



Thermoforming Quarterly®

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INSIDE

- ... Optimizing the Cut Sheet Thermoforming Process with Syntactic Foam
- ... PET Thermoform Recycling: Its Time Has Come
- ... Key Trends for APET in 2012

page 6
page 16
page 30



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Contents

■ Departments

Chairman's Corner | 2

Thermoforming in the News | 4

Thermoforming and Sustainability | 30-31



Front Cover

■ Features

Lead Technical Article | 6-12

Optimizing the Cut Sheet Thermoforming Process with Syntactic Foam

Industry Practice | 16-20

PET Thermoform Recycling: Its Time Has Come
The National Association for PET Container Resources (NAPCOR) Provides an Overview & Status of Project Work in Canada and the USA

ANTEC Paper | 22-27

Multi-Layer Blown Films for Thermoformed Food Packaging Applications



Page 20

■ In This Issue

2012 Conference | 15

SPE News | 34

Thank You Letter - Illinois University | 35

Sponsorships | 40



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Passing the Torch

Wow, has it been two years already? Well, it is time for me to pass on the gavel and the keys to **Phil Barhouse**, your new Thermoforming Division Chairman. Phil began serving the board in 1999 and was elected in 2000. He has been the technical chair of the Materials Group, committee chair of Opcom, and in 2009 he was elected to run the annual conference (Milwaukee). Please provide Phil with all your support during his term as your new Chairman.

I would like to thank all the members of the Thermoforming Division. It has been an honor to serve as your Chairman. I truly appreciated the emails and phone calls with suggestions and comments regarding board activities. The words of encouragement and praise, however, were most inspiring and they served as tribute to the strength and vitality of this community of plastics professionals. Over the last two years I have received a number of letters from leaders in our industry, praising the accomplishments of the division. All of you, members and volunteers, deserve to share in this praise.

I also need to acknowledge my colleagues on the executive committee. Without guidance and insight from leaders like **Roger Kipp**, I could not have done this job. **Brain Ray**, prior Chair, was instrumental for his tutorage, enabling me to continue in the steps of his leadership, navigating through some pretty bleak times for our industry. **James Alongi** ensured that our division continues to be financially sound. The board relies on volunteer time, and **Mike Sirotnak**, our secretary, provided the structure and focus we need to manage our time efficiently and complete the specific tasks that we identify for ourselves.

As mentioned late last year, the board has been very busy redefining the division's website. This upgrade will provide enhanced services and resource management for membership. In addition, the site will provide information, technical knowledge and other resources for the industry as a whole. The new website will be our serve as a focal point for the years to come as we expand our communication resources to you and our industry.

For those that attended and sponsored the conference in Schaumburg, Illinois, thank you again for your support! We are looking forward to seeing you

again at the September Conference in Grand Rapids, Michigan. The Conference will focus on specifically targeting and increasing our exposure to the OEM market. The Conference planning team members are in the process in fine-tuning the plan to attract more attendance and exhibitors to this year's event. Stay tuned for more details on speakers and content over the next few months.

At the time of writing, we are still developing our plan for the division to attend NPE in Orlando. The last time we undertook this feat, in Chicago in 2009, it was a huge success. The event provided global attendees an opportunity to understand and appreciate the many benefits of thermoforming. We believe we can build on this success and deliver another impressive showing that is worthy of our community.

Thank you again for your support over the past two years. I encourage you all to help and support Phil Barhouse and your new executive members of the Thermoforming Division. |

Sincerely,

A handwritten signature in red ink that reads "Ken Griep". The signature is written in a cursive style.

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

Why Not?

Pactiv Invests \$5.5 Million in S.C. Plant

By Jessica Hobrook, *Plastics News Staff*
Posted January 31, 2012 LAKE FOREST, IL
(UPDATED February 1, 2012, 5:50 p.m. ET)

Pactiv LLC will expand its operations in South Carolina, investing \$5.5 million to add a new production line to its Beech Island thermoforming facility.

The expansion is slated to begin in February, and also includes plans to expand the facility's warehouse to consolidate Pactiv's regional operations.

South Carolina's Coordinating Council for Economic Development awarded Pactiv a \$150,000 grant for site preparation. The business also received a five-year tax abatement from Aiken County, South Carolina.

The expansion is expected to generate 25 new jobs over the next three years. The South Carolina Technical College System – a network of 16 technical colleges across South Carolina – will provide pre-employment training.

Plastics is a growing industry in South Carolina, Aiken and Edgefield counties in particular, said Will Williams, Director of the Economic Development Partnership, a non-profit aimed at boosting economic development in the area.

“Obviously new jobs in a community is something

that we're always looking for, especially from an already existing company,” Williams said in a recent phone interview.

Pactiv did not return calls seeking comment.

Pactiv is a subsidiary of Reynolds Group Holdings Ltd., based in Auckland, New Zealand. Pactiv, based in Lake Forest, Ill., is the top thermoformer in North America, and is ranked No. 25 in film and sheet manufacturing, according to the most recent *Plastics News* rankings. |

Global Expansion Under Way at Medical Packaging Thermoformer Prent

By Mike Verespej, *Plastics News Staff*
Posted February 15, 2012 ANAHEIM, CA (2:35 p.m. ET)

Medical packaging thermoformer Prent Corp. is building on its strategy of supplying customers globally, with expansions under way in Costa Rica, Malaysia and Denmark.

All that growth is on top of a 50,000-square-foot expansion at its headquarters plant in Janesville, WI, last year that boosted the square footage of that facility to 300,000 square feet.

“We started on the Costa Rica project in late 2011,” said President and CEO Joseph Pregont in an interview at the Medical Design & Manufacturing West show, held

February 14-16 in Anaheim. “It's going to be ready late in the second quarter.”

The Heridia, Costa Rica, plant will be approximately 20,000 square feet and the company's seventh plant globally.

“It is primarily to serve our medical device customers who manufacture their devices or products in Costa Rica,” Pregont said. “They will get a lot of savings because we will be shipping raw materials there now, instead of shipping products from the mainland United States to Costa Rica.”

Pregont also said that Prent will be moving into “a brand-new facility this month” in Johor, Malaysia, that is approximately 180,000 square feet. The new plant will replace its current 80,000-square-foot facility in that country.

“It's a greenfield facility with Class 8 clean rooms. We've been working on it for about six months. Our expansion in Malaysia is based on a recovery in electronics markets and the growth in the medical device market.”

That's similar to a move two years ago when Prent moved into a new plant in Shanghai that doubled its capacity in that country, and increased the number of clean rooms in China from one to three.

Additionally, the company's 30,000 square foot facility in Holbaek, Denmark, is “getting itself in position for an additional

equipment expansion sometime this year” that will increase the production capacity of that plant by 50 percent, he said.

“We are continuing to position ourselves for the next move for where we need to be for our customers,” Pregont said. “We have to continue to supply our products where our customers wants us to manufacture them. Prent is dedicated to our customer base and our global supply concept.”

Pregont credits the company’s continued expansions and double-digit growth the past decade to “good people who are willing to work hard to improve our quality.”

“We are the only true global supplier to our customers, and we offer superior design and better quality,” Pregont said. “We are working hard to be innovative, develop new product solutions and ways to reduce costs because that is the objective of our customers. With the continued spiraling resin costs, our customers are demanding we come up with cost savings. So we continue to take costs out of our products and processes through more labor-efficient equipment, better designs and lighter products.”

Prent currently has approximately 1,600 employees – about one-third of them in Janesville. Prent custom builds its own thermoforming equipment and designs all of its facilities to be identical so that it can move production and equipment from plant to plant.

Prent also has plants in Yauco, Puerto Rico, and Flagstaff, AZ. Prent’s sales are estimated to be in the neighborhood of \$300 million. |

Ohio Packaging Firm Rohrer Buys Hogue Printing

By Frank Esposito, *Plastics News Staff*
Posted February 14, 2012 WADSWORTH, OH
(4:00 p.m. ET)

Packaging firm Rohrer Corp. is off to a roaring start in 2012, making two acquisitions in the first two months of the year.

The latest addition for Wadsworth, Ohio-based Rohrer is Hogue Printing Solutions, a commercial and package printing specialist based in Mesa, AZ. In a February 13 news release announcing the deal, Rohrer President and CEO Scot Adkins said that Hogue’s “equipment, products and culture fit us very nicely, and their location is perfect for serving the western part of the country.”

In addition, Hogue uses botanical inks and recycles 95 percent of its waste. No purchase price was disclosed in the deal.

News of the acquisition comes only five weeks after Rohrer bought thermoformer Buckell Plastic Co. of Lewistown, PA. Rohrer itself has been owned by private equity firm ShoreView Industries of Minneapolis since early 2010.

Rohrer generates about 30 percent of its sales from thermoforming, with the remainder coming from paper cardstock and folding paper cartons. |



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Optimizing the Cut Sheet Thermoforming Process with Syntactic Foam

By Kathleen Boivin, Materials Engineer, CMT Materials, Inc., Attleboro, MA

Abstract

Common problems encountered in the cut sheet thermoforming process include thin spots, webbing, poor part definition and plug/pusher mark off. Syntactic foam can be used in various ways with both positive and negative tooling to alleviate these issues. Syntactic plugs result in improved material distribution leading to opportunities for down-gauging. Compared to other common plug/pusher materials such as wood and felt-covered wood, syntactic foam results in minimal plug mark-off and improved plug durability. The diverse uses of syntactic foam will be covered along with two case studies that illustrate its benefits.

Background

Syntactic foam is class of material containing pre-formed hollow spheres held in position by an epoxy, a urethane or a thermoplastic binder. For heavy gauge thermoforming grades of syntactic foam, the most common combination is hollow glass spheres bound together in an epoxy matrix. A magnified view of hollow glass microspheres is shown in Figure 1. The resulting product, easily machined to smooth surface, is approximately 50% air by volume.

