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THERMOFORMING QUARTERLY®

TECHNICAL SECTION

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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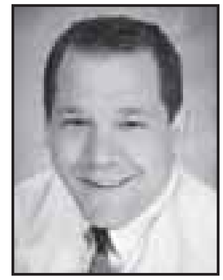
TIME FOR A CHANGE



BY MIKE SIROTNAK, MEMBERSHIP CHAIRMAN

I joined the SPE Thermoforming Division in 1996, shortly after accepting a position with Solar Products. I went to my first Board of Directors meeting in January of 1997 in Las Vegas to find out what this was all about. The people at this meeting were not only very big players in the Thermoforming Industry but were exceptional people. It did not take long for Randy Blin, Steve Hasselbach, Steve Spelts, Phil Scalvini and Dick Roe to take me under their wings and get me elected to the Board. A year later, Cathy Hall (Membership Chair) left our Industry and Randy and Steve convinced me that being Membership Chair was in my best interest. They could not have been more right. It has been a privilege to be your Membership Chair for the last 8 years. I have accepted the responsibility of being on the Executive Board and taking the position of Secretary. I will be replacing Roger Fox who has done an excellent job for many years.

I am very excited about our upcoming conference in Nashville. Marty Stephenson has done an excellent job along with his Technical Chair, Mike Book. Nashville is an excellent site for our Conference and provides excellent entertainment within walking distance to most hotels. I ask that you continue to support our Parts Competition and send James Alongi the parts you are most proud of.

Your new Membership Chair will be Conor Carlin of Sencorp Industries. I believe that Conor's youth and international experience will be a great bonus to the Division. I have known Conor for many years and consider him one of my closest friends in this industry. I hope that all of you will continue to support this Division and continue to support the recruitment of new members.

A good friend of mine always tells me that change is good. I guess we will have to wait and see.

See you in Nashville.

God Bless America!

MEMBERSHIP REPORT
as of 3/15/06

Primary Paid	1,164
Secondary Paid	507
Total Membership	1,671
Goal as of 6/30/2007	2,000

To Our New Members

Kimberly N. Acinger
Pittsburg State University
Pittsburg, Kansas

Leandro Preter Afonso
Ford Motor Company
Sao Paulo, SP

Oswaldo Aparicio
Envaica SA
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Productive Plastics
Mt. Laurel, New Jersey

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Hector Molina
Lamiempaques SA
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Francois Pariseau
Bain Ultra
Saint Nicholas, QC Canada

Jerome Romkey
GN Plastics
Chester NS, Canada

Craig S. Scott
St. Paul, Minnesota

Ron Smith
Fabri - Form Company
New Concord, Ohio

Dan Tall
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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.

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• keeps you informed
• keeps you connected

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

WHY NOT?

Paul V. Alongi, CEO

MAAC Machinery, Carol Stream, Illinois

Paul Alongi was born and raised in Chicago. His first job out of college was to work for Power Transmission Equipment Co. (PTE), one of Chicago's largest and most prestigious power transmission engineering firms. There for 15 years, he honed his skills as a transmission specialist and also where, in 1970, he was introduced to the thermoforming industry. One of his assignments was to become account manager to Comet Industries, where he provided engineering and product selection to one of the largest manufacturers of thermoforming equipment in our industry.

As the years progressed with the engineering firm, Paul was provided with an opportunity to become the engineering source with start-up companies named Kostur and CAM. These were short-lived arrangements, but whetted his appetite for manufacturing thermoforming equipment. In 1982, he created MAAC Machinery Co. He has managed his firm to become one of the largest cut-sheet thermoforming machinery manufacturers in the world. MAAC machines are located all across the world and are known for their performance, innovativeness, long life, and low maintenance. In 1996, he purchased Comet Industries and had the pleasure, once again, of working with Bob Kostur during the final years of his career. In 1998, he purchased CAM and now all three companies are represented by MAAC.

Paul has always been very supportive of the SPE Thermoforming Division and its mission to advance technology through education, application, promotion and research. MAAC is one of the senior sponsors of the conferences since 1993. Paul has orchestrated numerous fund-raising events for the scholarship fund, donating all proceeds from these events to the Thermoforming Division's scholarship fund. The latest event at Milwaukee was the most successful ever and netted $30,000 to the scholarship fund. Beginning in 2001, Paul pledged to match the SPE Thermoforming Division's equipment grant of $10,000 per college. This program is ongoing today and has been very successful in providing many universities with brand new equipment.

Paul has been an engineering force behind the technical development of the cut-sheet thermoforming machinery. Many of the industries' standard machinery features today are the direct result of his creativity. Paul, along with his engineering department, has developed many of the innovations that have since become the benchmark for today's machinery standard. For example, high sheet line design, breathable ovens, color changing elements, finite element zoning, on voltage heating elements, oven energy saving software, standard non contact sheet temperature measurement, adjustable clamp frame, absolute encoder motorized platens, etc.

During his career, Paul has taken on many difficult projects to assist thermoformers across the country and the world. Providing turn-key services which takes on full responsibility for the machine, mold, material, process, finished part and cycle time, which has eliminated the age old problem of split responsibilities. There are many people who are successful in the thermoforming business today because of Paul Alongi. Paul has always been a proponent of education. The training program at MAAC could have been limited to instructions on how to operate the machinery. Instead, it encompasses oven zoning techniques and includes training on forming temperatures, materials, molds and forming sequencing. He is a long standing member of the Society of Plastics Engineers (SPE) and has been active and supportive towards the SPE Thermoforming Division. Many of our members will testify that Paul was responsible for their introduction to our division. MAAC has been a sponsor for the annual conference since 1993, a sponsor for the European Division since its inception, and has funded MAAC employees to be active members of the Thermoforming Division here and in Europe.

Paul is CEO and Director of Engineering of MAAC Machinery and is continually driving the processes' capabilities to the next level. Paul's 25 years at the helm has produced a consistent direction of business development of new equipment for the thermoforming industry. His most recent new product line was the Royce Router, which was introduced last September. Paul is very active in the business and also has the pleasure of working with three of his four sons and his brother who have joined him in his pursuit of making the best thermoforming equipment. ■

Need help with your technical school or college expenses?

If you or someone you know is working towards a career in the plastic industry, let the SPE Thermoforming Division help support those education goals.

Our mission is to facilitate the advancement of thermoforming technologies through education, application, promotion, and research. Within this past year alone, our organization has awarded multiple scholarships! Get involved and take advantage of available support from your plastic industry!

Start by completing the application forms at www.thermoformingdivision.com or at www.4spe.com. The deadline for applications is January 15th, 2007. ■

Thermo Forming Division

"FORMING EDUCATIONAL OPPORTUNITIES: GRANTS AND SCHOLARSHIPS OFFERED BY THE SOCIETY OF PLASTICS ENGINEERS – THERMOFORMING DIVISION"

The Thermoforming Division of SPE has produced a new six-minute DVD for educators.

The DVD discusses the 13 matching equipment grants of up to $10,000 and how to apply for the grant. The 20 scholarships to college students are discussed and information is provided as how to apply for a scholarship. The Thermoforming Division of SPE has contributed over $150,000 in equipment grants and scholarships as of this date.

The DVD is free of charge and available from SPE through Gail Bristol at 203-740-5447 or Gwen Mathis, Thermoforming Division, at 706-235-9298.

Visit the SPE website at www.4spe.org

THERMOFORMER OF THE YEAR CRITERIA FOR 2007

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

2005
Manfred Jacob
Jacob Kunststofftechnik

2006
Paul Alongi, MAAC Machinery

THERMOFORMER OF THE YEAR 2007

Presented at the September 2007 Thermoforming Conference in Cincinnati, Ohio

The Awards Committee is now accepting nominations for the 2007 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 2007 meeting. The deadline for submitting nominations is December 1st, 2006. 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 BOARD MEETING SCHEDULE

May 3rd - 7th, 2006
Hilton Oceanfront Resort

23 Ocean Lane
Hilton Head, South Carolina
www.hiltonceanfrontresort.com

(Fly into Savannah, Georgia Airport - 40 Minute Drive; Take I-95 N to Exit #8 Hwy. 278 East – take left at Palmetto Dunes – two miles to Hilton Gate)

Roundtrip via Low Country Adventures from Airport – $24.00

Cab Roundtrip – $24.00

FOR RESERVATIONS: Call 843-842-8000
Request SPE Room Rate of $189.00

Wednesday, May 3rd, 2006

Executive Committee Arrive
Technical Chairs Arrive

Thursday, May 4th, 2006

7:30 am – 8:00 am – Breakfast
8:00 am – 10:00 am – Technical Chairs Meet with Executive Committee
10:00 am – 5:00 p.m. – Executive Committee Meeting
11:00 am – Noon – James Alongi, Finance Committee Meet with Executive Committee

Friday, May 5th, 2006

9:00 am – 11:00 am – Materials Committee - Promenade 1
9:00 am – 11:00 am – Machinery Committee - Promenade 8
9:00 am – 11:00 am – Processing Committee - Captain's Galley A
12:00 pm – 1:00 pm – Lunch - Captain's Galley B
1:00 pm – 5:00 pm – All Other Committees - Captain's Galley B
5:30 pm – Trolley departs from hotel lobby for dinner at Charley's Crab

Saturday, May 6th, 2006

7:30 am – 8:30 am – Breakfast – Promenade 8
8:30 am – Noon – Board of Directors Meeting - Promenade 6-7

Sunday, May 7th, 2006

Depart

Microthermoforming Technology and Applications[1]

BY R. TRUCKENMUELLER, FORSCHUNGSZENTRUM KARLSRUHE, GERMANY
S. GISELBRECHT, FORSCHUNGSZENTRUM KARLSRUHE, GERMANY
AND J. L. THRONE, SHERWOOD TECHNOLOGIES, INC., DUNEDIN, FLORIDA

Abstract

Unlike injection molding, thermoforming has not participated in the growing polymer microengineering industry. This paper points out why and how this may change in the near future. We detail the recent development of thermoformed microproducts at Forschungszentrum Karlsruhe, Germany. The microformed parts shown in this paper represent promising early applications. Thermo-formed microparts have some unique properties that result from their special morphologies. Some of the many potential applications that may take advantage of these characteristics are discussed in this paper.

