



# Thermoforming

## Quarterly®

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

THIRD QUARTER 2009 ■ VOLUME 28 ■ NUMBER 3

## Thermoforming Makes a Big Impression at NPE 2009



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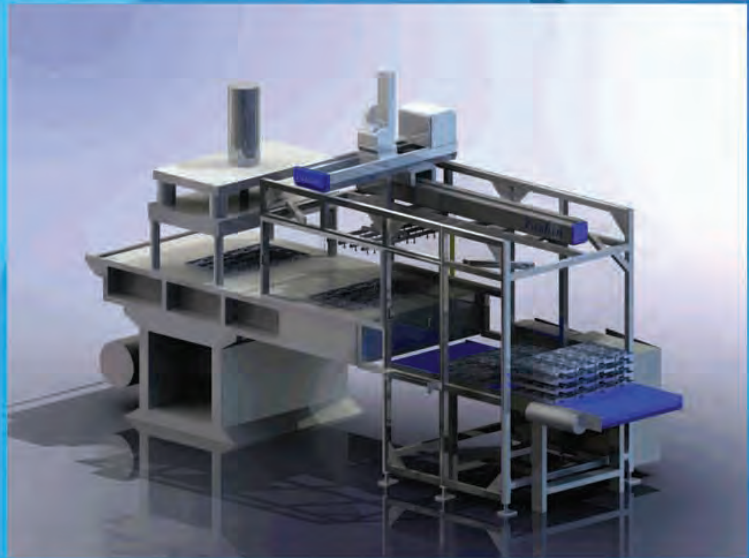
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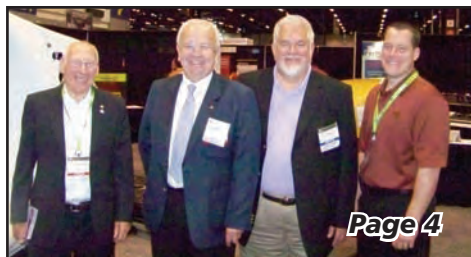
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## Thermoforming Quarterly®

A JOURNAL PUBLISHED EACH CALENDAR  
QUARTER BY THE  
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One of the great things about being chairman of the division is that I have the opportunity to meet other industry leaders. When you get this group together, you get a very clear understanding of the opportunities that lie ahead for thermoforming.

I recently returned from NPE 2009 in Chicago, where our division sponsored the first ever Thermoforming Pavilion. The Pavilion was a tremendous success for a variety of reasons. First of all, the booth was very interactive and allowed visitors to see innovative thermoformed parts. Secondly, industry professionals were in the booth to answer questions and provide technical information about the process. The Pavilion became a crossroads of everything related to thermoforming. At any given time you could look around and see attendees holding parts saying, "I did not know that you could do this with thermoforming," or "Is this injection molded?" or "How is this part made?" All these

questions created a buzz and a sense of excitement that reinforced the fundamental optimism that I have about our process and markets.

As processors, we often compete against each other. The sooner we channel our competitive energy back into the process and markets we serve, the sooner we will reach the individuals that are seeking the benefits that our process provides. As our customers become more educated about the thermoforming process and its capabilities, we should begin to see additional growth as successful programs lead to future projects. For this to happen, we need to do our part to ensure that we showcase a repeatable process. This is accomplished through part development, tooling design and material selection paired with forming equipment and secondary capabilities to ensure that a cost-effective product meets exacting specifications. Although we compete amongst ourselves as an industry, we must not forget that we also compete with other processes such as sheet metal, fiberglass, structural foam, pulp, corrugated, folded cartons, injection and blow molding.

The board of directors, as a group, will actively pursue those interested people that visited our booth at NPE. With targeted follow up, we will attempt to

enroll them as active members in the division and hopefully attract new faces to the board. We will talk to the suppliers and invite them to participate in the conference and to consider a sponsorship in the *Quarterly*. We will make contact with the designers and engineers and let them know about the annual conference and provide them access to educational information. Lastly, we will keep the information flowing to the processors to ensure that they have the most up-to-date information for themselves and their co-workers. We will remind everyone that there is a time and place each September that allows them to review technical data, meet with industry leaders and see the latest innovations that our industry has to offer.

### **The next Thermoforming Conference has been scheduled for September 18 – 21, 2010 in Milwaukee, Wisconsin.**

The theme of the conference is "Embrace the Challenge." You can be sure that this conference will provide the technical instruction and hands-on supplier interaction that are crucial to the continued progress and innovation that our customers demand. |

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Chair

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## Why Join?

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



Active membership in SPE – keeps you current, keeps you informed, and keeps you connected.

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

## Why Not?

# Thermoforming in the News

## Some Comments on NPE 2009

Editor's Note: The following comments were provided by representatives of several thermoforming machinery manufacturers. They are subjective observations based on company experiences at NPE 2009 and not representative of any official show commentary.

“Although the attendance numbers were way down, the people we were talking to were decision makers. The show was actually very good for us. We saw all of our key customers and target customers. We also met many people (many foreign) that we may not have had contact with otherwise.” |

– Lyle Industries

“We felt the show traffic was noticeably lighter but that most of the principal manufacturers in our sector were present. While the quantity of visitors was lower we found the quality to be very good in that many visitors were decision makers not just there to make idle inquiries. We learned of some interesting developments in green or compostable materials that have developed to the point of being practical in terms of process and cost.” |

– Irwin Research & Development

“Due to the economic situation, we expected a slow show. The opposite was the case. We had lots of good meetings and inquiries which is very promising for the near future. The quality of the talks was high.” |

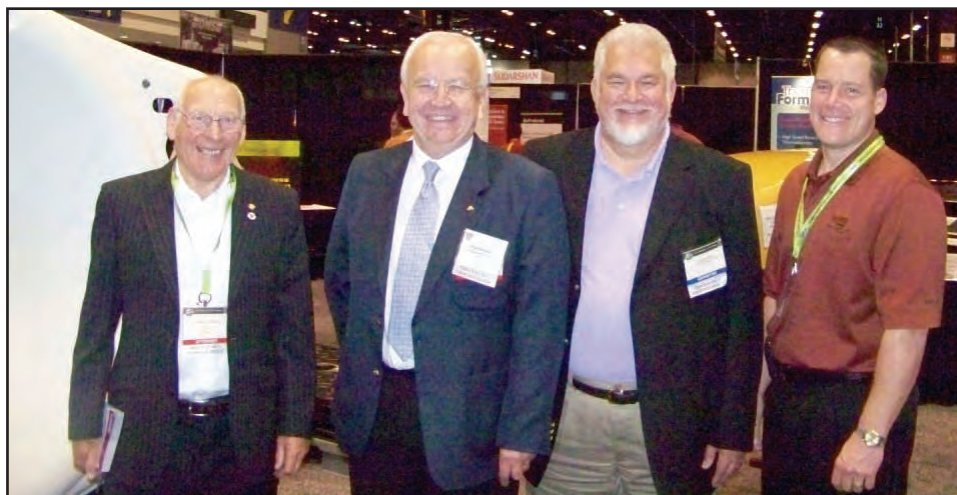
– Gabler Maschinenbau

“Our expectations were low due to the general economic situation. We saw fewer visitors but those we talked to resulted in medium-to-high quality of discussions. Good and interesting meetings to specific projects, especially biodegradable applications.” |

– Kiefel Technologies



*Jennifer Kaye of the Thermoforming Institute presents an award to outgoing president John Knight.*



*L-R: Ken Darby (Conference Chair, ETD), Ken Braney (SPE President-Elect), Roger Kipp (SPE Councilor), and Brian Ray (Chairman, Thermoforming Division).*



*Example of thermoformed parts on display at the SPI Thermoforming Pavilion, NPE 2009.*



# Thank You from 2009 Thermoformer of the Year



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June 22, 2009

Society of Plastics Engineers  
Thermoforming Division

Gentlemen:

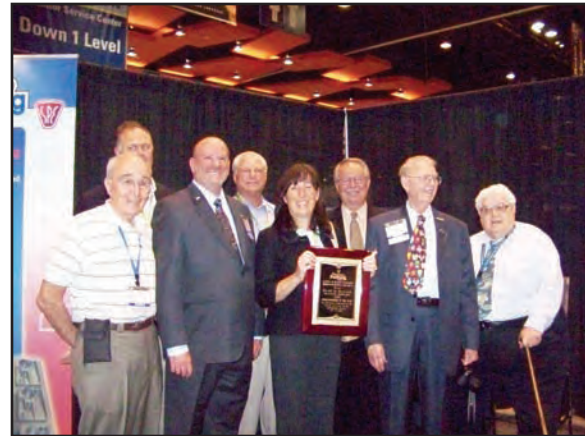
I've asked Randy Simcox, our President, and Nancy Bestwick Tietbohl to accept the Thermoformer of the Year award that you awarded our company and all of our employees.

