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Plastics Technology®

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Gains in Drains

AWD Relies on Flexibility and Innovation To Provide a Host of Drainage Solutions

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Plastics Technology

ABOUT THE COVER AWD blends extrusion and thermoforming technologies to manufacture geocomposite sheet drain products. See cover story on page 36. Photo Source: AWD

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Plastics Technology®

ptonline.com @plastechmag

PUBLISHER Jeff Sloan
jsloan@gardnerweb.com

EDITOR-IN-CHIEF Tony Deligio
tdeligio@ptonline.com

ASSOCIATE PUBLISHER/ EDITORIAL DIRECTOR Jim Callari
jcallari@ptonline.com

ASSOCIATE EDITOR Matthew Stonecash
mstonecash@ptonline.com

MANAGING EDITOR Angela Osborne
aosborne@gardnerweb.com

CONTRIBUTING EDITORS Matthew Naitove
mnaitove@gmail.com
Lilli Manolis Sherman
lillisherman17@gmail.com

SENIOR CONTENT MANAGER Sarah Barnett
sbarnett@gardnerweb.com

ADVERTISING SALES Jackie Dalzell
jdalzell@ptonline.com
Dale Jackman
djackman@gardnerweb.com
Madeline Kline Peters
madeline.kline@gardnerweb.com

ART DIRECTOR Sheri Kuchta Briggs
sbriggs@gardnerweb.com

MARKETING MANAGER Andrew Roe
aroe@gardnerweb.com

AD PRODUCTION COORDINATOR Patty Caldwell
pcaldwell@gardnerweb.com

Subscription Inquiries: For questions or issues related to your subscription, please call 513-527-8800 or email subscribe@ptonline.com.

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GARDNER Business Media, Inc.
6915 Valley Avenue
Cincinnati, OH 45244-3029
Phone 513-527-8800
Fax 513-527-8801
gardnerweb.com

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Maintaining Constant Content Contact

Plastics Technology has installed a 'content gate' on its premium articles online. What does that mean and why should you care?

Remember reader service cards? For our younger audience, there was a time when magazine subscribers could request everything from free product samples to printed marketing materials from advertisers in a particular issue of a magazine. All they had to do was locate the reader service number on a display ad; fill in the corresponding numbered oval on the card; drop the piece of prepaid postage in the mail; and wait to hear back from all the companies they circled.

Tony Deligio
Editor-in-Chief

These cards, of course, in a pre-World Wide Web world, simplified the task of learning about various companies and their products at a time when the only other way to do so would be through printed advertisements and articles about them, or physically visiting with that business at a trade show or maybe in a local showroom or tech center. As the web grew and companies enhanced their online presence, the reader service card was relegated to marketing's trash heap of obsolescence.

In the years since, websites and an overall digital presence have only grown in importance in all manner of industries, including for the publishers that formerly supplied those reader service cards. If you're reading this in print — unless a colleague passed along the magazine to you — you're likely a qualified subscriber who has agreed to share some of your demographic data with us in return for a free subscription (pretty sweet deal!). Every month, you know your mailbox will deliver important information about the industry you're working in.

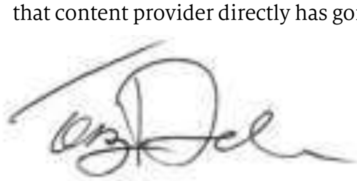
If, however, you're reading this online, unless a future search brings you back to our site — and we do try to write our content and structure our stories in ways that will — you might miss out on relevant future articles. Missing out could occur because of the vagaries of online search or because these days search engines and newer technologies like generative AI scrape publications for "answers" to users' queries, with mixed results. Instead of pointing users directly to expert content sources, they serve up a mishmash of content cobbled together from across the web or a response that quite often plagiarizes the original source material.

As the nature of search and online media change, *Plastics Technology* is changing as well to better serve our community. Source: Getty Images

This dynamic is one reason why on October 1, *Plastics Technology* implemented a content gate. What does that mean? Well, for our unique articles that are based on the reporting of our experienced staff or curated from expert industry sources, we'll ask that site visitors share some demographic information about themselves before being granted free access to the full article. Chances are, if a search query brought you to *PT* once, there will be future content at *PTonline* that will also be of interest.

Also, by sharing some demographic data for free content (again, pretty sweet deal!), you can allow us in the future to serve you only the most relevant articles and advertising. Inboxes are so very, very full, and we want to ensure we're not contributing to your overstuffed email with articles and ads that don't interest you.

In the same way that filling out the old "bingo" cards with companies you want to receive more information about seems quaint, consuming content from websites you trust without connecting with that content provider directly has gone the way of the fax machine.



Apollo Funds To Acquire Barnes Group

Barnes Group — which starting with the 2012 acquisition of Synventive Molding Solutions went on a six-company buying spree in injection molding technology over the proceeding five years — is being acquired by Apollo Funds for $3.6 billion. Barnes Group is divided between aerospace and industrial, with Molding Solutions falling under the industrial umbrella along with automation, and force and motion control businesses. In its most recently reported financial results for the second quarter of 2024, the company generated sales of $382 million, up 13% compared to the year-ago period.

Barnes began building out its Molding Solutions business in 2012, with the acquisition of hot runner supplier Synventive Molding Solutions for $335 million. Over the next five years, it went on to acquire a mix of hot runner, mold, and injection molding sensing and process monitoring businesses, with the purchases of männer, Foboha, Thermoplay, Gammaflux and Priamus.

After Synventive, männer was acquired in 2013 for €275 million, with Thermoplay purchased in 2015 for €50 million. Priamus was purchased the same year, with the acquisition of Foboha completed in 2016 for CHF 133 million. The plastics acquisition spree ended in 2017 with the purchase of Gammaflux.

The agreement holds that Barnes shareholders will receive $47.50 per share in cash, with that price representing a premium of approximately 22% over Barnes' undisturbed closing share price on June 25, 2024. The transaction is expected to close before the end of the first quarter of 2025, subject to customary closing conditions, including approval by Barnes shareholders and required regulatory approvals.

In April 2022, Apollo Funds acquired a majority stake in plastics packaging manufacturer Novolex. A year prior, it acquired automotive plastics supplier ABC Technologies, with capabilities in injection molding, blow molding and extrusion.

Leadership Changes at Husky

Husky Technologies, Bolton, Ontario, announced that longtime company CEO John Galt has transitioned to the role of chairman, and Husky COO Bradley Selleck became CEO, effective Oct. 1.

Husky, a portfolio company of Platinum Equity, is a global provider of injection molding technologies, including molding machines, hot runners and tooling that primarily target the beverage, consumer goods and medical device markets. Platinum completed the acquisition of Husky from Berkshire Partners and OMERS Private Equity in March 2018 for $3.85 billion.

Galt joined Husky in 1985 and was appointed CEO in 2005. Over that time, Husky says Galt has "played a pivotal role growing the business from its early days as a founder-led creative enterprise into a global industrial leader."

Selleck joined Husky in 2022 with over 25 years of experience in operations, supply chain and quality for large-scale global industrial firms, including L3Harris, United Technologies and Otis Elevator.

Abu Dhabi's ADNOC To Acquire Covestro

An investment agreement has been signed by Covestro with certain entities of ADNOC (Abu Dhabi National Oil Company) Group, including ADNOC International Ltd. (ADNOC International) and its subsidiary, ADNOC International Germany Holding AG (bidder). When this transaction is finalized, two Middle Eastern companies — SABIC and ADNOC — will control a big chunk of engineering thermoplastics. Covestro's major engineering thermoplastics include Makrolon PC, Apec high-heat PC and Makroblend PC/PBT blends, as well as the Texin and Desmopan family of TPU resins and composites technologies.

The signed agreement stipulates, among other items, that the bidder will make a public takeover offer for all outstanding shares of Covestro at a price of €62 per share. In addition, ADNOC International is committing itself to fully supporting the company's "Sustainable Future" strategy. At the same time, the board of management and the supervisory board of Covestro decided that upon completion of the transaction, the company's share capital shall be increased by 10% (18,900,000 shares) and that, at and subject to closing, the new shares shall be issued to the bidder against payment of a price per share equal to the offer price, thus, based on an offer price of €62 against a total amount of €1.17 billion, under simplified exclusion of subscription rights. Shareholders benefit from a premium of 54% on the unaffected share price, prior to any media coverage of a potential transaction.

In a press release, Covestro's CEO Dr. Markus Steilemann stated, "We are convinced that the agreement reached with ADNOC International is in the best interest of Covestro, our employees, our shareholders and all other stakeholders."

Techmer PM Acquires OptiColor

Techmer PM has acquired OptiColor Inc., a full-service color compounder specializing in color concentrates and masterbatches for critical applications. The acquisition is designed to further bolster Techmer PM's position as a leading supplier of colorants and additives for the plastics industry.

Established in Huntington Beach, California, in 1995, OptiColor has expertise in compounding custom concentrates, precolored materials and specialty dyes into transparent, translucent, opaque, clear, white and color products for critical applications, including performance eyewear, military lasers and sustainable lighting solutions.

Jennifer Bryan, who has been with OptiColor since 2012 and became president and CEO when she acquired the company in 2021, has been in the industry for more than 30 years. She will join Techmer PM as vice president of technical sales for optics, laser, lighting and sheet.

The addition of OptiColor follows Techmer PM's successful 2023 acquisition of Advanced Color Technologies, and the company continues to look to expand its offerings in technical, innovation-driven markets through acquisitions.

First Water Bottles With Ultrathin Glass Coating

German spring water and soft drink producer Vilsa Brunnen Otto Rodekohr GmbH has achieved what's said to be a world first by demonstrating that even mineral water can benefit from a wafer-thin glass coating inside PET bottles. The company supplies premium mineral water containing various levels of carbonation, as well as fruit spritzers, soda pop and "near water" (flavored water) beverages. Vilsa is particularly proud of the pure, natural flavor of its spring water afforded by its pH and "gentle," low-sodium mineral content. According to a Vilsa source, the extra barrier provided by the interior glass coating preserves carbonation and also prevents introduction of off-flavors — such as from acetaldehyde in the PET. In addition, Vilsa's fruit spritzers benefit from oxygen protection provided by the glass coating.

In 2019, Vilsa switched all its nonreturnable bottles to rPET. Adding the coating technology furthers the company's drive for sustainability, because the glass coating — unlike the use of additives to improve PET barrier — enables full bottle-to-bottle recycling as the interior coating is completely washed off during the reclaim process. Consequently, the company has adopted interior glass coatings for all its nonreturnable PET containers from 0.5 to 1.5 L. The first coated bottles were distributed to retailers this autumn.

At its mineral-water plant in Bruchhausen-Vilsen in Lower Saxony, Vilsa installed the latest-generation KHS innoPET Blomax stretch-blow molder. That unit was later combined with a KHS FreshSafe PET Plasmax barrier unit to form an InnoPET FreshSafe block. After stretch-blowing, cooling and transfer, the PET bottles are interior coated according to the Plasmax PICVD (plasma impulse chemical vapor deposition) process, which was first used in the pharmaceutical industry. The bottles are turned upside down and passed into the coating chamber, where a reaction gas mixture is introduced into the bottles in a vacuum and is then transformed into a plasma (ionized) state by microwaves. The result is a deposit of silicon dioxide (glass) inside the container — the coating is less than 0.1 micron (100 nm) thick and chemically bonded to the inside wall. The coating is completely transparent and flexible, so it will not flake off when the bottle is flexed, according to KHS. The coating separates from the PET only in the recycling process.

