions also took place on the following topics:

State of the Society Discussion
ANTEC Activity Plan
Technical Advisory Board Update
SPE Europe Update
Committee/Officer Reports
2005-2006 Operating Plan
SEP Foundation Update
Membership AIM Update

2nd Reading Bylaw Amendment B-9.7:

The following second reading of a proposed amendment to the SPE Bylaws took place as follows:

All votes by Section Councilors, Division Councilors, Councilors at Large, or their proxies on issues that concern changes to fees, dues, and/or rebates shall be recorded to include the name of the Section or Division they are voting for (in the case of Councilors at Large, they shall be listed as "Executive Committee"), the name of the individual, and how the person voted. The records of any such vote shall be available to any member of SPE via the SPE International website. This posting shall be available no later than ten business days after the vote is counted.

This amendment was voted down.

1st Reading of Bylaw Amendment B-51:

The following first reading of a proposed amendment to the SPE Bylaws took place as follows:

The Executive Director shall remit to each Section, Section-in-Formation, Division and Division-in-Formation Treasurer ~~in January of~~ each year rebates and/or funds as set by the Council following the approved procedure set forth in Bylaw B-9. A rebate to a Section-in-Formation or Division-in-Formation shall be for a period of no more than two years.

Committee Meetings:

Eleven committees met prior to the Council meetings including:

Communications Committee
Conference Committee
Constitution & Bylaws Committee
Divisions Committee
Education Awards Committee
Executive Committee
Finance Committee
International Committee
Sections Committee
Student Activities Committee
SPE Foundation Executive Committee

Presentations:

All presentations and supporting documentation for Council and committee discussions can be viewed on the SPE website at: http://www.4spe.org/communities/leadership/0501/materials.php.

Contributions:

SPE is grateful to the following organizations that made contributions in support of SPE and The SPE Foundation:

- Jim Griffing, Composites Division: $2,800 presentation from proceeds of the Composites/Auto Division Conference
- Tom Sloss, Connecticut Section: $1,000 to The SPE Foundation, representing the fifth payment of a 5-year pledge
- Jordan Rotheiser, Decorating & Assembly Division: $3,800 for 38 members; and profit share of $5,437 from TopCon
- Roger Kipp, Gwen Mathis and Jack Hill, Thermoforming Division, presented $49,136.68 from the proceeds of the Thermoforming Conference ■

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Questions?

Please Contact:
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From The Editor

Thermoforming Quarterly welcomes letters from its readers. All letters are subject to editing for clarity and space and must be signed. Send to: Mail Bag, Thermoforming Quarterly, P. O. Box 471, Lindale, Georgia 30147-1027, fax 706/295-4276 or e-mail to: gmathis224@aol.com.

Thermoformers, have you discovered a forming tip that you are willing to share with your fellow formers?

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Forming TIPS

column is for you!

Just send Jim Throne a fax at 727-734-5081, outlining your tip in less than a couple hundred words. You can include drawings, sketches, whatever. Thanks!

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• • •

Due to the many surveys requesting that we change the dates of the annual Thermoforming Conference, the Board has listened and beginning in 2006, we are pleased to announce the new dates.

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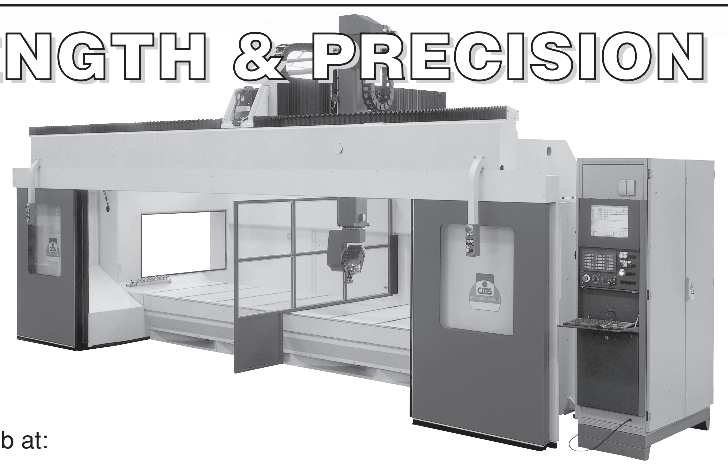

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