Thermoforming Quarterly®

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

FOURTH QUARTER 2012 ■ VOLUME 31 ■ NUMBER 4

Post Conference Edition

Wrapping Up 2012 in Style

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FOURTH QUARTER 2012
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Phil Barhouse

Looking Back at 2012

I enjoyed seeing all of you at our 21st Annual Thermoforming Conference in Grand Rapids. For those of you who did not attend, you missed an excellent conference. You can read all about it in the Conference Wrap-Up Report and see the Parts Competition winners in this issue. I would like to thank our Conference Chairs, Haydn Forward and Lola Carere, and their entire committee for the outstanding work with this conference.

Next year's conference will be hosted in Atlanta, so mark your calendars for September 9 -12. We have recently revised this date to avoid conflicts with other industry events; so please check the website for further details.

On behalf of the Board of Directors, I wish to express my deepest sympathy to the Benjamin family on the passing of Mr. Bill Benjamin. Bill was President of Benjamin Manufacturing Company that he and his wife Beverly started in 1961 (see page 27). Bill was a true pioneer in the industry and was a huge supporter of this Division for many years. He was named Thermoformer of the Year in 2003 and continued to attend board meetings up until very recently. I will personally miss his warm friendly smile, the advice and the guidance that he gave me over the years. He will be greatly missed.

On page 9, you will find the form and nomination criteria for the 2013 Thermoformer of the Year. This is the highest award that the Board presents. Please help us by identifying worthy candidates. This prestigious honor will be awarded to an individual who has made significant contributions to the thermoforming industry in a technical, educational, or managerial aspect capacity. Nominees will be evaluated prior to voting by the Board of Directors at the February 2013 board meeting. Each of us in the thermoforming industry knows at least one person whose contributions deserve to be recognized in front of their peers. Please feel free to contact me or another board member if you have questions about this award.

As always, I would like to hear your ideas, comments and feedback. |

Phil Barhouse

Phil Barhouse

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Thermoforming in the News

Plastic Ingenuity Buys Vitalo de Mexico Assets

By Jessica Holbrook, *Plastics News* Staff
Posted October 17, 2012
MONTERREY, MEXICO (4:35 p.m. ET)

Plastic Ingenuity de Mexico, an affiliate of Plastic Ingenuity Inc., has purchased the assets of thermoformed packaging producer Vitalo de Mexico.

The acquisition allows Plastic Ingenuity to boost capacity and capabilities, as well as expand operations – the company will now operate two plants in Monterrey, Mexico, along with Vitalo de Mexico's facilities in Guadalupe, Nuevo León.

It also allows the company to "capitalize on the return of manufacturing business to North America from Asia," said Tom Kuehn, president of Plastic Ingenuity, in a news release.

Vitalo de Mexico is a branch of Belgium thermoforming giant the Vitalo Group.

Terms of the deal were not disclosed.

Plastic Ingenuity de Mexico was formed in 2006 through a joint venture between Plastic Ingenuity and Converforma of Monterrey. Prior to the acquisition, the company operated eight vacuum forming lines at its Monterrey plant.

Based in Cross Plains, Wisconsin, Plastic Ingenuity makes custom thermoformed packaging for a variety of markets including food, medical, electronics and retail. The company has approximately 500 employees, and operates 11 extrusion lines and 46 thermoforming lines across its four U.S. locations.

Plastic Ingenuity had sales of $80 million in 2012 and was No. 24 in the most recent *Plastics News* ranking of North American thermoformers. |

Faerch Plast Tests Recyclable Black CPET

By Charlotte Eyre, *European Plastics News* Staff
Posted October 30, 2012
HOLSTEBRO, DENMARK (1:45 p.m. ET)

Danish thermoformer Faerch Plast A/S is developing a type of crystalline PET that can be detected by infra red technology in recycling streams, meaning the material can be separated from mixed plastics waste.

"When recycling plastics, companies have infra red cameras to identify what the plastics are," spokesman Joe Iannidinardo told European Plastics News. "But when the plastic is black light can't shine through it, meaning it can't be detected by the cameras."

Faerch Plast has reformulated its CPET material with a different pigment arrangement. This allows some of the infra red light to reflect back into the cameras, meaning the material can be recycled in mixed waste streams.

The company developed the material at its R&D center in Denmark but is currently testing using the material to manufacture trays for ready meals in the UK, which is the main market for these products. The firm is now carrying out tests with stakeholders, including WRAP and various supermarkets.

"We're excited about the project because it brings the idea of a closed loop system closer and closer," said Iannidinardo, adding: "The aim is to have the trays come back to use as flakes, perhaps even three or four times."

Iannidinardo did not go into detail about how Faerch Plast plans to manufacture the material but says the company aims to make the process "cost neutral" compared to other materials on the market. |

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Gwen Mathis Named Emeritus Director

In recognition of her years of dedicated service to the SPE Thermoforming Division and the industry at large, Gwen Mathis was named Emeritus Director, Board of Directors, Thermoforming Division.

Emeritus Director status replaces current board member status and has a term of three years. Emeritus Directors can be involved in all board activities including conference preparation and involvement with technical committees. Emeritus Directors continue to receive quarterly newsletters and all other Board of Director announcements and emails. They are not required to attend board meetings and do not have voting responsibilities. Emeritus members are encouraged to be members of the Society of Plastics Engineers (SPE). Qualified candidates are recommended through the Membership Committee and brought to the attention of the Executive Committee for consideration and approval.

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Thermoformer of the Year 2013

The Awards Committee is now accepting nominations for the **2013 THERMOFORMER OF THE YEAR**. Please help us by identifying worthy candidates. This prestigious honor will be awarded to a member of our industry who has made a significant contribution to the thermoforming industry in a technical, educational, or managerial aspect of thermoforming. Nominees will be evaluated and voted on by the Thermoforming Board of Directors at the Winter 2013 meeting. The deadline for submitting nominations is **January 15th, 2013**. Please complete the form below and include all biographical information. Total submission, including this application page, must not exceed four (4) pages.

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- 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.

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(ALL NOMINATIONS MUST BE SIGNED)

Please submit all nominations to: Juliet Goff,
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Phone 323.581.6194, ext. 223 or email at: Juliet@kal-plastics.com

Understanding Industrial Investment Decision-Making

By Christopher Russell and Rachel Young,
American Council for an Energy Efficient Economy

Editor's Note: The following excerpts are reprinted with permission from the American Council for an Energy Efficient Economy (ACEEE). *We offer this synopsis to our readers because the report has broad implications for thermoforming OEMs, processors, suppliers and toolmakers surrounding capital and operational investments. The complete report includes in-depth survey results from NAICS-coded industrial sectors, including plastics (326). Please visit www.aceee.org for more details.*

Executive Summary

After a prolonged recession, the U.S. economy is poised for recovery. Economic rebound implies growth and renewal to accompany the ongoing evolution of energy markets, regulations, and technologies. And because manufacturing is by nature a capital-intensive activity, we anticipate that the sector's economic renewal is partially dependent on capital investment in new and efficient technologies. Industrial energy efficiency opportunities coincide with economic recovery and the growth and modernization of domestic production capacity.