Introduction

For more than two decades, polymer microengineering [1] has been a rapidly growing industry producing microproducts, defined here as products containing structures with dimensions between 0.1 and 1000 μm. These products may be simple parts, single sensor and actuator microcomponents, or complex microsystems consisting of several components including packaging, electronics, and power supplies. Microproducts have become an integral part of our daily life, with applications ranging from automotive to life sciences.

Injection molding is the major polymer microreplication method [2]. To date, thermoforming has not participated in microengineering. The apparent reason for this is that there seemed to be no appropriate microthermoforming production process and no specific innovative applications for microthermoformed products. Researchers at Forschungszentrum Karlsruhe have now developed a microscale thermoforming process and have fabricated microproducts for a promising important application.

The novel process discussed herein is called 'microthermoforming.' It seems particularly suited for mass production of polymer microchips for fluidic applications. The primary application is in life sciences for single use products such as "lab on a chip" or LOC microdevices [4] or for "micrototal analysis systems" or μ TAS [3]. Synthesis and analysis of biochemical agents for pharmaceutical active substance research take places in these microfluidic chips.

Below we discuss the novel microprocess, the corresponding press, the tolls and the semi-finished goods, being chips for capillary electrophoresis (CE) and a chip for the in-vitro cultivation of living cells. Some of the many potential applications that can be derived from the unique properties of thermoformed microparts are discussed.

Microthermoforming Process

The current microprocess is a microscopic adaptation of the macroscopic trapped sheet forming technique [5]. In a press, a thin thermoplastic film is heated by contact with hot plates and formed with compressed gas into evacuated microcavities in a mold. In a second step in the same press, the thermoformed film is heat-sealed onto another polymer film without demolding it. With this technique, liquid-tight fluidic microstructures such as microchannels and reservoirs are fabricated in one unit. This process is more efficient than microinjection molding or the special micropolymer replication method known as vacuum hot embossing [6].

In addition, the process provides various pre- and post-processes such as surface and bulk modification normally associated with thermoforming but not

(continued on next page)

[1] A portion of this paper was presented at the 2006 European Thermoforming Division Conference, Salzburg, Austria, 18 March 2006.

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possible with other processes. The technology yields unique patterned, functionalized, and perforated three-dimensional microstructures such as those for in-vitro cell cultivation shown below.

The Press

As noted, the new microthermoforming process evolved from the relatively simple trapped sheet forming process. The three-part mold consists of the plate-shaped mold with micromold cavities, a counterplate with holes for evacuation and gas pressurization, and a seal between the mold and the counterplate. The thermoplastic film is inserted in the mold and the mold assembly is mounted in a heated laboratory press. The press is closed to the point where vacuum sealing is achieved but the film is not yet clamped between the mold plates. The mold is evacuated, then completely closed, completely clamping and heating the film. When the polymer has reached forming temperature, the film is forced into the evacuated mold cavities with compressed gas. The mold is cooled. When the mold is about 20°C below the forming temperature of the polymer, the gas pressure is released, the mold opened, and the microstructure is demolded.

Secondary Process

If the part is to be a closed container, a second film is inserted into the press after the first film is formed but before the microstructure is demolded. The second film contains a heat-activated adhesive. The press is closed again, pressing the second film against the formed microstructure to activate the adhesive and form the container. In essence, the microproduct is twin-sheet thermoformed. Liquid-tight products that compete with microinjection molded and vacuum hot embossed products, such as microchannels and reservoirs are produced in this fashion. Pre- and post-processing of the sheet to achieve surface and bulk modification can be combined with the twin-sheet forming process. Examples include ion bombardment before forming, ion track etching after forming, UV-based surface modification through appropriate masks before forming, and wet chemical functionalization after forming. In this way, patterned, functionalized, and perforated, three-dimensional (3D) microstructures are produced from membranes that find use in in-vitro-like three-dimensional cell cultivation as seen below.

The Mold

Molds for polymer microreplication can be fabricated by various methods and from various materials. Mechanical micromachining [7], lithographic-based methods in combination with electroplating [1], wet or dry etching, laser ablation, powder blasting, and electrical discharge machining have been used. Metal, ceramic, glass, and silicon carbide have been used as mold materials. Nickel molds with high-resolution, high-aspect ratio structures with smooth sidewalls are fabricated using the "LIGA" process [1]. Large area brass or special steel molds with high planarity and plane parallelism have been fabricated using high-speed, high-precision cutting. End-mill cutters are commercially available in diamond with diameters down to 200 µm and in special steel with diameters down to 30 µm.

For fabrication of the CE and cell culture chips discussed below, the molds and counterplates were made of circular brass (Ms58) with a diameter of 116 mm, Figure 1.

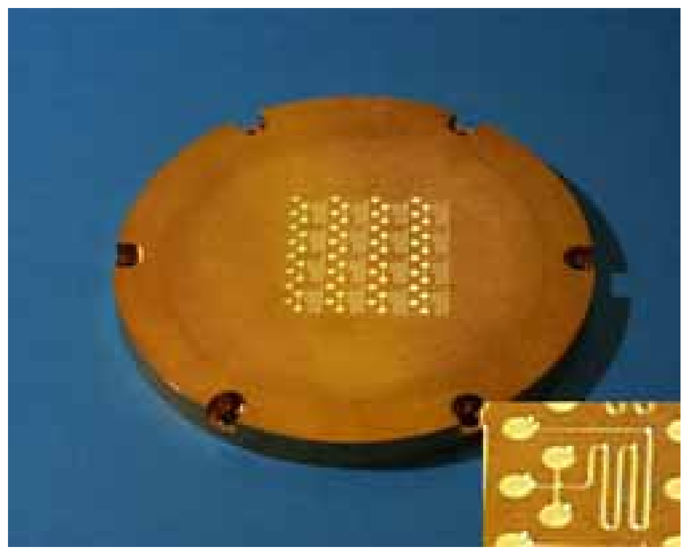

Figure 1. Brass mold with 16 microcavities for microthermoforming of CE chip.

The flatness and parallelism of the ground brass plates are about three mm and the surface roughness (R_a) is about 0.2 µm. The mold cavities were mechanically micromachined using diamond end-mills, Figure 2.

The cavities have a surface roughness of about 0.15 µm and draft angles of 1.5 to 2 degrees. The outer edges of the microcavities were not deliberately smoothed. For the CE chips, the cavities had draft angles of 5 degrees. They also had 20 µm wide 45-degree bevels to facilitate demolding, Figure 2. The mold was used not only for thermoforming of the PS

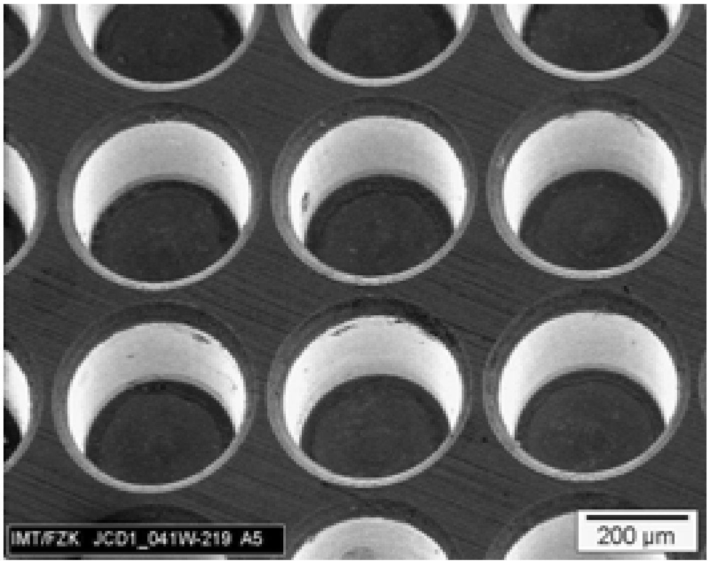

Figure 2. SEM of the micromold cavities for the cell culture chip. Diameter and depth of microcavity is 300 µm.

film, but also for subsequent heat-sealing of the formed film onto another PS film. The mold did not require remanufacture to include the heat-sealing step.

Film Materials

For the CE chips, a 25-µm film of impact-resistant, biaxially oriented PS (Norflex from Norddeutsche Seekabelwerke, HIPS styrene butadiene blown-film polymer) was used as the semi-finished product. For fabrication of the cell culture chip, 50 µm thin films of polycarbonate (Pokalon from LOFO, cast film) and of COP (Zeonor from Zeon) were chosen.