While you've made me the recipient, it is all the employees of Tray-Pak who have made this award possible. On behalf of all the employees and myself, I gratefully accept this honor that I will always cherish. Our industry is filled with many entrepreneurs who are as deserving of this honor as Tray-Pak. I sincerely thank you for this honor and want you all to know how proud I am to have been a part of the Plastics Industry these past 34 plus years.

Sincerely,

A handwritten signature in blue ink, appearing to read 'David Bestwick', written over a white background.

David M. Bestwick  
Chairman

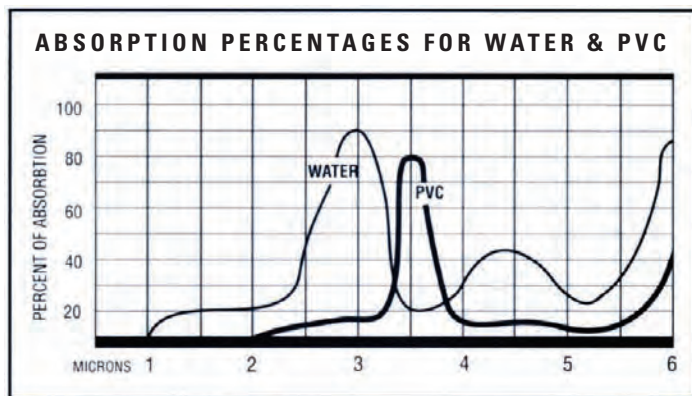


# INFRARED HEAT: A Simplified Approach – Part Two

Mike Sirotnak, Solar Products

*Technical Editor's Note: This is the second and final installment of the paper on heating elements for the thermoforming process. Together these two parts provide a complete understanding of the types of heaters that are used in out process. We thank Mike Sirotnak for submitting the content and editing for this publication.*

**N**ow that we understand how to calculate heater wavelength output, the question becomes: how does wavelength affect my process? Infrared radiation is reflected, absorbed or transmitted when it hits an object. All materials have absorption curves which show what wavelength the materials will best absorb.



As an example, the graph above illustrates the difference in absorption curves for water and PVC. Find the peak absorption areas of the graph above. For most plastics, the CH (carbon/ hydrogen) bond will peak in the 3.2 - 3.4 micron range. For water, the OH (oxygen/hydrogen) bond will peak at 2.9 - 3.0 microns. Ideally, you would like your heater to output the majority of its energy in the area where it will be absorbed best.

Some manufacturers sell their heaters on the ability of a customer to tune the output to a product, when in fact every heater can do this if you have the ability to control the temperature of the heater.

## **What is Emissivity?**

Emissivity is defined as a measure of radiant efficiency. If an object has an emissivity factor of 1.0, then it is the perfect radiator and absorber. This is referred to as

the “perfect blackbody.” If an object has an emissivity of 0, then it is a perfect reflector, and does not absorb any radiant heat.

How does this affect your heater’s performance? Imagine two heaters with the same wattage and voltage. One has an aluminum face and the other has a black-coated steel face. Because aluminum is a poor radiator, you can hold your hand close to the surface without feeling any heat. In contrast, black steel is a good radiator, therefore when you hold your hand close, it is emitting heat. If the heater was constructed with a face that acts like a “window” allowing all the energy to pass through (e.g. quartz and vycor), then you are concerned with the emissivity of the source (coil or wire) of the energy.

Most sources are very close to a 1.0 emissivity factor.

## **What is Quartz?**

Quartz is a highly misused term. Quartz glass is fused sand (SiO<sub>2</sub>) and is available in plate or tube form in either clear or opaque materialization. Quartz cloth is woven quartz fibers very similar to fiberglass. All quartz materials are excellent transmitters of infrared energy.

## **Applying These Theories to Heaters**

We have learned that an infrared heater must output wavelengths between .72 and 1,000 microns. We also know that heaters can be short, medium or long infrared depending on where the majority of output falls within the infrared spectrum. We know that temperature affects the curve of the wavelength, and therefore heaters that are rated the same but constructed differently, can have different energy output.

We know that all radiation is reflected, absorbed or transmitted when it hits an object. The degree to which an object either reflects or absorbs radiant heat is measured by its emissivity factor.

We can now apply these facts in determining the kind of heater you need and how it should be constructed.



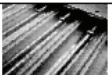




## All Heaters Have 3 Parts:


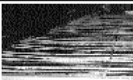


- The SOURCE of the energy which can be coil, foil or wire
- The SOURCE SUPPORT OR REFLECTOR which supports the coil or directs the heat
- The FACE which electrically insulates the source and acts either as a “window” allowing all primary radiation to pass through or as an absorber which will absorb the heat and then release it as secondary radiation.

## There Are Two Kinds of Infrared Heaters:

- PANEL heaters have a face and are in a box type construction with a length, width and depth. The panel IR heater directs its energy out its face via different construction techniques.
- TUBULAR heaters have either a metal or quartz sheath which houses a resistance coil.

You can now begin to research the kind of heater that is needed for your particular needs. There are many different types of heaters available, so choosing the right one

ELECTRIC INFRARED HEATERS					
DETAILS	T3 LAMPS	METAL RIBBON OR SITUATED WIRE	QUARTZ TUBES	FUSED QUARTZ PANEL HEATERS	QUARTZ COMPOSITE OR GLASS FACE PANEL HEATERS
Radiant Efficiency	75 - 90%	80 - 95%	75 - 90%	80 - 95%	70 - 90%
Typical Life Expectancy (Hours)	5,000	10,000	10,000	25,000	25,000
Source Temperature Range (°F)	up to 4000	up to 1900	up to 1900	up to 1900	up to 1700
Input Power Density (watts/in <sup>2</sup> )	up to 200 wsi †	up to 55 wsi	up to 60 wsi	up to 60 wsi	up to 25 wsi
Warm-up Time in seconds	1 - 2	30 - 60	10 - 40	300 (5 minutes)	300 (5 minutes)
Temperature Uniformity	Verygood	Verygood	Verygood	Excellent	Excellent
Surface Material	Vacuum Sealed Quartz Lamp	None (Bare Element)	Quartz tube	Quartz plate	Glass, Ceramic, Metal or Quartz Composite
Picture of the Heater					

ELECTRIC INFRARED HEATERS				
DETAILS	CERAMIC ELEMENTS	METAL SHEATHED TUBULAR (CALROD™)	COILED METAL SHEATHED WITH PARABOLIC REFLECTOR	CERAMIC GENERATOR WITH PARABOLIC REFLECTOR
Radiant Efficiency	70 - 90%	60 - 65%	70%	70%
Typical Life Expectancy (Hours)	10,000 - 15,000	10,000 - 15,000	10,000 - 15,000	10,000 - 20,000
Source Temperature Range (°F)	up to 1400	up to 1400	up to 1500	up to 1100
Input Power Density (watts/in <sup>2</sup> )	up to 30 wsi	up to 20 wsi	up to 20	up to 7
Warm-up Time in seconds	300 (5 minutes)	300 (5 minutes)	300 (5 minutes)	300 (5 minutes)
Temperature Uniformity	Good	Good	Verygood	Verygood
Surface Material	Ceramic	Metal	Metal	Ceramic
Picture of the Heater				

can be relatively easy. Your choice will fortunately be limited by examining your intended process application.