Economic recovery prospects across the manufacturing sector are stronger for some industries than for others. As the manufacturing sector changes, so should the nature of energy efficiency programs. Industry's motivation for achieving energy improvements still lags its true potential, as the propensity to adopt energy management principles remains irregular, even across facilities of the same company. As facilities continues to capture many of the low- and no-cost energy improvement opportunities, future improvements will be increasingly linked to industry's capital investment activity. Industrial energy program administrators will need a better understanding of capital investment processes as these vary throughout industry. By influencing capital investment decisions, the next generation of energy efficiency programs can influence the profile of industrial energy use for years to come.

Despite a decade of sluggish economic growth (2000-2009), output and productivity data from 1998-2009 reveal an industrial sector with elements of growth, recuperation, and surprisingly little retrenchment. Productivity gains achieved by many industries during this decade despite their low growth of output are evidence of the muscle needed for an economic rebound, while capacity utilization and investment rates point to opportunities for industrial expansion.

Introduction

In 2012, the U.S. economy is poised for recovery from a prolonged recession. Aiding the recovery is the trend of re-shoring of industrial production facilities from overseas locations (MAPI 2012, BCG 2012). Recovery will in part reflect capital investment in new and more efficient manufacturing facilities on U.S. soil. At the core of this activity is capital investment in industrial assets. Investment in durable facility and production assets will shape industrial energy intensity for years to come. This is an opportunity to evolve and intensify industrial energy efficiency programs to support the implementation of efficient technologies. Successful industrial energy programs will increasingly depend on knowledge of industry's capital investment decision-making process. This report examines

industrial capital investment experience, using macroeconomic data as well as a survey of industrial energy users and related market and program facilitators.[1] The findings suggest an evolution of energy program design and conduct.

Trends in manufacturing output have direct implications for the national economy on three broad dimensions. First, while U.S. manufacturing output is decreasing as a proportion of total GDP, the absolute volume of manufacturing output is still increasing. This simply means that manufacturing as a whole is not growing as quickly as some other sectors (Pollack 2012). Still, each dollar of manufacturing output also generates an additional $1.40 worth of non-manufacturing services throughout the domestic economy (NAM 2009). Second, the industrial sector represents 31 percent of all domestic energy consumption (EIA 2010). The sector is therefore an inescapable component of ongoing energy policy and program development. Finally, prospects for the national economy and its energy resources are inextricably linked by capital investment in more efficient productive assets.

Because energy is a universal ingredient in all manufacturing, improved energy technologies provide potential benefits to all industries, regardless of their product mix or facility size. Similarly, the sheer magnitude of manufacturing energy consumption makes it an unavoidable focus for achieving the state and regional energy supply balances sought by regulators of energy distribution utilities.

At first glance, the growth of U.S. manufacturing output during the first decade of the 21st century appeared to be stagnant. Observers have raised a variety of concerns about this performance, debating the need for a national manufacturing policy (Romer 2012, Sperling 2012). But in 2012, after a decade capped off by a prolonged recession, manufacturers have an unprecedented opportunity for contributing to economic recovery. Several facts point to this opportunity. First, publically-traded U.S. corporations are sitting on a lot of cash. Their balance sheets have cash balances of over $2.2 trillion, up from $1.5 trillion at the end of 2007 (Fortune 2012). The same decade was characterized by the off-shoring of some industrial production capacity combined with reluctance to reinvest in domestic capacity due to economic uncertainty. As noted in an earlier study, by 2008 the U.S. manufacturing sector was not only reaching full capacity, it was also beginning to reverse the trend of production off-shoring, thanks to the costs and difficulties of global supply chains (Elliott et al. 2008). Additionally, the manufacturing sector reflects pent-up demand for new capacity after a decade of tepid capital investment (Kaushal et al. 2011). Together, these facts suggest that domestic manufacturers have an opportunity to not only build new capacity, but to obtain the competitive edge that new technology will provide. Reinvestment in domestic manufacturing should directly contribute to U.S. economic recovery. New macroeconomic data, not yet available at the time of this report, may verify the recovery's relationship to capital investment.

Recently, an unprecedented volume of public and utility ratepayer funds have been poured into energy incentive and assistance programs for the manufacturing sector (Chittum and Nowak 2012). While assistance programs frequently reveal improvement opportunities of all kinds and magnitudes, many facilities tend to favor solutions that involve low- and no-cost improvements to existing assets. Meanwhile, a sluggish economic recovery combined with uncertain future tax and regulatory consequences have discouraged many companies

[1] See Acknowledgements, p. iv, for a definition of survey respondent types.

(continued on next page)

from making strategic capital investment in energy-intensive systems. In sum, great potential remains for industrial energy improvement. However, various industries experience cycles of **capital infrastructure** renewal over intervals of five, ten, or more years (Elliott et al. 2008). This means that recently-gained awareness of potential energy improvements should lead to implementation of efficiency measures throughout the coming decade.

Various manufacturing corporations respond differently to energy program incentives. Each company demonstrates a unique combination of motivations and investment decision-making processes. This is an ongoing challenge for energy efficiency program administrators. To improve their future effectiveness, program administrators will need a better understanding of the industrial sector's prospects for investment, as well as the nature of the corporate decision process. While previous studies of industrial output and energy consumption typically examine energy intensity (e.g., Kolwey 2005), there is a need to study capital investment dynamics as these may shape the design and conduct of future energy efficiency programs.

Competing Considerations

Broadly speaking, industrial asset management is a trade-off between two choices: squeezing incremental value from existing facilities and equipment – *doing things right* – versus updating facilities to obtain a strategic competitive advantage – *doing the right thing*. The trade-off reflects management strategy, and has direct implications for capital investment. By choosing to *do things right*, a company implicitly commits to refining its current products, markets, and processes. By contrast, a company wishing to *do the right thing* is thinking beyond today in anticipation of tomorrow's opportunities for innovation, relocation, expansion, and growth. This choice determines whether business returns are maximized for the short run or for the long term. These strategy differences explain why two manufacturing facilities, similar in every physical aspect, can demonstrate vastly different appetites for investment in energy efficiency.

At least seven respondents indicate that business growth is the primary goal of capital investment. Aside from meeting business growth needs, many manufacturers are compelled by statutory safety and environmental compliance needs to invest in existing facilities. Add to this the capital requirements to simply repair and maintain current facilities. According to most respondents, energy improvement proposals compete with (rather than contribute to) these primary investment goals. While "efficiency" is not entirely dismissed, it is usually a secondary priority. One respondent states that the primary goal for energy management is to ensure that energy supplies are distributed adequately throughout a facility in a timely fashion – a task that is sometimes at odds with efficiency rather than because of it.