CE Chip Manufacture

In today's chemical and bioanalytical areas, CE is a family of related techniques for separation of small and large molecules. In its simplest form, a small sample volume is injected into a long capillary tube or microchannel that has been filled with a buffer solution. A high voltage is applied by electrodes to both ends of the capillary and an electrical field is impressed along the capillary length, causing the sample to separate into components having different charge-to-mass ratios. Component detection includes light absorbance, fluorescence, electrochemical conductivity, and mass spectrometry measurements. Miniaturized CE systems [8] offer a number of advantages when compared with conventional systems, including lower sample consumption, higher resolution, shorter response time, and parallel architecture [9].

The thermoformed CE chip contains 4 x 4 CE structures arranged in a 10 mm x 10 mm grid, Figure 3.

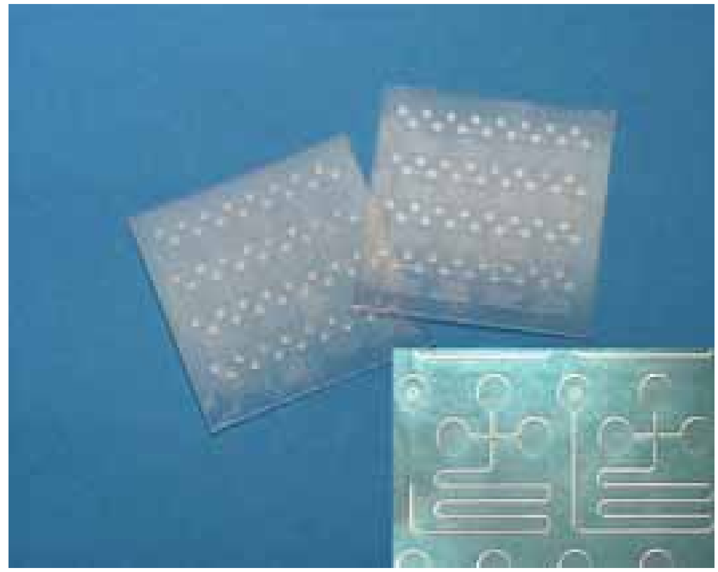

Figure 3. CE chips from PS with 16 CE structures (side length of square chip is 47.5 mm).

Each structure consists of two crossed microchannels with reservoirs at their ends. One channel is for sample separation, and the other for injection of the sample into the separation channel, Figure 4. Each channel has a width of about 150 µm and a depth of about 75 µm. The corner radii of the channel intersections are 125 µm.

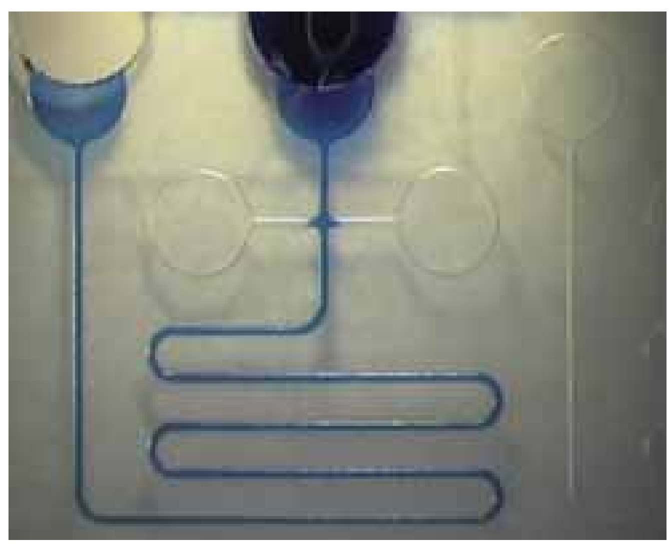

Figure 4. CE chip structure being filled with colored water for flow and leak testing (width of separation and injection channel approximately 150 µm, channel depth approximately 75 µm).

Thermoforming and sealing of the CE chips was performed in two consecutive cycles of the heating press, with an intermediate feed of the second film. During this interim opening of the mold, the

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thermoformed film was not demolded. The fluidic microstructures were formed into the PS film at 115°C with nitrogen at an absolute pressure of 0.5 MPa. The formed first film was then heat-sealed to the second planar film at temperatures between 75 and 80°C. This was above the minimum heat activation temperature of the heat-activated coating (about 60°C) on the second film but well below the glass transition temperature of the PS film. As a result, dimensional stability of the films was not affected by the heat sealing.

Cell Culture Chip

Cells extracted from native tissues can be cultured in artificial environments if they are sufficiently supplied with nutrients and oxygen. In the past few years, in-vitro culturing of cells has become increasingly important to the investigation of the structure and function of cells. This is particularly important in the study of biochemical pathways and developmental processes. And cell cultures are also being routinely used in pharmaceutical and biomedical industries to develop and produce vaccines and antibodies. It is known that three-dimensional or 3D cultures have superior properties when compared with standard two-dimensional or 2D monolayer cultures, particularly in long-term maintenance of cellular functions.

An interdisciplinary group at Forschungszentrum Karlsruhe has developed a platform based on bioreactors. The platform contains a varying number of microstructured polymer scaffolds for 3D cell cultivation in a chip format [10]. When compared with other 3D culture strategies [11], this device allows for better adjustment and control of specific culture conditions. In particular, the supply situation is improved.

The up-scale versions of these bioreactors are not only intended to be used for high throughput screening applications in pharmaceutical research but also as extracorporeal organ support units in the rapidly growing field of regenerative medicine. For a bioartificial liver, for example, a large number of long-term viable and functional liver cell, approximately 10 to 30% of the total liver mass, is essential to guarantee sufficient support of a patient's impaired liver [11]. Although several million cells can be cultured on a single microchip, more than 10,000 microchips are still needed for one patient.

Microscale thermoforming opens up the possibility for a high-volume mass production of low-cost disposable cell culture chips as a fundamental premise for this application. A smaller number of cell chips have already been fabricated [12]. The thermoformed cell culture chip contains 25 x 25 cell containers arranged on a 400 x 400 μm grid, Figure 5.

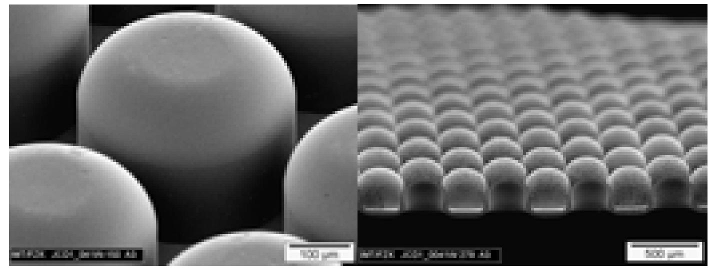

Figure 5. SEM photos of COP cell culture chip (formed as 625-up).

The cylindrical microcontainers have a diameter and depth of about 300 μm. The microstructures were thermoformed at a pressure of up to 6 MPa. Because of the high local stretch ratio, the microcontainer bottoms have thicknesses down to about 5 μm. Figure 6 shows a PC microcontainer that has been formed from a film that has been treated with ion track technology. The micropores provide for two-sided supply of the cell aggregates in the containers with dissolved nutrients and oxygen.

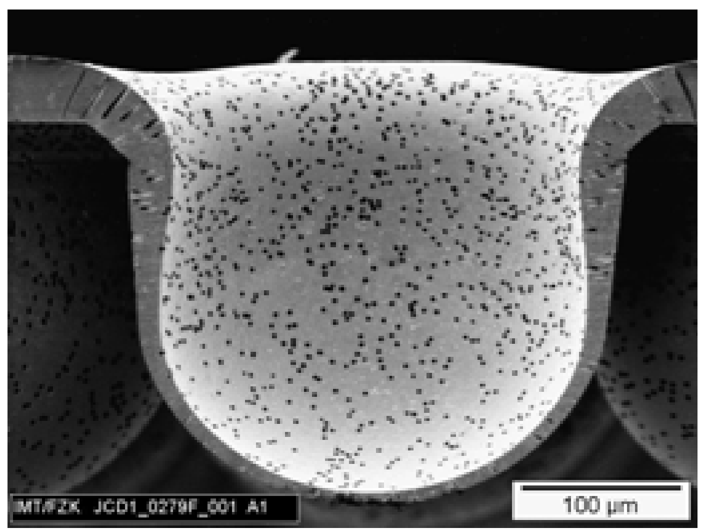

Figure 6. SEM of cell container, microthermoformed of ion-track treated PC (diameter, depth ~ 350 μm, pore size < 3 μm).

Different kinds of cells, cell lines and primary cells, have already been three-dimensionally cultured in these chip containers, as shown in Figure 7.

It is expected that the combination of microthermoforming and various surface and bulk modification techniques will enable the tailoring of the cell microenvironment within the scaffold [13], as seen in Figure 8.

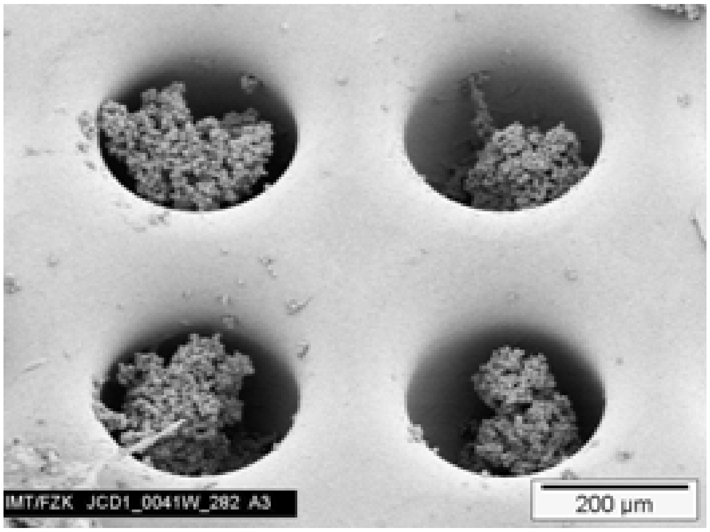

Figure 7. SEM of cell containers with 3D HepG2 cultivated cells inside.