## Consider These Points When Selecting A Heater:

**RESPONSE TIME** – Is your application one where you need optimal heat in seconds, or are minutes acceptable? If time is a key factor, then quartz tubes or an exposed coil, ribbon or panel is your only choice.

**SHORT OR LONG WAVES** – If your product or process is more responsive to shortwave, then quartz lamps with a filament in vacuum is appropriate. If medium wave, then quartz tubes or panel heaters are best.

**POWER EQUIPMENT** – Heater output is measured in watts per square inch. For example a 12" x 12" heater with 5760 watts has a watt density of 40 watt/inch. A 12" x 12" heater with 1440 watts has only 10 watt/inch. With tubular/quartz tubes, you measure watts/linear inch of tube length. Then you decide on what centers you are mounting the tubes. For example, a 12" tube with 600 watts has 50 watts/linear inch of tube. If the tubes are placed on 1" centers, then you have 50 watts/inch. There is no magic formula for deciding total power, because so much depends on the environment and the product to be heated.

**ENVIRONMENT** – Is it clean or dirty? Are you making computer chips or printing t-shirts? Are you working with an existing production line or designing a new one? Will the heaters be installed in an abusive environment? Does your process involve harmful solvents or vapors? Will anything be falling on the heater face? These are important questions to answer before selecting a heater.

**CONTROL METHOD** – Infrared heaters can be controlled in one or two ways (Open Loop) Percentage Timer or (Closed Loop) Temperature Control. The Temperature Control method is the most accurate way to control your heaters and keep them at a consistent temperature. If you choose to pursue the temperature control method, then you will need to decide whether to use a thermocouple or a pyrometer to measure temperature.

Armed with the answers to these questions the heater that fits your needs can easily be selected. Selecting one becomes a straightforward and simple procedure if you don't get bogged down in the vendor mumbo-jumbo. Just keep it simple, use common sense, and you'll find the right heater for your application. |

# Operating in a Shrinking Market

Jeff Mengel, Plante & Moran

*“I haven’t seen a good company with a bad balance sheet since the late 1980s or early ’90s. I think in this cycle, we’ll start to see some great companies with bad balance sheets.”* (Michael Psaros, KPS Capital Partners)

Sad but true. We have already started to see this trend and we will likely see more of it before this recession comes to an end. This led us to wonder, how are plastics companies dealing with the economy, and what will the industry look like coming out of the recession?

To answer these questions, Plante & Moran examined the bookends of the industry by selecting 40 high-leveraged and low-leveraged companies identified from our 2008 North American Plastics Industry Study (NAPIS). Out of 172 participating companies, 20 had more than a 4:1 debt-to-equity position and 20 had less than a 1:1 debt-to-equity position. The following provides an overview of how plastics processors (injection, extrusion, thermoforming, and blow molding) are faring and what to expect from the plastics industry going forward.

### **How Bad Is It?**

According to NAPIS data, approximately 30% of the industry is heavily leveraged, and 25% has a debt-to-equity position of

4.5 to 1 or higher. According to the Original Equipment Suppliers Association’s February 2009 survey of 82 members, 23% had covenant violations, and an additional 18% had violations pending; 9% revealed that bankruptcy was imminent, and an additional 22% said bankruptcy was extremely likely. These results were not entirely caused by bad management – liquidity may determine these companies’ fates more than skill or strategy. While larger companies may seek reorganization, smaller ones will be less likely to find financing and be forced into liquidation, resulting in 240,000 available tools (an additional 120,000 tools may be transferred by customers to maximize leverage).

However, the question of “How bad is it?” really depends on the degree to which plastics companies are leveraged. According to the NAPIS, the majority of low leveraged companies have greater than 62% sales as engineered components and only 5% sales as simple shoot-and-ship parts. The majority of these companies had anticipated to grow revenues over 2% in 2009 from 2007. In contrast, a majority of highly leveraged companies have greater than 90% sales as a shoot-and-ship processor and the majority of these companies had anticipated losing more than 17% in sales in 2009 from 2007.

Subsequent to this survey, as the economy continued to sour, the demand for plastic products was

more dependent on whether the purchase was capital or consumable in nature. Capital items are showing demand declines averaging 30% to 40% while consumable items are showing declines of 10% to 20%. Very few companies have enjoyed an increase in sales in 2009.

### **How Are Companies Dealing With the Downturn?**

Surprisingly, low-leveraged companies were more aggressive with headcount reductions, both in overall numbers and the timing in anticipation of demand reduction. While highly leveraged companies focused on production employees in their headcount reductions, low-leveraged companies were far more proactive with permanent reductions in general and administrative headcount as they positioned themselves to become smaller companies in 2009.

As expected, highly leveraged companies have been much more aggressive with expense reductions, including wage reductions, while low-leveraged companies have been selective in application. For example, they are shown to be more apt to cut people than wages.

In terms of investment activity, both highly leveraged and low-leveraged companies are maintaining equipment. However, low-leveraged



organizations are still acquiring some equipment, while highly leveraged ones have ceased buying equipment altogether.

And what about financing? Low-leveraged companies have little debt and few bank restrictions. Unsurprisingly, highly leveraged companies are seeking debt restructuring, as many are in covenant default. Still, the highly leveraged have done an excellent job of reducing expenses and paying down debt as the reduction in demand has allowed them to convert receivables into cash.

## Tool Time

The anticipated level of tool transfer, unprecedented in our industry's history (240,000 available tools and an additional 120,000 tools that may be transferred by customers) will provide substantial growth opportunities for those prepared for transfer work. There has been a fair amount of tool movement, and it is not over yet. Unfortunately, there will be additional casualties, as some highly leveraged companies will not have the working capital to recover when

the economy recovers.

Everyone wants to take on new work when sales are faltering, but it is important to note that not everyone is designed to take on transfer work. You have to be very adept at working with older tools, dealing with shorter production runs, and navigating multiple programs. Additionally, you cannot predict when such events will happen; you just have to let your customers know that you are ready, willing and able to capitalize on opportunities as they arise.

## Going Forward

While our industry has its challenges, it's not all gloom and doom. We are pleasantly surprised at how aggressively both low-leveraged and highly leveraged organizations have restructured to become smaller companies. In addition, there is immense opportunity to create more strategic impact going forward than at any other time in your company's history. As differentiation becomes more noticeable, companies should focus on creating a meaningful message and developing a core competency that resonates. Companies with strong balance sheets can acquire improved talent, additional facilities, additional capabilities, and increase their books of business. |

*Jeff Mengel is a partner at Plante & Moran and leads the firm's Plastics Industry Team. Jeff is a CPA with over 30 years of experience that has been studying the industry through benchmarking studies for over 14 years and can be reached at [jeff.mengel@plantemoran.com](mailto:jeff.mengel@plantemoran.com).*

# TEMPCO Infrared Technology

## Product Showcase



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Precise Wavelength Halogen Lamp Infrared Technology with High Efficiency Reflective Ceramic Housing



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- Custom Arrays with Power Control Panels will complete your Thermal Loop System



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# The Latest Tooling Options: Quality and Speed versus Cost

Excerpted from:  
**The Latest Advancements in Thermoforming** by Frank Karai, ODC  
(Thermoforming Quarterly 2007 Volume 26, Number 2)

## **[F.K.] Large thermoforming companies are driving advances in tooling.**

The larger the thermoforming company, the more refined their thermoforming process and the greater the expectations to use state of the art tooling. Equipment is typically larger and engineering and forming process support is greater than smaller regional thermoformers. The interest in cycle time reduction and speed of tool changes is driven by the large formers competing for high volume national accounts which are very competitively bid. The overriding fact, however, is that proper tool design is always dependent on the application.