Unless it is to replace a failed asset, an energy efficiency improvement is more difficult to justify than a growth-oriented investment. At least five respondents indicate that energy improvements are more easily addressed in new construction than in the retrofit of existing facilities. About half the respondents indicate that **capital allocations** favor proposals that promise growth, address mandatory safety or environmental compliance, or both. A similar number of respondents (not always the same counted for the last point) say that energy impacts are at least one of many factors to be considered when evaluating a capital investment. Six respondents (four of them large companies) indicate that energy improvements compete with all other capital funding requests. However, three respondents (all were large companies) indicate that their organization maintains a capital budget track for energy separate from all other investment purposes. A dedicated energy

fund ensures that at least some capital is available each year for energy improvements. Of note is the claim by at least five respondents that energy projects are often the kind of items paid for from either non-capital funds or from any budget remainders at the end of the fiscal year. To the extent that this is true, it suggests that industrial energy improvements happen more by chance than by deliberate effort.

It is not accurate to conclude that energy improvements always "compete" with all other capital investment opportunities. As one large company respondent points out, energy improvements are sometimes the consequence of modernization or automation efforts. Documenting these impacts will help when assembling justifications for future improvements.

Impacts of Energy Improvements

Despite the many difficulties, many energy managers can and do overcome barriers. Two SME respondents note that their organizations originally avoided energy improvements in favor of other investments. But once some initial energy project results were available, managers were convinced and wanted more! Four respondents reiterate that project success is often predicated on non-energy benefits. Specifically: 90 percent of energy projects also have a productivity impact (one large company, one facilitator); energy improvements provide a four-fold return in the form of production improvements (one large company); and two other large companies claim that non-energy benefits "dominate" the returns from energy projects. There's still room for improvement: at least one large company respondent says the company experiences an implementation success rate for energy proposals of 30 percent or less. A facilitator claims an 80 percent implementation rate.

At least one respondent notes that energy improvements are harder to justify with today's relatively low gas prices. Upon reflection, this may reveal a strategic opportunity. As discussed in Part 1 of this report, the industrial sector is experiencing a re-shoring of production facilities on domestic soil. This is due in part to lower gas prices. But does this not underscore the need to invest in new facilities? If so, this investment is an opportunity to implement advanced, energy-saving technologies that will hedge these new facilities against future energy price increases.

Conclusions for Future Program Design and Conduct

The U.S. manufacturing sector reveals varying readiness for economic recovery after a decade of capacity destruction and overall stagnant growth. Segmentation of the sector per trends in output and productivity reveal that most of the manufacturing sector (94 percent of value produced) in fact increased its productivity between 1998 and 2009. Considering also the sector's potential for increased capital investment in modernized facilities, the muscle for economic recovery seems to be in place. The industrial segmentation described in this report suggests where future energy program outreach should be focused.

Overall Conclusions and Recommendations

Opportunities for manufacturing sector expansion are emerging after a decade of economic turmoil. With this expansion comes the opportunity to modernize industrial infrastructure, which can have direct, positive impacts for energy efficiency as well as industry competitiveness and overall economic growth. Manufacturing assets are employed for years or even decades at a time. Should companies fail to implement efficient technologies from the onset of facility construction, the cost liabilities will be long-lasting. |

Thermoforming Quarterly® | ANTEC Paper

Thermoformable Liquid Crystal Polymer (LCP)

By Bing Lu, Achim Hofmann, Paul Yung, Ticona Engineering Polymers, Florence, Kentucky

Abstract

Thermoforming is an economical process for forming large shape products. High performance liquid crystal polymer (LCP) has high thermal stability, excellent dimensional stability and high chemical resistance, which offers new application opportunities in demanding applications. In this paper, a new thermoformable LCP resin is compared with injection molding LCP on mechanical, thermal and rheological properties. Sheet extrusion and thermoforming process conditions are discussed.

Introduction

Thermoforming is a method widely used for processing of polymers into desired shapes from extruded sheets. It is a process typically suited for low volume large parts where injection molding is non-ideal due to its high fixed costs. Liquid crystal polymer (LCP) is a high performance polymer with high thermal stability, high heat defection temperatures (HDT), excellent chemical resistance and high dimensional stability. [1-4] Ticona has introduced the first commercially available extrudable and thermoformable LCP resin Vectra® *T.rex*™ 541. This novel LCP resin formulation permits the fabrication of extrusion sheets with high thermal stability for thermoforming parts in applications such as industrial baking trays and high performance heat shields. For example, in industrial baking trays, LCP provides values of energy saving and maintenance cost reduction compared to traditional PTFE-coated steel trays or stainless steel trays because of its fast heating, lightweight and long operating life. LCP properties also inherently add non-stick and microwave-ability to these applications.

Unlike most semi-crystalline resins, the rigid, rod-like molecular structure of LCP resins imparts a unique melt behavior (nematic transition). This property requires special resin selection and processing consideration to meet the requirements in both sheet extrusion and in the thermoforming process. In this paper, we review the properties of *T.rex*™ thermoformable LCP, and its processing conditions for sheet extrusion and thermoforming. Thermformability is also discussed.

Materials

Thermoformable Vectra® *T.rex*™ 541 LCP resin manufactured by Ticona Engineering Polymers is a high melt viscosity LCP resin with >30wt% mineral fillers. The resin was converted into sheets on a laboratory scale using a standard lab film/sheet extrusion line with 4" (~100mm) die and commercially on a sheet extrusion line with 18" (~457mm) die. LCP sheets were tested for thermoformability using a lab Technoform® tester and also formed into parts on a commercial thermoforming line.

Results and Discussion

Property Overview

Table 1 lists an overall comparison of *T.rex*™ thermoformable LCP resin and an injection molding LCP resin on mechanical, thermal, physical and rheological properties. Both resins are based on the same polymer composition and filler package.

Table 1. Comparison of Properties of Injection Molding LCP and Thermoformable LCP

Properties	Injection Molding LCP	Thermoformable LCP
Physical		
Density (g/cm^3)	1.74	1.74
Melt Viscosity at 400 s^{-1} (Pa.s)	56	180
Melt Viscosity at 1000 s^{-1} (Pa.s)	37	114
Mechanical		
Tensile Modulus (G Pa)	8.5	10.8
Tensile Strength (M Pa)	96	118
Break Strain (%)	2.7	3.6
Flexural Modulus (G Pa)	9.1	11.6
Flexural Strength (M Pa)	119	128
Notched Izod Impact (KJ/m^2)	5	7.4
Thermal		
Melting Point (°C)	357	357
DTUL @1.8 M Pa (°C)	240	245

As indicated from melt viscosity, thermoformable LCP (TF-LCP) has much higher molecular weight than injection molding LCP (IM-LCP), which enhances HDT and mechanical properties, including modulus, strength, elongation and impact strength of TF-LCP.

Figure 1compares the capillary melt viscosity of TF-LCP and IM-LCP. The much higher melt shear viscosity

of TF-LCP improves its melt strength, a key property for extrusion and thermoforming. The slope of viscosity/shear-rate of both LCP types are very similar, indicating similar shear thinning behavior contributed from similar molecular structure rigid rods. The slope is higher than that of typical semi-crystalline polymers.