This high air content gives syntactic foam its key property of low heat transfer. The thermal conductivity of commercially available grades typically ranges from 0.11 to 0.19 W/m²K. This low heat transfer property makes syntactic foam an ideal material for use in the thermoforming process to address any issue caused by excessive cooling of the sheet being formed.

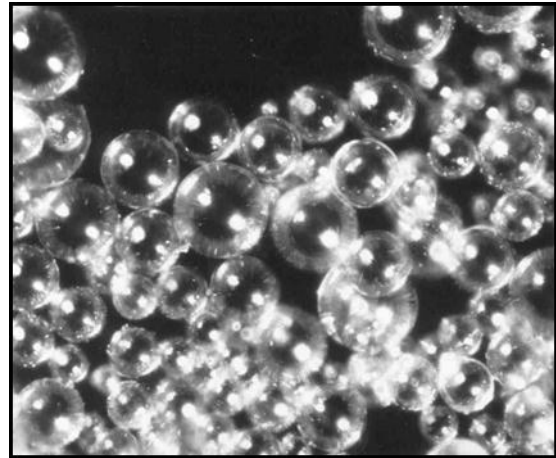


Figure 1. Hollow glass microspheres.

Traditionally, cut sheet thermoformers have used forming assists called plugs and pushers to improve material distribution and quality of parts. The term plug applies to an assist that is used to pre-stretch the sheet being formed across the entire area of the tool. Typically, plug volume is equal to 80 to 90% of the tool volume. The term pusher applies to an assist that is used to pre-stretch the sheet in a localized area. Syntactic foam has become popular as a replacement for plug/pusher materials made of wood, felt covered wood and aluminum.

One of the critical properties of a plug/pusher material is low heat transfer to ensure that chilling of the sheet during contact with the assist is minimized. In order to meet this requirement, the material needs low thermal conductivity, low specific heat and the ability to maintain uniform temperature. Coefficient of friction at the plug/sheet interface is also critical since this will determine how much material the plug/pusher can carry into the tool. Coefficient of friction is dependent on the plug material itself, the sheet being formed and

the sheet surface temperature. A high-friction plug assist material will tend to pull more material into the tool and require smaller plug geometry (greater clearance between the plug and the tool). Conversely, a low-friction assist material will tend to require larger plug geometry.

Other important plug/pusher properties are: durability/stability, value/cost ratio, machining/preparation characteristics and design predictability. Toughness of the material will determine how well it survives the production environment. Ideally, the material should be dimensionally stable with a low coefficient of thermal expansion and be non-hygroscopic. Hygroscopic materials such as wood tend to swell in humid environments and contract and crack in dry environments. The plug/pusher material should be consistent from lot to lot to achieve good design predictability.

Traditionally, wood, felt or foam covered wood, and aluminum have been used as plug assist materials for cut sheet thermoforming. Wood and felt are good insulators, easy to machine and low cost. However, wood is not dimensionally stable. The coefficient of thermal expansion is dependent on the grain direction so it can be difficult to build a dimensionally stable part. In addition, wood is hygroscopic and will change dimensions as the relative humidity of the environment fluctuates. Although wood is a good insulator, it tends to build heat over time which leads to poor part repeatability. Wood “marks off” on the part being formed. Covering wood with felt can reduce mark-off but felt can stick to the sheet being formed. Finally, wood has limited temperature resistance.

Aluminum is commonly used as a plug assist for heavy gauge applications. The benefits of aluminum include its durability and excellent surface characteristics. However, aluminum does not meet the key attribute of low heat transfer. Aluminum has high thermal conductivity and readily transfers heat. In order to get an aluminum plug to work well, it must be heated and the temperature has to be precisely controlled. Aluminum is high cost material and heating the plug increases the cycle time.

Unlike aluminum, syntactic foam does not require heating and temperature control. Syntactic foam is

also lightweight, heat resistant and dimensionally stable. Syntactic foam has low coefficient of thermal expansion (ranges from 18 to 23 x 10⁻⁶ in/in°F) and is not affected by humidity. Syntactic foam has been engineered specifically for use with thermoformed plastics and is available in a variety of grades to control the surface friction and release characteristics. The disadvantages of syntactic foam are cost and manufacturability. The cost ranges from about \$500 to \$1,000 per cubic foot. The manufacture of large plugs can be challenging but major advances have been recently made.

Syntactic Foam with Positive Tooling

When most people think of syntactic foam as an assist for thermoforming, they think of it being used as a positive plug or pusher with negative tooling. In reality, syntactic foam may be used anywhere that excessive cooling of the sheet is an issue, often with positive tooling used as a negative plug or pusher to eliminate webbing and improve material distribution. Improved material distribution allows for down-gauging of the starting sheet thickness and therefore offers opportunities for raw material cost savings. Examples of full size negative plugs, which are approximately 24 inches x 36 inches, are shown in Figures 2 and 3.



Figure 2. Full size negative plug assist.

Poor part definition around sharp details on a positive mold is an issue which can be addressed with a syntactic foam mold insert. Since the foam has low heat transfer, the sheet will have more time to conform to the mold surface before chilling off. For the same reason, syntactic foam can be used on the clamping frame. Excessive chilling of the sheet in the vicinity of the clamping frame can be an issue

(continued on next page)



Figure 3. Full size negative plug assist.

when high heat transfer materials such as steel and aluminum are used. Syntactic foam on the clamp frame will minimize chilling of the sheet giving it time to stretch properly before solidifying. Another use for syntactic foam with positive tooling is prototype or low volume tooling for applications such as windshields for recreational vehicles.

Syntactic Foam with Negative Tooling

When syntactic foam is used as a positive plug or pusher with negative tooling, the function of the foam is to pre-stretch the polymer sheet to provide better material distribution. Improved material distribution eliminates thin spots and webbing while providing an opportunity to down-gauge the starting sheet thickness. Compared to other plug assist materials, syntactic foam provides better clarity and gloss while minimizing chill marks. In addition, process consistency and productivity improves.

When deciding whether to go with a full-size plug (80 to 90% of cavity volume) or a pusher, run volume is one of the main considerations. For parts run in high volume, the cost of a full-size syntactic plug can be easily justified by the 15 to 20% savings per part. The bulk of this savings is achieved through better material distribution which allows for down-gauging of the starting sheet thickness. In addition to raw material cost savings, down-gauging leads to reduced cycle time and lower energy costs. A thinner sheet will require less time and energy to heat up and cool down. Other considerations when deciding between a plug and a pusher are design requirements, equipment limitations and the limited history of plug design for cut sheet.

While the manufacture of large full-size plugs can be challenging, the manufacture of pushers is relatively straightforward. Syntactic foam producers supply the foam in standard stock sizes of sheet and rod. Small pushers can easily be machined from a standard stock size as illustrated by the fog light cavity pusher in Figure 4. If the pusher geometry does not fit well with a standard size, syntactic producers can either custom cast a near-net billet or custom cast directly into a part or mold.

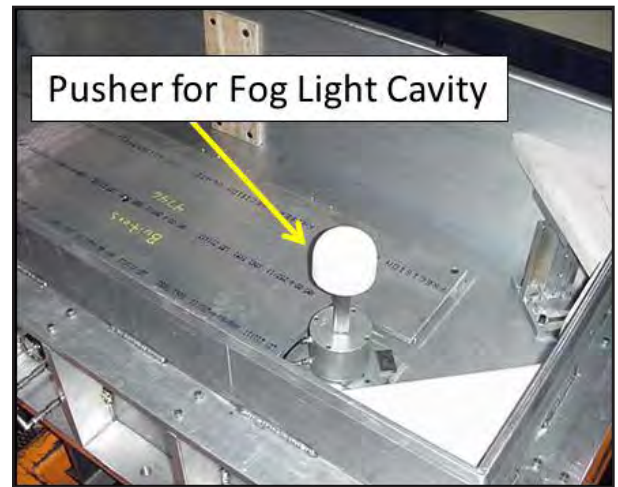


Figure 4. Fog light cavity pusher.

Large plugs can be manufactured in different ways. If the plug is made of wood, pieces are often bonded together and then machined. Downsides to bonding include mark-off on the thermoformed part due to bond lines, coefficient of thermal expansion mismatch and cracking. Alternatively, if a large plug is made of syntactic foam, it can be formed as a solid syntactic casting or made from a two-part system. Heat generated as the epoxy cures limits the size of solid syntactic castings to 12 to 15 inches in thickness. Too much heat results in stress in the finished part, which can then lead to cracking of the plug. Too high of an exotherm can cause stresses in the finished part which can then lead to cracking.

A unique two-part system has been developed to manufacture plugs greater than 15 inches thick. The system consists of an inner core made of reinforced composite spheres and an outer shell of solid syntactic foam, as shown in Figure 5. The composite core reduces stress in the final part. The core also reduces the weight and cost of the part compared to a solid syntactic.



Figure 5. Two-part large plug system.

The two-part system is available in several different types of syntactic foam including epoxy-based, copolymer syntactic and copolymer syntactic with PTFE. Epoxy-based syntactic is an entry-level material that provides good material distribution at low cost. However, it is dusty to machine and tends to be brittle, lowering its abuse resistance. Copolymer syntactic is a new class of material that offers improved toughness and durability versus standard epoxy syntactics. The unique composition forms chips rather than dust when machining and improves the processing of the material. In addition, copolymer syntactic improves material distribution while reducing mark off. Copolymer syntactic with PTFE has good durability and machinability with the added benefit of excellent release of tacky materials.

Large plugs made of the two-part system can either be manufactured as a custom cast or a near-net billet. During custom casting, a customer part or mold is used as the starting cavity. As illustrated in Figure 6, the composite core is formed smaller than the cavity to allow for a solid syntactic shell. The core is then placed



Figure 6. Customer part and core.

in the cavity and syntactic is cast around and through the core, as shown in Figure 7. The part is cured at a low temperature, demolded and post-cured to minimize stresses and maximize durability. Figure 8 shows the finished plug made from the customer part shown in Figure 6.