*[B.S.] This, in my opinion, is the most important factor for growing thermoforming companies to know. It is widely understood that people are first and foremost for companies with ambitions to be leaders in their field. The job of engineering the machines and tooling is best handled by experienced professionals with comprehensive knowledge of all the options. As with any other industry, R & D to maximize efficiencies takes place at those companies that can afford to hire professional staff. However,*

*Technical Editor's Note: So often the question of tool cost becomes a discussion among Engineering, Production and Sales. Each department weighs in with their arguments about set-up time, production speed, part quality and, of course, how the cost is impacted. If times are good and the backlog is overflowing, the tendency is to build tooling that will set-up and run good parts as efficiently as possible with less regard for tool cost. This is the case regardless of whether the tooling is billed, absorbed into the part cost or sold as part of the project development. When cash flow is tight, however, tooling cost becomes a higher priority. Larger companies have thermoforming engineering staff to deal with this question on a daily basis and generally have access to the most advanced tool design capabilities. With this service comes an added cost which invariably is justified by the promise of higher returns from volume sales. With his approval, I have reprinted parts of an article written by Frank Karai of Ontario Die Corporation in the Fall 2007 issue of Thermoforming Quarterly. I have added my comments (in italics).*

*there are government programs for smaller thermoformers, especially in difficult economic times, to assist with such things as improvements in cycle time and tool setup. They would do well to look at hiring a qualified engineer to head up this initiative. The cost of that person can sometimes be paid for in the first year or two of cost savings and will lead to increased sales by being more competitive and more innovative.*

## **[F.K.] The pressure to down gauge**

The move to down-gauging material has resulted in the use of more engineered molds and plug materials. Air actuated water cooled individual cavity clamping is common.

*[B.S.] Down-gauging, even minor reductions in material thickness,*

*is now considered a step in the right direction towards a greener environment as well as shaving dollars from part cost. Forming thinner parts while achieving the same wall thickness as with heavier gauge material can only be achieved by fine tuning the tool design and by utilizing the latest machine upgrades.*

## **[F.K.] Third motion plug assist**

The use of high-speed European equipment is growing in North America. Many of these machines are equipped with third motion plug drives that increase process control and improve material distribution leading to down gauging opportunities. Third motion plug activation is especially useful on deep draw and heavy gauge applications where sheet-sag may



be of concern (female mold on top; third motion on bottom).

*[B.S.] I consider third motion plug drives to be one of the most significant advancements in our industry. Thermoformers who purchase new equipment now are missing out on the best way to improve material distribution and down gauge if third motion plug assist is not included on the form press.*

### **[F.K.] Temperature control**

Flood-cooling improves mold temperature control versus contact-cooled molds. Increasingly sophisticated mold cooling techniques such as cooling pins and thermal calculations are optimizing cycle times. The use of smaller diameter lines, multiple cooling lines, advanced manifolding techniques, in-line turbulators, higher volume and flow rates are improving BTU removal. The use of thermolators on tower water ensures optimal mold temperature is reached even on start-up and there is an added benefit of increased flow and turbulence which improves cooling efficiency.

*[B.S.] Consistent mold temperature is a must in order to maintain good quality. Faster cycle times translate into greater difficulty in controlling the mold temperature. Cooling lines throughout the mold cavities as well as the mold base provide a better chance of getting the same temperature on all tool surfaces. All the advances mentioned above are aimed at keeping form tooling at the same temperature while removing heat from the sheet at fast cycle times.*

### **[F.K.] Pressure and vacuum advancements**

Air distribution has become more advanced allowing for faster forming, leading to better definition and faster cycles. Pressure/vacuum combination is now the norm with air being distributed throughout the mold at multiple points of distribution. The use of baffles to diffuse pressure forming air avoids spot chilling parts. Vent-hole sizes have gotten smaller allowing more of them to be used. The use of slot venting is useful when possible.

*[B.S.] Getting air pressure and vacuum to and from the tool as fast as possible has been given more attention as the need for fast cycle times has grown. While these features may not be as important as other advances they all contribute to better thermoforming.*

### **[F.K.] Reduced downtime**

Quick change cavities and plugs are commonly used to allow parts with common footprints to be run with very little downtime for tool changes resulting in greater machine throughput.

*[B.S.] Several companies have developed locking devices that are being used to make clamping molds and plugs a simple operation that can be done in a matter of minutes without removing bases from the press.*

### **[F.K.] Plug materials and simulation software**

Advanced plug materials such as B1X and WFT improve plug performance, resulting in down gauging and better material

distribution. Plug materials are more thermally stable allowing for faster cycle times. Solid modeling software and forming simulations are more commonly used allowing for more intricate and thorough design investigations which impact cycle times.

*[B.S.] There have been many technical papers written on the latest developments in plug material and almost as many on the use of computer simulations to predict the forming results using these new materials. Again, these advancements may seem minor when assessing the gains in efficiency but thermoformers must pay attention to anything that makes them more competitive.*

### **[F.K.] Every application is unique**

Mold design needs to respect the particular demands of the part geometry, part structural integrity, lock designs and undercuts plus unique properties of materials including multi-layer barrier materials and biodegradables such as PLA.

*[B.S.] Many variables come into play when designing a thermoform tool especially when one considers the latest options available. We must look beyond the simple questions of number of cavities and type of trim tool and start asking ourselves, "Are we utilizing all the tooling options available to us today?" |*



# Texturing and Engraving for Thermoforming Molds

Jack Hill and Pete Kambouris  
Wisconsin Engraving Company / UNITEX

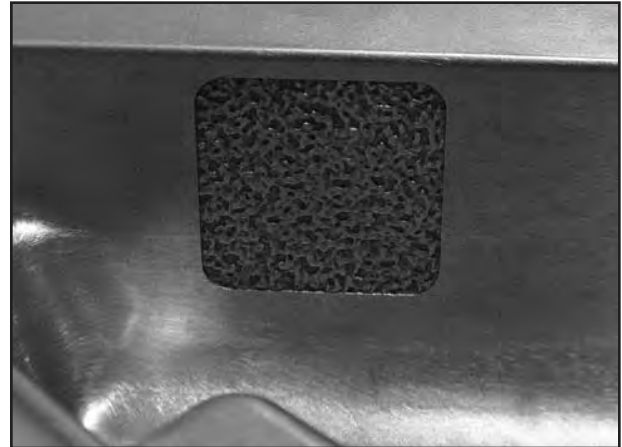
**T**he look and feel of quality has a significant impact on the marketing appeal of a plastic part whether it a package or a product. In today's competitive marketplace, making a product stand out from its competition is critical in the race to win sales.

Texturing of thermoform molds can add features including the look of simulated leather, the feel of a geometric grain, the sheen of a multi-gloss pattern or even gloss control. Detailed engraving of logos, recycling codes, part numbers and cavity identification can be incorporated into all surfaces adding quality and structure to the part.

### **Thin-Gauge Mold Applications**

Multi-cavity molds can be engraved by hand, by chemical etching (Chem-Grave®), by EDM (Electronic Discharge Machine), by CNC or by using a pantograph. Artwork for the engraving, typically of logos, cavity identifications, recycle codes or part numbers, can be sent electronically or by supplying camera ready artwork. Unless the part is pressure formed, the thermoforming process does not always pick up all the details of the engraving (unlike injection molding) it is always best to have clean, crisp, detailed artwork in the tooling. A high quality engraving facility will have the capabilities to offer multiple ways of engraving your tooling. Also, the engraver should have knowledge of how deep an engraving should be in the tooling to maximize quality and readability after a part has been formed.

When texturing aluminum tooling, you must first start by determining what type of pattern is desired. In order to properly pick a texture for your project, a texture house should be consulted to determine if the tooling is designed to handle the requested



*Textured area on tray mold sidewall is used to block out printing on the contents*

specification. The most important factor in specifying a texture is the draft requirement. Not having enough draft in your tooling will cause a part to stick or scuff upon ejection from the mold. The general rule of thumb is 1.5 degrees of draft per every 0.001" of texture depth. Other important considerations when dealing with draft include material shrink rate and whether or not the vertical wall is an inside or outside wall.

Vacuum holes require unique processing to ensure they do not become damaged during texturing. It is preferable that the vacuum holes be drilled in after texturing, though that is not always possible.

Where gloss (measured by the amount of light reflected off the part) is important, texturing can be used to provide the desired affect. For example, a leather or matte finish will reduce gloss. However, the color and type of plastic, mold surface (cast or machined), mold hardness, venting and forming pressure will all have an effect on the gloss of the part. By letting the texture house know ahead of time what type of plastic material is being molded, they can usually supply the proper gloss on the surface of the tool. Gloss can be adjusted after the tool has been sampled.