Additional studies were conducted on both resins with a dynamic rotational rheometer. Figure 2 compares complex melt viscosity of both LCPs with frequency sweep at 360° C. It clearly shows much higher zero melt viscosity of TF-LCP compared with IM-LCP. There is no significant viscosity plateau near zero to low shear rate region as normally observed in typical semi-crystalline polymers. This phenomenon is attributed to both the LCP rigid rod molecular structure and the filler effect.

Figure 1. Capillary Melt Viscosity at 370° C

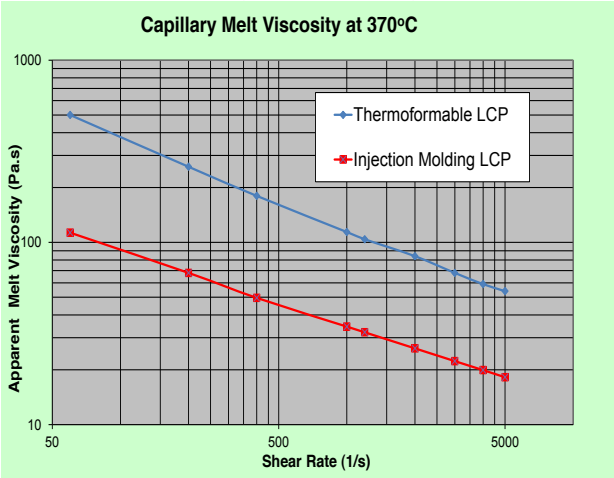
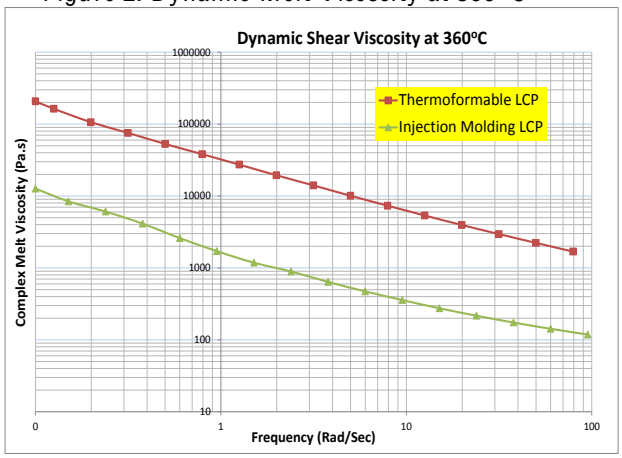


Figure 2. Dynamic Melt Viscosity at 360° C



The DSC thermogram (Figure 3) of TF-LCP shows a small high temperature transition (melting), which peaks at 357° C and has ΔH about 1.6 J/g. No other peak was observed. A change in the slope of the heat capacity curve was observed around 290-300° C, which can be considered as an α transition.

To further demonstrate the target forming temperature, dynamic mechanical analysis (DMA) was performed from -50° C to 300° C. As shown in Figure 4, at 280° C there is a peak of loss modulus, which reflects the α-transition observed in DSC. Both storage and loss modulus decreased rapidly around 300° C, which can be used as an initial target forming temperature. This property is common between IM-LCP and TF-LCP grades.

Figure 3. DSC of thermoformable LCP

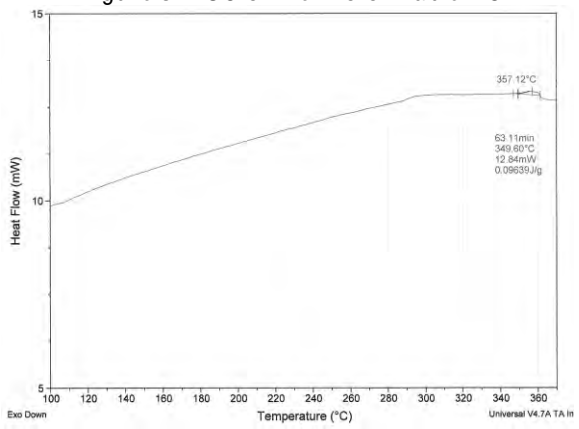
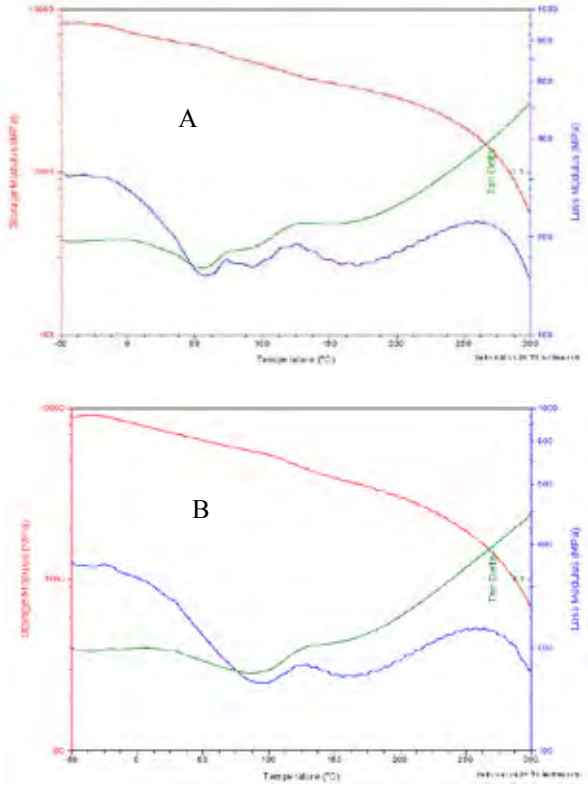


Figure 4. DMA curves of injection molding LCP (A) and thermoformable LCP (B)



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Sheet Extrusion

The quality of extrusion sheets is a key factor for thermoforming process and final part quality. A lab film/sheet extrusion line was first used to make a 50-80 micron film to identify process conditions.

The setup of 4" (~100mm) die film line is: 1.5" (~38mm) single screw extruder, L/D=20; coat-hanger die, up to 100mmX100micron opening; no-rip roller, twin stacked 100mm diameterX152mm width polished chrome roller to a varied speed powered take-up roller. The roller temperature was set to 120° C for good surface film quality. The LCP resins were dried at 150° C for 6 hours before extrusion. It is important to note that the drying process is critical. Residual moisture has been observed to lead to polymer degradation and blister formation on the sheet surface.

Table 2 lists the processing conditions and observations of film extrusion of TF-LCP and IM-LCP. This analysis demonstrated conclusively that TF-LCP produced films with significantly higher quality than IM-LCP. It is believed that the high melt strength is the necessary feature for film/sheet extrusion. From Table 2, the optimal extrusion melt temperature range was determined to be between 345-360° C. (This relatively narrow processing temperature range of LCP compared to traditional semi-crystalline resins is due predominantly to its narrow nematic melt transition behavior.)