Figure 7. Syntactic is cast around and through core.



Figure 8. Finished two-part plug.

If a part or tool is not available to cast into, a two-part large plug can be made as a near-net billet. In this case, a low cost wood mold is made slightly larger than the finished size to account for machining. The composite core is made smaller than the wood mold to end up with a solid syntactic shell along the outer surfaces. The core is placed in the mold and syntactic is cast around and through it. An example of a near-net two-part billet is presented in Figure 9. The near-net billet would then be processed at a machine shop to the final plug dimensions.

(continued on next page)



Figure 9. Near-net two-part billet.

Case Studies

In order to illustrate the benefits of syntactic foam over other materials for plug/pusher applications, two case studies were run. The first case study involves a pusher application while the second study shows the benefits of a full-size syntactic plug.

In the first study, a pusher material comparison trial was run for a truck parts manufacturer. The manufacturer was forming truck bedliners from 0.195 in black HDPE sheet with an anti-skid layer on one side. The anti-skid layer became tacky during the forming process and transferred to the surface of the wood pushers being used to pre-stretch the corners. The pushers required a high degree of maintenance and caused significant downtime due to the build-up issue.

To simulate the application, plugs made of wood, HYTAC®-W (W), HYTAC®-WF (WF) and HYTAC®-FLXT (FLXT) were evaluated. W and WF are standard epoxy based syntactics while FLXT is a copolymer syntactic that is impregnated with PTFE for excellent release properties. Sheet surface temperature was varied from 450°F to 610°F. To evaluate the results, the plugs were assessed visually for signs of build-up and any deterioration. In addition, the formed parts were cut in half and measured for thickness along the cross-section.

The wood and W plugs had issues with immediate build-up of the anti-skid layer on the plug surface even at the lowest sheet temperature of 450°F. The wood plug exhibited poor durability and started to crack and splinter at 500°F. With the W plug, some

of the microspheres on the surface of the plug pulled out of the epoxy matrix due to the tacky nature of the anti-skid layer. The WF and FLXT plugs showed no signs of build-up until the sheet temperature reached 600°F. Of the two materials, FLXT had the least amount of build-up and was easily wiped clean. At 600°F, the sheet was smoking and there were concerns that the HDPE would degrade. Both WF and FLXT exhibited excellent durability and showed no signs of deterioration.

In terms of material distribution, the syntactic foam plugs performed better than the wood plug at optimum sheet surface temperatures of 450°F to 520°F. Within this temperature range, the average minimum thickness achieved with syntactic foam was 0.012" greater than that achieved with wood, as illustrated in Figure 10. The wood plug was capable of providing higher minimum thickness values but only at extremely high sheet temperature between 600°F and 610°F. The syntactic plugs allowed the sheet to be run at lower temperatures than the wood plug and still achieve acceptable minimum thickness values. The data indicated that the starting sheet thickness could be down-gauged by 5% with a syntactic plug.

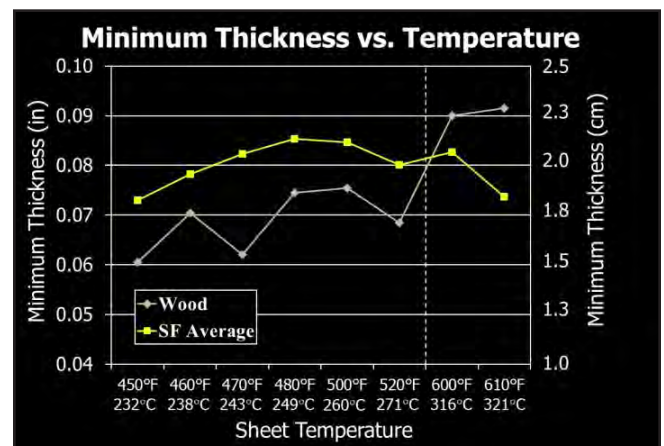


Figure 10. Minimum thickness.

The first case study showed that FLXT could be used to minimize plug build up and improve plug durability. These improvements lead to significant savings due to lower maintenance costs and less machine downtime.

In the second case study, the benefits of a full-size two-part syntactic plug assist were assessed for an appliance manufacturer. The manufacturer was forming a 17 foot³ (0.48 m³) freezer linerout of 0.170 inch (4.32 mm) thick HIPS using a full-size heated aluminum

plug. The corners of the liner were below the minimum target of 0.030 inch (0.76 mm) and had to be reinforced in a secondary operation. The goal of the project was to achieve material cost savings and eliminate the reinforcement step.

Trials were run on a Brown rotary four station machine with the following stages: 1) Preheat – gas catalytic preheat on both sides of sheet, 2) Heating – ceramic heaters on both sides, 3) Forming – positive plug on top, negative tool on bottom, and 4) Load / Unload station. A baseline trial with the standard 0.170 inch (4.32 mm) thick sheet and heated aluminum plug was run. Then the changeover to the syntactic plug shown in Figure 11 was made and trials with 0.170 inch (4.32 mm) and 0.150 (3.81 mm) sheet were run. When the changeover to the syntactic plug was made, the cycle time per stage was kept constant at 59 s but the heat input was adjusted to account for the low heat transfer properties of the plug. In addition to eliminating heating of the plug, the gas catalytic preheat step was eliminated. To evaluate the results of the trials, ultrasonic thickness measurements were made in forty-four locations per liner.



Figure 11. Syntactic foam plug for freezer liner.

The material distribution results for the trials are shown in Figure 12 with a plot of thickness versus location. In addition, a table with the thickness values is included in Figure 13. The white line shows the data for the heated aluminum plug. As seen in the plot, the critical corner thickness is well below the minimum target of 0.030 inch (0.76 mm). In addition, there are extreme high spots on the back and bottom of the liner. The yellow line shows the data for the combination of the syntactic foam plug and the 0.170 inch (4.32 mm) sheet. The thickness of the critical corner area

increased 58% by switching to the syntactic plug. The green line represents the data for the syntactic plug with the 0.150 inch (3.81 mm) sheet. Even with the down-gauged sheet, the syntactic plug increased the corner thickness by 38% and met the minimum requirement of 0.030 inch (0.76 mm).

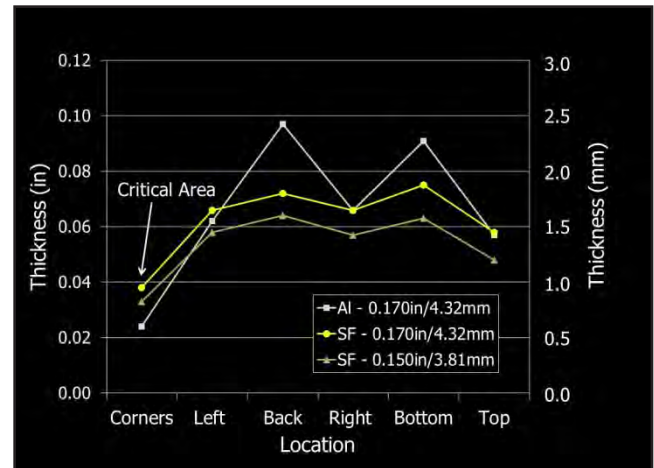


Figure 12. Freezer liner thickness profiles.

Starting Sheet Thickness:	0.170 in 4.32 mm	0.170 in 4.32 mm	0.150 in 3.81 mm
Plug Type	Aluminum		Syntactic
	Corner – Average Thickness	0.024 in 0.61 mm	0.038 in 0.97 mm
Increase vs. Aluminum		0.014 in 0.36 mm	0.009 in 0.23 mm
Increase vs. Aluminum		58%	38%
Corner - Relative Std Dev.	38%	13%	24%
Overall - Relative Std Dev.	25%	12%	15%

Figure 13. Freezer liner thickness data.

The second case study illustrates the benefits of a full-size syntactic foam plug versus a heated aluminum plug. The manufacturer was able to reduce material cost by 12% through down-gauging while secondary reinforcement of the corners was eliminated. In addition, significant energy savings were achieved through elimination of both the gas catalytic preheat step and heating of the plug. Based on material cost savings alone, the payback for the syntactic plug was two weeks.

In conclusion, syntactic foam offers improvement anywhere that chilling of the sheet causes issues with cut sheet forming. It can be used with positive or negative tooling as a plug/pusher to improve

(continued on next page)

material distribution, eliminate webbing and allow for down-gauging. With full-size plugs, using syntactic foam instead of other materials can result in a 15 to 20% total cost savings. Syntactic foam can also be used on the clamping frame and as prototype tooling. The benefits of syntactic foam include no bond lines, improve durability compared to other materials, ease of machining and minimal mark off.

Author

Kathleen Boivin is a Materials Engineer at CMT Materials, Inc. working in process and materials development of syntactic foam for thermoform tooling. She has a career history of development of polymer products and processes working for diverse companies such as Texas Instruments, Mobil Chemical, Eastman Kodak, Bixby International and Fortifiber Corporation. Ms. Boivin holds a BS in Chemical Engineering from Clarkson University and an MS in Plastics Engineering from the University of Massachusetts at Lowell. |





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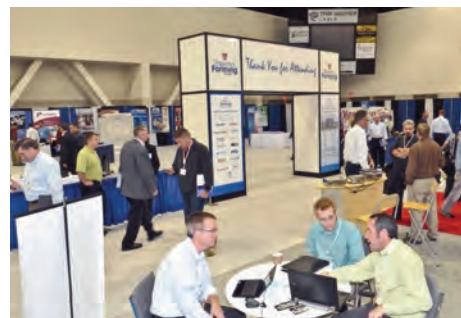
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PET Thermoform Recycling: Its Time Has Come

*The National Association for PET Container Resources (NAPCOR)
Provides an Overview & Status of Project Work in Canada and the USA*

By Michael Schedler and Kate Eagles, NAPCOR Staff

Author

In late 2007, three major sheet/thermoformed package manufacturers, Pactiv, Placon and Genpak, petitioned the National Association for PET Container Resources (NAPCOR) for membership. Up until that point, NAPCOR membership had been limited to PET bottle and resin manufacturers and suppliers to these two industry segments, the primary mission of the organization being to facilitate the recycling of PET bottles. The petition to join reflected these companies' desire to develop recycling opportunities for PET thermoformed packaging, a rapidly growing package choice due to both strong organic growth in retail and food service applications, and conversions from other resins.