*Textured with woodgrain*

## **Heavy-Gauge Mold Applications**

Using the above methods, texturing or engraving of solid aluminum castings or cast aluminum cavities can be easily done on cavity sidewalls or cavity bottoms. As with thin gauge molds, chemical etching (Chem-Grave®), EDM, pantograph, CNC and manual engraving methods can be employed. Surface finishing with glass bead or vapor blasting is common. Where mold surfaces have been welded, a skilled engraver can machine the weld and blend it into the original surface. If the tool needs to be textured in an area that has been welded, special care has to be taken both by the welder and the texture house. If not approached properly, the welded area will stand out visually after texturing.

## **Determining the Optimal Process**

After studying the project in question, an engraver should be able to judge the best method for engraving your molds. Certain criteria such as depth, location



*Close-up of deer engraving*

and character width will determine if the engraver will use the chemical etch (Chem-Grave®), EDM, pantograph or CNC method. Always be sure to provide the highest quality artwork available for details such as logos. Failure to do so can result in additional costs.



*Preparing for texture*

Pricing of the texturing and engraving process is determined by the complexity of the texture pattern (random or geometric, depth tolerance), mold material and complexity of the mold (size, tool components, area to be textured and accessibility of textured areas). Delivery also plays a role in pricing. Because texturing and engraving is commonly the last process before production, communication between the processor and the texturing / engraving vendor is critical to ensure there is enough time available to provide a quality product. In order to give your parts the look and feel of a quality product, the mold engravers should be a part of any decision on tool design for thermoforming. |



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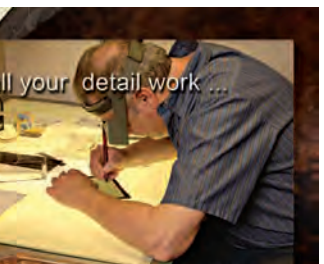


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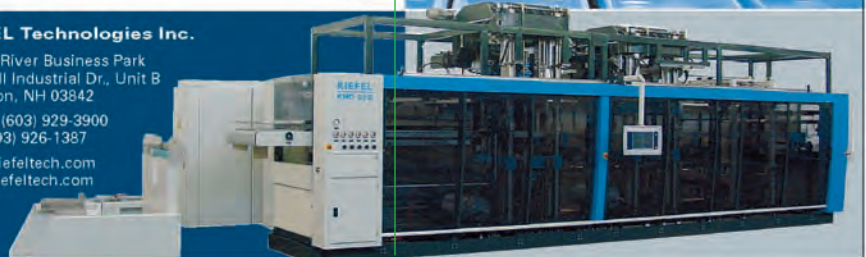
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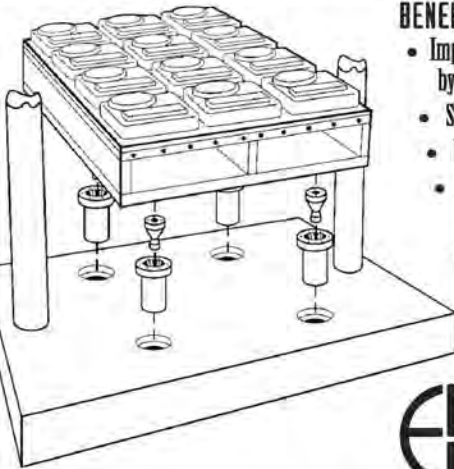
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Ken Darby  
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### **3<sup>rd</sup> European Thermoforming Parts Competition**

On behalf of the Society of Plastics Engineers – European Thermoforming Division, thermoformers are invited to participate in the 3<sup>rd</sup> European Thermoforming Parts Competition from 23 – 24 April 2010 in Antwerp, Belgium. Originality, creativity, mould complexity and technical ability will be the judging criteria in order to promote advanced design and developments from a structural innovation perspective.

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The 2-day conference will be held in Antwerp from 23 – 24 April 2010. More details are available at [www.e-t-d.org](http://www.e-t-d.org).

*Information about the Conference and the Parts Competition may be obtained from Yetty Pauwels*  
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## Processing Costs and Environmental Impact of Bio-plastics

Julius Vogel, Iowa State University, Materials Science and Engineering; Dr. David Grewell, Rob Anex, Iowa State University, Agricultural and Biosystems Engineering

### *Abstract*

This work studied bio-plastics such as polylactic acid (PLA) and protein based plastics from corn and compared to petroleum based plastics such polyethylene (PE) and polystyrene in terms of their ecological as well as economical performance from a “Cradle to Grave” perspective. This study included energy input, emissions output of green house gases and costs from their life cycle steps of raw material acquisition to the final product disposal. It was found that products manufactured from bio-based feedstocks were relatively higher in cost, they resulted in less green house gas emissions.

### *Introduction*

An increased interest in bio-plastics due to ecological as well as economical concerns has promoted interest in analysis of their performance from a “Cradle to Grave” perspective. While there are ASTM standard methods for Life Cycle Analysis (LCA) [1] the complexity of these models require significant assumption or the collection of an enormous amount of data. This report takes a simpler approach and only considers the direct energy, costs and green house gas emissions. For example, in the study for PLA the emission of green house gases during harvesting of the corn, transportation of the corn, processing of the corn to PLA, manufacturing and disposing products is included.

There are several additional driving forces for the increased interest in bio-polymers. These include, e.g., the limited volume and acceptance of landfill, the negative public image of plastics, which are considered as a threat to the environment, and the ambitions to return to a carbon neutral economy.

However, even if bio-plastics are environmentally preferable, they will not be commercially used to replace petroleum based plastics unless they are economically viable. Thus, the two goals of this study are to compare the bio-based and petrochemical plastics and to identify any specific barriers for adoption of bioplastics. This report is based on numerous published reports, articles and interviews and reflects a best effort of data collection.

### *Presented Materials*

Three polymers with similar application usage, namely packaging were chosen for this study, namely PLA, zein protein plastic and PE. While zein protein plastics are currently not commercialized it has potential

adoption by the packaging application. The potential supply of zein was estimated to be 750 million tons annually, while only one million pounds were used for speciality applications like pharmaceutical coatings food packaging [3].

The production of PLA includes the fermentation of dextrose or glucose -rich crops, such as corn or sugar cane which produces lactic acid, the monomer which is then polymerized to PLA [2].

Corn protein (zein) is found in the outer layer of the maize endosperm and makes up 4-5% of the total weight of the corn. It is available only as a co-product of the corn wet milling-, and recently from the dry milling-, process of the ethanol industry. By blending zein with an appropriate amount and type of solvents and plasticizer it can be used for extrusion, blow molding and injection molding [3,4,5].

Polyethylene is either produced from crude oil or natural gas. In distillation units the refinement of oil produces ethane among other co-products, which is then processed to ethene in a steam cracker which is reacted to polyethylene in a polymerization process resulting in PE pellets that can be shaped into a desired form going through processes such as extrusion, injection molding or blow molding [6]. It was shown that for the production of HDPE 80 MJ/kg are required, while 4.8 kg CO<sub>2</sub>/kg are produced [7]. Some mechanical properties of these plastics are compared in Table 1.

### *Methods*

The method used to compare energy consumption and CO<sub>2</sub>-equivalent emissions of the presented materials is an adopted version of the ASTM D 7075 – Standard Practice for Evaluating and Reporting Environmental Performance of Bio-based Products. This application of a “Life Cycle Analysis” (LCA) is a holistic environmental energy audit that considers the entire life cycle of a product. It is a tool to define the system boundaries of a manufacturing system and to quantify the flows crossing these system boundaries [8]. The energy consumption and emissions generation are summarized in the elementary Life Cycle Steps which are 1. Raw Material Acquisition; 2. Transportation; 3. Manufacturing; 4. Consumption; 5. End product treatment, where applicable.