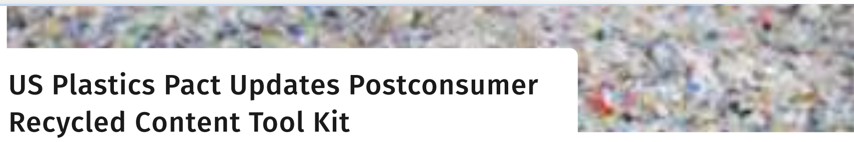
PCE Adding Space To Help European Suppliers Enter US Market

The Polymer Center of Excellence (PCE) is expanding its facility in Charlotte, North Carolina by 12,000 ft.^{2} and is creating a "nesting strategy" to help European companies enter the U.S. market.

The new add-on will consist of six, fully furnished 10 × 10 offices, which PCE is offering for lease. Companies will also have access to PCE's lab for its equipment, along with support services and a conference room. PCE stresses they are not looking to attract startups but "existing companies in Germany, Switzerland, Austria and Italy that have a proven product but have no office in the U.S."

The PCE has one signed lease already. The expansion is expected to be completed by mid-November.

The PCE assists companies in the polymer and plastics industry with research and development, toll compounding, injection molding and material testing.



US Plastics Pact Updates Postconsumer Recycled Content Tool Kit

The U.S. Plastics Pact has updated its Postconsumer Recycled Content (PCR) tool kit. The tool kit is aimed at making it easier to switch toward use of recycled resin in manufacturing. The update emphasizes collaboration among cross-functional stakeholders — such as procurement, R&D and corporate sustainability — who often have competing priorities such as sustainability commitments and cost control. The tool kit offers guidance on bringing these teams together to procure and qualify PCR, even when their goals initially seem misaligned.

A new section for consumers explains PCR in more straightforward terms to raise awareness and understanding among the broader public. From 2020 to 2022, U.S. Pact Activators increased their PCR usage from 7% to 9%, showing progress toward sustainability goals. According to the Association for Plastics Recyclers (APR), PCR can decrease carbon emissions by up to 70%.

The tool kit offers guidance, case studies and strategies for addressing environmental challenges and proactively managing risk for businesses working to reduce their reliance on virgin plastics and integrate more recycled content into their operations.

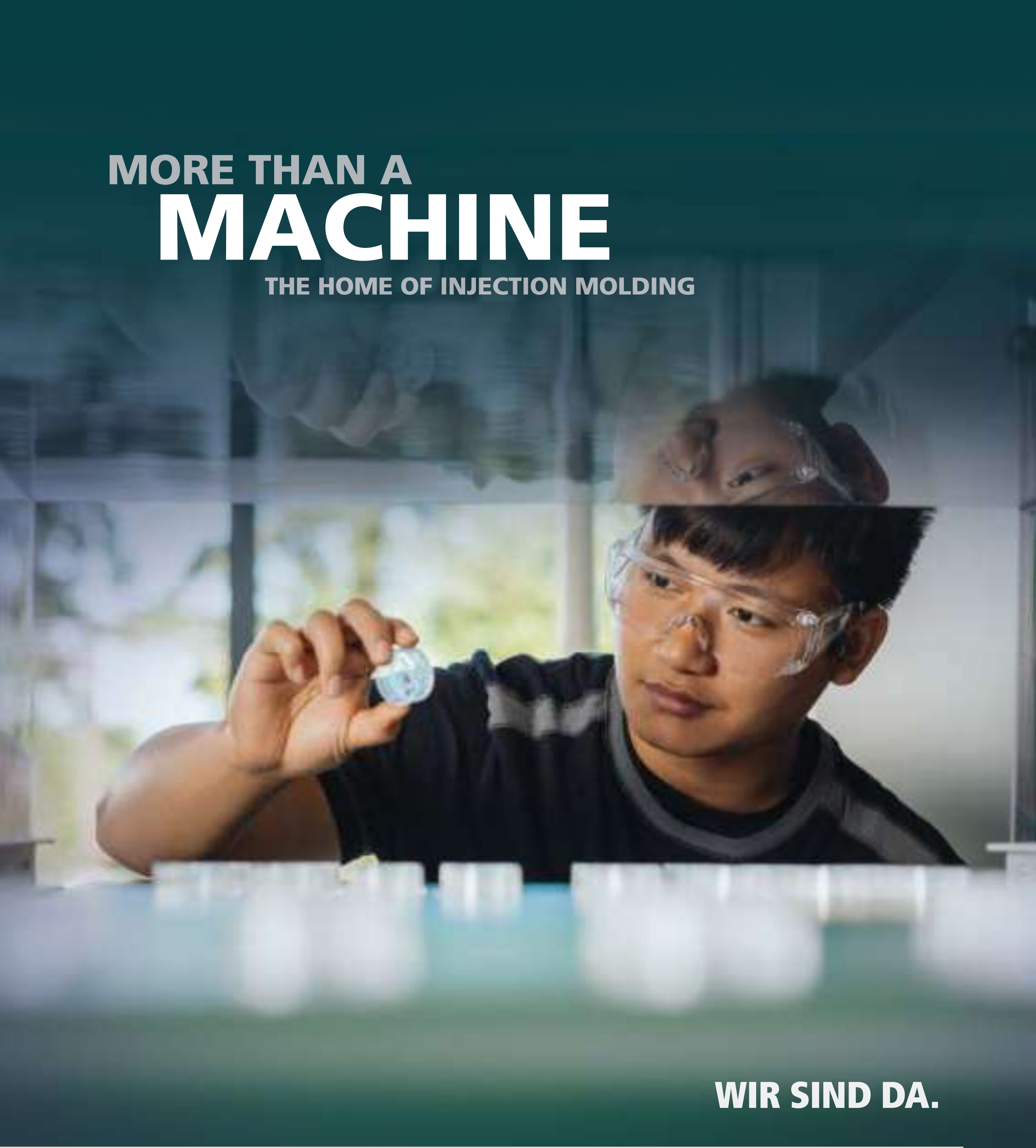
In Memoriam: Blown Film Specialist Eric Hatfield

Eric Hatfield, considered by many to be one of the top technical minds in blown film extrusion, passed away recently due to complications from Parkinson's disease. He was 67.

A graduate of the Illinois Institute of Technology with a bachelor's degree in chemical engineering, Hatfield's career in film extrusion spanned five decades. He held technical and engineering positions for companies such as James River, Clopay, Novolex and Charter Next Generation. He was also co-founder of two companies, FlexTech Packaging Ltd. and MDO Engineering, both of Cincinnati.

At FlexTech, Hatfield became one of the first advocates of utilizing machine direction orientation (MDO) technology to improve blown film properties and yield. He was also an expert in blown film die design, and in fact wrote two articles for *Plastics Technology* on that subject in 2010 that are still relevant today and available on **PTOnline.com**.

Rick von Kraus is a longtime blown-film machinery executive who co-founded Addex Inc., where he still serves as chairman of the board. The first time von Kraus encountered Hatfield was when the latter worked for James River in Indiana, and they kept in touch from time to time. He recalls their last enounter: "Just a few weeks before he left us, he asked me whether I could help find venues for his presentations on MDO technology and another of his creations, the Green Dog die. The latter was a concept of a multilayer die that Eric discussed with (us) … in 1997. Eric wanted to have one more chance to share his acquired knowledge. But Parkinson's wouldn't allow it."


MORE THAN A
MACHINE
THE HOME OF INJECTION MOLDING
WIR SIND DA.

Circular Network for Returnable Cosmetics and Personal Care Bottles

A consortium has emerged in Germany to provide brands and consumers of cosmetics and personal care products with a closed-loop circular system to collect and reuse glass and plastic bottles, and recycle the caps and pumps. The network of brand owners, bottle and cap makers, and recyclers is called “zerooo.” It was started in 2020 by German startup SEA ME, which was launched the year before to produce and market a variety of hand, face and body care lotions, dishwashing detergents, hand soap, shampoos and more in a sustainable manner. Shortly after its launch, SEA ME sought to enlist other brands in its circular packaging system, dubbed zerooo.

SEA ME enlisted plastic packaging and recycling specialist ALPLA Group in Austria as well as glass bottle makers to design and develop standardized 300-ml (10.1-ounce) returnable/reusable PET bottles, and 250-ml and 50-ml reusable glass bottles and jars — all in clear, milky white and brown versions. Other partners in zerooo are 900-plus retailers and hotels that provide consumer drop-off points to collect empty containers for return to brand owners for refilling; as well as recyclers for the caps and pumps — which are designed as monomaterial PP for easier recycling. Another key element is a laser-engraved 2D data matrix code that provides information on the contents of each bottle and its history of use and reuse. A bottle cleaning system for reuse was also developed by and for zerooo partners.

Stock PET bottles, made by ALPLA, are the newest additions to the zerooo system. Initially available in Germany and Austria, these PET bottles (as well as glass containers) are used by SEA ME and at least six other brands in the zerooo network.

Record Number of Industrial Robots in Use on US Factory Floors

The International Federation of Robotics’ (IFR) new World Robotics report registered 381,964 industrial robots in use on U.S. factory floors in 2023 — an increase of 10% over the prior year. The report stated that annual installations reached 37,587 units in 2023, down 5% but still making it the third best result in U.S. history.

The U.S. accounted for 77% of total installations in North America in 2023, according to IFR, placing it third in the world behind Japan and China. IFR noted that a sizable number of investments have been announced by the automotive industry, which should stimulate demand for robots going forward.

The automotive industry remains the largest U.S. market for industrial robots, accounting for 33% of total installations in 2023. Canadian automotive industry installations grew 95% to a new peak level of 2,500 units installed 2023. In Mexico, automotive demand surged in 2021 and 2022, before declining by 5% to 4,087 units in 2023.

The new World Robotics report recorded 4,281,585 units operating in factories worldwide — an increase of 10%, as annual installations exceeded half a million units for the third consecutive year. By region, 70% of all newly deployed robots in 2023 were installed in Asia, 17% in Europe and 10% in the Americas. China is by far the world’s largest market, with the 276,288 industrial robots installed in 2023, representing 51% of global installations.

Japan remained the second-largest industrial robot market with installation of 46,106 units in 2023 (down 9%). South Korea — which is the fourth-largest robot market in the world in terms of annual installations (after the U.S., Japan and China) — trended sideways in 2023 with installations of 31,444 units down 1% year on year. India remains one of the fastest-growing emerging Asian economies, with robot installations up by 59% to 8,510 units in 2023 — a new high.

Materials Suppliers Team on PFAS-Free Solutions

Baerlocher PFAS-free process aid passes muster in resin manufacturer's testing on production-sized blown film line.

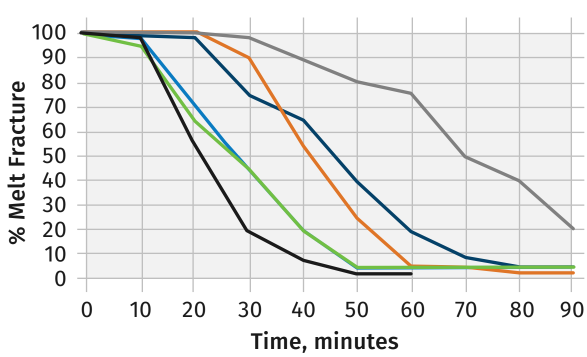
By Jim Callari
Editorial Director

As states and other government entities move to ban so-called "forever chemicals," material suppliers are working together to supply process aids free of polyfluoroalkyl substances (PFAS), which is a significant issue among blown film and other polyolefin-based extrusion processors that have relied on these additives to keep throughputs high.

According to Safer States, a national alliance of environmental health organizations and coalitions working to safeguard people and the planet from "toxic chemicals." As of this writing, 34 states have introduced 294 policies to protect people from these materials, with 154 state policies adopted in 30 states. As of April 2024, Safer States adds, some 30 U.S. attorneys general have initiated litigation against the manufacturers of PFAS chemicals for contaminating water supplies and other natural resources.