Much of this move to PET was attributable to the material's superior environmental footprint, mainly owing to widespread use of PET bottle recyclate. (PET sheet and thermoform manufacturers have been successfully incorporating recycled PET content into their food and non-food packaging for over 20 years.) The concerns of the PET thermoformers were two-fold: 1) their packages were not being recycled, and 2) they needed more recycled content. Existing NAPCOR members understood these concerns as relevant to the larger NAPCOR organization and, as a result, opened membership to PET sheet/thermoformers. These members immediately formed the NAPCOR Thermoformers Council, expanded their membership to eight companies within 12 months, and embarked on addressing these issues. What follows is a summary of that work and where it stands today. We hope it will

provide a comprehensive understanding of the current status of PET thermoform recycling.

Definitions, Market Data & Critical Mass

NAPCOR has defined a PET Thermoformed Package as, *PET packaging other than bottles and jars, made from PET sheet of 0.008 inch thickness or greater, and that has the Resin Identification Code #1, including but not exclusively, clamshells, cups, trays, tubs and lids.* Converting this definition to consumer-friendly education is something that will ultimately be necessary, but it allowed us to identify and agree on our working "universe" in the meantime.

In 2009, NAPCOR determined that there were 1.4 billion pounds of these packages produced in the U.S. and Canada, representing about 25% of the thermoformed packages made from all resins. It's important to note that this data, so essential to the planning process, is not readily available. To come up with these numbers, NAPCOR commissioned a survey of all thermoformers for the past three years; purchased independent data; obtained proprietary member information; and cross-pollinated all of this with data obtained from both waste composition studies and numerous production tests, as will be further discussed below.

This answers the first question that is asked when programs contemplate collecting a new material: is there critical mass? Certainly, estimated PET thermoform volumes exceed The Association of Postconsumer Plastic Recyclers (APR) criteria of a minimum of 400 million pounds. More importantly, when looking at growth and conversion rates, it is not unreasonable to assume that by the end of 2013, the annualized volume

of PET thermoforms may be half that of bottles, or around three billion pounds. It is not inconceivable that PET thermoforms will be the most prevalent rigid plastic packaging in the waste stream, after PET bottles. This ratio of bottles to thermoforms was used as the basis for all of the laboratory research, as will be further discussed below.

The Objective ... and How to Get There

NAPCOR's objective was simple: to identify and remove obstacles throughout the recycling system (from collection to end use) that prevent PET thermoforms from being recycled and by doing so, increase the amount of RPET available to be incorporated back into packaging. The additional challenge was to do this without jeopardizing the existing PET bottle recycling infrastructure. The plan embraced was threefold:

- 1) Conduct laboratory research to identify potential technical issues that would impede or prevent the recycling of PET thermoforms as either a dedicated stream or mixed with bottles.
- 2) Work with collectors and intermediate processors to move truckloads of post consumer thermoforms through the system, to reclaimers and technology providers, in order to identify and remedy logistical as well as technical issues.
- 3) Create partnerships wherever possible.

The Obstacles

Prior to embarking on this initiative, when NAPCOR staff was asked why PET thermoforms could not be recycled with bottles, the response was that the thermoformed packages currently in the waste stream all look alike, although made from a variety of different resins (OPS, PVC, PLA, PETG, other). Contamination levels would potentially be too high to successfully process the material. A secondary concern was that PET thermoforms' Intrinsic Viscosity (IV) was lower and/or more variable than that of bottles. (IV is a measure of molecular weight or density.)

After much R&D, the reality proved to be a bit different. Indeed the primary issue is that of unwanted contamination, a result of look-alike packages. Until

the percentage of these look-alikes is greatly reduced, manual sorting at intermediate processing operations will be a very difficult proposition. However, with more and more MRFs (material recovery facility) installing autosort technology, this issue can be overcome. The IV variation did not prove to be a show-stopper with more technologies in place to mitigate this, so the obvious question emerged: if a bale is produced using autosort technology, why can't the bottles and thermoforms be recycled together?

The Rest of the Story

Moving forward – and to ultimately answer the question posed above – the strategy employed was to run a parallel course of laboratory research and production trials, as previously mentioned. In this undertaking, NAPCOR was fortunate to have the support of Waste Diversion Ontario (WDO), Stewardship Ontario (SO), the Canadian Plastics Industry Association (CPIA), and the APR, all of which provided both the staff time and financial resources critical to success. Also, the Region of Waterloo, Ontario, provided a total of over half a million pounds of PET thermoform bales – to nine PET bottle reclaimers and six technology providers – without which little progress would have been made. Plastics Technologies, Inc. was retained to perform a series of laboratory tests and evaluations, including APR applications protocol for PET bottles and sheet, on a range of samples from different locations in the U.S. and Canada. Briefly, here are what were determined to be obstacles, aside from the look-alike contamination issue.

- 1) The biggest surprise was that fluorescent material was found in most of the samples produced and evaluated, at levels up to 5%. The presence of this material is unacceptable for PET carpet manufacturers as it causes inconsistent dye uptake and streaking. Further research found that the fluorescent matter was coming from produce containers shipped from Chile.
- 2) Most labels used on thermoforms tend to be pressure-sensitive paper labels with substantially more aggressive adhesives than

(continued on next page)

those typically found on bottles. Removal to acceptable levels required either more residence time, more caustic, higher wash temperatures, or in most cases, all three.

- 3) Thermoform packages behave differently than bottles within the recycling system because of their shapes and how they are manufactured, causing a wide range of mechanical engineering issues.
 - Baling thermoforms at the same platen pressure as bottles results in a bale density more than 25% greater than that of bottles. Early bales of thermoforms produced were bricks that could not be de-baled without totally destroying the material.
 - Even bales produced at a lower platen pressure tend to come apart in “sheets” that can pass through trommels and de-clumpers and jam transition points.
 - Many belts, augers and transition points in bottle reclamation plants were not designed to handle the larger thermoforms, such as catering trays and lids, resulting in line stoppages.
 - Thermoforms, particularly clamshells, have different aerodynamics than bottles and tend to “flutter” going through autosort units, greatly reducing the accuracy.
 - Thermoform granulate can have less bulk density and uniformity than that of bottles.

All of this amounts to quite a challenge for the collective industry to overcome and will require cooperation from a lot of different industry segments. For example, the mechanical engineering issues are just that; they really fall in the domain of individual reclaimers that want to pursue recovering this material. While the retrofits required may be substantial in some cases,

there is nothing insurmountable here, rather the need for innovation, something that has unquestionably been one of reclaimers’ strengths over the years. Of course, MRF operators will have to retrain their baler operators to make sure the density issue is addressed. So, that leaves the look-alike contamination, fluorescence, and non-recycling friendly adhesives as the major obstacles.

On the positive side with respect to performance tests, testing blends were made from 67% bottle RPET and 33% thermoform RPET, reflecting the likely PET bottle/thermoform market mix as mentioned above. This blend was used at a 25% content level for bottles and a 50% level for sheet; both applications passed all performance tests prescribed in the APR Applications Guidance. The only exception was some color issues (B values) that were once again traced back to adhesive residue.

Canadian Grocers Ride to the Rescue

About the time that these issues were being understood in their entirety, Loblaw Companies Limited, the largest grocer in Canada, approached NAPCOR for an update on the status of PET thermoform package recycling. Their attempt to better understand this issue formed part of Loblaw’s initiative to move toward having only recyclable packaging in their stores, and they digested the complex situation accordingly. Shortly thereafter, the same information was requested by Walmart Canada and subsequently, by the Canadian Council of Grocery Distributors. After these discussions, the question back to NAPCOR was threefold:

- 1) Did these grocers control enough of the market to solve the look-alike issue by requiring suppliers to switch to PET?
- 2) If they further required that their suppliers provide packages that do not fluoresce and that labels use only recycling-friendly adhesives ...
- 3) ... would it then be reasonable to expect that the thermoforms could be recycled with the bottles, clearly the most efficient and desirable option for intermediate processors?

After reviewing sales data by channel, and the information gathered with respect to adhesives was reviewed by both the NAPCOR Technology Committee and the NAPCOR Thermoformers Council, we agreed that if the grocers were to move forward with these actions, then it would be reasonable to assume that the bottles and thermoforms could be recycled together in Canada.

The Grocers then asked NAPCOR and APR to develop a test protocol that would determine what adhesives are recycling friendly. This protocol has now been finalized and is posted on the APR website <http://www.plasticsrecycling.org/pet-thermoforms>. Through their trade association, the Retail Council of Canada (RCC), grocers including Loblaw's, Sobeys, Walmart Canada, Metro and Safeway Canada, are urging their suppliers to register for testing with the intention that only approved label adhesives will be used after January 1, 2012. To their credit, Walmart Canada has taken on the Chilean fluorescence issue since they have assets in that country. The five grocers named above are moving forward in converting to PET for their in-store packaging, category by category, according to their own particular schedules. The future for PET Thermoform recycling in Canada is bright.

So What About the USA?

There is reason to be optimistic. Placon Corporation has recently opened its Ecostar reclamation plant in Madison, Wisconsin. The new plant used test loads of PET thermoforms, as described above, in order to design the plant with the capability to process them. The recycle produced is going back into PET thermoforms suitable for both food and non-food products. Other existing plants are being retrofitted, and new ones are being designed, with thermoform processing capability in mind. Many reclaimers are now processing 4-5% thermoforms with their bottles while some have pushed the ceiling to 10%. Others are removing them from the stream, re-baling and selling them to reclaimers that are better able to process them. In total, these efforts are expected to result in an excess of 50 million pounds of PET thermoform material being recycled in 2012. However, unless the two main obstacles can be addressed – the look-alike contamination and aggressive adhesives

– indiscriminate inclusion of thermoforms in PET bottle bales will most likely result in a devaluation of the material.