The costs of the final parts are calculated according to a so called “Economic Engineering Approach”. This approach includes: (1) Description of the processing plant; (2) Determination of the process parameters; (3) Calculation of the processing costs on a “per part” (\$/part) or “per unit” (\$/kg) base. In detail, a representative model



process, such as injection molding, is chosen that is capable of producing consumer goods from all presented materials. In addition, the consideration of additional equipment is included for non-conventional plastics. For example, the processing of zein and soy proteins requires additional extrusion and pelletizing systems because these materials cannot be processed in their raw form.

The final cost of extrusion are calculated on a per mass basis (\$/kg) according to eq. (1).

$$C_{unit} = \frac{C_{equip} + C_{el} + C_{maint}}{M} \quad (1)$$

where:

- $C_{unit}$ : cost of material pellets "per unit" (\$/kg) base
- $C_{equip}$ : cost of process equipment including a mixer, extruder and pelletizer
- $C_{el}$ : cost of electricity
- $C_{maint}$ : maintenance cost
- $M$ : amount of material processed

The final cost of injection molded parts are calculated on a per part basis (\$/part) according to eq. (2):

$$C_{part} = C_{proc} + C_{mat} + C_{tool} \quad (2)$$

where:

- $C_{part}$ : cost of one part (\$/part)
- $C_{proc}$ : cost of processing one part; includes a injection molding machine, a grinder, the cost to run the equipment which includes maintenance cost, cost of electricity
- $C_{tool}$ : cost of a injection molding tool
- $C_{mat}$ : cost of material on a per unit base

The cost per part for each plastic are calculated according to market prices for processing equipment and raw material and are detailed in Figure 1. It is seen that for increasing production capacity the cost difference decreases. However, because of the relatively high material price of the corn protein zein, these parts are more expensive.

The final end product treatment includes 3 options. These are the beneficial effects of energy recovery through incineration or through methane recovery and material recovery through recycling and the non beneficial effect of landfill. Material recovery through recycling is not an option for protein plastics and PLA because these materials are currently not capable of being reused. Methane recovery is not an option for PE because of the slow degradation rate of this material. The financial and environmental effects of the end treatment are detailed as:

1. Landfill: the costs of landfill are estimated to be approximately \$120 - \$140/ton of waste and include the costs for the tipping fee, leachate control, decline of the surrounding property value for the landfill side [9].

2. Methane Recovery: in 2005 approximately 2.79 million tons of methane from waste was used for energy in the U.S. resulting in 1400 MW of electrical energy [10]. In addition 60 million tons of CO<sub>2</sub>-equivalent are

prevented, because of the combustion of the methane. The financial benefit is approximately \$980 million or \$0.0037/kg of waste. These costs and energy values are assumed to be valid for both PLA and protein plastics having a similar methane generation rate to MSW [11].

3. Municipal Solid Waste Incineration: The average heat value of MSW ranges 10 – 14 MJ/kg and the amount of electricity generated from burning one ton of municipal solid waste ranges from 0.5-0.6 MWh [12]. The CO<sub>2</sub>-equivalent emissions are approximately 0.926 tons per MWh electricity produced. Because the heat of the waste incineration can be used to produce electricity, is assumed to prevent CO<sub>2</sub>-equivalent emissions of 0.463 tons per ton of waste incinerated. The financial benefit from waste incineration can be calculated according eq. (3).

$$C_{MSWI} = E_{MSWI} \times h_i \times c_E \quad (3)$$

where:

- $E_{MSWI}$ : amount of electricity produced per ton MSW incinerated
- $C_{MSWI}$ : financial benefit from MSW incineration
- $c_E$ : cost of electricity
- $h_i$ : percentaged contribution to the heat value of MSW from each plastic type

The environmental benefit from waste incineration can be calculated according eq. (4).

$$CO_{2MSWI} = CO_{2FFI} \times E_{MSWI} \times h_i \quad (4)$$

where:

- $CO_{2MSWI}$ : amount of CO<sub>2</sub>-equivalent prevented through incineration of municipal solid waste
- $CO_{2FFI}$ : CO<sub>2</sub>-equivalent emission per MWh produced from fossil fuel incineration on a national fuel average

4. Material recovery: recycling of conventional plastic material has several beneficial effects, including conservation of oil and natural gas. Recycling is less energy demanding than the production of the virgin plastic and reduces the amount of required landfill space. Figure 2 details a "closed loop" recycling option as an end product treatment. Only a defined amount of plastic 'r', is recycled. Correspondingly, the non-recycled plastic which is landfilled or incinerated is denoted by '1-r'. The energy required for the production of the virgin material resin and the emission generation is defined as 'E<sub>v</sub>' and 'CO<sub>2v</sub>', respectively. The energy consumption and emissions for the production of recycled plastic is defined as 'E<sub>rec</sub>' and 'CO<sub>2rec</sub>'. The beneficial effect of recycling plastic can be expressed as a reduction of the energy demand and CO<sub>2</sub> emissions during its production. The energy and emission saving by producing recycled plastic can be calculated according to equation (5) and (6):

(continued on next page)



$$E_{sav} = E_v - (E_{rec} \times r + E_v \times (1-r)) \quad (5)$$

$$CO_{2sav} = CO_{2v} - (CO_{2rec} \times r + CO_{2v} \times (1-r)) \quad (6)$$

where:

$E_{rec}$ : average energy consumption of producing a recycled plastic resin per kg,  $E_{rec} = e * E_v$

$e$ : ratio of energy consumption for production of recycled material to virgin material

$E_v$ : energy demand to produce virgin plastic material

$r$ : recycling rate

$CO_{2rec}$ : average CO<sub>2</sub> emission of producing a recycled plastic resin per kg

$c$ : ratio of CO<sub>2</sub> emission for production of recycled material to virgin material

$CO_{2v}$ : CO<sub>2</sub> emission for production of virgin plastic material,  $CO_{2rec} = c * CO_{2v}$

The "Collecting and Processing" costs of recycling must also be considered. In a report entitled "Collecting and Recycling" these are costs estimated to be \$239/ton, while the cost of disposing are "only" \$132/ton [13].

The beneficial effect of recycling HDPE with its specific energy consumption (80 MJ/kg) and emissions creation (4.8 kg CO<sub>2</sub>/kg) during its production is detailed in Figure 3. It can be seen that for an increasing recycling rate the energy and emission savings increase. However, for a recycling rate of  $r=1$ , which is technically not possible, the savings are at maximum.

## Data Review and Collection

In a "Cradle to Gate" life cycle analysis on fermented products from corn it was shown that the raw material acquisition of corn, which includes all agricultural activities, produces 0.15 kg CO<sub>2</sub> emissions and absorbs 1.47 kg CO<sub>2</sub> during the growth of the plants. The energy consumed is 2.5 MJ/kg corn grains harvested. For the production of one kg glucose 1.46 kg corn are required, resulting in an absorption of 2.14 kg CO<sub>2</sub>/kg glucose produced. The process of glucose production requires 4.9 MJ/kg of energy input while 0.35 kg CO<sub>2</sub> are set free. The overall energy balance of glucose production results in 7.5 MJ/kg, while the emissions balance is -1.79 kg CO<sub>2</sub> [14]. In a "Cradle to Factory Gate" analysis conducted for PLA by the "European Science and Technology Observatory", the overall energy consumption for PLA production was reported to be 54.1 MJ/kg, while the fermentation process and lactic acid production consumed most of the energy, 36 MJ/kg (see Figure 4). The overall emissions are 1.8 kg CO<sub>2</sub>-equivalent per kg PLA, while the market price is approximately \$3.40/kg [15].