Table 2. Film extrusion result comparison

Resin	Test No.	Roller Speed (inch/sec)	Melt Temp (°C)	Die Temp (°C)	Observation
Injection Molding LCP	1	1.3	330	332	Holes in film, difficult to roll, uneven width
	2	1.35	342	340	Few holes, still difficult to roll, unven width
	3	0.95	331	335	Few holes, still difficult to roll, unven width
	4	0.95	327	330	Mlet freezing in the die, few holes, cracking on edge
Thermoformable LCP	1	1.3	347	345	Very smooth surface, no flow mark/gel/holes
	2	1.3	347	345	Increased width, very smooth surface, nogel/holes, very few flow marks
	3	1.45	357	355	Increased width, very smooth surface, nogel/holes, very few flow marks
	4	1.45	370	365	Surface became rough, edge starting to crack
	5	1.5	375	375	Rough surface, edge cracking

To translate this technology to a commercial scale, TF-LCP was extruded into sheets on a commercial sheet extrusion line with an 18" (~457mm) die at melt temperature around 355° C and roller temperatures around 120° C. The sheets had the thickness about 0.80-0.90 mm. The sheets had excellent surface quality with no hole/gel/flow mark.

Tensile-bar samples were cut from the sheets, and tensile properties were measured. Table 3 shows the tensile properties of the sheet in flow and transverse direction.

Table 3. Tensile Properties of TF-LCP Sheets

Property	Flow	Transeverse
Modulus (G Pa)	11.2	5.8
Tensile Strength (M Pa)	84	42
Break Strain (%)	1.3	1.8

As shown in Table 3, the TF-LCP sheets exhibited anisotropic mechanical properties. On flow direction, the rig rod-like molecules aligned together to enhance modulus and strength. In the sheet extrusion, it is preferable not to stretch the sheet much so that the sheet can have reduced anisotropic effect. Furthermore, in thermoforming part design, anisotropic factor needs to be considered to provide the best mechanical strength requirement. Figure 5 shows a typical LCP rod structure and skin-core layer structure scheme.

Figure 5. LCP rod and skin-core layer structure scheme

Thermoforming Test

Thermoforming ability was tested on TF-LCP sheets obtained from 18" (~457mm) extrusion sheet line using Technoform® Tester by Transmit Technology Group.

127mmX127mm samples cut from extrusion sheets were held firmly between two aluminum plates (sample tray) having 57mm diameter opening. A 32mm diameter 100mm long polished aluminum plug tool was used for forming. Plug was heated to 150° C. Samples were heated

by two independently controlled and movable ceramic IR heaters. The top heater position was varied from 38 to 76mm and bottom heater was kept at 76mm from the sample surface. Both heaters were maintained at 830°C. After samples reached the set temperatures, they were moved to be formed with the plug. Test temperatures were varied. Figure 5 shows the plug and sample tray, and Figure 6 shows the Technoform® tester.

Figure 6. Test Plug and Sample Tray

Figure 7. Technoform® Tester

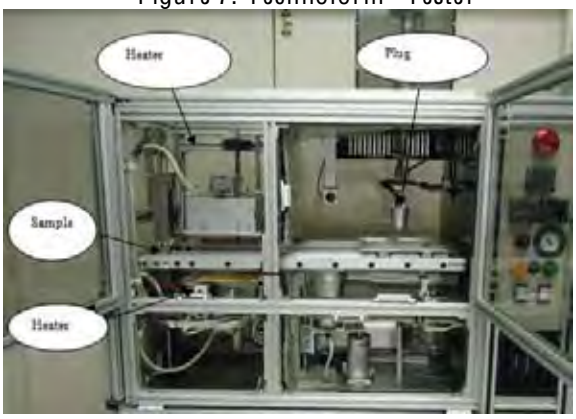
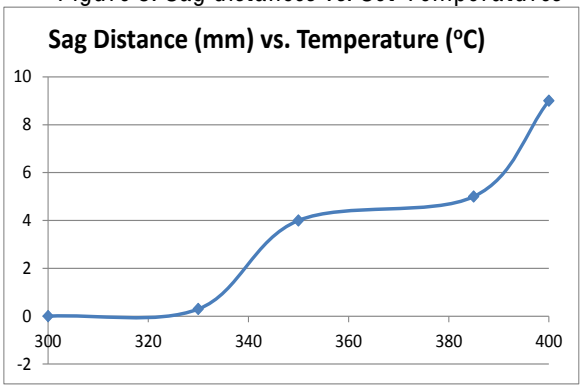


Figure 8. Sag distances vs. Set Temperatures



The sag resistance is an indication of melt strength. The sheet samples were heated to 300, 330, 350, 385 and 400°C. Figure 8 shows the sag distances of thermoformable LCP sheet samples with set temperatures. Below 330° C, sample didn't show any sag. There was a rapid increase of sag distance around 340°C, and then a plateau around 350-370°C, and then a sharp increase above 380°C. Sag was uniform in these temperature ranges, and the sheets didn't show bulk flow or failure, indicating adequate melt strength of TF-LCP resin. Figure 9 shows a sag sample and a formed sample.

Figure 9. Pictures of a sag sample (at 400° C) and a formed sample (350° C/plug speed 60mm/sec)

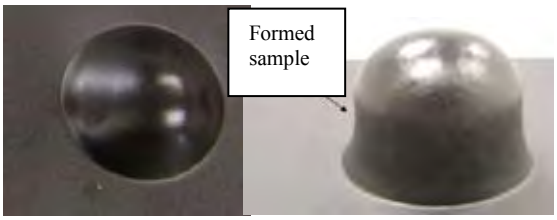


Table 4 lists the thermoformability test conditions. Plug speed and set temperature were mainly investigated for forming. From all tests, we saw rapid temperature drop from set temperature to form beginning temperature and form ending temperature. To retain heat is very important for thermoforming because the loss of heat or rapid cooling can result polymer loose melt elasticity. LCP has very small heat fusion of nematic transition, so it solidifies quickly, and to maintain sample hot during forming by certain ways is essential. Increasing plug speed means short time to form to specific distance, and shorter time means less heat loss and smaller delta T drop.

Table 4. Forming Test Conditions and Results

Test Run No.	1	2	3	4
Thickness (mm)	0.83	0.83	0.83	0.83
Plug speed (mm/sec)	60	60	100	120
Plug dwell time (sec)	30	30	30	30
T (set) (°C)	350	400	350	380
T (form beginning) (°C)	313	358	315	340
T (form ending) (°C)	307	344	312	338
T(set)-T(form beginning) (°C)	37	42	35	40
T(form beginning)-T(form ending) (°C)	6	14	3	2
Forming Observation	Good uniform shape, no hole	Uniform, some holes around neck	Good uniform shape, no hole	Good uniform shape, no hole

Thermoformability of materials depends on melt strength (similar to hot modulus in tensile test) as well as melt elasticity (similar to strain break in tensile test) at forming temperatures. Materials with high melt strength but low melt elasticity cannot be formed to deep drawn parts. Materials with good melt elasticity but decreasing

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melt strength can be formed but will exhibit thickness variation and wall thinning. Crystalline materials lose melt strength and melt elasticity above their peak melting point. Crystalline materials also require a lot higher energy to heat but a lot less "time" to cool from melt than amorphous materials. Generally, amorphous polymers have a wider forming process temperature range than crystalline polymers. LCP has small heat transition, which means it is heated fast in heating stage and cooled rapidly during forming stage.