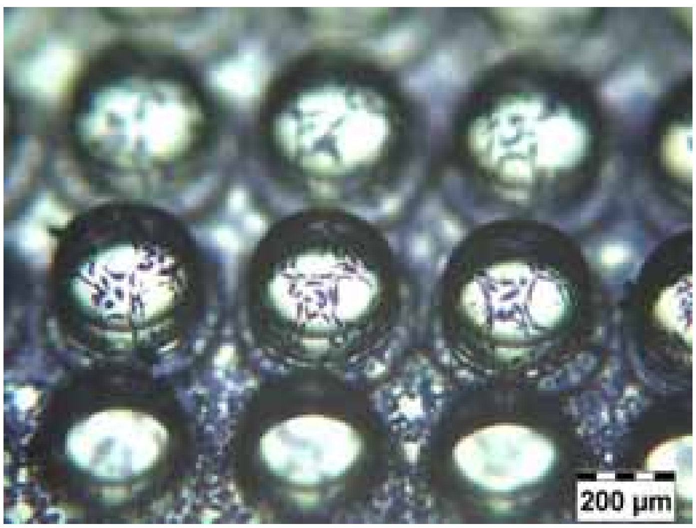

Figure 8. PS thermoformed cell container with L929 fibroblasts (crystal violet stained) selectively adhering to DUV-exposed areas on the inner container surface.

Properties That Lead to New Microthermoformed Part Applications

The microscopic version of contact sheet forming has the same process advantages as the familiar macroscopic version. However, there are additional specific advantages that are achieved only in microscale dimensions. For example, thermoformed microfluidic products have unique combinations of properties that are unattainable with other polymer microreplication methods. The microthermoformed hollow membrane microstructure are free standing, they have walls of a few micrometers in thickness, and can have very smooth inside surfaces that are difficult or impossible to achieve with other methods. Characteristically they have small volume and mass, high flexibility, low thermal resistance and heat capacity, and low light absorption, light scattering and background fluorescence.

These properties should result in improved current products and products that are just now being conceived. The small amount of formed material allows for biodegradable human implants having short lifetimes and organism-gentle decomposition. The small amount of formed polymer also provides for one-way medical diagnosis applications where contaminated clinical waste must be reckoned with. The properties of low stiffness and high flexibility of the thermoformed microproducts provide for combinations with "polytronic" applications. These properties are also desired in functional or 'smart textiles,' and in applications onto the free-form surface of human skin and in implantation applications under the skin or into soft tissue. Because of the flexibility of the film format, reel-to-reel processes are possible not only in production but also in application such as in high throughput screening of active or toxic substances. For example, hermetically sealed thermoformed fluidic microstructures that are sterilized and empty, or partially liquid filled, can be opened at the instant they are to be used, simply by puncturing the thin stretched film at the reservoirs, Figure 4.

Conclusions and Observations

In this paper, we have presented an early look at thermoforming of microproducts. We have developed a new process, called 'microthermoforming.' Currently, it is a microscopic version of conventional macroscopic trapped sheet thermoforming. In essence, a simple three-part mold is mounted into a heated laboratory press. Commercially available thin thermoplastic films on the order of 25 to 50 µm are used. Flexible CE and cell culture chips have been fabricated. Many potential applications using the unique properties of thermoformed microparts have been discussed.

Work continues on the technology. Automated pressure build-up and mechanized demolding technologies are underway. As noted, the current technology requires the mold to be sequentially heated and cooled. Work is continuing on advanced heating concepts where the mold temperature will remain constant and the film feed heated prior to entering the press. The objective of this work is to

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reduce the process cycle time and improve the process reproducibility. ■

References

1. W. Menz, J. Mohr, and O. Paul, **Microsystem Technology**, Wiley-VCH, Weinheim Germany, 1st Ed., 2000.
2. V. Piotter, K. Mueller, K. Plewa, R. Ruprecht, and J. Hausselt, "Performance and Simulation of Thermoplastic Micro Injection Molding," Microsystem Technologies, **8**, 2002, pp. 387-390.
3. A. Manz, N. Graber and H.M. Widmer, "Miniaturized Total Chemical Analysis Systems: A Novel Concept for Chemical Sensing," Sensors and Actuators B1, 1990, pp. 244-248.
4. S. C. Jacobson, R. Hergenroeder, L. B. Koutny, and J. M. Ramsey, "High-Speed Separations on a Microchip," J. Analytical Chemistry, **66**, 1994, pp. 1114-1118.
5. J. L. Throne, **Technology of Thermoforming**, Hanser, Munich Germany, 1996.
6. M. Heckele, W. Bacher, and K. D. Mueller, "Hot Embossing – The Molding Technique for Plastic Microstructures," Microsystem Technologies, **4**, 1998, pp. 122-124.
7. T. Schaller, M. Heckele, and R. Ruprecht, "Mechanical Micromachining for Mold Insert Fabrication and Replication," ASPE Proc. Spring Topical Meeting, Chapel Hill, NC, 1999, pp. 4-8.
8. A. Manz, D. J. Harrison, E. Verpoorte, J.C. Fettinger, A. Paulus, H. Luedi, and H.M. Widmer, "Planar Chip Technology for Miniaturization and Integration of Separation Techniques into Monitoring Systems: Capillary Electrophoresis on a Chip," J. Chromatography, **593**, 1992, pp. 253-258.
9. D. J. Harrison, K. I. Fluri, K. Seiler, Z. Fan, C.S. Effenhauser, and A. Manz, "Micromachining a Minia-turized Capillary Electro-phoresis-Based Chemical Analysis System on a Chip," Science, **261**, 1993, pp. 895-897.
10. G. Knedlitschek, F. Schneider, E. Gotwald, T. Schaller, E. Eschbach, and K. F. Weibezahn, "A Tissue-Like Culture System Using Microstructures: Influences of Extracellular Matrix Material on Cell Adhesion and Aggregation," J. Biomechanical Engineering, **121**, 1999, pp. 35-39.
11. J. W. Allen, T. Hassanein, and S. N. Bhatia, "Advances in Bioartificial Liver Devices," Hepatology, **34**, 2001, pp. 447-455.
12. S. Giselbrecht, T. Gietzelt, A. E. Guber, E. Gottwand, C. Trautmann, R. Truckenmueller, and K. F. Weibezahn, "Microthermoforming as a Novel Technique for Manufacturing Scaffolds in Tissue Engineering (CellChips)," Proc. Nanobiotechnology, **151**, 2004, pp. 151-157.
13. S. Giselbrecht, E. Gottwald, G. Schlingloff, A. Schober, R. Truckenmueller, K. F. Weibezahn, and A. Welle, "Highly Adaptable Micro-structured 3D Cell Culture Platform in the 96 Well Format for Stem Cell Differentiation and Characterization," Proc. 9th International Conference on Miniaturized Systems for Chemistry and Life Sciences (μTAS), Boston, 2005, pp. 376-378.

Router Bits for the Sign Industry[1]

VAN NISER CUTTER, LP, LIBERTYVILLE, ONSRUD, ILLINOIS

Signs and the information they convey have become an integral part of daily life. Companies of various sizes serve this vast market, but they all have common problems when it comes to routing of the materials common to the industry. Wood, aluminum, foam and plastic all have different cutting characteristics and no individual tool can solve all routing problems. This is particularly evident in the routing of plastics in the sign industry.

As a starting point, plastics can be placed into two general categories: flexible and rigid. The tools of choice for flexible plastic usually involve the use of single or double edge "O" flute tools, which are available in straight or spiral flute configurations. In terms of rigid plastics, double edge straight "V" flute tools, spiral "O" flutes with hard plastic geometry, and two and three flute finishers are recommended. The tool materials for most of these router bits are readily available in high-speed steel for hand operations and solid carbide for CNC routing. Solid carbide is a very durable material when utilized in a controlled environment of CNC, but not reliable in hand routing, which tends to be less rigid with more opportunity for tool breakage.

The aforementioned recommendations are general in nature and are just a beginning for tool selection. In order to target an application, the sign maker has a new resource on the Internet at www.plasticrouting.com. This site provides a specific tool recommendation for a variety of plastic materials. The major emphasis of this web site is to recommend router tools that provide the best finish at a productive feed rate. Sign makers, who historically use smaller diameter tools to achieve the necessary radii associated with lettering, will be pleasantly surprised. The tool diameter is the controlling factor in feed rate, but larger diameters were not necessarily superior in terms of finish. The use of micro grain carbide with the necessary geometry to achieve chip evacuation has made smaller diameter tools more effective for the sign industry. The site can also be accessed via a link on IAPD's website at www.iapd.org.

Recently, there have been several new styles of specialty tools developed to improve finishes with faster cycle times without tool changes and or advanced programming techniques. Both should prove to be advantageous to the sign industry.

The first of these tools was developed to provide a smooth bottom surface in lettering or pocketing applications. Most router tools are designed to plunge and rout with the emphasis on the side geometry rather than the point. Consequently, the point end would always leave swirl marks, which required a secondary operation to remove the swirls. The new tool, Figure 1, utilizes a near flat point with radiused corners to create a smooth bottom with an aesthetically pleasing result.