Because the raw material for zein is corn, the same as for PLA, the raw material acquisition consumes 2.5 MJ/kg while 1.32 kg CO<sub>2</sub> are absorbed. The transportation of corn from storage facilities to ethanol plants required an additional 0.234 MJ/kg [16]. Zein is primarily produced in

the corn wet milling process, where it is extracted from the corn gluten meal. According to the net energy balance of nine major corn producing states 34% of the energy consumed for ethanol production can be allocated to co-products, such as corn gluten meal which would be 2.23 MJ/kg [17]. The utility costs for of the zein extraction from corn gluten is \$0.044/kg zein and CO<sub>2</sub>-equivalent emission of 1.54 kg per kg zein produced [18]. Because there is no clear cost for zein cost, the summarized data for energy consumption is detailed in a "high" and "low" scenario based on the weight ratio of zein. In corn wet milling plants the production can be shifted according to market prices of each co-product and the energy must be allocated according to the energy requirements for the production of those materials, the co-products would replace. The accumulated emissions for the production of zein are estimated according to the national fuel average with 0.57 kg CO<sub>2</sub>-equivalent per kg zein. Additionally ethanol and glycerol need to be added to the material formulation of zein with its specific energy consumption and emissions generations [16]. The energy consumption for PLA and zein are detailed in Figure 4 and Figure 5 respectively. The energy consumption and emissions generation for the production of PLA, zein and PE are shown in Figure 6. It is to see that energy consumption and emission generation are almost proportional to each other, because energy is produced mostly through the combustion of fossil fuels.

## Conclusions

It is seen that for both bioplastics (zein and PLA) the emissions as well as the energy demand for the production are lower that for HDPE. However, because of the higher material price and because of the additional process steps of extrusion and pelletizing, zein is significantly more expensive than PE and PLA. The high cost of zein plastic parts will prevent its commercial application as long as it is financially not viable to produce parts from zein instead of petroleum based plastics. Because of that more research is needed to improve its mechanical properties to make it more competitive with established plastic types as well as new applications need to be found.

While the "cost per part" of PLA is higher than for PE, this plastic is superior in its mechanical performance. Having a low density of 1.25 g/cm<sup>3</sup> and a strength of 70 MPa, while it has good gas barrier properties and high moisture resistance make it comparable to plastics such as PET which has a density of 1.35 g/cm<sup>3</sup> [2] and is higher in its value compared to PE.

## Acknowledgements

Thanks goes to the USDA - Office of Energy Policy and New Uses for support of this work. |



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Table 1 Mechanical properties of compared plastics [2, 3, 4, 5, 19]; \*for ultrasonic compacted zein, \*\* casted zein films

	PLA	Zein	HDPE
Strength [MPa]	70	12* 10.9-22**	18-35
Modulus [GPa]	3.6	0.55	0.7-1.4
Density [g/cm <sup>3</sup> ]	1.25		0.94-0.96
Price [\$/kg]	3.4	10	2.2

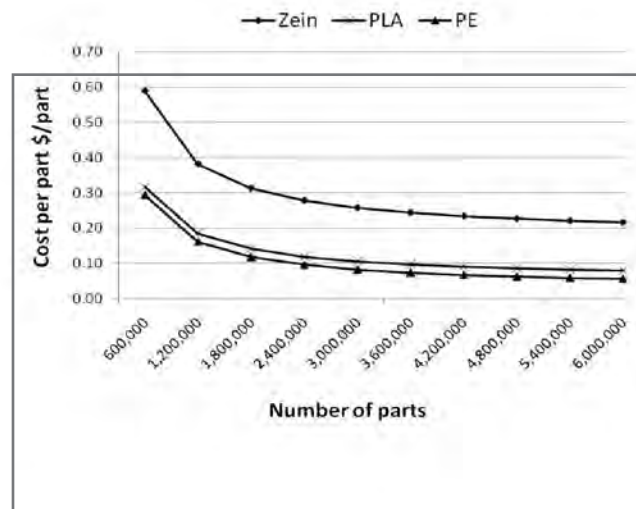


Figure 1. Cost per part comparison.

*(continued on next page)*

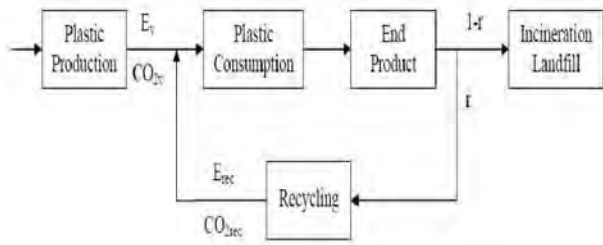


Figure 2. Flow chart of recycling as end product treatment.

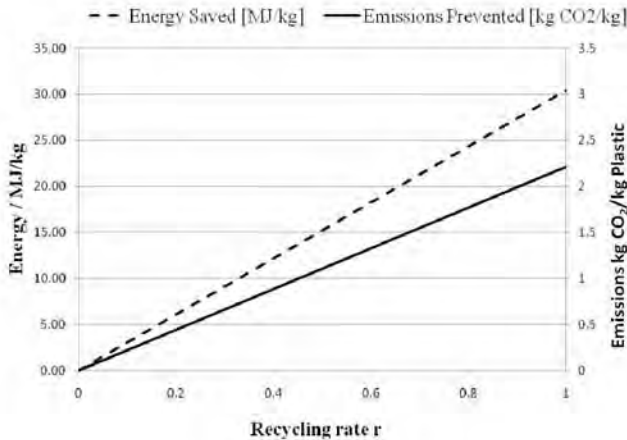


Figure 3. Energy and emission savings from recycling.

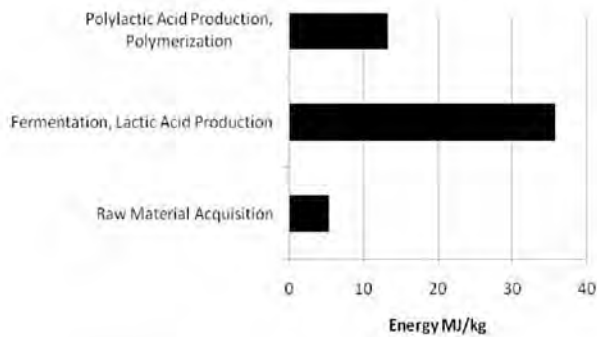


Figure 4. Energy consumption of PLA production.

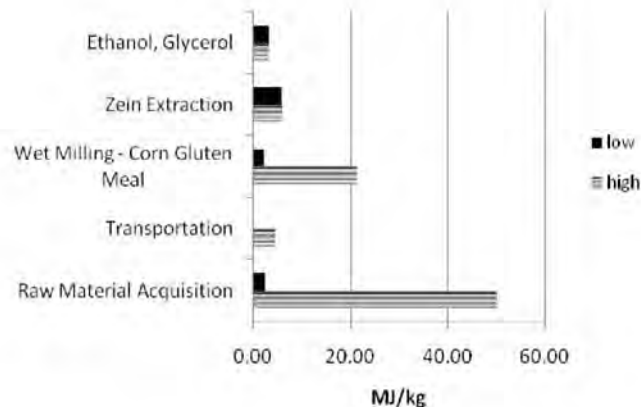


Figure 5. Energy consumption of zein production.

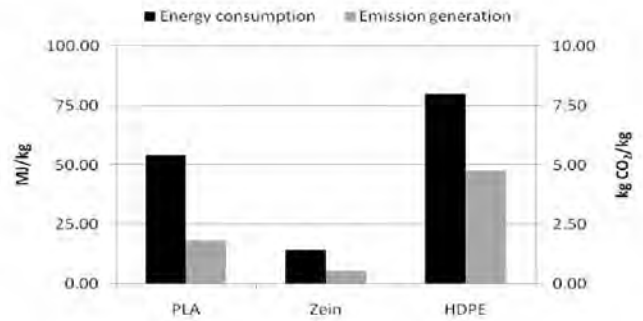


Figure 6. Energy consumption and CO<sub>2</sub> emission of plastic production.

**Key Words:** Life Cycle Analysis, Bio-plastics, zein, PLA, Cradle to Grave Analysis

(This paper was first presented at ANTEC 2009. The editors wish to thank both the authors and the organizers for giving us permission to reprint the article in Thermoforming Quarterly.)



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**Roger Kipp**  
Councilor

# COUNCIL SUMMARY



The June council meeting was held in Chicago prior to ANTEC and NPE. I was pleased to attend representing the Thermoforming Division at the division meeting, foundation meeting, communications committee meeting, as well as council. The following is a summary of the council meeting. If you have any questions, please feel free to contact me.