The matter is critical in extrusion, where fluoropolymer-based polymer processing aids (PPA) have been used for decades to control melt fracture by lowering the surface friction of films and other extrudates as they pass through the die body and die lips, enabling processors to run at maximum throughputs. Transitioning to non-PFAS products is no small task and impacts the entire material supply chain in polyolefin extrusion. These PPAs are used by resin manufacturers as they formulate polyolefin-specific extrusion grades, masterbatch suppliers and even processors themselves.

FIG 1 Traditional PPA vs. Non-PFAS PPA: Clearing of Melt Fracture



– Traditional Fluorinated PPA – Si-Free (G) – Si-Free (D)
– Si-Free (H) – Si-Free (E) – Baerolub 2201 AID

Melt fracture content as a function of run time for different polymer processing aid options with ZN catalyzed ethylene-hexene resin (density 0.918, melt index 1) extruded at a melt temperature of 420°F. The Baerolub AID 2201 has the fastest time to clear from melt fracture among all possible non-PFAS PPA candidates. Source: *Use of Non-Fluorinated Polymer Processing Aid for Polyethylene Applications*; researchdisclosure.com.

And the issue with getting rid of "forever chemicals" has been brewing for some time. Notes James Lloyd, director, new business development of Baerlocher USA's Special Additives Business Unit, "PFAS [have] been under the environmental microscope since the late 1960s — being found in water supplies, fish and fowl. In 1998, the EPA was first alerted to the risks of human-made forever chemicals that build up in humans and never break down, and they have increasingly become a mainstream topic over the last several years."

The EPA was first alerted to the risks of forever chemicals in 1998.

In polyolefin extrusion, PPAs are an essential material component to enable processors to keep line rates at desired levels and avoid the need to constantly clean buildup on the die lips. While additive suppliers were investigating PFAS-free formulations, some blown film machine builders began investigating die-lip coatings that would provide more slip; though, as one put it, "Ultimately this will be a material supplier solution."

About a year ago, Baerlocher brought to market a PPA aimed at helping extrusion processors transition from per- and polyfluoroalkyl substances. Called Baerolub AID, the additive targets blown film, pipe, and wire and cable; is said to be free of PFAS and siloxanes; and is compatible with other additives used in film, such as antiblock or slip agents. Baerlocher says Baerolub AID PPAs deliver rapid melt fracture clearing for metallocene and Ziegler Natta linear low-density polyethylene (LLDPE) and high-density polyethylene (HDPE), equaling or surpassing clearing times of traditional PPAs containing PFAS.

"Current and evolving European Union and U.S. federal and state regulations are forcing the plastic industry to look for new alternatives to PFAS-based processing aids," notes Chad Harlan,

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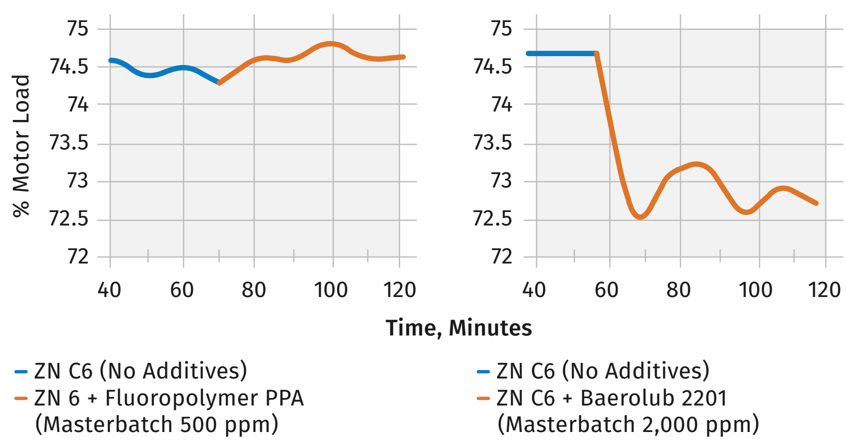
strategic business unit head, Baerlocher. "To meet this need, Baerlocher USA developed Baerolub AID PPAs featuring proprietary, PFAS-free chemistry — a breakthrough that has propelled us into a leading position in the PPA space. Our new products check all the boxes for performance, cost-effectiveness, regulatory compliance and reliable supply. Upstream customers are enthusiastically adopting Baerolub AID products and blown film converters routinely request our technology."

Because Baerolub AID PPAs are soluble in the polymer matrix, they are said to provide better haze performance than insoluble PFAS-containing PPAs and excellent control of frost line height in blown film. Moreover, the additive can reduce die buildup and extruder pressure. Because they are designed for maximum compliance with global food contact regulations, Baerolub AID PPAs are well suited for applications such as polyethylene films for food packaging and resins for potable water pipe.

Baerlocher USA rolled out two grades. Dr. Robert Sherman, the company's technical director, notes that Baerolub AID 2201 offers processors the fastest time to clear the melt fracture in metallocene LLDPE. He adds, "In certain conditions, you may wish to select Baerolub AID 2202, which provides excellent melt clearing times compared to traditional PPAs."

Baerolub AID products are available as neat additives (pastilles, rods, granules and powders), custom blends and in masterbatch form. Baerlocher also offers customers regulatory expertise and support for lab and technical screening, blown film testing and preparation for production trials.

FIG 2 **Motor Load Over Time**



Melt temperature as a function of run time for the ZN ethylene-hexene resin (melt density 0.918; melt index 1) without PPA, with the fluoropolymer PPA (left), and with the Baerolub AID 2201 (right) fed in masterbatch form. Melt temperature shows a more pronounced decrease for the Baerolub AID 2201 PPA (about 7°F).

RESIN COMPANY TEST RESULTS

Baerlocher ran successful trials using the new PPA at its laboratory-sized blown film line in Cincinnati, Ohio, and the company notes Baerolub has also been trialed at a handful of unnamed polyolefin producers in their labs, on production-sized equipment. Efforts by *Plastics Technology* to engage resin producers for an on-the-record discussion of how the PFAS-free process aid performed were not successful. However, *Plastics Technology* has obtained a study titled, "*Use of Non-Fluorinated Polymer Processing Aid for Polyethylene Applications*," that was posted in January 2024 by an unnamed polymer producer on the Questel website ***researchdisclosure.com***. The 13-page presentation can be purchased for $45. Key findings are presented here verbatim.

While Baerlocher would not divulge its PFAS-free formulation, the study notes that Baerolub PFAS-free PPAs are based on blends of vegetable lubricants and concludes: "(The additives) have demonstrated the ability to reduce/eliminate melt fracture, minimize die lip buildup and provide reduction in extruder torque.

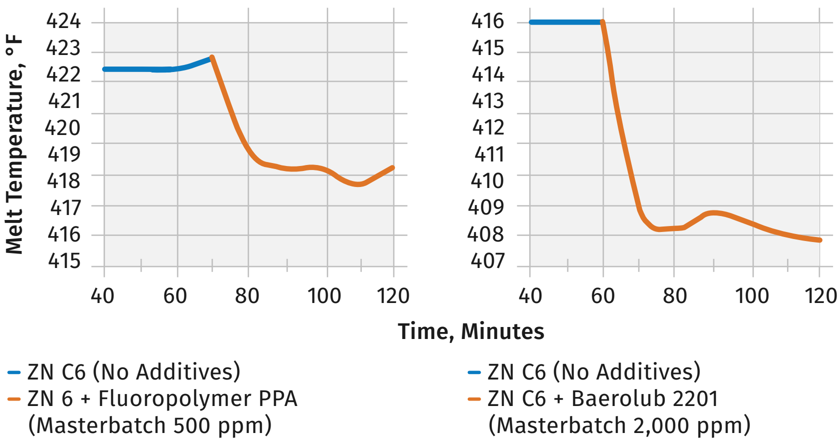
"While purposely meeting the technical requirements of a PPA, the non-PFAS formulations produced by Baerlocher also satisfy a broad spectrum of criteria required for the use of said products in film applications that are destined for food-contact film applications. After exhaustive screening and multiple evaluations, the Baerlocher products were the only non-PFAS PPAs that satisfied all the following criteria:

- Designed for maximum global food-contact approvals and meets existing taste and odor requirements.
- Environmental considerations: not noted on the "List of Substances of Very High Concern" (SVHC).
- Similar processing advantages compared to current PFAS containing PPAs at economical loadings (1,000-2,500 ppm).
- No noticeable depositions (die lip buildup or leaching/dust formation) during extrusion.
- Minimal changes in performance properties of extruded film samples, including optics (haze and gloss) and printability after corona treatment and heat sealability performance.
- Multiple product forms (pastilles, prills, granules and more), which can be introduced neat or formulated as a masterbatch or as a preblend mix.
- Compatibility with other conventional polyethylene additives (primary and secondary antioxidants, catalyst neutralizers, antiblock and slip additives)."

The anonymous resin supplier reported data from evaluations conducted utilizing a commercially available Ziegler Natta (ZN) ethylene-hexene LLDPE resin (melt density of 0.918, melt index of 1) and a commercially available metallocene-LLDPE (m-LLDPE) resin (melt density of 0.918, melt index 1). The evaluations were conducted using three methods of introducing the PPAs into the process: fully compounded resins containing 2,000 ppm of Baerolub AID 2201; the addition of Baerolub AID 2201 as a concentrated masterbatch (5% Baerolub AID 2201 in LDPE with 4% let down ratio); and the direct addition of 100% active Baerolub AID 2201 pastilles into the base resin to achieve a 2,000 ppm concentration.

The resins utilized in the evaluations are commercially available and contained traditional blown film additive packages (primary and secondary antioxidants, catalyst neutralizer/acid scavenger). They were run on a Hosokawa Alpine monolayer blown film line utilized for evaluating the performance of the Baerolub AID 2201 against an incumbent PFAS containing PPA3. The line had a die diameter of 250-mm; a die gap of 2 mm; a 75-mm extruder with a 30:1 L/D screw; dual-lip air ring; and internal bubble cooling. The screen pack configuration consisted of a 20-mesh square weave/30-150 Dutch Weave/20-mesh square weave.

FIG 3 Melt Temperature Over Time



Melt temperature as a function of run time for the ZN ethylene-hexene resin (melt density 0.918; melt index 1) without PPA, with the fluoropolymer PPA (left), and with the Baerolub AID 2201 (right) fed in masterbatch form. Melt temperature shows a more pronounced decrease for the Baerolub AID 2201 PPA (about 7°F).

The line was run at a target output of 400 lbs/hr. using a blowup ratio of 2.25, resulting in a film thickness of approximately 1.25 mils (31 mm). The experiments were conducted to evaluate the differences in "time-to-clear" of melt fracture in the film and other processing parameters (extruder rpm, motor load, melt temperature/pressure, gauge variation).

Each evaluation followed the protocol of comparing a base resin without PPA (control) to a resin containing a fluorinated PPA and a resin containing Baerolub AID 2201.

"Time to clear" was defined in the study as when melt fracture was less than 5% around the complete circumference of the bubble. Examination of the entire bubble circumference was performed for each sample as they were collected at prescribed intervals. For consistency in determining the level of melt fracture being observed, each of the film samples was analyzed for melt fracture against a clear glass backdrop. Percentage melt fracture determination protocol was established prior to the beginning of the evaluations.

Each of the individual evaluations were typically run for two hours to track time to clear for melt fracture and to observe the stability of the processing parameters. Extended runs (12-plus hours) were also performed to determine if there were any indications of die lip buildup and to monitor for deposits either on the top of the die and/or on the film handling equipment. Experiments were also conducted with other non-PFAS PPAs that are currently being developed as potential replacements for the PFAS containing PPAs. These experiments were conducted at the recommended levels of the respective suppliers.