As shown in Table 4, good uniform shapes were formed in Run 1, 3 and 4. For Run 2, some holes were formed around thin neck, which indicated that an over-drawing ratio caused breakages. This breakage may relate to two factors: one is fast decrease of form temperature, another is strain hardening. Overall, forming temperatures around 320-340^{o} C offer a good forming window.

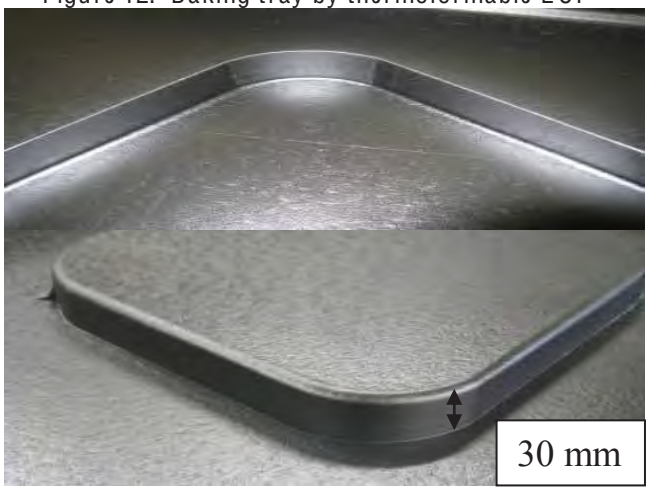
To further verify the melt elasticity, vacuum forming without a plug on pre-heated samples was tested. Vacuum forming is a very rapid process. Figure 10 shows a vacuum formed sample. It has good, even thickness in the bulb and there is no hole/breakage, which indicates that the TF-LCP has excellent melt elasticity.

Figure 10. Vacuum forming sample

Thermoformable LCP sheets were also formed at commercial thermoforming units. Figure 11 shows an example of a heart shape tray, and Figure 12 shows an example of a baking tray.

Figure 11. Chocolate heart shape form tray by thermoformable LCP

Figure 12. Baking tray by thermoformable LCP



Conclusions

Thermoformable LCP shows very high melt viscosity and high heat deflection temperature. It can be extruded into sheets for thermoforming. Due to its unique melt transition, compared with semi-crystalline or amorphous polymers, thermoformable LCP resin needs special processing conditions for extruding quality sheets and forming good parts. For TF-LCP discussed in this paper, the sheet extrusion melt temperature is about 345-360^{o}C and the forming temperature range is about 320-340^{o}C. The TF-LCP has good melt strength and elasticity based on thermoformability tests. Due to its rapid heating and cooling characteristics, special means for heat retention is needed during forming. Vacuum forming is preferred because of fast forming cycle and minimum heat loss.

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Key Words

ANTEC, thermoforming, sheet, extrusion, process, liquid crystal polymer (LCP), thermoformability, performance

SPE Thermoforming Division's 21st Annual Conference Report

By Lesley Kyle, *OpenMindWorks, Inc.*

The Thermoforming Division hosted its 21st Annual Conference in Grand Rapids, Michigan, September 23-25. Over 730 industry professionals representing 16 countries attended the Conference to learn about trends and new developments in technology, machinery and materials. The City of Grand Rapids rolled out the red carpet for the Thermoforming Division and Conference attendees who had the opportunity to partake in Art Prize – a huge, citywide indoor and outdoor art exhibition – when they weren't busy attending sessions or walking the show floor.

Conference attendees had their choice of two full-day workshops, led by McConnell & Company and Mark Strachan. The workshops, attended by nearly 200 industry professionals, addressed fundamental principles and troubleshooting for both roll fed and sheet fed thermoforming. At the conclusion of the Conference, more than 150 attendees participated in the plant tours hosted by Allen Extruders, Formed Solutions, and Fabri-Kal.

Approximately 85 companies exhibited at the Conference with over 10 new exhibiting companies in attendance. Nearly 30 presentations on technical and business-related topics were delivered during two days of conference sessions. Wim DeVos, CEO of the Society of Plastics Engineers, delivered a keynote presentation on plastics in the OEM industries. Todd Shepherd, President of Shepherd Thermoforming, headlined the second day of sessions with his keynote presentation, "Re-Shoring to North America."

One of the highlights of the Conference was the Thermoformer of the Year and Parts Competition Awards Dinner. Randy Blin of Blin Management Company was honored as the 2012 Thermoformer of the Year. Mr. Blin, a part of the second father-son winning duo in the history of the award, accepted hearty applause in front of his family, friends, prior winners and several hundred conference attendees.

A variety of awards in different categories were also presented to winners of the Parts Competition. See pagse 28-29 for full details on and photos of the Parts Competition winners. A special presentation highlighting the professional accomplishments of Gwen Mathis, Conference Coordinator, was delivered by Jim Armor of the Thermoforming Division Board of Directors. Ms. Mathis is retiring from her position as Conference Coordinator at the end of this year.

Planning is already underway for the SPE 2013 Thermoforming Conference®! Please join us in Atlanta, Georgia, for the 22nd Annual SPE Thermoforming Conference: September 9-12. The conference dates will shift from the weekend to a weekday pattern in 2013. For the most up-to-date information, visit the website at www.thermoformingdivision.com or contact Lesley Kyle at thermoformingdivision@gmail.com. |

Thermoforming Continues to Create Job Opportunities

By Zach Ernest, *KLA Industries, Inc.*

Thermoforming continues to be a job-creating segment of the plastics industry. In thick-gauge forming, this can be attributed to increasing applications in the rebounding auto industry and to major manufacturers who are re-shoring their thermoforming operations. In thin-gauge thermoforming, the growth and increased competition in the food and medical packaging markets are driving material and product innovation.

Increased competition and rising material prices continue to constrict margins for plastic thermoformers. As a result, companies are looking for areas that they can control in order to maintain and, where possible, increase profitability. Many organizations have focused their efforts on process improvement with formal training in LEAN manufacturing principles in order to reduce scrap and maximize production rates. One of the primary metrics that thermoformers are targeting for improvement is their Overall Equipment Effectiveness (OEE). To ensure profitability in what can be a high volume, low margin industry, one must minimize downtime for extrusion and thermoforming lines.

The implementation and execution of a strong Preventative Maintenance Program is paramount for sustained performance, especially in order to optimize equipment efficiency and increase the life of expensive assets and machinery. This need for an organized maintenance system is creating opportunities for engineers with strong preventative and predictive maintenance and Reliability backgrounds.

Steady M&A activity in the industry has caused some headcount reduction due to synergies created when companies merge. However, the competition for top talent remains fierce due to demographic changes in the industry and the first wave of retirement for the baby boomer generation. In fact, last year the oldest members of this generation turned 65. Every day for the next 19 years, about 10,000 more will cross that threshold. Companies need to plan for this shift and ensure that they are prepared for the replacement of retiring employees as they will be losing their most experienced people.