## ANTEC

ANTEC was 1,312 with the combined ANTEC at NPE total reaching 44,000. A total of 66 registrants attended eight Society seminars.

Incoming President Paul Andersen's SPE mantra is: "*Seize the Opportunity.*" An edited version of his speech will appear as an editorial in the July/August issue of *Plastics Engineering*.

## Council Meeting

Council observed a moment of silence in honor of long-time councilor Elliot Weinberg and 1956 SPE President Jerry Formo.

## Bylaws & Policies

Bylaws 6.2.2 and 6.2.3 pertaining to Council Meeting Times and Places and Quorums at Council Meetings were approved as distributed. The changes were effective immediately to allow electronic participation at the Council meeting.

Bylaws 5.1, 5.3 and 5.4 pertaining to Annual Meetings, Special Business Meetings and Quorums at those meetings were approved as distributed. The changes were effective immediately to allow electronic participation at the Annual Meeting and Special Business Meeting.

Bylaw 14.7 pertaining to Participation and Voting was approved

as distributed. Bylaw 14.7 allows electronic participation for Society-level committee meetings. It also states that if the committee votes via a paper or electronic ballot, the identity of the voter relative to his/her vote may not be identifiable to any SPE member.

Council approved the following previously read and published Bylaw and Policy changes: 6.1.3 pertaining to Council to take effect at the end of the meeting; 7.1 pertaining to Officers of the Society; 7.5.5 pertaining to the Staggering of Terms; 14.7.1.1 pertaining to the Executive Committee Membership. Council approved as amended Policy 022 pertaining to Vice Presidential Transition. The amendment allows this transition to begin in 2009-2010.

Council approved changes to Bylaws 4.3.12 and 4.3.13 pertaining to election of Fellows of the Society and Honored Service Members. Since this was a first reading, these changes will be published in *Plastics Engineering* and read again at the next Council meeting for final approval. The amendments allow Special Interest Groups to nominate Fellows and Honored Service Members.

Policy 012 pertaining to Disciplinary Review was approved as distributed.

The full text of these Bylaws and Policies can be found on the SPE Council meeting extranet.

## Executive Director Report & Staff Update

SPE staff continues to work through a host of new projects and initiatives to keep SPE current and competitive in the information marketplace.

## Staff Restructuring

SPE underwent a planned staff restructuring in the first quarter of 2009. Overall full-time staff was reduced from 26 in early 2008 to 15 as of this writing.

## Building Sale

The SPE headquarters building sale

closed on June 30, 2009. SPE moved its offices into roughly 3,700 square feet in Newtown, CT. At the present time, SPE's P.O. Box and phone numbers will not change.

## General Financial Condition

Incomes have stabilized somewhat, but at a very depressed level. Registrations for events, book sales and seminars have all been hit hard in the first quarter of this year. Membership likewise is continuing to decline. SPE is more reliant on its contracted publishing revenues and incomes from NPE in 2009.

## Overall Membership

Overall membership as of June 1, 2009, is 16,039. Membership acquisition numbers continue to trail 2008 rates due to budget challenges at SPE and the continuing global economic situation, which is particularly acute in many of the industries SPE serves.

## Corporate Affiliate Program

The Corporate Outreach Committee worked last year to develop a program to provide companies with an exclusive opportunity to gain recognition within the plastics industry through the Society. The Corporate Affiliate Program is being officially announced at ANTEC@NPE.

## Technical Volumes Program

Two of the most important publishers of technical volumes on the subjects of plastics and polymers, Hanser and Wiley, have joined forces with SPE to rejuvenate this program that provides royalty income to SPE every year in exchange for encouraging SPE members to publish new volumes.

## Plastics Engineering Website

Wiley and Sons, Inc. has taken over the publishing responsibilities for SPE's *Plastics Engineering* magazine, and intends to develop an all-new web presence for the publication at [www.plasticsengineering.com](http://www.plasticsengineering.com). The arrange-



ment with Wiley will help make *PE* more cost neutral for the next two years. The savings generated will begin to hit SPE's books in June.

### ANTEC® 2010

ANTEC will be held at the Orlando World Center Marriott Resort and Convention Center in Orlando, Florida, May 16-20. Wiley has agreed in principle to sell ANTEC 2010 exhibition space. Negotiations are underway.

### Virtual Conference

SPE's first virtual conference on failure analysis and prevention was postponed because of low registration. The event has been repositioned as a Virtual Processors Conference, and will be held October 1-2, 2009.

### e-Live® Webinars

These presentations performed moderately well through Q1 and Q2, garnering \$38,400 in sales to date. This compares unfavorably (down from \$44K) with the same period in 2008. Attendance has ranged from 4 to 42.

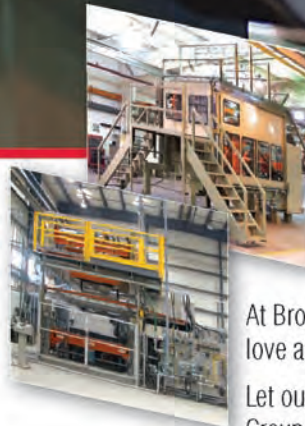
### SPE Foundation Update

Gail Bristol reported on the financial health of the SPE Foundation. The SPE Foundation awarded \$138,500 in scholarships to 33 students in 2008.

Foundation grants totaling \$16,700 were made in 2008. At their April 2009 meeting, the Foundation Board approved two new grants totaling \$5,306 for Rochester Institute of Technology and Georgia Southern University. RIT's grant will help cover the development of a biodegradability testing laboratory. The Georgia Southern grant will cover the purchase of training materials for their composites program.

Outgoing President Bill O'Connell thanked his Executive Committee for their hard work. Incoming President Paul Andersen introduced his Executive Committee. New Executive Committee Vice Presidents are: Russell Broome and Brent Strong. Vijay Boolani is the 2009-2010 Secretary and James Griffing is the 2009-2010 Treasurer. |

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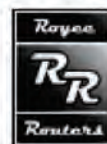
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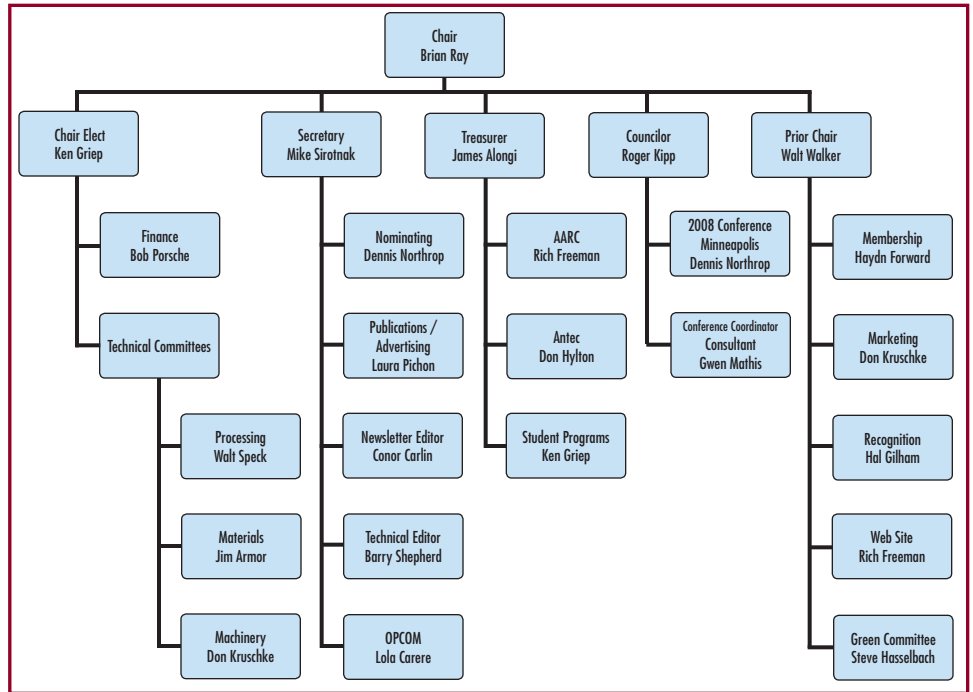
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