CRITICAL FINDINGS

What follows is a verbatim account of key findings published in the study:

- ***Melt Fracture:*** Figure 1 illustrates the extent of melt fracture in the extruded film vs. the run time for the different non-PFAS PPA solutions used in the evaluations along with the PFAS PPA option. It was shown that the Baerolub AID 2201 has the fastest time to clear from melt fracture among all available non-PFAS PPA candidates.
- ***Extruder RPM:*** This showed a small increase for both the conventional process aid with fluorinated chemistry and non-PFAS Baerolub AID 2201 PPA evaluations when the additive versions were introduced. This increase in rpm was attributed to the change in coefficient of friction (lubrication/slippage) in the extruder due to the addition of the PPAs.
- ***Motor Load:*** The motor load (Figure 2) shows slightly more slippage for the Baerolub AID 2201 PPA compared to the conventional process aid.

- ***Melt Temperature:*** Similarly, tests revealed (Figure 3) a more pronounced decrease for the Baerolub AID 2201 PPA (about 7°F) compared to the conventional process aid (about 3-4°F).
- ***Melt Pressure:*** The melt pressure shows minimal increase for Baerolub AID 2201 option (Figure 4), while there is a slight increase over time for the conventional PPA.
- ***Gauge Variation:*** The gauge variation of the film shows an initial increase for the conventional PPA that dissipates over time (Figure 5), while the Baerolub AID 2201 gauge variation remains consistently low across the entire length of the evaluation. This observation is also consistent with the difference in mechanism of melt fracture elimination that is observed in the extruded film samples.

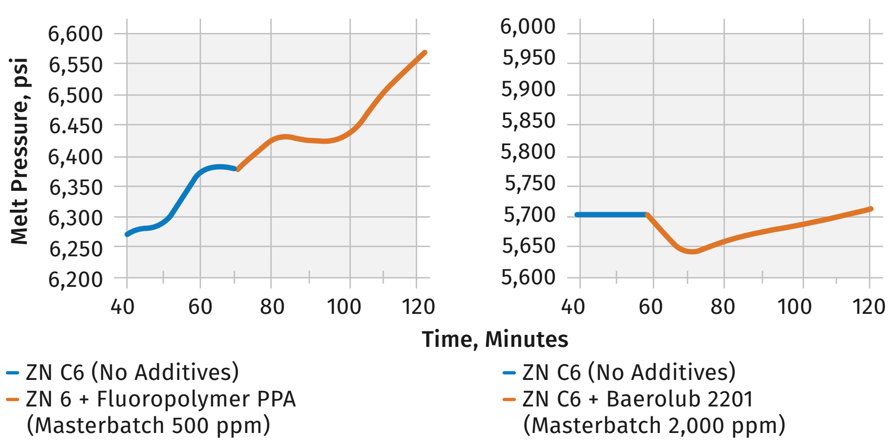
The run was continued at rate for an additional 3 hours. The "time to clear" melt fracture was around 30 minutes, and all the processing parameters continued to be stable over the entire run period. Following the three-hour run, the line was transitioned to a fully compounded m-LLDPE resin formulated with fluorinated PPA for the last hour. The "time to clear" for this formulation took approximately one hour.

Similar to the runs with the ZN LLDPE resin, it was observed that the extruder rpm increases slightly to maintain the desired output for both the Baerolub AID 2201 and the fluoropolymer 0% containing PPA. This change in rpm was attributed to screw slippage due to the introduction of the processing aids. The motor load was also consistent with slippage for both the Baerolub AID 2201 PPA and the fluorinated PPA compounded resins.

The melt temperatures increased significantly (~60°F) in comparison to the startup resin as the m-LLDPE catalyzed resins have a narrower molecular weight distribution, resulting in increased shear heating. The increase in melt temperature is similar for both the Baerolub AID 2201 PPA and the fluoropolymer PPA. With respect to the ZN LLDPE startup resin, the melt pressure also shows an increase for both the Baerolub AID 2201 and the fluoropolymer PPA compounded in the m-LLDPE resin due to the increase in melt viscosity.

The gauge variation showed a considerable reduction for the m-LLDPE compounded with the Baerolub AID 2201 PPA across the run time, while it shows fluctuations even at the end of the hour run for the fluoropolymer PPA. This is consistent with the differences in the mechanisms for melt fracture elimination, which is observed in the extruded film samples (as also observed for the ZN LLDPE runs conducted with PPA masterbatches). While the melt fracture elimination occurs in stripes with the fluorinated PPA, (reflecting the port line positions of the die), the resin containing the Baerolub AID 2201 had a gradual fading of melt fracture, and the reduction occurred uniformly across the circumference of the bubble.

FIG 4 Melt Pressure Over Time



Melt pressure as a function of run time for the ZN ethylene-hexene resin (melt density 0.918; melt index 1) without PPA, with the fluoropolymer PPA (left), and with the Baerolub AID 2201 (right) fed in masterbatch form. The melt pressure shows minimal increase for Baerolub AID 2201 option while there is a slight increase over time for the fluoropolymer PPA.

It was observed that the elimination of melt fracture for the traditional PPA occurs in bands and/or stripes (reflecting the port line positions of the dies), while the elimination of melt fracture for Baerolub AID 2201 was observed as a gradual fading of melt fracture uniformly across the film. This observed difference in clearing mechanisms is attributed to the effective dosing of Baerolub AID 2201 (2,000 ppm) being much higher than the traditional PPA solution (500 ppm), which reflects a weaker interfacial mechanism of the non-PFAS solution compared to fluorinated chemistry.

A trial was also conducted using two m-LLDPE ethylene-hexene resins (melt density of 0.918, melt index 1) in fully compounded formulations with either the Baerolub AID 2201 (2,000 ppm) or a fluoropolymer polymer processing aid (500 ppm).

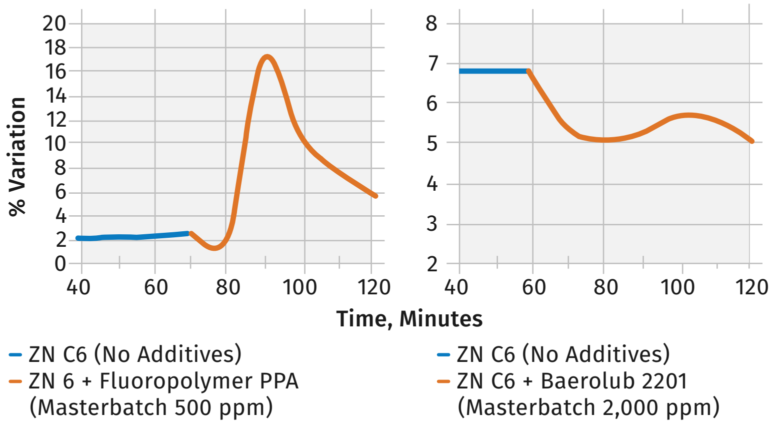
In these runs, the line was started up and stabilized with the ZN ethylene-hexene resin, then transitioned after 1 hour of run time to the m-LLDPE resin with the Baerolub AID 2201.

The study concluded that:

- Within the context of the evaluations and compared to other non-PFAS containing polymer processing aids that were evaluated, the Baerolub AID 2201 shows a clear advantage for both ZN LLDPE and m-LLDPE film applications as a functional polymer process aid for blown film applications.

- The Baerolub AID 2201 demonstrated a significant improvement in “time to clear” versus both the fluoropolymer PPA (for example, 3M F5929M PPA) and the other non-PFAS PPAs evaluated in the experimental runs.

FIG 5 Gauge Variation Over Time



Gauge variance as a function of run time for the ZN ethylene-hexene resin (melt density 0.918; melt index 1) without PPA, with the fluoropolymer PPA (left), and with the Baerolub AID 2201 (right) fed in masterbatch form. The gauge variation of the film shows an initial increase for the fluoropolymer PPA that dissipates over time, while the Baerolub AID 2201 gauge variation remains consistently low across the entire length of the evaluation.

- The Baerolub AID 2201 was evaluated as a masterbatch, as a concentrate (pastilles) and as a fully compounded resin, and shows similar performance in each of the introduction methods as evidenced in the evaluations with both the ZN LLDPE and the m-LLDPE resins.
- The use of the Baerolub AID 2201 also results in faster transitions with less purging being required to remove the PPA coating from die surface versus all of the other PPAs evaluated.
- Improvements in gauge variation were also observed compared to the existing PPAs that were evaluated. This improvement was due to the different melt fracture clearing mechanisms being employed. The Baerolub AID 2201 also has a more uniform removal of the melt fracture compared to the port line elimination of melt fracture observed with the fluorinated PPA.
- Within the context of the evaluations, the Baerolub AID 2201 demonstrated the potential to replace the current fluoropolymer-containing PPAs while also satisfying a broad spectrum of criteria required for the use of said products in film applications that are destined for food-contact film applications.

Direct Solar Heating for Rotational Molding Enables Feedback Control and Rapid Deployment

Light Manufacturing offers rotomolding factory in a box, with no utilities needed.

By Matt Stonecash
Associate Editor

Karl von Kries began his career as a staff engineer at Hardigg Industries, a Massachusetts manufacturer of protective cases. It was a good place to learn rotational molding (rotomolding), but von Kries saw one problem. In the summer, as the sun beat down on the roof of the building, the air conditioning struggled to keep the temperature inside comfortable. At the same time, the facility was burning natural gas to heat the ovens it used for rotomolding. There had to be a better way. Years later, von Kries found one.

Heating the molds directly using reflected sunlight seemed an unlikely solution at first. Surely, someone somewhere had tried this and failed. But after a literature search came up empty, von Kries started a new company, Light Manufacturing, to explore the idea, experimenting with molds that had been painted black, a two-axis molding machine and a heliostat, which is a mechanism that automatically moves a mirror to track the sun's path. The initial system didn't make good parts, but it showed that the concept was feasible.

LM's rotational molding systems can be set up in two weeks with no need to connect to utilities. Electricity is provided by photovoltaics mounted on the container roof, while heat is provided by the array of heliostats at right. Source: Light Manufacturing.

Several iterations later, the company now offers solar rotational molding (SRM) systems that can operate without the utilities or infrastructure needed for a conventional manufacturing operation. Molds are heated directly by an array of heliostats that deflect energy from the sun, using the same principle as concentrated solar power generation plants. Electricity to power the motors, control computers and heliostats comes from photovoltaic panels.

The system can ship in two or three standard shipping containers, depending on the model, which include the rotomolding machines, photovoltaics, heliostats and batteries. The containers themselves double as enclosures for the molding chamber and operator's cabin. The system can be set up on bare ground, in about two weeks, anywhere that gets sufficient sun. According to the company, this includes nearly half of the world's land area. If a location turns out to be suboptimal, the system can be packed up and moved.

The SRM's ease of deployment could make it the obvious choice for extreme locations with ample sunlight and scarce utilities. And it could be used that way, but the low startup cost, advanced controls and sustainability could appeal to a broader market.

DIRECT HEATING SAVES ENERGY AND ENABLES CLOSED-LOOP CONTROLS

Conventional turret or shuttle rotomolding machines heat the mold in an oven, requiring air temperatures of 500-600°F to get the mold and the plastic inside up to the required temperatures in a reasonable amount of time. To establish process parameters like cycle time, a shielded and cooled box is built into the arm of the machine, and electronics are placed inside and connected to thermocouples measuring mold temperature.

Because solar rotational molding reflects radiation from the sun directly onto the outer surface of the mold, most of the heat is directed just where it is needed. "What's crazy is that you can actually stand in the chamber while 100,000 watts of heat are being pumped into that mold, 2 feet away, and the air is maybe 120[°F]," von Kries says. "That means we can have advanced electronics and robotic components right there in the chamber, and they're fine."