NAPCOR understands that there is still a tremendous amount of work to be done, particularly in the areas of consumer education, intermediate processing, and recycling for cups at special events. To that end, in July 2011, the Plastics Industry Trade Association (SPI) and NAPCOR announced the availability of up to \$100,000 in grant funds to support a model program(s) for PET thermoform recycling. We received 13 responses to this RFP and were so pleased with the scope and quality of the proposals that we're seeking to fund several of them in different locations across the United States. Three are confirmed thus far and will be announced publicly in February 2012. Program implementation of these program(s) is still targeted for July of 2012. Updates on this project can be found at <http://www.napcor.com/PET/thermoRFP.html>.

While the last chapters in this story have yet to be written, the events summarized with respect to the Canadian experience on this project are illustrative of what can happen when all of the various stakeholders work together. The Association of Postconsumer Plastic Recyclers, Adhesives and Sealants Council, Canadian Plastics Industry Association, the Retail Council of Canada, Stewardship Ontario (SO), the Tag and Label Manufacturers Institute, and Waste Diversion Ontario (WDO) all provided input, resources and leadership while respecting the concerns of each others' constituencies. The roles played by RCC, SO and WDO especially cannot be minimized as they provided the forum where the essential question was asked: what is it going to take to get this material recycled, and what is the best way to do it? Although there is no equivalent forum in the USA, it doesn't preclude us from asking and answering the same question. NAPCOR feels that the time has come, and will continue to work with U.S. stakeholders to overcome the barriers to successful PET thermoform recycling. |

(see photos on next page)

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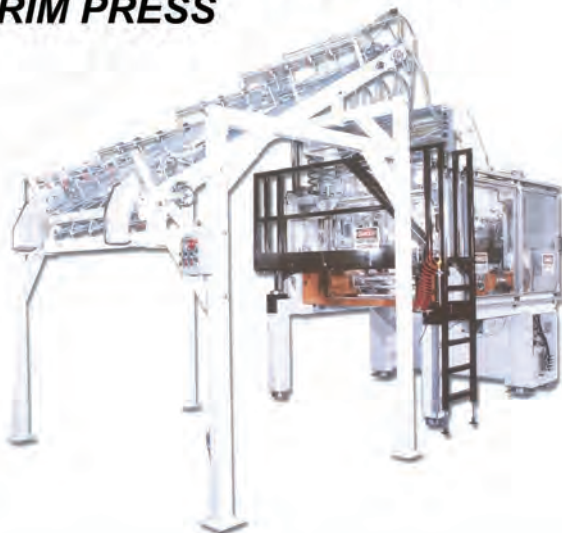
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Multi-Layer Blown Films for Thermoformed Food Packaging Applications

By Kam Ho, Daniel Ward, Kevin Kuklisin and Amanda Murphy, NOVA Chemicals Research & Technology Centre, Calgary, Alberta, Canada

Abstract

Polyethylene and nylon are used in thermo-formable, multilayer films for food packaging. Through this study, we have developed film structures with up to 30% less nylon and equivalent or better oxygen and moisture barriers than a commercial pizza packaging film structure. These structures exhibited good thermoforming behavior at several draw ratios. We have applied three thermoformability indices for the assessment of a film's thermoformability in this study. One of them was the dimensional thermoform-ability index reported by NOVA Chemicals Corp. ⁽¹⁾. The combination of all three indices provides rapid and accurate assessment of the thermoform-ability of film structures.

Introduction

Polyethylene provides a good balance of processability and physical properties that make it an excellent choice at a relatively lower cost than other plastics used in flexible food packaging. This is evident as the amount of polyethylene used in flexible food packaging structures is increasing while the amount of higher cost materials like ethylene vinyl alcohol copolymer (EVOH) and nylon is being minimized. NOVA Chemicals has developed and commercialized several new polyethylenes with unique properties for food packaging applications. Recently 7-layer blown film structures were designed for thermoformed food packaging. These structures consisted of a varying number of nylon layers and/or total nylon contents. The films were tested for their physical strength, barrier properties, and thermoforming behavior. Field thermoforming trials can be expensive and time consuming. Therefore, three laboratory tests were evaluated for their potential to provide quick and accurate prediction of multilayer film thermoform-ability. When used together, these tests provide a comprehensive evaluation of the thermo-formability, to which no single test is always applicable ⁽²⁾.

Experimental

Film Structures

Five 7-layer blown films of thickness 190µm were made with air cooling. These structures consisted of various amounts of linear low density polyethylene (LLDPE) and

low density polyethylene (LDPE1 and LDPE 2) resins produced by NOVA Chemicals as well as nylon 6. The resins are listed in Table 1 and the structures in Table 2.

Testing and Characterization

Permeability:

The moisture permeability of the films was measured using a MOCON PERMATRAN at 37.8°C and 100% relative humidity. The oxygen permeability was measured on a MOCON OXYTRAN at 23°C and 0% relative humidity.

Heat of Fusion (Melting) at the Thermoforming Temperature ⁽³⁾:

It is generally accepted that materials with a lower fraction of molten material at the thermoforming temperature can better resist blow-out. Differential scanning calorimetry was used to determine the fraction of molten material from the overall heat of fusion (melting) and the heat of fusion at the thermoform temperatures. The heating rate was 10°C/min. The heats of fusion of pure nylon 6 and polyethylene are taken as 158.8 J/g and 295 J/g, respectively ⁽⁴⁾.

Dimensional Thermoform-ability Index ⁽¹⁾:

This method was first reported by Alan Wang from NOVA Chemicals at 2010 ANTEC, Orlando. It has been applied to predict the thermoform-ability of the films by examining the uniformity of film dimension after high temperature stretching. In this method, area-draw ratios of the cross-sections of the film strips at different extension along the draw direction are calculated from the thickness and width before and after stretching. The differences between the area-draw ratios in the machine and transverse directions at the same extension are calculated and averaged. Film structures with lower DTI, that is smaller MD-TD difference, are predicted to form parts of even thickness upon thermoforming. The specific details of this method can be found in the original paper.

Strain-hardening Behavior ⁽⁵⁾:

This test was used to assess the film's ability to be formed without blow-outs or sagging at elevated temperatures. The film structures were stretched to break uni-axially on an Instron 4202 at 100°C along both the transverse and machine directions. True stress was plotted against $(\lambda^2 - 1/\lambda)$ where λ is the true strain ⁽⁶⁾. The elastic modulus was calculated from the slope of this plot (Figure 1). For

true strains of 2 or above, the elastic modulus is designated as $G1$. Structures with higher $G1$ are believed to have better resistance toward blow-out and sagging. On the other hand, the elastic modulus at low strain, $G2$ (λ lies between 0.3 – 0.6) offers an indication of the film structure's pliability. Materials with lower $G2$ are more pliable and can fill the mold more easily.

Thermoforming Window by Dynamic Thermal Testing⁽⁷⁾: Dynamic thermal testing was performed on 3 cm x 0.6 cm test film strips using the Rheometrics RDS2, equipped with an oven test chamber. This test was used to estimate the upper and lower temperature for thermoforming. The strain was either 1% or 2%. The frequency was 10 rad/s. Oven temperature was raised from 30°C to 150°C at a rate of 1°C/min and the elastic modulus was recorded.

Thermoforming

The film structures were thermoformed at 95, 100 and 105°C. The films were fed into the molding area continuously. The mold configuration consisted of four long rectangular cavities 85-mm wide and 267-mm with round corners at the bottom. Four pockets were arranged across the transverse direction. The depth of the cavities was 25.4mm, 50.8mm, 76.2mm and 63.5mm. The calculated draw ratios for the four cavities are 1.78, 2.57, 3.36 and 2.96, respectively. Each thermoform cycle was approximately 5 seconds.

Results and Discussion

Barrier Properties

Low oxygen and moisture permeability is deemed necessary to extend the shelf-life of the packaged food substrates. The oxygen and moisture permeability of the film structures at ambient temperatures are tabulated in Table 3. In Figure 2, we have mapped the oxygen and moisture permeabilities for the film samples before thermoforming. The vertical line and horizontal line represent the oxygen and moisture permeabilities of a commercial pizza packaging film. This commercial film consists of 23 wt% of nylon with a measured oxygen permeability of 2.063 cm³.cm/m²-day-atm and moisture permeability of 0.253 g.cm/m²-day-atm. All test structures had lower moisture permeabilities than that of the commercial film. Structures 1 through 4 all had equivalent or lower oxygen permeabilities than the commercial film. Structure 5 is most likely not suitable for replacement of the commercial film in use due to its much higher oxygen permeability.

Dimensional Thermoform-ability Index(DTI)

The fraction of molten material at 100°C measured by DSC and the DTI of the film structures at measured 95°C are tabulated in Table 4 and compared in Figure 3. Although there may not be a cause and effect relationship between the DSC results and DTI, the two factors do show a similar trend with the nylon content of the structures - the less nylon content, the more melted material and the higher the DTI. It is important to note that the lower the DTI, the better will be the thermoform-ability in terms of gauge and dimensional uniformity. Figure 4 shows the variation of thickness of films thermoformed into the 76.2mm cavity. A film with good thermoform-ability will have its thickness be uniform and close to the value predicted by the draw ratio. Apparently, the thickness of film structures 1, 2, and 4 after thermoforming are closest to the predicted thickness of 57 µm represented by the broken black line. These three films have the lowest DTI. Structure 5 which has the highest DTI has the worst variation of film thickness and it was thicker than the predicted thickness.