To attract top talent, companies must position themselves as innovators who are capable of fostering the career of potential candidates, whether they are hiring new college graduates or trying to lure away engineers or technicians from competitors. Employers are combing resumes for skills including, SPC, Lean, Six Sigma and TPM. Candidates need to make sure that they have both formal training and a wide breadth of skills in order to differentiate themselves.

The future is bright for this growing industry and schools like Mid Michigan Community College and Penn College are taking notice by adding thermoforming programs to their curriculum. Whether you are a degreed engineer or a highly skilled maintenance or production worker, one thing is certain: opportunities to advance yourself professionally are all around you. |

Zach Ernest, CPC is VP of Thermoforming for KLA Industries, Inc., an Executive Search Firm specializing in the Polymer and Plastics Industry.

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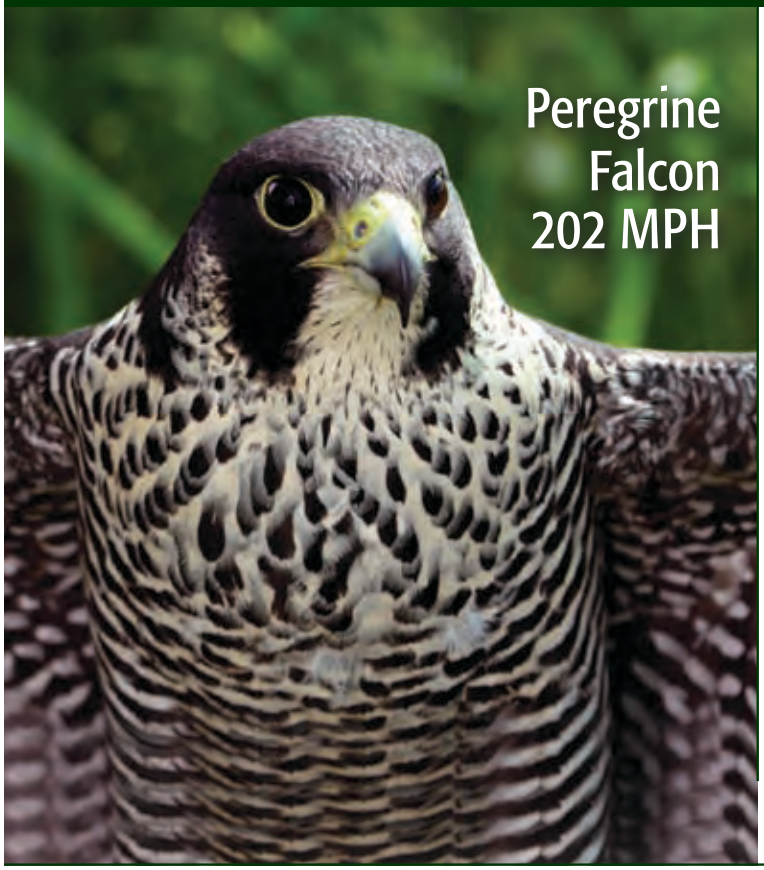

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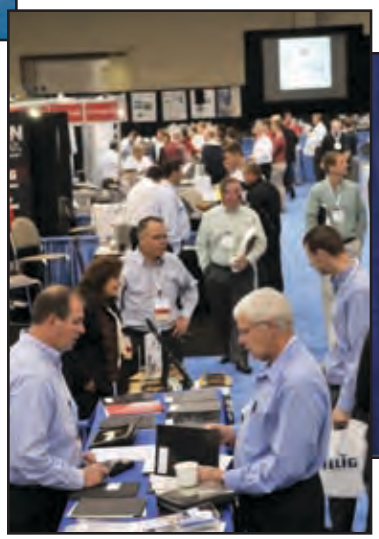

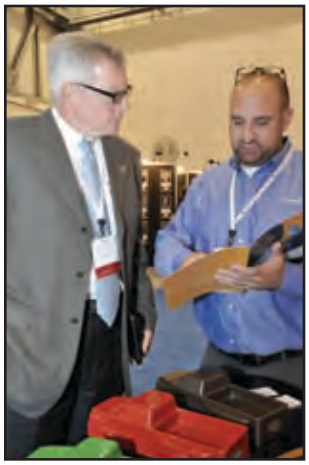

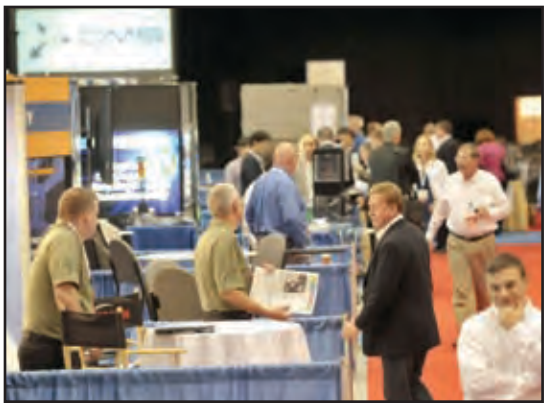

From the Editor

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
- Innovative technologies
- Industry partnerships
- New or expanding laboratory facilities
- Endowments

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 Brian Winton, Academic Programs, at:

bwinton@lyleindustries.com or 989.435.7718, ext. 32

UW Stout Students Visit Wisconsin Manufacturers

By John Shultz, Assistant Professor & Engineering Technology Program Director

On October 26th, sixteen UW Stout students and two Engineering and Technology Department instructors toured Portage Casting and Mold, Inc. in Portage and Flambeau Corporation in Baraboo, WI. The students are enrolled in MFGT 342, Thermoforming and Blowmolding Technology, taught by John R. Schultz. They are BS Engineering Technology or BS Packaging students with a Plastics Concentration. Professor Wendy Stary, Plastics Engineering instructor, also attended.

It was a long, two-and-a-half-hour drive from Menomonie to Portage, yet well worth it according to the students. When they returned to class the following week, the students were asked to submit comments about what they learned. The paragraphs below summarize their responses.

Students had a great experience on the Portage Casting and Molding tour and came away with a greater appreciation of the entire manufacturing process. All found it very interesting to learn about the different ways the molds are made and how the sand was used with a chemical binder for all casting molds. Being able to watch the entire process from prepping the sand to the finished tool was very eye-opening. The most impressive part of the tour was seeing all of the advanced machinery and the sizes of molds and CNC machines.

The Flambeau tour was also very enlightening and students enjoyed every part it, from the blow molding to injection molding. The students thought it was awesome to see all the different types of products that were being made, and how they compared to products being made by other processes. Most of the blow molding molds are produced in-house. With injection molding, the students found it interesting to see the different sizes of the machines and the various parts that they could produce. It was very exciting to see advanced machinery making complex parts and all the various jigs and fixtures used. Every student mentioned how impressive it was to see how the bullets for the military were produced and wanted to learn a little more about this process.