Light Manufacturing takes full advantage of this, implementing feedback control with real-time temperature monitoring. Temperature data is looped back to the control, adjusting processing parameters on the fly and ending cycles exactly when the plastic has cured. A morning part run, or one on a cloudy day, may require a longer cycle or more mirrors focused on the mold.

A solar rotational molding system with a sample rain catchment tank.

The part design may need more heat on one side, if wall thickness needs to vary. No problem. The system can adjust the speed of the motors to leave that side of the mold in the target area longer. "The recipe for the part and the target temperatures are built into the brain of the system," von Kries explains. At the appropriate time, the system goes into cooling mode automatically, the fans are activated and when cooling is complete, a tone alerts operators that they can begin demolding and refilling.

SOUND ECONOMICS COMPLEMENT ENVIRONMENTAL SUSTAINABILITY

Since 2016, Light Manufacturing has been making rotomolded components for Technomad, an outdoor audio systems manufacturer also founded by von Kries. It has also been supplying parts to other customers on a contract basis.

Light Manufacturing has three models of various capacities, with the largest capable of molding an 8,000-liter tank. According to von Kries, the system is now "ready for prime time," and the company is exploring partnerships with manufacturers who would purchase or license the technology.

The economics of such a system should be attractive. Energy costs for rotomolding can be 15-30% of operational expenses, positioning Light Manufacturing's technology for significant potential savings. Energy cost could even be effectively negative in regions that tax carbon emissions or incentivize low carbon manufacturing. The option to skip the normal infrastructure could also tilt the economics. "It's been an exciting journey to go from expecting it to fail to building this advanced machine. We're excited to see where it's going to go next," von Kries says.

Research Deems Bioplastics, Wood Pulp a Sustainable, Economic Alternative for Rigid Packaging

Farrel Pomini and FPInnovations produce biodegradable compound for molding, extrusion and thermoforming applications.

By Jim Callari
Editorial Director

Recent research conducted by Farrel Pomini, FPInnovations and a consortium of industry leaders has reportedly demonstrated the commercial viability of biobased, compostable compounds such as polylactic acid (PLA) and polyhydroxyalkanoates (PHA) mixed with high levels of fiber in a variety of disposable packaging products, paving the way for eco-friendly products like food trays and disposable cutlery (Figure 1).

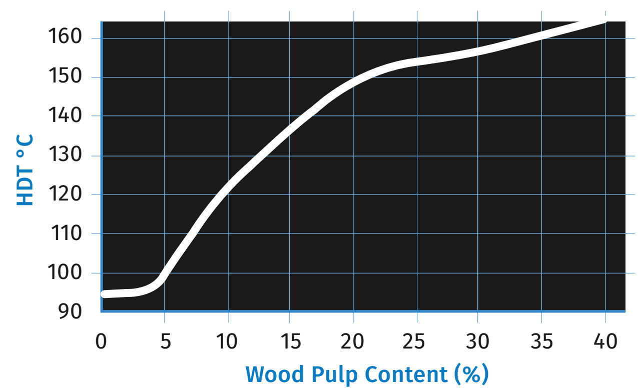
Compounding equipment builder Farrel Pomini and Montreal-based FPInnovations, the world's largest nonprofit research technology organization for forestry, have proven the technology to produce industrial-grade biobased compounds with fiber content up to 60%. The compounds, produced on the Farrel Continuous Mixer have been used to manufacture various products, including injection-molded disposable knives with up to 40% fiber, extruded sheets and thermoformed parts with fiber content ranging from 0.5% to 10%.

FIG 1

Applications for bioresin and wood pulp compounds include disposable cutlery. Source: FPInnovations

The final products are odor-free with light coloration, attributed low processing temperatures. Dr. Peng Ye, applications development manager for Farrel Pomini, presented the results of this project in May in Orlando, Florida, during NPE2024.

FIG 2 **HDT Boosted With C-PLA, Cellulose Fiber**



The heat deflection temperature of crystalline PLA-based parts significantly improves with the addition of cellulose fiber, surpassing 100°C with 5% wood pulp and reaching 150°C with 20% pulp content.

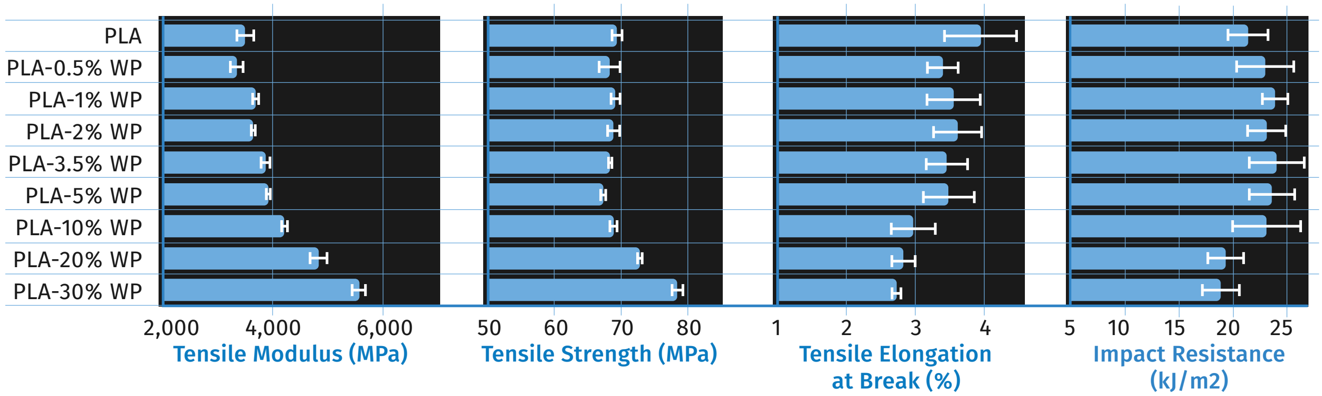
LEVERAGING CELLULOSE FROM WOOD PULP

Development of these cellulose-filled biodegradable resins is a result of a collaborative effort led by FPInnovations, based in Montreal. Farrel Pomini played a crucial role in producing these compounds at pilot and industrial scales using its continuous mixing technology at its lab in Ansonia, Connecticut.

The key to these innovations lies in using refined wood pulp, sourced for this collaboration from sawmill residue provided by West Fraser, a major wood products company. This refined wood pulp undergoes a process that removes most of the lignin, leaving cellulose and hemicellulose.

The low-lignin content of this wood pulp makes it suitable for food-contact applications, and enhances processing conditions and heat resistance. Moreover, its wide commercial

FIG 3 Wood Pulp's Impact on PLA Properties



Adding up to 5% wood pulp maintains or enhances tensile modulus, tensile strength and impact resistance without significantly affecting elongation properties.

availability and inherent compostability make it well suited for sustainable everyday products solutions, notes Dr. Yann Gabet, FPInnovations' senior scientist and the project leader for the Biocomposites Initiative.

Farrel Pomini and FPInnovations found that adding cellulose fibers in PLA and PHA compounds provided several advantages, notably:

- *High dispersion quality*: The compounds demonstrate excellent dispersion up to 60% cellulose content.
- *Enhanced heat resistance*: The heat deflection temperature (HDT) of crystalline PLA-based parts significantly improves with the addition of cellulose fiber, surpassing 100°C with 5% wood pulp and reaching 150°C with 20% pulp content. This makes the compounds suitable for hot food and liquid contact applications (see Figure 2).
- *Mechanical properties*: Adding up to 5% wood pulp maintains or enhances tensile modulus, tensile strength and impact resistance without significantly affecting elongation properties (see Figure 3).

Ye and Gabet note that a critical feature of these cellulose-filled PLA compounds is their accelerated biodegradation compared to pure PLA. Testing conducted in accordance with ISO 14855-1 standards showed that PLA compounds with 20% cellulose demonstrated a faster biodegradation rate within the first 25 days compared to PLA alone. Additionally, compounds with 5% of another type of cellulose product achieved 90% biodegradation nearly 30 days earlier than pure PLA.

Moreover, according to Ye, Farrel Pomini's compounding technology helps reduce the impact of the compounding process on sensitive materials (like cellulose and biopolymers) by utilizing low processing temperatures. This process also enables a reduction in moisture content from an initial 3% to 4% in the fiber to a final compound moisture of 0.05% to 0.1%.

The Farrel Continuous Mixer (FCM) is a continuous compounder well suited to processing highly filled, temperature/shear-sensitive applications and excels at processing biodegradable plastics in addition to white and black masterbatches, PVC, flooring, halogen-free flame-retardant compounds, and wire and cable applications.

The FCM melts feedstock resins and homogenizes them under specific temperature and pressure parameters. Ye explains that the mixer's low process temperature, short residence time and efficient rotor shear make it well suited for processing temperature-sensitive materials or materials with prior heat history. The mixer has been used to process PLA, PHA, PBS, recycled PVC and film scrap.

ENVIRONMENTAL AND ECONOMIC BENEFITS

Incorporating cellulose fibers into biodegradable resins offers several economic and environmental advantages, the partners in this project determined. These include:

- Lower costs compared to pure biopolymer
- Improved compostability of final products
- Optimized mechanical properties
- Improved heat resistance
- Lower carbon footprint

States Gabet, "The successful development and scaling of cellulose-filled biodegradable resins highlights a significant leap toward sustainable solutions for plastic-based everyday products. By combining innovative technology with the abundant resource of wood pulp, these advancements offer a practical and environmentally friendly alternative for various applications." PT

New Screw Boosts Mixing, Enhances Polymer Properties

Device mixes at the 'molecular level,' inventor says, to boost mechanicals and in some cases make pre-drying redundant.

By Jim Callari
Editorial Director

Undaunted by commonly held beliefs that "there is nothing more that can be done to improve single-screw extrusion," and forever the tinkerer, Keith Luker has for the last 20 years been working on the next iteration of his SFEM Elongational Mixer. What the founder and president of Randcastle Extrusion Systems, Cedar Grove, New Jersey, has perhaps stumbled onto is a novel device that is not only a more effective mixer but, in some cases, improves material physical properties and makes pre-drying unnecessary.

Luker has dubbed it the Molecular Homogenizer (MH). It's a new device that he says could have broad appeal across the material supply chain — beginning with resin manufacturers. It's so named, he maintains, because it mixes material at the "molecular level." He elaborates: "The mixing is so fine that the properties of polymers change. Physical properties of polymers (virgin polymers processed through the screw) improve. In hygroscopic polymers, water-vapor absorption is postponed. Undried hygroscopic polymers show no bubbles. Rheological properties show incredible improvement."

Randcastle's Molecular Homogenizer is a 36:1 L/D screw with seven mixing sections. According to the inventor, it has been shown to enhance mixing and also improve material properties in some cases. Inset shows single mixing element. Source: Randcastle Extrusion

Luker has presented papers on this mixing device in 2022 and 2023 at *Plastics Technology*'s Extrusion Conference, and more recently this past June at the SPE Extrusion Division Screw Design TopCon. Luker is the first to admit that more work, testing and research need to be done to adequately explain why the design is performing as it is. That said, he has patents pending in five countries and Europe, and had the MH tested on a wide range of materials, including PLA, PMMA, PET, PET with 25% reclaim, PEEK, PVA, PVA with 3% reactive agent, PLA, SAN color concentrate, PC, nylon and coffee chaff in LDPE. The mixer is also being used by at least one extrusion processor in a production environment.