Strain-Hardening Behavior

During the thermoforming process, a film is sequentially heated then forced into a mold cavity which causes rapid elongation of the film. As the film's temperature increases, its strength and modulus decrease followed by elongation and gauge reduction. High temperature tensile testing can be used to simulate the thermoforming process and predict a film's resistance to blow-outs and sagging. However, it is important to keep in mind that the elongation rate is slower than the stretching rate in the thermoforming process.

In Figure 5 $G1$ - *high strain* was plotted against $G2$ - *low strain*. Structures with lower $G2$ and high $G1$ are expected to have good thermoform-ability; low $G2$ would be expected to fill the mold easily while high $G1$ would resist blow-out. The high $G1$ and $G2$ of structure 1 suggest a strong resistance to blow-out and sagging but low pliability. Structures 2 and 4 have a good balance of $G1$ and $G2$ and would be expected to thermoform well. Structure 5 will be likely subjected to severe blow-out due to its low $G1$. Structure 3 is expected to have a performance between the two groups.

Table 5 lists the elastic moduli of the film structures at both the low and high true strain from the tensile curves at 100°C as well as the passing rates of blow-out. All structures were thermoformed and filled the cavities well at 100°C. As predicted by this study, structures 1, 2 and 4 have 100% passing rates (no blow-out) while structure 3 has a passing rate of only 15-20% and structure 5 the lowest passing rate of 5%, that is, 19 out of 20 films suffered from blow-out.

(continued on next page)

Thermoform Window by Dynamic Thermal Analysis

As temperature rises, polymeric materials transition from tough/brittle behavior – high modulus and low ultimate strain – to rubbery behavior – low modulus and large strain. In thermoforming, this implies that the pliability and therefore draw-ability (depth of draw or maximum film draw ratio) should increase with increasing temperature. However, the film will reach a temperature at which its reduced strength cannot sustain any applied stress without extensive plastic deformation and the film fractures abruptly as if it were a fluid. For more amorphous polymers like very low density polyethylene, this transition is gradual and occurs over a temperature range typically at or near the Vicat softening point. However, semi-crystalline polymers such as nylon and higher density polyethylenes do not transition into the rubbery phase but remain slightly deformed until the melting point of the crystal is reached. It is therefore expected that the thermoforming temperature window of a semi-crystalline polymer will be narrower than the temperature window for a more amorphous polymer. Yu and Hylton^(7,8) suggested that materials with an elastic modulus of between 10 MPa and 1 MPa at the thermoforming temperature perform best. A material with elastic modulus higher than 10 MPa typically has poor mold copying while a material with elastic modulus lower than 1 MPa suffers from thinning and eventual blow-out.

Using this standard, the thermoforming window was correlated with the film's elastic modulus; the lower temperature corresponds to an elastic modulus of 10 MPa and upper temperature corresponds to an elastic modulus of 1 MPa. The wider this temperature range, the wider is the operating window for thermoforming. The results are compiled in Table 6.

As the nylon content of the film structure increased, the predicted thermoforming window broadens and shifts to higher temperatures. The narrow thermoform window of structures 5 correlates with its low nylon content. The selected three thermoform temperatures were well within the predicted windows of structures 1, 2 and 4. These three films are therefore expected to have good thermoforming performance. On the other hand, the predicted upper temperature of structure 5 is too close to the selected temperatures and its performance is expected to be inferior. Apparently, the thermoform performance of the film structures at the three selected operation temperatures agrees qualitatively with the operating window predicted by dynamic thermal analysis.

Thermoforming

It was observed that certain film differences such as the type of polyethylene or the location and thickness of coex layers often resulted in very different forming characteristics. The thermoform-ability was very sensitive to temperature (both heat plate and mold temperature). Different films showed different temperature sensitivities; usually hotter was better, but not always. Table 6 summarizes the observations of thermoforming behavior for the five film structures. The thermoformed films were rated for their mold copying, shaping and integrity.

The thermoforming performance generally correlates well with the combination of the three thermoform-ability indices applied in this study. The films with low DTI, and relatively low *G2* and high *G1* at forming temperatures had better overall mold copying with lower failure rates. The temperature ranges provided in Table 6 generally corresponded with thermoforming test results: Structures 3 and 5 generally had poor formability at the temperatures selected for this study as expected.

Conclusions

Five 7-layer films made of LLDPE and LDPE from NOVA Chemicals Corp. and different amounts of nylon and/or number of nylon layers were evaluated for thermoforming performance. Four of these structures showed good to excellent thermoform-ability. The fact that structure 5 contained much less nylon (5.7 wt% compared to 13.5% or higher) and did not form well suggest that a minimum amount of nylon is required for good thermo-formability in multilayer films.

Three laboratory tests at elevated temperature have been applied to these films to and examined as a predictive tool for thermoform-ability. The combination of all three thermoform-ability indices – dimensional thermoform-ability index, strain-hardening elastic modulus by hot tensile test, and thermoform window by dynamic thermal analysis – was found to provide a quick and accurate assessment of the thermoform-ability of the structures. Among the structures investigated in this study, structures 2, 3, and 4 which have lower nylon contents than a commercial pizza packaging film were found to have equivalent or better moisture and oxygen barrier performance.

Acknowledgements

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Keywords: Thermoforming, multilayer films, nylon, polyethylene, thermoform-ability index, permeability, barrier properties |

Table 1. List of resins used film structures

<i>Resin</i>	<i>Density (g/cm³)</i>	<i>Melt Index (ASTM D1238) (190°C/2.16kg) (dg/min)</i>	<i>Remarks</i>
LLDPE	0.916	0.65	from NOVA
LDPE 1	0.922	0.25	Tubular grade from NOVA
LDPE 2	0.918	2.3	Tubular grade from NOVA
Tie Resin	0.910	2.7	DuPont™ Bynel® 41E710
	<i>Specific Gravity (g/cm³)</i>	<i>Melt Flow Rate (ASTM D1238) (235°C/1.0kg) (dg/min)</i>	
nylon 6	1.13	1.2	Honeywell Aegis® H135QP

Table 2. Layer structures of films (the unit of thickness is μm).

Structure 1	nylon	LLDPE/LDPE1/ Tie Resin	nylon	LLDPE/LDPE1/ Tie Resin	nylon	LLDPE/LDPE1	LLDPE/LDPE2
Thickness	0.8	1.2	0.5	1.2	0.5	1.2	2.0
Structure 2	nylon	LLDPE/LDPE1/ Tie Resin	nylon	LLDPE/LDPE1/ Tie Resin	nylon	LLDPE/LDPE1/ Tie Resin	LLDPE/LDPE2
Thickness	0.4	1.6	0.4	1.4	0.4	1.2	2.0
Structure 3	nylon	LLDPE/LDPE1/ Tie Resin	nylon	LLDPE/LDPE1/ Tie Resin	LLDPE	LLDPE	LLDPE/LDPE2
Thickness	0.4	1.2	0.6	1.2	1.0	1.0	2.0
Structure 4	nylon	LLDPE/LDPE1/ Tie Resin	LLDPE	nylon	LLDPE/LDPE1/ Tie	LLDPE/LDPE1/ Tie Resin	LLDPE/LDPE2
Thickness	0.4	1.4	1.0	1.0	0.6	1.0	2.0
Structure 5	nylon	LLDPE/LDPE1/ Tie Resin	LLDPE	LLDPE	LLDPE	LLDPE	LLDPE/LDPE2
Thickness	0.4	1.2	0.8	0.8	1.0	1.0	2.0

Note: Blend ratio of LLDPE/LDPE1/Tie Resin = 76.8/3.2/20; LLDPE/LDPE2 = 80/20

(continued on next page)

Table 3. Permeability of film structures.

	nylon Wt%	Moisture Permeability	Oxygen Permeability
Commercial Film	23.0	0.253	2.063
Structure 1	24.0	0.162	1.014
Structure 2	16.0	0.160	1.569
Structure 3	13.5	0.145	2.006
Structure 4	17.0	0.162	1.854
Structure 5	5.7	0.151	4.727

Note: The unit of moisture permeability is $g.cm/m^2.day.atm$ and the unit of oxygen permeability is $cc.cm/m^2.day.atm$.

Table 4. Fraction of material melted between 20 and 100°C and Dimensional Thermoform-ability Index.

	% of Fraction Melt between 20-100°C by DSC	DTI
Structure 1	15.7	0.43
Structure 2	16.4	0.59
Structure 3	16.9	0.79
Structure 4	16.5	0.47
Structure 5	17.7	0.86

Table 5. Elastic moduli at low strain ($\lambda = 0.3 - 0.6$), G_2 and high strain ($\lambda \geq 2$), G_1

	G_2 , Modulus (MPa) at low λ (MD/TD)	G_1 , Modulus (MPa) at high λ (MD/TD)	Passing Rates (% of perfectly thermoformed films without blow-out)
Structure 1	4.90 / 3.66	233.15 / 218.45	100
Structure 2	3.80 / 3.04	116.96 / 119.51	100
Structure 3	3.73 / 3.11	91.22 / 101.09	20
Structure 4	3.24 / 2.48	132.69 / 144.76	100
Structure 5	2.07 / 2.07	39.54 / 26.01	5

Table 6. Predicted thermoforming temperature ranges for film structures and visual observations of thermoforming behavior for different film structures

Structure	Temperature (°C) at which the Elastic Modulus \geq 10 MPa	Temperature (°C) at which the Elastic Modulus \geq 1 MPa	Thermoformed Films Appearance			Observations on Performance
			95°C	100°C	105°C	
Structure 1	88	119	G	E	E	At 95°C, passing rate was 65%. Also, poor definition in the 25.4 mm cavity. Excellent appearance and formability with 100% passing rate at higher temperatures.
Structure 2	81	115	E	E	Not tested	At 95°C, passing rate was 95%. Good mold copying and uniform definition in 63.5 and 76.2mm cavities. At 100°C, uniform thinning and excellent definition in all cavities with 100% passing rate.
Structure 3	92	130	F	G	E	At 95 and 100°C, the passing rate was about 20% with corner blow-outs in the 76.2mm cavity. The passing rate was improved to 100% at 105°C.
Structure 4	89	127	G	E	E	The passing rate was 80% at 95°C and increased to 100% at 100 and 105°C. It had consistent thinning with the lowest neck-in among all films.
Structure 5	75	102	P	F	F	At 95°C, blow-out occurred in all 76.2mm cavities with poor mold copying of all cavities. The passing rate was 0-5% at 100°C. The pass rate was slightly improved at 105°C.