The second innovation, Figure 2, is the development of a rout and chamfer bit designed for plastic sheets.

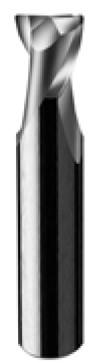

Figure 1. Solid Carbide Bottom Surfacing

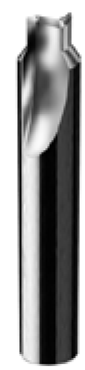

Figure 2. Solid Carbide Rout and Chamfer

By combining both a straight flute optimized for cutting plastics with a cutting edge sized for specific sheet sizes and a 45 degree chamfer edge, these tools can rout out plastic parts and apply a variable depth edge chamfer in a single pass. By combining these features into a single tool, tool changes within the machining cycle are eliminated and CNC routers without tool changing spindles have new capabilities for parts production.

The advances in router tooling have generally followed the rapid growth and usage of CNC routers or router tables as they are commonly called in the sign industry. These machines have revolutionized the speed and accuracy of sign making and the ability to produce intricate shapes and designs with specialized software. Router tooling has enhanced the CNC user by providing

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stronger tools with improved cutting geometry specific to the material being machined. However, merely choosing the correct tool without effective machining practices is an exercise in futility. Consequently, a review of proper machining practices would be in order.

- Maintain CNC machines per manufacturer's recommendation with proper lubrication of machine slides and drive systems
- Check for play in the table or spindle mounting systems
- Establish a collet, collet nut, and tool holder maintenance program and replace collets after 600-700 hours of usage
- Insure part rigidity by following proper spoilboard technique
- Establish colleting procedures to maximize tool rigidity
- Maximize chipload to minimize tool wear
- Select tools with the shortest possible cutting edge length to achieve depth of cut
- Use straight through tools where the cutting edge length and shank are the same size to reduce breakage
- Maximize dust collection to completely evacuate gummy chips produced by some plastics

The right tool for the job and sound CNC machining practices will improve throughput, product quality and profitability in the sign industry. ■

History of Thermoforming – Part IV

BY STANLEY R. ROSEN, PLASTIMACH CORPORATION, LAS VEGAS, NEVADA

Ed. Note: The philosopher Santayana said "Those who cannot remember the past are destined to repeat it." Stan Rosen is undertaking a prodigious project – identifying the pioneers who laid the foundations of the industry we know so well. Although shaping of sheet extends back to pre-history – oil-heated and shaped tortoise shell and steam-heated and shaped wood. In TFQ 24:3, Stan started his history with developments in the 1930s. We hope you are enjoying the trip!

Mechanically Forming Thermoplastics Parts Prior to the Thermoforming Age – Part Two

Eventually Celluloid or camphorated cellulose nitrate (a close cousin to the explosive nitrocellulose) was supplanted by the safer, much slower burning cellulose acetate. During World War II the Celanese Corp. produced various-shaped nitrocellulose deep drawn packaging to be filled with explosive charges, Figure 4.

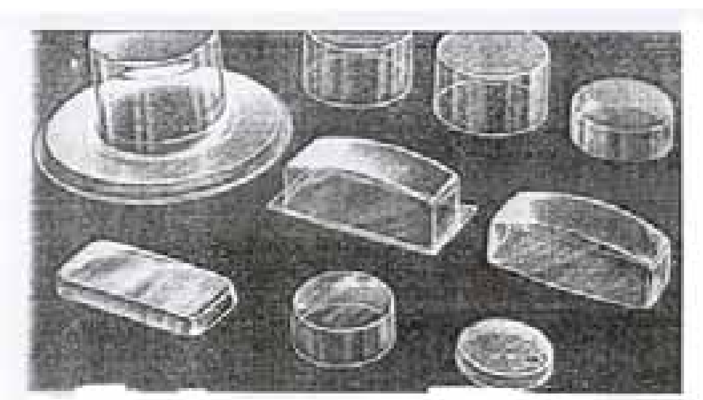

Fig.4 Nitrocellulose packaging for explosives that were formed by deep drawing.
Courtesy of Modern Plastics 1945

This package material added to the explosive force and left no residue. Initially these package components were deep drawn using the inefficient manual forming methods of the period. Because of the high military demands, the process was automated and a continuous web was fed from a roll into the machine instead of the manual placement of individual blanks, increasing production tenfold. After the war ended, versions of the automated deep drawing machines were available for civilian production.

A patent filed in May 1944 was issued to Earl F. Middleton and assigned to Design Center, NYC, one of Plaxall Corp.'s divisions, for a "Process and Apparatus for Shaping Plastics," Figure 5.

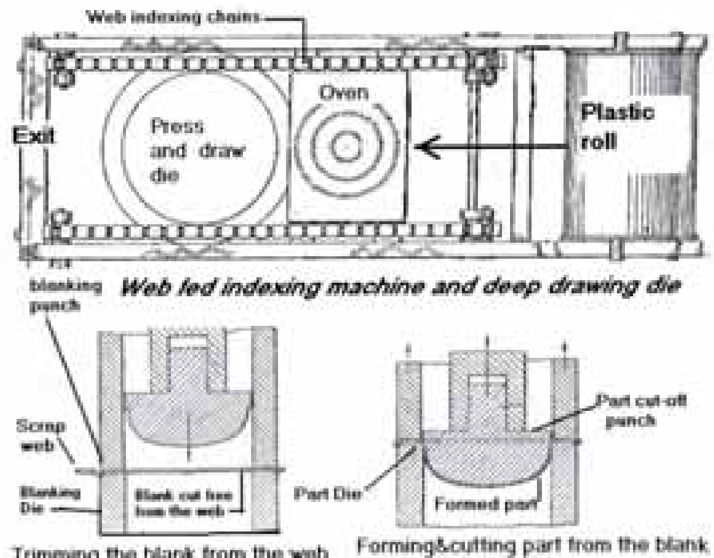

Fig.5 Continuous plastic deep drawing machine
E.A. Middelton filled for this patent in 1944

This machine fed a web from a roll of plastics into clamps built on each of two parallel chains that gripped the sheet edges. The web is then indexed through a heating station and forming press, with the waste skeleton ejected from the press. The process is similar to a modern in-line thermoforming machine except vacuum or air pressure was not used to form the finished parts. As the press closes, the punch trims out a plastic blank which when free from the web is located concentric to the forming die. The forming proceeds in the same manner as the manual deep drawing process described in a previous part. This machine and its later modifications provided Plaxall Corp. with a very productive asset to supply deep drawn transparent packaging to the industry during 1945-1950s, see Figure 6 on next page. Jim Pfohl, President of Plaxall Corp. indicated that during this period, Design Center Inc. successfully licensed this machine for use in European countries.

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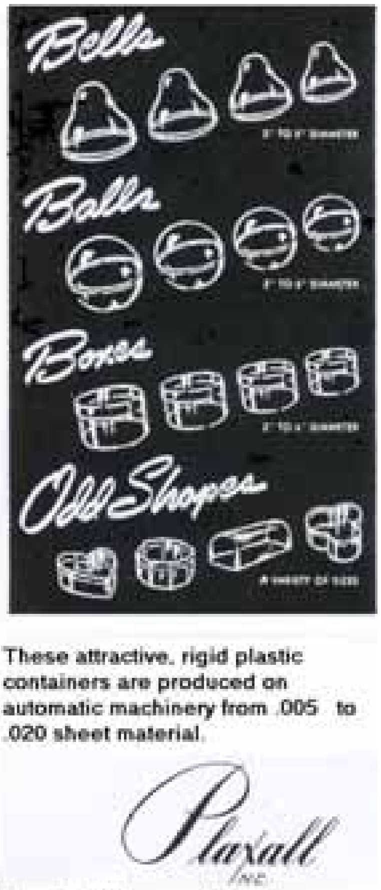

Fig.6 Ad for a deep drawn transparent package-1948
Courtesy of Modern Packaging Encyclopedia

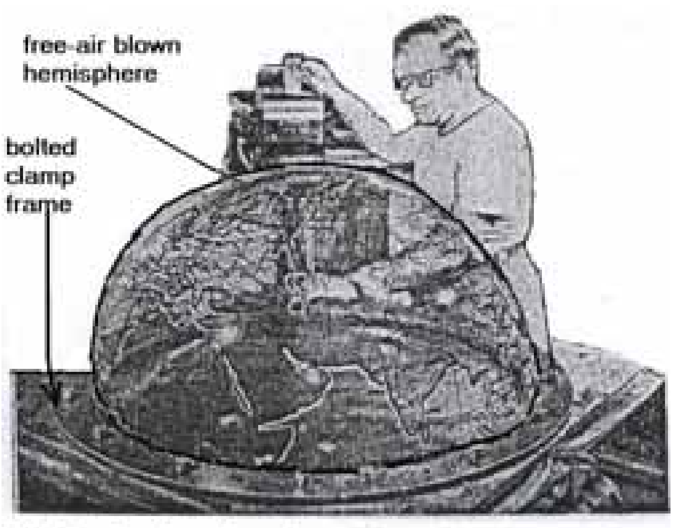

Fig.7 A clear imprinted Acrylic sheet, is free air blown into a perfect hemisphere. Courtesy of Plastics World 1953

Another wartime technique of free-air blowing of acrylic developed for forming transparent aircraft cockpit canopies was adapted to form plastic map globes on very simple equipment, Figure 7.