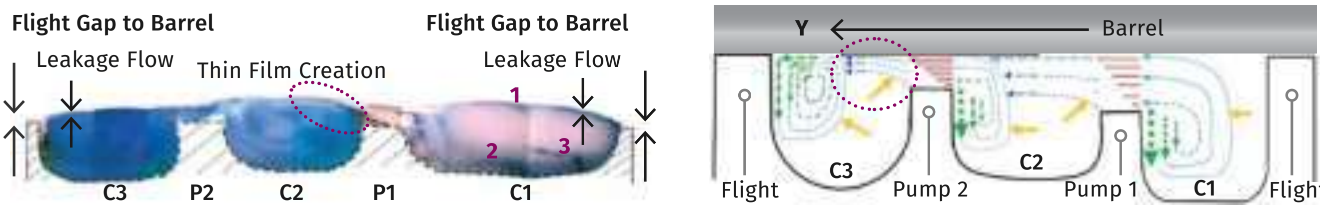
The tested screw had at least 100^7 (100 trillion) mixing actions along the XYZ dimensions. "Such an increase resulted in mixing to the small molecule level (such as 3 atom water vapor)," he says. "Because the sequence is orderly, the mixer imposes organization to the messy, tangled mixture produced by a polymer reactor. We believe this mixing changes the alignment of long polymer chains; distributes small molecules (monomer, water vapor), additives, particulate, actives, etc. This results in the improvements we see at the macroscopic level. The mixing may enhance, indirectly, diffusion."

MIXING FORCES

Luker notes that many conventional mixers rely on shear with compression forces to push material through narrow gaps. Compression forces, he contends, are negative and counter mixing. That is, when compression is combined with shear or elongation, mixing performance is significantly impaired.

Luker elaborates: "When compression is applied equally and opposite in all three dimensions, it is called pressure. When we apply compression or pressure to a cube, sphere or bubble, mixing does not occur. The force is applied in all three dimensions inwardly. If the cube or sphere were made of loosely held particles, then compression or pressure will push these particles together, causing agglomeration. When pressure is applied to the bubble, it shrinks, becoming denser and this too is agglomeration." Agglomeration is the opposite of mixing and is caused by compression and pressure. Think of pressure as an antimixing force.

On the other hand, reorienting or interrupting shear makes "order of magnitude improvements" possible, he adds. Further, when a mixing flow is oriented in one direction and then another,



Pullout (left) of MH predecessor SFEM Mixer (C=Channel; P=Pump). C1 shows 2.5 striations, C2 more than 25; C3 more than 250. This results in a 100-fold improvement in mixing. Right depicts new MH. Orange arrows show extensive free surfaces. Red shows 1-dimensional shear in two places. Black oval indicates 3D trilongation in three places. Red oval reveals 2D elongation in two places.

"The orientation imparted by the first section is destroyed, and each 'stage' of the device behaves as a separate unit."

In 2005, Luker developed the SFEM mixer, which created significant elongational mixing. Dow Chemical presented a paper at ANTEC 2011 which showed mixing results that were eight times better than their twin with immiscible polymer blends. This new mixer uses first principal arrangements of interrupted shear, interrupted elongation and a mixing flow called inversive mixing.

"Until this arrangement, it was not understood compression was so detrimental to extrusion mixing," Luker says. "Stated another way, if there were no compression mixed in with shear and elongation, they would mix vastly better. Fundamentally, this is why the MH produces such surprising results."

The design arrangement, Luker maintains, "creates exponentially improved mixing such that surprising results start to become mundane." For example, processing through the unvented MH has been shown to:

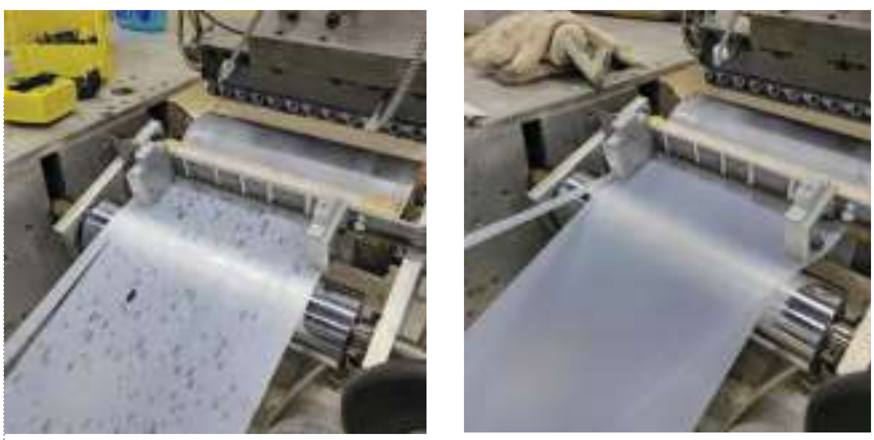
- **Improve Physical Properties:** Increase tensile-at-yield greater than the virgin polymer.
- **Increase Viscosity:** Restore undried hygroscopic regrind to the viscosity of the unprocessed virgin polymer.
- **Slow Water Absorption:** Processing slowed water absorption from the typical 4 to 6 hours when exposed to atmosphere to over 72 hours.
- **Sequester Water Vapor:** Moisture analyzer measurements showed the moisture content of an unprocessed

material entering the Molecular Homogenizer at 0.328%; it then reported that the Molecular Homogenizer processed polymer had 0.171% moisture.

HOW IT WORKS

Randcastle's Molecular Homogenizer has a 36:1 L/D and features seven mixing sections. According to Luker, this design promotes a powerful dispersive mixing force called trilongation, where all the flow is stretched in three dimensions. Each of the mixing elements of the device creates a repetitive mixing sequence twice: 3D trilongation, 2D elongation and 1D shear. Each mixer is known to improve the mixing by more than 100 times, Luker says.

He says that unlike a twin-screw extruder, the entire flow moves through this sequence. Each time it does, the 100-fold improvement is created, a bit like a static mixer multiplication except this is dynamic. He says this creates more than 100 trillion mixing events in the screw. At the end of each mixing element, the flow is inverted where the inside becomes the outside. This reorientation enables the friction-warmed material at the screw to move to the barrel where cooling takes place before the start of the next mixing element. In degassing applications, it moves the trapped bubbles to the extensive surface for rupture and venting.



Here, undried nylon was processed on the MH. Bubbles were still created, left. After a single atmospheric vent was opened, exposing the extensive free surfaces, the film on the right was produced with no bubbles at the same rate.

TEST RESULTS

Undried hygroscopic polymers are known to produce visible bubbles in unvented extruders. Luker reports that in his lab the new mixing screw processed PMMA, PET, PET with 25% amorphous reclaim, PEEK, PVA, PVA with 3% reactive agent, PLA, SAN color concentrate (black and white), PC and coffee chaff in LDPE. None of these materials was predried, and none showed any evidence of bubbles (water). More specifically:

- **PET With 25% Reclaim.** Undried PET is well established to absorb water vapor and form bubbles. Undried PET reclaim is amorphous and known to absorb even more water. No bubbles were seen.
- **Reactive Extrusion of PVA:** Undried PVA produces a bubbled extrudate. A reactive chemical was added to dried PVA and created a bubbled extrudate in a conventional screw — implying that the bubbles were not water vapor. Yet, in an undried PVA with 3% reactive agent, no bubbles were seen in the Molecular Homogenizer extrudate.
- **Coffee Chaff:** Coffee chaff is the thin papery skin that comes off the coffee bean. When heated with LDPE, the chaff breaks down, releasing gases such as carbon dioxide (CO_2), water vapor (H_2O), carbon monoxide (CO), and various volatile organic compounds (VOCs). The Molecular Homogenizer produced no bubbles in the extrudate.
- **Black and White SAN Color Concentrate:** SAN is hygroscopic. Both carbon black and TiO2 are hydrophilic and also absorb water vapor. The undried materials were both pelletized. No bubbles were visible in the strand cut pellets. The pellets were then processed in a conventional screw on a film line and again there were no bubbles.
- **Nylon:** Nylon is a very hygroscopic polymer absorbing moisture in the 2%-9% range. It is expensive to dry polymers. In the Randcastle lab, Luker processed a nylon blend into film on a conventional screw for a week. Drying was necessary. Conditions were well established.

  He then swapped out the screw with the MH and processed the same nylon but didn't dry it first. Bubbles were still created. He then opened a single atmospheric vent, exposing the extensive free surfaces, and the film on the right was produced. He notes the output rate was the same (rpm was increased and extruder starve fed); the temperatures were kept the same as the dried material; no die adjustments were necessary to produce the same tolerance film — implying the viscosity was the same; and pressure was the same as the dried material.
- **Undried PVA With More Than 3% Reactive Agent:** PVA with 3% reactive agent was one of the materials where the strand did not show bubbles. However, the experiment also mixed 6, 9 and 12% reactive agent. At 6%, bubbles were created. A single atmospheric vent was opened. No bubbles were seen. The experiment proceeded and no bubbles were seen at 9 or 12%.

Luker reports the Molecular Homogenizer has been shown to slow the rate of moisture absorption, which he notes is particularly useful for regrind where it takes more than a couple of hours to grind and reprocess the material. For example, PMMA regrind will absorb moisture in 4 to 6 hours, creating problems (bubbles, lower viscosity, property degradation and roughened surfaces), he points out.

He recalls that the screw was used to process dried PMMA through a water trough and strand pelletizer on a rainy, summer Friday afternoon in New Jersey. The bag of pelletized material was left exposed to the atmosphere over the weekend, and it continued to rain. On Monday afternoon, the pellets were extruded (undried) in a conventional screw. There were no bubbles. This, Luker says, demonstrates that the time for processing regrind can be substantially extended for product improvement.

In yet another test, a Molecular Homogenizer and a general-purpose control screw were used to process virgin dried PETG. The pellets were then molded in a family mold and compared at the Pennsylvania College of Technology. Concerning properties of test samples, says Luker:

- **Elongation at Yield:** The MH was 17.9% better than the general-purpose screw and improved this property 6.7% vs. the virgin material.
- **Izod Impact Strength:** The new mixing screw was 22.4% better than the general-purpose screw. The Molecular Homogenizer screw was 18% worse than the virgin pellets.

WHO WOULD BENEFIT?

Luker says many applications will benefit from the use of this new mixing screw technology. He states: "Start with polymer producers. The Molecular Homogenizer has demonstrated postreactor improvement in physical properties and rheology — despite an additional processing history. Since the reactor operation already includes a pelletizing processing history, we expect the same or better results from a Molecular Homogenizer placed at the end of a polymer reactor for pelletizing. This will create polymer with better properties and lessened or no need for drying."

For compounders and those involved in direct extrusion (bypassing the pelletizing step), Luker says the MH serves as a stable, high-pressure pump that eliminates the need for a gear pump. In reclaim operations, meantime, he asserts that the lower water absorption rates demonstrated translate into increased time for processing without the need for drying. Viscosity improvements with reclaim also mean more consistent die flow, he adds. Higher quality and improved viscosity often lead to increased output, Luker notes.

Other applications that Luker believes to be well suited for the MH include: processing of PP, PFA and rigid PVC powder, which he says have been shown to run at higher rates with the new screw; research and development, as greater mixing performance could pave the way for new material combinations; and users of twin-screw extruders, where the screw can be used as an add-on. PT

EXTRUSION

What's Restricting My Output Rate?

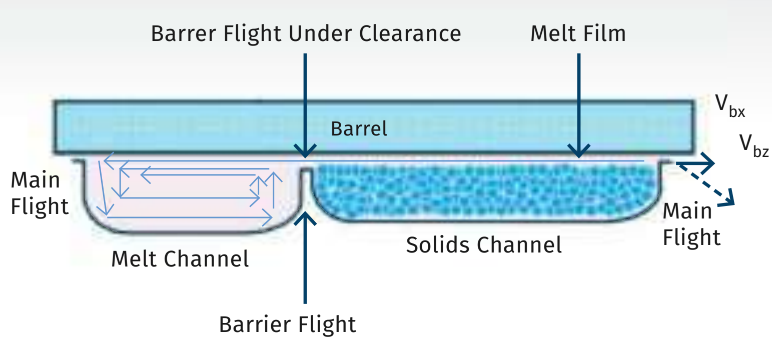
In a single-screw extruder, it could be an improperly designed barrier flighted entry section. Here's why.