Note: Visual Rating: - E = excellent; G = good; F = fair; and P = poor; Passing rate = percentage of no blow-out in 20 copies.

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Key Trends for APET in 2012: Sustainability and Source Reductions Result in Significant Industry Growth

By William J. Barenberg, COO, OCTAL

The packing industry will see continued growth in 2012. According to a recent report from Pike Research¹, worldwide packaging industry revenues will increase from \$429 billion in 2009 to \$530 billion by 2014.

Companies such as OCTAL have invested heavily in new capacity to support this growth and to allow for wholesale conversion from other substrates. Demand for APET products in the U.S. and in other key packaging markets, such as the BRIC group of countries, continues to grow.

“The overall packaging market for US customers seems to be bouncing back from the 2008 recession. BRIC customers seem to be on track for what forecasters were predicting for their growth. For example, Brazil’s production of packaging has seen a cumulative growth of about 10% and the Indian packaging industry has been growing at 14-15% annually². China is seeing an average annual growth rate of 6%³ and the Russian rigid plastic market is forecasted for the fastest growth, reaching U.S.

\$3.9 billion by 2015,” stated William J. Barenberg, COO of OCTAL.

Solid indication of the industry’s continued growth was confirmed by the organizers and the exhibitors at Interpack 2011 who considered the show to be one of the best in the 53-year history of the event. There was a marked increase in interest for APET, especially for meat, cheese, yogurt and dairy products in Europe. Emerging markets were also considered to represent increased growth potential for APET in dairy products, such as yogurt and cheese in China, India and Russia, due to the increasing governmental emphasis on nutrition in those countries⁴.

But the thermoforming industry also faces challenges for 2012. Perhaps one of the largest is to find methods to address upcoming global recycling laws intended to decrease packaging waste. It is evident that the sustainable packaging sector is growing much faster than the overall packaging industry.⁵ However, if the challenge can be met packaging companies will be rewarded because eco-friendly packaging is expected to nearly double in revenues between 2009 and 2014, from \$88 billion to \$170 billion.⁶ A case in point, OCTAL stated in 2011 many thermoformers in the US and emerging markets were finally making the switch to APET because of the recyclability of the product, compared to PVC and OPS (Oriented Polystyrene) which are less eco-friendly.

“However, please keep in mind,” Barenberg notes, “just telling thermoformers of APET in the US and BRIC countries that our company is sustainable was far from being enough to convince major manufacturers to make the switch to our company. We had to prove our carbon footprint through third party testing to attract the attention of some of these large packaging companies.”

In early 2011, Intertek Expert Services, an internationally-recognized independent testing service, generated a carbon footprint of OCTAL’s DPET™ sheet and compared the results to other leading alternative plastics. The proprietary study considered all emissions related to the production of resin and sheet at OCTAL’s Salalah facility in Oman, and established a carbon footprint characterizing the delivery of OCTAL resin and their sheet to world markets.

Intertek then compared DPET™ versus alternative plastics⁷. The following findings (shown on page 31) were in the results of the study.

It is important to note that sustainable results like these do not happen overnight. In reality, a commitment to a strategy of sustainability requires ongoing management and metrics, the results of which may not be seen for years. At OCTAL, for example, it took nearly five years to truly see that their commitment to sustainability has direct links to their ability to capture and maintain new business. This long-

¹ <http://www.pikeresearch.com/newsroom/sustainable-packaging-market-to-reach-170-billion-worldwide-by-2014>

² <http://www.iom3.org/news/indian-market-potential-packaging?c=575>

³ http://www.packagingdigest.com/article/344584-China_s_Packaging_Industry_Development_Trend_Forecasted_by_B2B_Search_Platform.php

⁴ <http://www.allbusiness.com/marketing/market-research/260770-1.html>

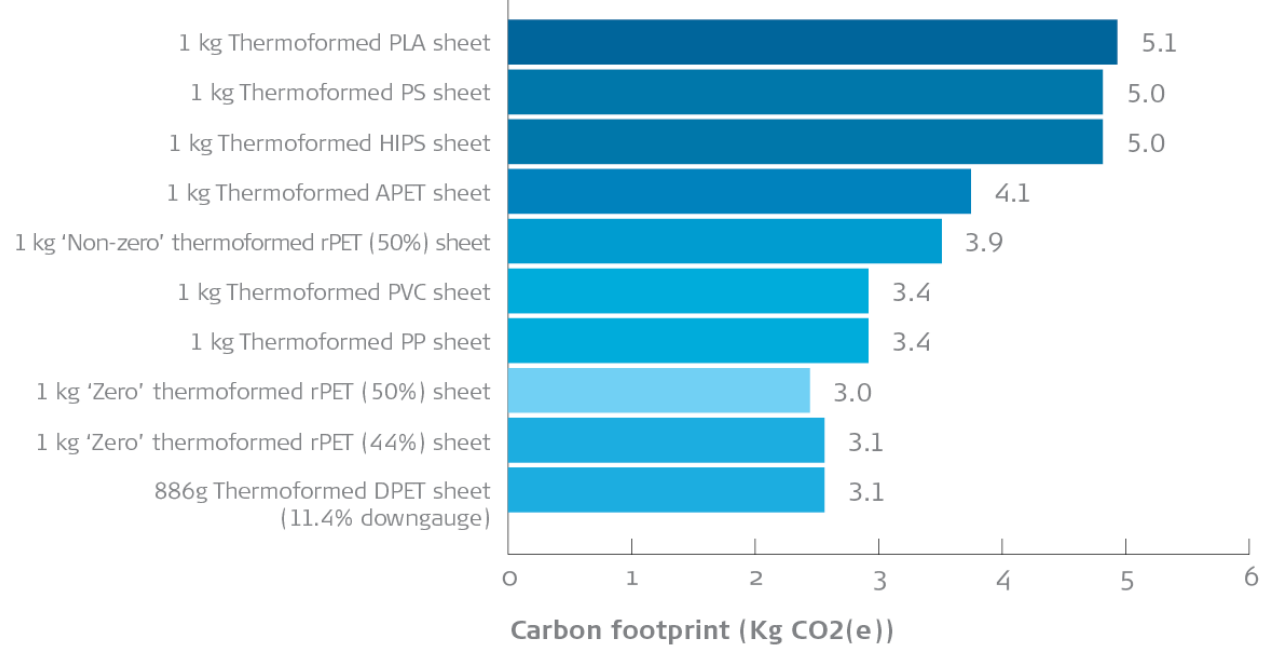
⁵ <https://www.environmentalleader.com/2010/01/05/pike-research-finds-global-sustainable-packaging-market-to-double-by-2014/>

⁶ <http://www.pikeresearch.com/newsroom/sustainable-packaging-market-to-reach-170-billion-worldwide-by-2014>

⁷ The calculations for “Non Zero rpet” include energy to produce a recycled pack from PCW + 50% energy from the virgin PET polymereization process whereas “Zero rpet” is energy to produce recycled pack only

The below table compares down gauged DPET™ sheet with non-downgauged alternative plastics with a variety of density values.

Non-downgauged alternative plastics



term perspective needs to be based on knowledge of market potential but has become an key element in OCTAL's competitive strategy. Moreover, this long-term perspective needs to be applied to the source reduction efforts that many thermoformers started in 2011 and before.

For many thermoformers, source reduction initiatives began by looking at package redesigns. Today most of these new designs have thinner walls and additional ridges to maintain the structural integrity of the package. As a result, they have been able to see positive results. Yet redesign is not the only way to gain source reductions.

For example, as a supplier, OCTAL has helped some of their customers with source reduction by being able to deliver roll-to-roll uniformity and typical caliper variation of approximately +/-1% for APET. This enables thermoformers to downgauge,

using less material overall in the final part. Coupled with the additional benefits of better flow into the corners and fine features of a thermoformed tray, future savings of 8% to 15% are possible.

“The benefits of such consistency and quality are passed along to our customers,” says Barenberg. “Our customers are now able to order thinner gauge sheet while knowing exactly how much packaging they can manufacture from the material they buy.”

Both of these source reduction efforts are great starting points for the industry. However, other efforts need to be addressed. One recent example is offered by the Retail Council of Canada's Grocers who is encouraging companies to make the switch to PET/APET because of ease of recycling the material.⁸ This group went so far as to address the importance of

changing the adhesive used for labels on the package. For 2012 and beyond, the industry will need to start to incorporate additional source reduction efforts.

The overall success of the industry depends on companies focusing on key trends such as sustainability and source reduction. In today's world, this is critical for a company's very survival. Remember, winning companies aren't successful by accident. In-depth analysis reveals that most successful companies have analyzed their target markets and have focused on unique approaches to meet their customers' needs, values, and expectations. Fortunately, for those working in the packaging industry growth can be obtained by focusing on sustainability and continued source reduction actions. |

⁸ <http://plasticsnews.com/headlines2.html?id=11062700103&q=canadian+grocers+pet>

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From the Editor

If you are an educator, student or advisor in a college or university with a plastics program, we want to hear from you! The SPE Thermoforming Division has a long and rich tradition of working with academic partners. From scholarships and grants to workforce development programs, the division seeks to promote a stronger bond between industry and academia.