The plastic was oven heated, transferred and clamped to a round air pressure chamber and blown into a perfect hemisphere. Distortion- printed silk screened blanks with as many as five colors were used for the map details. After trimming, the southern and northern hemispheres were cemented together at the equator to complete the assembly. Free-air blowing required precision manual coordination between the operator and the heated sheet to produce an accurate map presentation consistently.

Conventional metal stamping equipment and dies were the preferred mass production method for factories in the 1940s and the plastic processes took second place. B. F. Goodrich, manufacturer of rigid PVC, sought to sell their resin to the metal fabricators by educating them on how to apply existing dies and presses to PVC sheet. A standard progressive die which may contain multiple stations that might emboss, bend, punch holes, draw shallow box sections, and finally trim out finished parts were used for plastics fabrication. Rolls of PVC stock are indexed into the die after being preheated by a bank of infra-red bulbs mounted inline with the dies. These punch presses operate at 50-250 strokes per minute rapidly enough so the web residual heat was retained thru the cycle. Any of the companies who still remain in the metal stamping business today, soon realized there are more effective ways of fabricating plastics to serve their customers.

Transparent PVC folding boxes were manufactured using a modified folding box die on a standard flatbed die cutting press, Figure 8.

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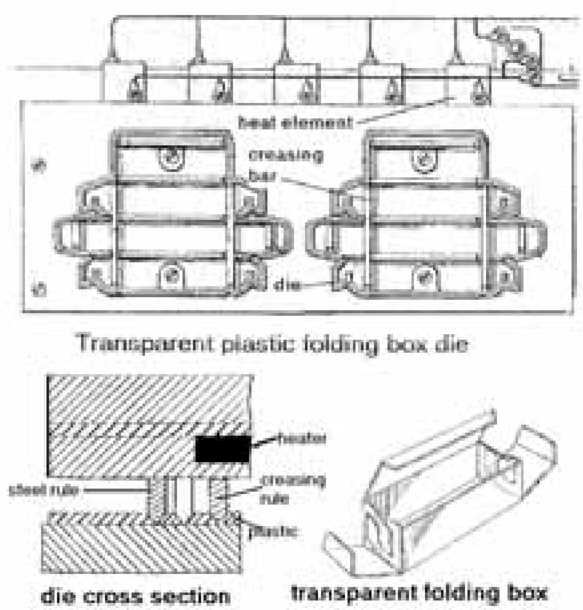

Fig.8 Plastic heat creasing and die cutting L.R. Page Patent filled 1948

Steel rule dies mounted in a metal base plate electrically heated and temperature controlled allowed the creasing blades to create a hinge which allowed the plastic panels to be bent 90˚ without cracking. The box perimeter profile was trimmed out, using standard steel rule blades cutting simultaneously with the creasing action. These folding boxes are favored by many retail shops that did not have sufficient storage space for packaging, yet favor a transparent platform for their products.

When thermoplastic sheet thicker than 0.060 inch or 1.6 mm became commercially available to form signs, displays, and components for refrigerators, they were fabricated on tooling similar to the metal forming dies steel used to stamp car fenders. Fortunately, heated plastics do not require the heavy force needed to form steel stamping, so low cost pneumatic presses were adapted for this purpose, Figure 9. Matched molds of epoxy or wood with conforming male and female cavities are mounted on the opposing press platens. This tool design is similar to modern thermoforming molds that produce foam styrene egg cartons.

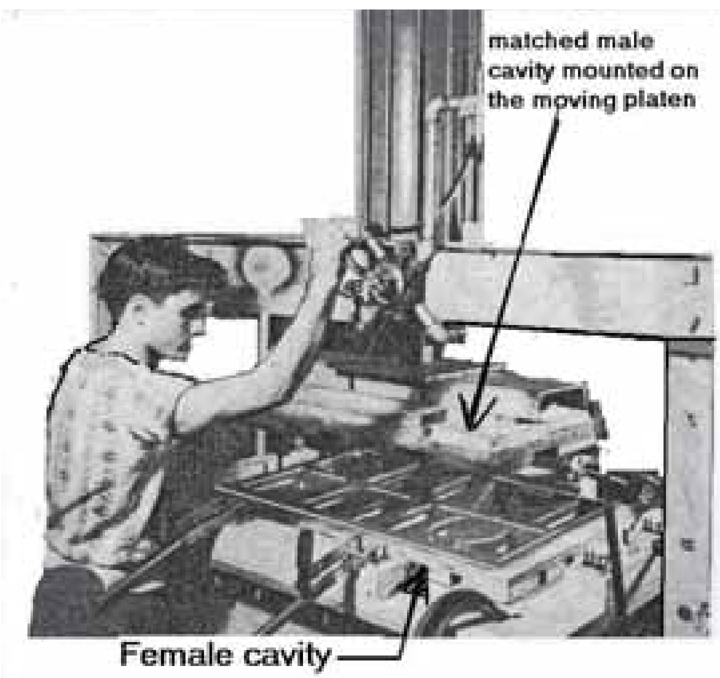

Fig. 9 Simple air powered forming press lacking vacuum assist and requiring pre-heated sheets and utilizing matched molds. Courtesy of a Modern Plastics Ad 1950

Matched mold forming of thick plastic sheet requires oven heated blanks which are manually transported to the forming press and clamped into custom welded steel clamp frames. Components to be formed are designed with generous draft angles and large radii to try to maintain uniform wall thickness. Since neither vacuum nor air pressure was utilized, the male tool is bottomed-out in the female cavity to sharpen critical part detail. By combining the matched mold process and pre-blowing a sheet bubble above the female cavity, a more uniform wall thickness can be achieved, Figure 10.

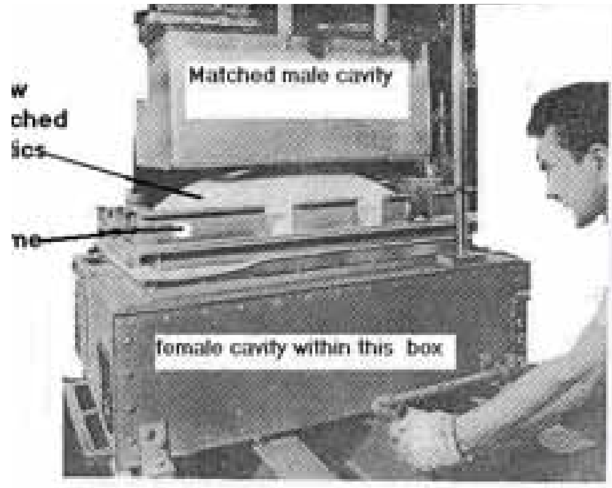

Fig.10 Pre-blowing a sheet bubble to effect a uniform wall thickness and then bottoming out the matched male cavity against the female cavity. No vacuum or pressure assistance is employed

Courtesy of Modern Plastics 1950

This process was employed from the 1940s to the late 1980s. When the author visited a large thermoforming plant in 1990 complete with the latest equipment, he spotted a battery of these ancient machines on standby. The owner indicated many of his sign maker customers need all types of individual plastics letters in various formats and colors. These were small quantity orders and he was able to accommodate the buyers using amortized stock molds and antique presses. The mechanical thermoforming techniques held center stage only for a short period until thermoforming took away their markets in the 1950s. *Thermoforming, with its obvious advantages of low cost tooling, versatility and high production, soon became the dominant process for forming plastic parts and mechanical forming became a historical footnote.* ■

Please contact the author with any relevant information, photos, articles, brochures, or stories about thermoforming during the 1950-1960 era at: Stan Rosen, thermoipp@earthlink.net, P/F: 702-254-3666 or write 10209 Button Willow Dr., Las Vegas NV 89134.

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References

Automatic Pressure Thermoforming, Plaxall Corp., L.I.C., N. Y.

Modern Plastics Magazine, July 1953.

Inline Roll-Fed Thermoformer, C. B. Strauch, Patent #2,229,613, filed 11-22-1938, assigned to Plax Corp. Hartford, CN.

Vacuum Forming Machine, G. W. Borkland, Patent #2,347,806, filed 7-8-1947, assigned to Borkland Laboratories, Marion, IN.

Figure 4 Automatic Deep Drawing of Nitrocellulose Packaging for Explosives, Celanese Plastics Corp., Newark, N. J. *Modern Packaging Magazine*, April 1945, pgs. 94-96 and 176.

Figure 5 Continuous Plastics Deep Drawing Machine, E. A. Middleton, Patent #2,522,956, filed 5-18-1944, assigned to Design Center, Inc., L.I.C., N. Y.

Figure 6 Ad for Deep Drawn Transparent Packaging, Plaxall Corp., L.I.C., N. Y. *Modern Packaging Encyclopedia*, 1948.

Figure 7 Free Air Blown Globes, Farquhar Transparent Globes, Philadelphia, PA. *Plastics World Magazine*.

Conventional Metal Stamping of PVC, B. F. Goodrich Chemical Co., Cleveland, OH. *Plastics World Magazine*, October 1954.

Figure 8 Method for Fabricating Folding Cartons, L. R. Page, Jr. Patent #2,589,022, filed 6-21-1948, assigned to Robert Gair Company, N. Y., N. Y.

Figure 9 Air Powered Press for Matched Mold Forming, ad for Hanna Air Cylinder, Chicago, IL, *Modern Plastics Magazine*, April 1950.

Figure 10 Pre-Blowing Plastic Sheet for Uniform Wall Thickness, *Modern Plastics Magazine*, May 1950, pg. 67.