By Mark A. Spalding

A well-designed screw using a barrier flighted melting section can provide higher rates — up to 20% — and lower discharge temperatures compared to a conventional flighted melting section. When combined with a downstream Maddock mixer, the quality and rate of the extrudate can be optimized for the application, maximizing productivity.

This technology was the first of its kind to use the concept of separating the compacted solid bed from the melt pool as it progressed down the transition section of the screw. A cross section of a barrier melting section perpendicular to the main flight edge is shown in Figure 1. The compacted solid bed is adjacent to the trailing side of the main flight. Melting occurs by dissipating energy in the thin melt film located between the solid bed and the barrel wall.

FIG 1



Schematic for a barrier melting section. The cross section is perpendicular to the main flight. Source (all photos): Mark Spalding

The dissipated energy conducts into the solid bed and melts resin at the interface. The molten resin is then conveyed over the barrier flight and into the melt channel. The barrier flight is undercut by about 0.5 to 1.5% of the diameter from the main flights. Thus, for a 6-inch diameter screw, the undercut would be about 0.030 to 0.090 inch. The barrier flight adds a level of dispersive mixing and prevents large solid resin fragments from entering the melt pool.

There are many barrier melting section designs that are used commercially. One of the highest performing designs uses lead lengths equal to the diameter in the feed section and in the meter section. The lead length of the main flight and the barrier flight in the barrier section are increased to 1.25 to 1.40 times the diameter. The lead length is increased to enable a larger total width in the section. The width of the solids channel is typically about twice the width of the melt channel. The solids channel is the deepest at the entry and it tapers to a shallow depth at the exit of the section. The melt channel is the opposite with the channel being shallow at the start and the deepest at the exit. As previously stated, there are many versions of the design practiced commercially.

THE RATE CONTROLLING PROCESS

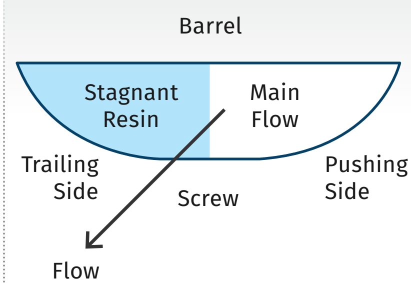
For smooth-bore plasticating extruders, the metering channel must be the rate controlling process. A poorly designed barrier section, however, can be the rate limiting step. When this happens, the extruder will run at low specific rates and can cause degraded resin to appear in the product. The specific rate is the rate divided by the screw speed — lb/(hr rpm). The rate restriction can cause portions of the metering section to operate partially filled and at zero pressure. For polyethylene (PE) resins, degradation gels can form in the partially filled portion of the screw. When the gels separate from the screw, they will cause defects in the product (as shown by Figure 2) for a cast film.

Scan for more expert advice in extrusion.

FIG 2

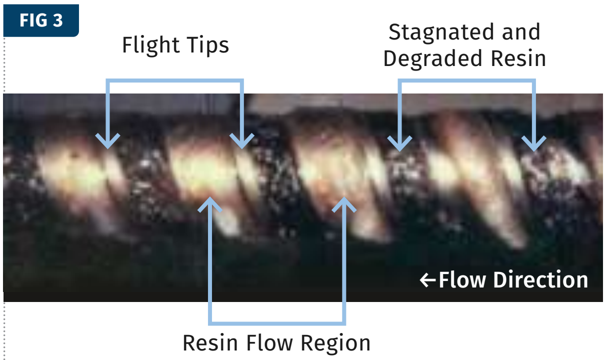
Crosslinked PE gel in a cast film.

FIG 4



Schematic of a partially filled metering channel.

FIG 3



Photograph of the metering section of a screw with a poorly designed barrier flighted entry. The white material is freshly melted LDPE while the dark material is degraded and crosslinked resin.

As an example, a 3.5-inch diameter extruder with a screw designed with a barrier melting section was operating at a specific rate of 3.6 lbs/(hr rpm). The calculated specific rate for the metering section, however, was 5.5 lbs/(hr rpm). Here, the metering channel was not controlling rate. Instead, some feature upstream of the metering section was controlling rate. The extruder was stopped, and the screw was removed hot.

The metering section of the screw is shown in Figure 3. It shows freshly melted resin on the pushing side of the channel. When the screw was first installed, the trailing side of the channel was void of resin, but after continued operation, this side of the channel became stagnant with resin. This pattern of degraded and fresh resin is shown schematically in Figure 4. It took about 13 days of operation to develop the steady-state level of degradation shown in Figure 3. Minor process ►

instabilities would cause a small portion of the degradation to break away from the screw. The downstream Maddock mixer would cause the fragment to break into many smaller fragments, causing a gel "shower" in the film product.

FIG 5

Photograph of the screw with a restrictive barrier entry. The width in the solids channel of the barrier section (W_2) is about 15% less than the width of the upstream solids conveying channel (W_1).

FIG 6

Photographs of barrier flight entries: (a) standard entry that had a rate restriction and (b) modified entry where the barrier flight was removed down to the root of the melt channel for the first 1.5 turns of the section.

The specific rate was reduced from 5.5 to 3.6 lbs/(hr rpm), a reduction of 35%. When the screw was removed from the extruder, compacted solids had formed at the entry to the barrier section. It was these compacted pellets that reduced the flow of material into the barrier section. Moreover, the reduction in specific rate was enough to cause the metering channel to operate partially filled, causing the resin to degrade and the eventual gels in the film product.

The restriction at the entry of the barrier melting section was caused by a reduction in the width of the channel for solids to flow. As an example, a 2.5-inch diameter screw with an entrance design shown in Figure 5 was rate restricted. For this case, the solids channel width (W_2) in the barrier section was 15% narrower than the upstream solids conveying section (W_1).

Even though the lead length was increased in the barrier section, the addition of the melt conveying channel reduced the width available for the flow of compacted solids. This barrier flight introduction can restrict flow to the downstream sections of the screw, causing parts of the metering channel to operate partially filled as shown in Figure 3. This restriction can occur even with a lead length in the barrier section that is 1.4 times the diameter.

At the entry, the compacted solid bed must rearrange as it is transferred from the solids conveying channel to the solids channel of the barrier flighted section. If the channel design allows rearrangement, then the extruder will operate at the designed rate. If rearrangement is restricted, the channel pressure increases upstream of the entry.

The high pressure will cause a higher level of energy dissipated from the friction between the surface pellets and the barrel wall, creating an energy flux that conducts through the barrel wall. Sometimes this energy flux is high enough that the barrel zone positioned over the entry will overshoot the set point temperature. During the troubleshooting process, it is always a good idea to see if this zone is overshooting set point or has a higher level of cooling compared to the solids conveying zone.

The rate restriction can sometimes be mitigated by removing metal at the entrance of the melt channel such that some solids are intentionally passed down the melt channel. A photograph of a modified screw is shown by Figure 6B. For reference, a similar screw without the modification is shown by Figure 6A. The barrier flight is removed at the entry down to the core of the melt channel for about the first 1.5 turns. Next the barrier flight should be tapered from the root of the melt channel to full height over the next turn. This mitigation process can be complicated for some commercial designs. Screw designers and fabricators are aware of the problem and the remedy to mitigate it.

ABOUT THE AUTHOR: Mark A. Spalding is a fellow in Packaging & Specialty Plastics and Hydrocarbons R&D at Dow Inc. in Midland, Michigan. During his 39 years at Dow, he has focused on development, design and troubleshooting of polymer processes, especially in single-screw extrusion. He co-authored *Analyzing and Troubleshooting Single-Screw Extruders* with Gregory Campbell. Contact: *989-636-9849; maspalding@dow.com; dow.com.*

INJECTION MOLDING

Important Factors and Approaches to Estimating Residence Time in Injection Molding

Residence time can have a dramatic impact on part quality and production efficiency, but determining its value can be tricky. Use these methods and formulas to accurately measure residence time and enable it to inform everything from scheduling jobs to optimizing a process.

By Umberto Catignani

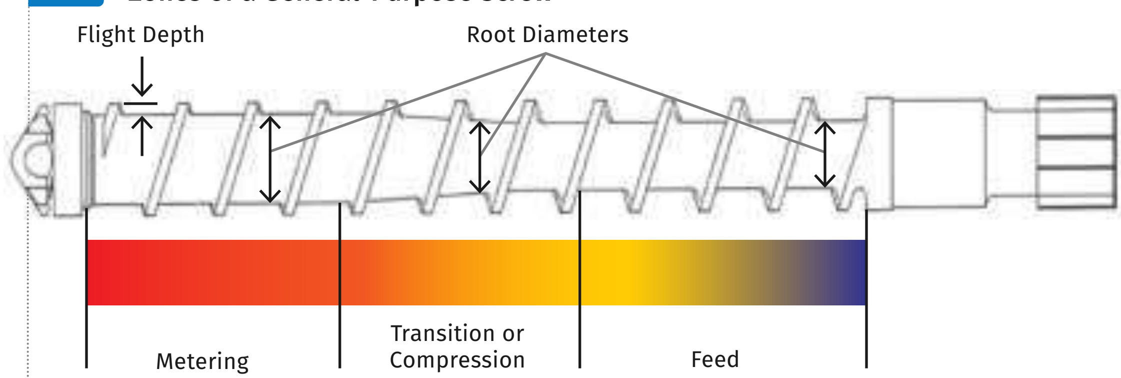
Residence time can be impacted by increasing or decreasing the amount of material the machine processes per hour or if the injection unit specifications have changed, which is common when moving molds among machines. The residence time is defined as the time a resin pellet is physically in the barrel and exposed to shearing or heating via conduction. Changing any time-related machine parameter — cooling time, packing time, holding time, mold open/close times, mold protection time, part ejection time and the addition or removal of a robot — will change the residence time.

This information is crucial, as it will be used to schedule molds for specific machines, determine the optimal placement for thermally sensitive materials to minimize residence time or assist a custom molder in purchasing a new machine and specifying the appropriate barrel size for a variety of materials and part weights.

As a plastics engineer, I often find that some of the simplest questions in our field can be the most challenging to answer. One such question is determining how many shots of plastic are present in the barrel and calculating the corresponding residence time. A commonly accepted target for residence time in the industry is between 2 to 5 minutes. However, this rule of thumb may not be applicable when working with high-temperature engineering thermoplastics, such as PEEK or thermally sensitive materials like PBT or PVC. Additionally, when PP and PE are applied in packaging applications, deviations from this guideline may also occur.

Throughout my career, I have observed that residence times for packaging applications utilizing reciprocating screw (RS) machines can at times fall below 1.5 minutes. This duration is typically inadequate for effectively elevating semicrystalline plastics to their optimal processing temperatures. In certain instances, increasing the barrel temperatures by 100°F to 200°F has been employed to enhance heat transfer through conduction, compensating for insufficient shear generated by the screw configuration. Although solutions such as utilizing a two-stage injection unit with parallel or simultaneous control; using an

FIG 1 Zones of a General-Purpose Screw



When determining residence time, molders should consider the different zones of a general-purpose screw. Source: Orbital Plastics Consulting

RS machine fitted with a barrier screw; or utilizing screws with higher L/D ratios and increased compression ratios may address these challenges, they often present impracticalities regarding cost and machine-capacity constraints.

I have also seen residence times as high as 15 minutes for thermally sensitive materials running in semiautomatic mode. In this case, no matter how much we attempted to lower the actual plastic temperature, we had to intermittently purge the barrel to remove degraded material.