Thermoforming Quarterly is proud to publish news and stories related to the science and business of thermoforming:

- New materials development
- New applications
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- New or expanding laboratory facilities
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We are also interested in hearing from our members and colleagues around the world. If your school or institution has an international partner, please invite them to submit relevant content. We publish press releases, student essays, photos and technical papers. If you would like to arrange an interview, please contact Ken Griep, Academic Programs, at:

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De Vos Appointment Wins Praise from Society of Plastics Engineers' Leaders

By Michael Lauzon and Bill Bregar, *Plastics News Staff*
Posted January 20, 2012 NEWTOWN, CT (12:25 p.m. ET)

The new CEO of the Society of Plastics Engineers believes speed is important in solving many of the challenges facing the plastics industry.

"I'm pretty direct and I like things to move fast," said Willem De Vos, a plastics and SPE veteran who took the reins January 19th. "The plastics industry has changed a lot in the past two decades."

De Vos, who goes by Wim, said in a telephone interview that his management style also includes directness and adapting to change. Increasing SPE membership and addressing raw material price hikes are a few big issues that will test his ability to effect change.

De Vos was CEO of Vitalo Group, a global thermoformer and packaging producer based in Meulebeke, Belgium. Since it was founded as a one-plant business in 1995, Vitalo has grown into a multifacility operation in Europe, the U.S., Mexico, India, Japan, China, Thailand and the Philippines. He is a native of Belgium.

De Vos brings his global view to his new job.

"The U.S. is a very important region, with more than two-thirds of SPE's members," De Vos said. "But plastics are strong in Asia and other emerging markets. We need to grow along with the markets. One of my focuses will be establishing SPE in emerging markets."

China, for example, is a key plastics market but SPE has almost no presence there. By going to emerging markets SPE will support U.S. members who are doing business in the regions.

Membership in Newtown, Conn.-based SPE is about 15,000, about half the size of a decade ago. SPE has been hit by plastics industry layoffs, globalization and the challenge of drawing young people into the society – problems faced by all trade associations.

Boosting membership in the U.S. and abroad will rely on providing more value

to SPE membership. The Internet has captured part of SPE's mandate to provide technical information, and to get it back SPE must convince prospective members of the society's value, according to De Vos. The new CEO said he will spend a lot of time with SPE's board over the next few months to find ways to improve value.

"In our worldwide search for a new [CEO], we were delighted to find in Wim a 20-year veteran of the plastics industry who is already active in and understands our society, has a truly global perspective and brings outstanding management experience at a time when SPE is focused on growth," said 2011-12 SPE President Russell Broome in a news release.

"His expertise in extending business activities into emerging markets and his global network in the plastics industry will be of enormous value in carrying out SPE's mission of strategic growth," said Broome, who is strategic accounts manager at PolyOne Corp. in Avon Lake, Ohio.

De Vos succeeds Susan Oderwald, who left SPE in December 2011. Oderwald had been executive director since 2004, two years after joining SPE as deputy executive director. Kellen Co. led the search for her replacement.

Prior to working at Vitalo, De Vos managed compounding and processing units of Recticel SA, a Brussels producer of polyurethane automotive components. He first supervised plants in Belgium and Detroit. Then, as director of Recticel's automotive interior solutions business, based in Germany, he was responsible for several European and Asian car brands. He set up Recticel's first plant in China and was a board member of a Japanese joint venture.

De Vos began his plastics career in 1991 with technical and sales positions at Eurocompound, a Belgium-based producer of latex emulsions for the textile and automotive industries.

As a member of SPE, De Vos most recently served as chair-elect of the European Thermoforming Division. He speaks Dutch, English, French, German and some Italian.

De Vos, 42, is married with two teenage daughters. He said he has spent half his working life traveling and will continue to be a frequent flyer. He plans to remain based in Belgium and will be a regular on trips to SPE's headquarters in Connecticut.

The selection of De Vos won praise from several members of SPE's executive committee who are outside of North America.

"He is a well-respected leader in the global plastics industry, and his will expertise will enhance the prospects of SPE as it grows over the coming years," said Ken Braney, SPE's immediate past president for 2010-11. Braney is managing director of Thermoforming Solutions Ltd. of Dartford, England.

SPE's vice president of marketing, Olivier Crave, from France, called the hiring of De Vos "great news for SPE" and said: "He will bring to SPE his international view, his excellent fund-raising capabilities due to his past job and will definitely embrace the change" SPE needs. Crave is president of sales and marketing firm O.C. Team in Vaux-en-Bugey, France.

SPE's vice president and treasurer, Vijay Boolani, is from India. He said board members spent a lot of time on the decision, "with the tough task of selecting from a sizable number of applicants."

"Willem De Vos was selected unanimously after his strengths were assessed, which [were] his vast experience and running an industry with a plastics background," said Boolani, president of Mumbai-based machinery maker Boolani Engineering Corp. "His approach to problem-solving and carrying SPE to greater global heights were the key reasons to zero in on him as the right candidate for this prestigious job."

De Vos holds an engineering degree in polymer chemistry from Industriële Hogeschool CTL in Gent, Belgium, and an executive MBA from Vlerick Leuven Gent Management School.

"I like to look at SPE as a company," De Vos concluded. |

Thank You Thermoforming Division Board



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To the Thermoforming Division Board:

September 20, 2011

I write to express my deepest thanks to the Thermoforming Division Board for inviting me and some of my students to attend the 2011 Thermoforming Conference.

Part of my job as an educator is to answer questions posed by students about materials, tooling, and design. I learned a lot this weekend speaking with vendors in the exhibit hall. These are just a few of the things I learned while speaking with vendors on the floor:

- I learned about the prototype tooling that can be made from the Stratasys fused deposition modeling technology. They even make production tooling from ABS and PC for pulp fiber packaging.
- Ex-Tech told me about their resins used for packaging: the importance of PET and the role of PVC and PLA in the markets today.
- CMT Materials has two materials I believe I will find very helpful during our next thermoforming project at ISU. The Metapor air permeable aluminum will allow us to make professional looking lettering in our next packaging mold. The glass bead vacuum fixture material will allow us to trim our heavy gage parts without the added design-and-build required for a conventional vacuum trimming fixture.
- Spartech showcased their Extreme TPO resins. I saw my first glass fiber reinforced thermoplastic sheet stock in the Envirotuf composite sheet by Spartech. I also was fortunate enough to get some product samples to show my students.
- Beyond the nuts and bolts of thermoforming, I had the pleasure of speaking with two students from Penn State College of Technology. I learned about the great program put on at the Plastics Manufacturing Center. Hearing about their success gives me something to take back to my program and consider the possibilities.
- Last year, while at the show in Milwaukee, I met a sales rep from Clinton Aluminum. He told me and one of my students, Brian Smith, about the benefit of using 7075 grade aluminum for injection molding tooling. A month later I placed an order for 7075 aluminum from Clinton Aluminum that Brian used to complete his injection molding product design project.

These are just a few of the conversations I had that will pay dividends back at my college. This show offers much to anyone coming with questions about materials, tooling, and design. As usual, too, the accommodations were great: the lodging and, especially, the food. My students who attended very much enjoyed the program. Finally, it is reassuring to hear so many people speak to the importance of manufacturing in maintaining a strong economy.

Thanks again for hosting another great conference.

Sincerely,
Lou Reifschneider

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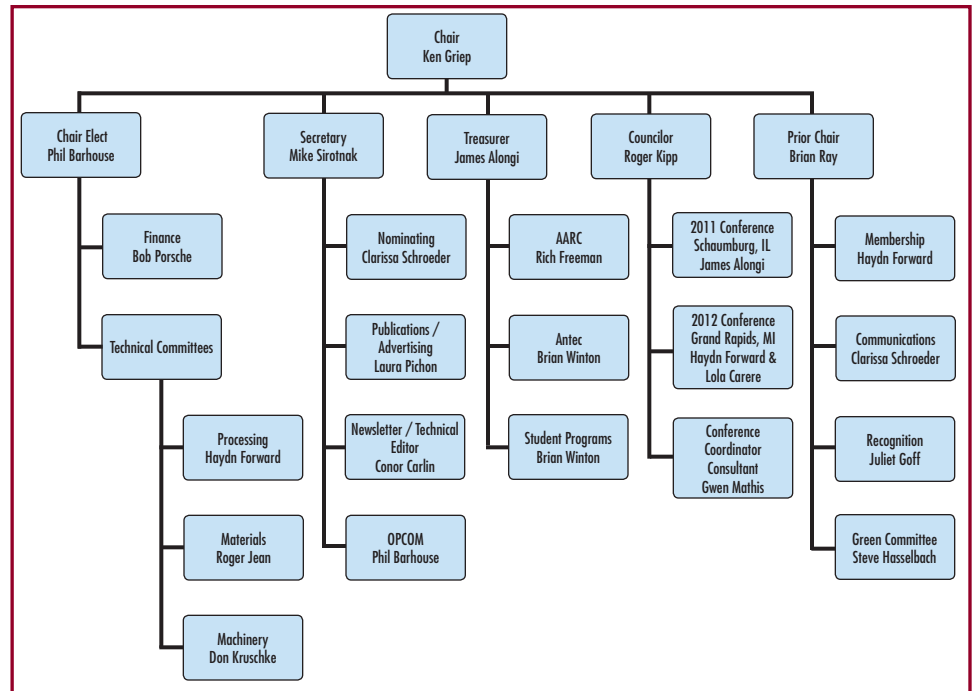
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- McClarin Plastics.....33
- Nova Chemicals.....14
- PCI38
- PMC.....Inside Front Cover
- Portage Casting & Mold.....33
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- Productive Plastics32
- Profile Plastics Corp.32
- PTi..... Inside Back Cover
- Ray Products.....32
- Solar Products.....33
- Spartech28
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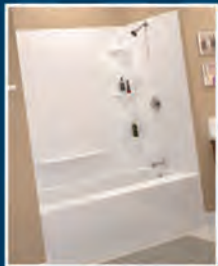
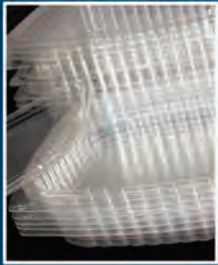
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