■

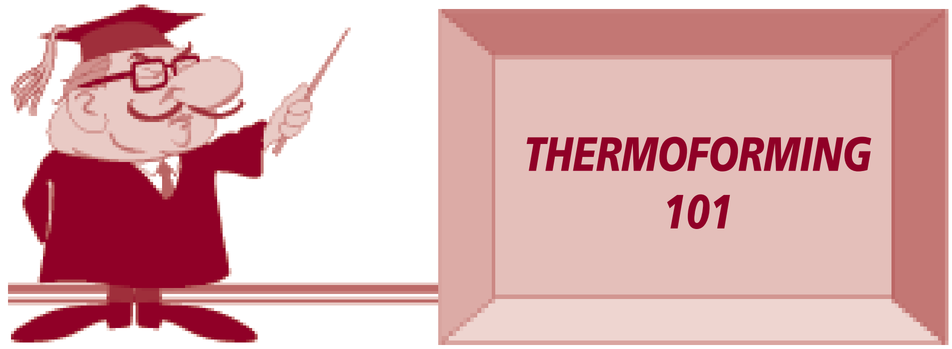
CORNERS

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

Most plastic parts have corners. And most corners are radiused. Designers often seek sharp corners or more properly, corners with very small radii. Aesthetics is often cited as the reason for this. But aesthetics is not the only reason. Often the container must contain material of a specific volume. For a given dimensioned container, the internal volume decreases with increasing corner radii. Conversely, for a given volume, the overall dimensions of the container (and thus the amount of plastic needed to make the container) increase with increasing corner radii. In this lesson, we consider the concept of the corner.

Can a Part Have More Than One Type of Corner?

Of course. Consider the simplest type of corner, being the place where two planes intersect. Picture the bottom edge of an axisymmetric part as a drink cup or a can, for instance. The vertical or near-vertical side of the container intersects the bottom of the container at a right or near-right angle, thus forming the corner, in this case, a bottom two-dimensional or 2D corner. Of course, any good thermoformer worth his or her salt would not make a sharp angle at the intersection. The reason for this is intuitively obvious but will be explained in a little more detail later.



Is there more than one type of corner on a five-sided box? Sure. There's the intersection between the vertical wall and the bottom. And the intersection between one vertical wall and another. And what about the intersection between two vertical walls and the bottom? So we have bottom two-dimensional or 2D corners, vertical 2D corners, and in the last case, three-dimensional or 3D corners. And, as with the cup or can example, corners should have radii.

We must keep in mind that the plastic stretches from the sheet that is not contacting the mold surface. As more and more of the plastic sheet contact the mold surface, the sheet not contacting the mold becomes thinner and thinner. For a part such as a cup or can, the plastic stretches into the bottom 2D corner last. As a result, the material in the corner is usually the thinnest. Although mechanical and pneumatic assists help redistribute the sheet during stretching, the part wall is usually thin in the corners. And smaller corner radii usually lead to thinner part walls. In other words, sharp corners lead to thin-walled parts in corners.

Wall Thickness in 2D Corners

The wall thickness in the bottom 2D corner of a five-sided box is proportional to the corner radius to about the 0.4-power. If the design calls for a radius in one area of the bottom of the part that is 50% of that in another area of the bottom of the part, the part thickness in that area will have about 75% of the thickness of the other area. If the design radius is 25%, the thickness in that area will be about 55% of that of the other area.

Interestingly enough, wall thickness in vertical 2D corners is about equal to wall thickness of surfaces adjacent to the corners. This is probably because the part walls in the vertical corners are formed at the same time the part walls of adjacent surfaces are formed and not

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afterwards, as is the case with bottom 2D corners.

Wall Thickness in 3D Corners

The wall thickness in the 3D corner of a five-sided box decreases in proportion to the corner radius to the 1.0-power. If a design calls for a 3D radius in one corner of the part that is 50% of that in another corner of the part, the part thickness in that corner will have 50% of the thickness in the other corner. If the corner design radius is 25%, the part thickness will be 25% of that in the other corner.

Why are we concerned about part wall thickness in 3D corners? Because many of our parts are similar to the five-sided box we've used as an example. And five-sided boxes are often filled and handled during shipping, installation, and use. And 3D corners of five-sided boxes are most susceptible to impacting. In an earlier lesson we discussed that when we stretched a sheet, we thinned it. We needed greater forces to stretch the sheet to greater and greater extent. And when we cooled the sheet we locked in the stresses we used to stretch the sheet. So when we impact the 3D corner of the formed part, we are applying stress on top of those already frozen into the corner. On top of this, the 3D corner is very thin. In short, sharply-radiused corners are often desired by designers but of great concern to thermoformers. As a result, the designer must often accept greater radiuses than he/she desires.

In a subsequent lesson, we consider alternative designs for corners, as well as other product features. ■

Keywords: vertical 2D corner, bottom 2D corner, 3D corner, corner radius

BOOK REVIEW

PVC Handbook, C. E. Wilkes, J. W. Summers, and C. A. Daniels, Eds., Hanser Gardner, Cincinnati OH, 2005, 723 + xxxvi pages, $202, $170 (SPE Member).

I love handbooks, don't you? They reside somewhere between multi-volume encyclopedias and dictionaries. Dictionaries present us with a brief sentence or two on a specific word. Encyclopedias give us paragraphs on essentially every aspect of the editors' intended topic area. A handbook, by definition, is " … a concise reference book providing specific information about a subject or location." In this case, the subject is polyvinyl chloride, in all its many forms. This one is probably not a fair representation of a concise book, as it is a truly weighty tome at just over 4 pounds (1.9 kg) and consisting of more than 700 pages and perhaps 150,000 words.

This one-volume compendium on nearly every aspect of polyvinyl chloride is, in essence, an update and recapitulation of materials found in the 1980's tomes such as Leonard Nass' four-volume **Encyclopedia of PVC**, Luis Gomez' **Engineering With Rigid PVC**, and R. H. Burgess' **Manufacturing and Processing of PVC**, and W. V. Titow's **PVC Technology and PVC Plastics**, and many others. The three editors, all former long-term BFGoodrich Geon Vinyl Division employees, are now each heading his own consulting firm. Many of the chapter authors are also former BFGoodrich employees from the Avon Lake, Ohio facility. The book is dedicated to Dr. Waldo Semon, a long-time BFGoodrich researcher who pioneered the development of plasticizers in PVC. The editors also credit the work by Jim White and Joe Kennedy and their coworkers at University of Akron for the renaissance in PVC polymer development, work funded in part by BFGoodrich. At least 18 of the 29 authors and editors are from Ohio. This would imply that the work is very parochial. Only the first chapter seems this way, with the frequent lauding of BFGoodrich accomplishments in the developmental days of PVC in the United States. And although many of the people are from Ohio, most have done their homework by carefully researching work done in other parts of the world.

The book consists of 19 chapters, beginning with the production of vinyl chloride monomer and continuing through polymerization, stabilizing, plasticizing, additives, fillers, blends and alloys. Sections on flexible PVC and specialty resins are included. The processing section includes chapters on compounding and fabrication processes. There are sections on property characterization, weathering, and flammability. There are chapters on product design, applications, and environmental concerns. And the book concludes with a chapter on global marketing. There are more than 1350 references, for those who need to know more. [And you thought that because PVC is such an old polymer, there was nothing left to write about!]

The good things about the work? It seems to be a fair compilation of nearly all aspects of PVC production. The Editors state that the "handbook contains both practical formulation information as well as a mechanistic view of why PVC behaves as it does." I believe nearly all the authors have posited well-written treatises on their selected topics. For the most part, the writing appears tight and well organized, and the chapters proceed logically from PVC creation through process and product to environmental issues. It appears that the editors have achieved their objectives.

The bad things? I believe that the work makes short shrift of the extensive work done outside the United States. I found few (if any) references to work in Russia, Japan, Germany, and France, where there have been extensive PVC developments in the past two decades. Although some chapters include patent references, many do not. I had hoped to find a complete listing of worldwide PVC producers and their capacities. But I was disappointed. As we all know, there are worldwide efforts afoot to ban or restrict the use of PVC in many products, particularly disposable packaging. These issues are addressed in several chapters, sometimes more shrilly than necessary to make a point. As an example, it is strongly argued that dioxin, a toxic byproduct of PVC combustion, has been found in lake sediments and ice cores from the 1860s, long before the creation or combustion of PVC. [Take that, Greenies!] And finally, the subject index is about 21-1/2 double-column pages, or about 1,700 citations, which this reviewer believes is quite short for such an extensive effort. There are some proper names mixed into the subject index but no "names" index.

Nevertheless, it's a major achievement in a mature technology and worth four-and-a-half books out of five.

~ Jim Throne

Council Report … Albuquerque, New Mexico

BY LOLA CARERE, COUNCILOR

This summary is intended to help you review the highlights of the Council meeting held in Albuquerque on January 21st, 2006. Please note that all supporting documentation remains available to Councilors and Section/ Division board members at: http://extranet.4spe.org/council/index.php?dir=January%202006%20Albuquerque/.

SPE President Len Czuba called the meeting to order.

The Council weekend format was as follows:

- Councilor Orientation – this session was provided as an orientation for new Councilors.
- Council Committee of the Whole – there was a separate shortened version of the Council Committee of the Whole meeting
- Special SPE Business Meeting – this Business Meeting was called in order to vote on the dissolution of the SPE Constitution. The motion carried.
- Council Meeting – a formal Council meeting was held. Officers were elected.