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In Memoriam

WILLIAM HAROLD "BILL" BENJAMIN

William Harold "Bill" Benjamin, 73, of Bellflower, CA, passed away on October 27, 2012 in Bellflower, CA. Bill was born July 19, 1939 in Youngstown, Ohio to Harold and Mary Benjamin. Bill was preceded in death by his parents Harold and Mary Benjamin, and his in-laws, George and Eleanor Grandy.

Bill passed away peacefully at his home surrounded by his wife of 54 years, Beverly "Weiser" Benjamin, and family.

Bill Benjamin was President of Benjamin Mfg. Co., Inc. which he and his wife Beverly started in 1961. His sons, Jeff and Rick, will continue his legacy at Benjamin Mfg. Co., Inc. in Paramount, CA and Lithia Springs, GA. In 1967, he started Benjamin Mfg. Co. in Downey, CA. Bill began thermoforming parts on machinery he designed and built himself since the type of machinery that he envisioned was not available for purchase. Bill continued to design and build several of these machines which are still in use at his plants in California and Georgia. Bill also designed and built a two-station biforcator thermoformer. Bill has six patented products and three trademarks. His first registered trademark was for his "Lustre-Lav" which was made from the forerunner of DR Acrylic ABS material. This material remains a big part of the spa and plumbing industries today. In 1980, a second plant was opened in Lithia Springs, GA. In 2003, Bill was awarded Thermoformer of the Year by the SPE Thermoforming Division where he also served several terms as a member of that group's Board of Directors.

Bill is survived by three children: Jeff and Toddy Benjamin of Rossmoor, CA; Laurie "Benjamin" and Mike Pike of Palm Desert, CA; Rick and Lisa Benjamin of Bellflower, CA; six grandchildren: Aubrey "Luas" (John) Weston and Amber Luas (Laurie Pike), Whitney "Benjamin" (Chad) Wilkinson, Kayla Benjamin, and Patrick Benjamin (Rick Benjamin), and Farren Benjamin (Jeff Benjamin); brother, Robert Benjamin of Chandler, AZ, sister, Cindy Benjamin of Bellflower, CA, and sister-in-law and her husband, Carol "Grandy" and Robbie Bertocchi, of Douglasville, GA.

In lieu of flowers, the family requests donations be made to: Bill Benjamin Memorial Scholarship Fund, (checks made out to: SPE TF Division, P.O. Box 471, Lindale, GA 30147.

2012 Parts ✶ Winn

This year's Parts Competition saw entries from as far away as Ecuador and as close as the Conference host-city, Grand Rapids, Michigan. From what this year lacked in quantity, it certainly made up for in quality of submissions. With a balance of small, design-challenging thin-gauge applications and large, complex assembled heavy-gauge parts, the Competition judges had no easy task in selecting the winners. The similarities ended there as thin-gauge winners were picked for efficiency of material use with increased functionality. Bigger was certainly better as all the heavy-gauge winners consisted of large-panel forming with integrated assembly techniques. I am proud to have been a part of this year's Parts Competition and look forward to seeing what new and innovative submissions will be made in next year's Conference in Atlanta, Georgia.

– Eric Short, Chair, Parts Competition

Industrial Roll-Fed

Gold Winner

Plasticos Ecuatorianos S.A.

Guayaquil, Ecuador

Vertically-Ribbed Cup

Silver Winner

Placon Corporation

Madison, Wisconsin

Evolutions™ Deli Container

Bronze Winner

Amros Industries, Inc.

Cleveland, Ohio

Centerpiece Ice Sculpture Drip Pan

Congratulations to all 2012 Winners!!!

Competition
ners

Photos courtesy of *Dallager Photography*

Heavy-Gauge Vacuum

Gold Winner

AMD Plastics
Euclid, Ohio

Agricultural Equipment Hood

Silver Winner

Hampel Corporation
Germantown, Wisconsin

Dairy Calf Housing

Heavy-Gauge Pressure

Gold Winner

SMI
San Diego, California

Medical Device Enclosure

Silver Winner

Molded Plastic Industries, Inc.
Holt, Michigan

Pressure Formed CNG Tank Cover

Judges' Award

Craft Originators, Inc./
Tasus Group
Hamilton, Ontario, Canada

Fiat 500 Dr Dre Speakers

People's Choice Award

SMI - San Diego, CA

Medical Device Enclosure

Have an Idea for an Article for TQ?

Submission Guidelines

- We are a technical journal. We strive for objective, technical articles that help advance our readers' understanding of thermoforming (process, tooling, machinery, ancillary services); in other words, no commercials.
- Article length: 1,000 - 2,000 words. Look to past articles for guidance.
- Format: .doc or .docx

Artwork: hi-res images are encouraged (300 dpi) with appropriate credits.

Send all submissions to Conor Carlin, Editor

cpcarlin@gmail.com

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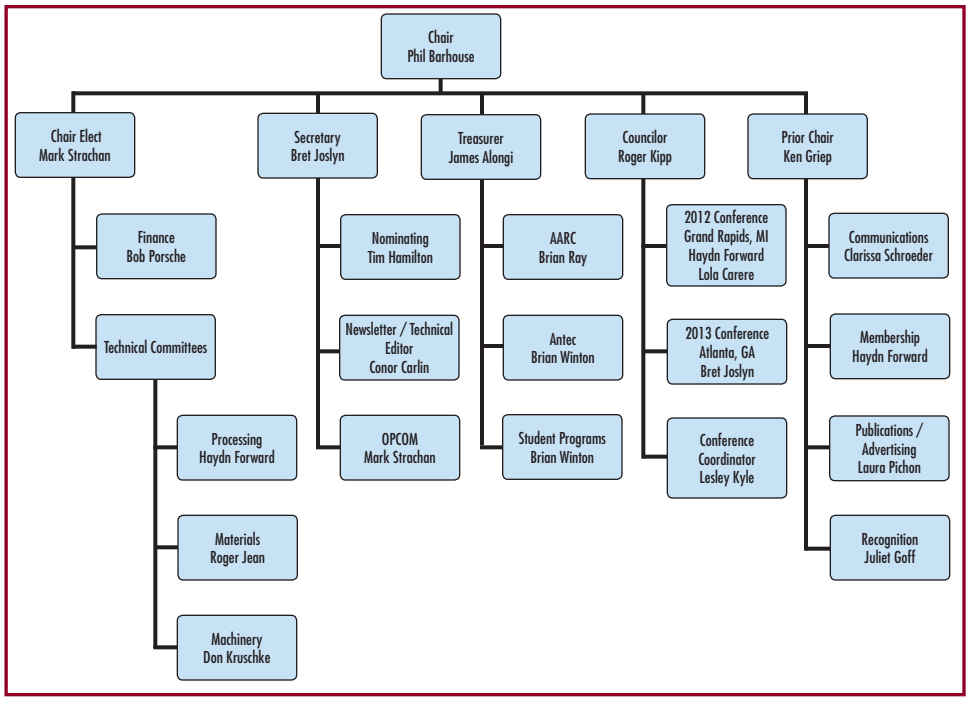

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