Elections:

Council elected the following people as Society officers for the 2006-2007 term, which begins at ANTEC (May 7th-11th):

President-Elect – Vicki Flaris

Senior Vice President – William O'Connell

Vice President** (nominated by the Sections Committee) – **Barbara Arnold-Feret

In addition to these formal offices, each year Council also elects a ***Chair*** for the ***Council Committee of the Whole***. ***Jim Griffing*** will hold this position for the 2006-2007 year.

Executive Director's Update:

Executive Director Susan Oderwald provided a report covering changes in staff, headquarters, and activities in developing and growing the Society.

Ms. Oderwald shared the activities of staff and major initiatives for the current and coming year and progress on those initiatives. Ms. Oderwald also discussed the financial close-out and communication process as well as planning work for the 2006-2007 SPE year.

International development activities were also reviewed. Ms. Oderwald presented the headquarters staff organizational chart. Ms. Oderwald fielded clarifying questions and comments.

Treasurer's Update:

Treasurer Paul Andersen reviewed the 2005 financial performance of the Society. Dr. Andersen reported that the rebate process and funds have been reinstituted and rebates are in distribution. Dr. Andersen indicated that the estimate for the net income for 2005 was approximately $75,000 versus a budget of $79,000. Dr. Andersen recognized the technical programming, staff, and leadership work that led to the net positive results.

Dr. Andersen also shared the activities of the ongoing Finance Committee review of *Plastics Engineering* magazine. Further, Dr. Andersen reviewed the critical components of the current budget to meet expenses and grow income leading up to and beyond ANTEC.

Other Business:

Presentations and discussions also took place on the following topics:

ANTEC 2008 GOC & TPC Candidates
Committee/Officer Reports
2006-2007 Operating Plan
SPE Foundation Update

2nd Reading and Vote to Adopt New Bylaws:

Mr. O'Connell moved that the Council approve the revised Bylaws, as presented at the September 2005 Council meeting, for implementation immediately following a successful membership vote to dissolve the Constitution, and further moved that this motion be declared null and void if, by January 1st, 2007, the membership has not voted to dissolve the Constitution. The motion was seconded. There were several clarifying questions that were answered by Mr. Czuba, Vice President Neward, and Mr. O'Connell. The motion carried.

Mr. Czuba reminded the group of the upcoming work to ensure that the general membership vote on this important issue. It was noted that a quorum was present for the above motion, with more than 70 Councilors voting. The vote was unanimous with no abstentions.

New Student Chapter:

Council approved the charter of a new Student Chapter at Bronx Community College, New York. Dr. Flaris provided a brief overview on the new Chapter.

Committee Meetings:

Fifteen committees met prior to the Council meetings:

- ANTEC Committee
- Communications Committee
- Conference Committee
- Constitution & Bylaws Committee
- Divisions Committee
- Education Awards Committee
- Executive Committee
- Finance Committee
- International ANTEC
- International Committee
- *Plastics Engineering* Editorial Board
- Sections Committee
- Student Activities Committee
- SPE Foundation Executive Committee
- Training Products Committee

Presentations:

All presentations and supporting documentation for Council and committee discussions can be viewed on the SPE website at: http://extranet.4spe.org/council/index.php?dir=January%202006%20Albuquerque/.

Contributions:

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

Detroit Section, acknowledged their sponsorship of the SPE International Essay Contest in 2005. Additionally, Vice President Smith acknowledged the contribution of the Detroit Section to the Katrina Hurricane Relief Fund.

Composites and Automotive Divisions, represented by Jim Griffing and Nippani Rao, jointly presented a total of over $13,000 to SPE.

Color and Appearance Division, represented by Austin Reid, presented $1,000 to the SPE Foundation and an additional $2,000 contribution to the ANTEC Student Travel Fund. Dr. Reid informed the Council that the Division will also be remitting a check of nearly $30,000 from the Topical Conference.

Thermoforming Division, represented by Roger Kipp, Gwen Mathis, and Lola Carere, presented SPE a check for $63,219.87 as the share from the 2005 Thermoforming Conference, their most financially successful conference ever.

Additionally, Mr. Kipp shared the use of the funds to add member value, develop student programs, educational grants and support, gifts to the Foundation, and a donation to the American Red Cross for Hurricane Relief.

The next formal Council meeting is scheduled for Sunday, May 7th, 2006 in Charlotte, North Carolina. ■

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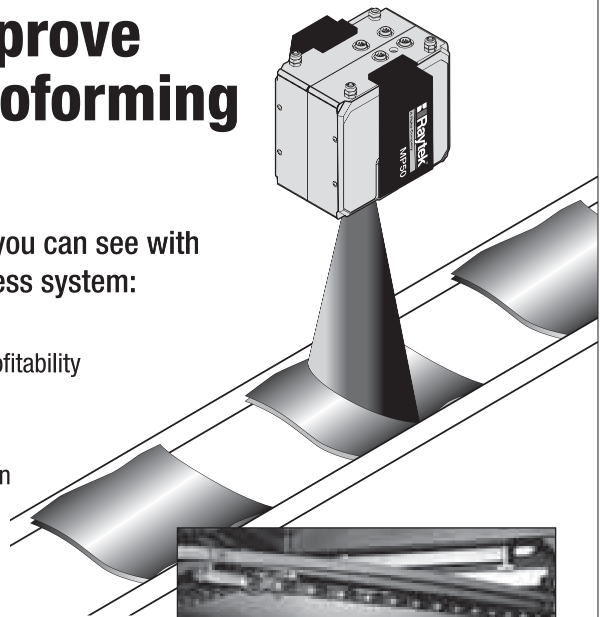

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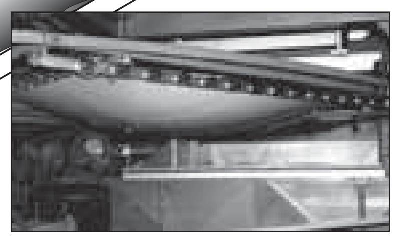

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May 10: Thermoforming Tooling / Arthur Buckel
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Registration and additional information available at:

www.antec.ws

ANTEC 2006

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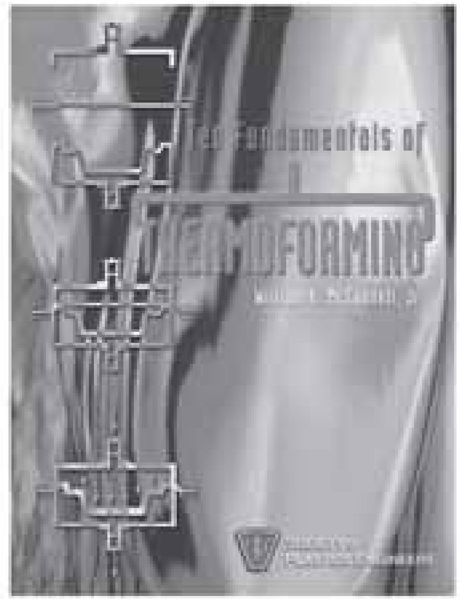

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❑ Extrusion
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Thermoforming Technology for Industrial Applications Seminar
Instructor: William "Bill" McConnell, Jr.
Duration: 2 Days Scheduled: June 19-20, 2006

Purpose & Overview

The seminar begins with a thorough review of the basics, allowing all the attendees to be immediately brought up to the same level. The segments on techniques and tooling create a thorough understanding of the practical application of the design theories. The purchasing and marketing segments introduce the production engineer to the realities of the marketplace, while developing a practical outlook for those engaged in those areas. The troubleshooting/heating session alone will be worth the cost and time to the majority of those attending.

Testing of Plastics – Its Application to Thermoforming
Instructor: Donald Hylton
Duration: 1 Day Scheduled: June 21, 2006

Purpose & Overview

This one-day seminar is designed to provide a basic understanding of material behavior in thermoforming, sheet extrusion, and part performance. It provides an overview of laboratory tests, the specific material property tested, and how it relates to thermoforming. An explanation of the applicability of tests and its importance is presented. The attendee will understand material properties, what properties to test, how it relates to thermoforming, and why it is important for quality management.

Thermoforming Design – Not Just for Designers Seminar
Instructor: Robert Browning
Duration: 1 Day Scheduled: June 21, 2006

Purpose & Overview

This intensive, fast-paced seminar has been taught worldwide, providing a better understanding of thermoforming design, its limitations and advantages. Both designers and non-designers appreciate this straightforward, hands-on course in expanding their knowledge and insight into today's fast-paced and competitive design world. An industrial designer presents this program with the use of lecture, slides, videos, sketches, samples, real case studies from around the world, along with questions and answers from attendees. Attendees are encouraged to bring questions and their design problems for discussion.

Thermoforming Tooling
Instructor: Arthur Buckel
Duration: 1 Day Scheduled: June 22, 2006

Purpose & Overview

This seminar is designed to provide detailed technical knowledge of thermoforming tooling, both forming molds and trimming fixtures and tools. The program is presented with lecture, slides, sketch sheets, and questions and answers.

Moving Beyond the Basics – Advanced Heavy Gauge Thermoforming Seminar
Instructors: Robert "Bob" Smart, James "Jay" Waddell, E.L. "Ed" Bearse
Duration: 2 Day Scheduled: June 22 - 23, 2006

Purpose & Overview

This seminar provides an in-depth look at materials and at new advances in the thermoforming process while highlighting advanced materials with an emphasis on TPOs and TPOs w/paint films. The first day focuses on materials, extrusion and quality issues for thermoformers. The second day is devoted to advanced thermoforming processes with advanced materials utilizing case studies. ■

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