The most straightforward method to assess residence time for an existing running application is to note the maximum machine shot size, actual shot size and cycle time, and with those figures calculate the residence time using the following equation:

EQUATION 1

$$\text{Residence Time} = \frac{\text{Maximum Machine Shot Size}}{\text{Actual Shot Size}} \times \frac{\text{Cycle Time}}{60}$$

In determining your actual shot size, the cushion and amount of postdecompression should be removed to determine the actual amount of plastic displaced. In this example, on a machine that has a maximum shot size of 12 inches with 1.5 inches of plastic being displaced that's running in a 15-second cycle time, the residence time would be 2 minutes.

EXAMPLE 1

$$\text{Residence Time} = \frac{\text{12 inches}}{\text{1.5 inches}} \times \frac{\text{15 seconds}}{60} = \text{2 minutes}$$

However, if we consider that true residence time is defined as the time a pellet is physically in the barrel, the above calculation omits the amount of plastic that is being conveyed down the length of the screw within the metering, compression and feed zones as illustrated in Figure 1.

Determining this involves pulling back the hopper or shot loader and noting when pellets are last seen between the screw flights in the feed zone and then allowing the machine to continue to cycle. (**Important**: DO NOT look down the feed throat but rather use a mirror and apply full PPE to avoid being burned by any hot plastic that could be discharged from the feed throat).

For example, you count five complete shots in automatic mode over a 30-second cycle with a 2-inch shot of actual displaced plastic, but on the sixth shot, the screw only recovered to a calculated 1.5 inches of actual displaced plastic, you can then calculate: 1.5 ÷ 2.0 = 0.75 inch, or three-quarters of a shot. In this case, you would add three-quarters of a shot to the fifth shot, resulting in a total of 5.75 shots. The residence time can then be calculated by multiplying the total number of shots ►

with the cycle time: 5.75 shots × 30 seconds equals a residence time of 172.5 seconds (or 2.9 minutes).

Another method would be to add a colored pellet of the same material or a pellet from a batch of color concentrate into the machine and note the moment pellets are last seen between the screw flights in the feed zone by moving the hopper or shot loader back over the feed throat and noting when parts are first molded with color. Of course, if you are running black material, this could be an issue.

John Bozzelli discussed this method in an article titled, "A Simpler Way to Calculate Shot Size vs. Barrel Capacity," first published in February 2017 and updated in June 2022. He puts forward other limiting factors, such as using the above method for an existing application in production and actually calculating the residence time for a machine purchase.

Bozzelli also points out a common error in calculating the barrel capacity — confusing melt density with specific gravity. The barrel is commonly specified in ounces or grams of general-purpose PS or at times PE. A common misconception is that parts can be produced with any material at the specified barrel capacity. We must convert the barrel size to accurately reflect the material that we are molding, whether it be more or less dense than GPPS, by using melt density versus specific gravity. This will result in the following equation:

EQUATION 2

$$\text{New Barrel Capacity} = \frac{\text{Barrel Capacity (GPPS)} \times \text{Melt Density of New Material}}{\text{Melt Density of GPPS}}$$

In the following example, we are interested in running PC with an L/D ratio of 22:1 and a 60-ounce barrel, where the melt density of GPPS is 0.97 g/cm³ and 1.02 g/cm³ for PC. This would yield a barrel capacity of approximately 63.1 ounces of PC.

EXAMPLE 2

$$\text{New Barrel Capacity} = \frac{60 \times 1.02}{0.97} = \text{63.1 ounces of PC}$$

Conversely, if a less dense material is molded — such as PP with a melt density of 0.75 g/cm³ — this yields a barrel capable of processing approximately 46.4 ounces of PP.

EXAMPLE 3

$$\text{New Barrel Capacity} = \frac{60 \times 0.75}{0.97} = \text{46.4 ounces of PP}$$

Because PP is less dense than GPPS, if a scheduler or someone providing quotes assumes that 60 ounces of PP can be processed, they'll find the actual amount is only 46.4 ounces. This misconception leads to an inaccurate calculation of the barrel's utilization percentage, which can affect the expected residence time. In some cases, this can result in the maximum machine shot size being inadequate to fill and pack the machine and mold combination, which results in short shots or the need for the molder to utilize intrusion to compensate.

As mentioned earlier, to achieve a more accurate residence time, it's also important to account for the material being plasticized in the screw's feed, compression and metering zones. A method I've been using comes from a guide published by Spirex, titled, "Plasticating Essentials." Originally authored by Paul and Illene Colby in 1979, the guide has been updated with additional information in versions released in 1985, 1992 and 2000.

Within this guide, they propose a barrel factor based on the work of Bernie A. Olmstead and Martin E. Davis in which a factor of 1.4 is used to calculate the residence time if the machine injection stroke is four diameters or more. If the machine screw stroke is three diameters, the multiplication factor is 2.0. This assumes the screw has a 20:1 L/D ratio with general-purpose compression factors and flight depths.

Thus, Equation 1 is modified with a barrel factor of either 1.4 or 2.0 to yield Equation 3.

EQUATION 3

$$\text{Residence Time} = \frac{\text{Maximum Machine Shot Size}}{\text{Actual Shot Size}} \times \frac{\text{Cycle Time}}{60} \times (1.4 \text{ or } 2.0)$$

As with Example 1, in calculating the residence time, we would either have 2 minutes x 1.4 or 2 minutes x 2.0 to yield a residence time of either 2.8 or 4.0 minutes, depending on the machine injection stroke and its screw diameter.

I have used a barrel factor of 1.4 throughout the bulk of my career with good results. What I did not consider is the source of these barrel factors. In reviewing Olmstead's and Davis' data in their book, "Practical Injection Molding," they developed a barrel factor based on the bore diameter of the barrel which is cited in the above table.

Barrel Factors Based on Bore Diameter

Bore Diameter	Barrel Factor
30 mm & less	1.80
31-49 mm	1.65
50-69 mm	1.45
70-79 mm	1.30
80-90 mm	1.25
90-104 mm	1.20
105-109 mm	1.15
110 mm & greater	1.10

Source: Practical Injection Molding, Olmstead and Davis

In order to use this data, we must first calculate what is called Screw Inventory (SI), which considers a L/D ratio other than 20:1

and utilize a barrel factor from the table. The equations are as follows for Screw Inventory and Residence Time:

EQUATION 4

$$\text{Screw Inventory} = \frac{\text{Machine Barrel Capacity (GPPS)} \times \text{Melt Density of New Material} \times \text{Barrel Factor} \times \text{L/D Ratio}}{\text{Melt Density of GPPS} \times 20}$$

Where:

EQUATION 5

$$\text{Residence Time} = \frac{\text{Screw Inventory (oz)}}{\text{Actual Shot Size (oz)}} \times \frac{\text{Cycle Time}}{60}$$

Thus, for a machine with a 60-ounce barrel, bore diameter of 75 mm (1.30 factor from the table), L/D ratio of 22:1 running 23 ounces of PC, at a cycle time of 30 seconds our screw inventory and residence time is as follows:

$$\text{Screw Inventory} = \frac{60 \times 1.02 \times 1.3 \times 22}{0.97 \times 20} = 90.2 \text{ oz of PC}$$

$$\text{Residence Time} = \frac{90.2 \text{ (oz)}}{23 \text{ (oz)}} \times \frac{30}{60} = 1.96 \text{ minutes}$$

Comparing the screw inventory of 90.2 ounces versus the previous calculated screw inventory of 63.1 ounces of PC (see example 2), the barrel capacity is increased by 27.1 ounces of PC. An increase of nearly 43%, this will clearly affect the residence time for this example.

If one chooses to calculate the residence time based on the maximum machine shot size or to include the amount of plastic that is between the screw flights, multiple residence times can be calculated. In my humble opinion, Equations 4 and 5 put forward by Olmstead and Davis provide an alternate calculation considering a different L/D ratio along with the bore diameter of the barrel.

Additionally, using specific gravity to convert barrel capacities for different materials is often a mistaken approach that assumes the injection unit is rated in grams or ounces of GPPS and that rating applies to all materials molded on a machine. PT

ABOUT THE AUTHOR: Umberto Catignani is president of Orbital Plastics Consulting Inc., a consulting firm with more than 100 years of combined experience in scientific injection molding, training, material selection, part design review, in-mold instrumentation, project management and equipment selection. Catignani is past president of the Southern Section of SPE and has more than 28 years of hands-on injection molding experience. Contact: *404-849-6714*; *umberto@orbitalplastics.com*.

PT On-Site

AWD • Monroe, North Carolina

By Jim Callari
Editorial Director

Making Gains in the Drain Game

AWD blends extrusion and thermoforming technologies with plenty of home-brewed equipment and processes to keep water away from where it isn't supposed to be.

(l-r) AWD President Scott Morris; Marsha Jarvis, customer service and key accounts manager; Khalid Bey, plant manager; and German Valdes, general manager. Source (all photos): AWD

Probably ever since humankind first discovered the need for shelter, folks have been trying to move water from here to there. And that's been the business of American Wick and Drain (AWD) for more than 40 years.

Owned and operated by two families, AWD was launched in 1980. Recalls Scott Morris, the company's president and part of its second-generation ownership team, "but we soon realized it didn't make sense to import wick drains, which were relatively simple to manufacture." So, in 1982, AWD opened a headquarters and production plant in Stallings, North Carolina, then moved to Monroe in 1988, where it has consistently added production capacity and developed new products.

"For centuries, civilizations have been developing technologies to create air space for various purposes, such as draining water out of fields to other structures," he says, "and that's been driving us since we launched our first product, a formed core and fabric. The fabric restricts the passing of soil particles but allows the flow of water to the core, which forms a prefabricated air space to allow the flow of water."

"We have more manufacturing flexibility because of the equipment that we have, some of which we buy, some of which we develop ourselves."

In 2006, AWD expanded its footprint to the west with a new plant in Carson City, Nevada. Its product lines include prefabricated single and double-sided sheet drain, strip drain, chimney drain, combination drain and prefabricated vertical drain. It also makes patented fittings and accessories to provide a complete drainage system solution.

Wick drains are used in soil consolidation, explains German Valdes, AWD's general manager. They are profile extrusions — flat extruded strips with channels that are wrapped by a geotextile filter. Before construction, a site must be dried so a wick drain, typically about 4-inches wide and about ¼-inch thick, is installed vertically about 40- to 80-feet deep into the soil. They are typically installed about 4 feet apart in a grid pattern. The drains shorten the pore water drainage path, permitting the soil consolidation to occur, typically in weeks instead of years. The drain is "sacrificial" in the sense that it is never extracted; once the soil is settled and the water is removed, construction can begin.

AWD runs numerous extrusion lines at its plants in North Carolina and Nevada, and recently commissioned a new sheet line from Davis-Standard.

AWD got into the sheet strip drain business in 1984. Shown is a sheet extrusion and thermoformed core with a geotextile lamination.

Primarily used in infrastructure projects, Morris says AWD is the largest manufacturer of wick drains in the U.S., but in 1984 it began producing geocomposite sheet drains. Sheet drains are typically found on a vertical foundation wall. These start out as 4-feet-wide extruded sheets with a geotextile lamination. As Valdes explains, the purpose of the geotextile laminate is to keep soil out of the plastic core and filter out the fines. "This lets the water flow into the core. From there, the water goes down the wall, and is taken away with the footing drains," which are basically pipe. AWD estimates that wick drains currently comprise 15% of its overall business, with sheet drains taking up roughly 65% of the rest.

As for the remainder, AWD also makes strip drains. These are 1-inch-thick profile extrusions which are completely wrapped in fabric and come in widths of 6 and 12 inches, and are used as an alternative to corrugated pipe.

At each of its plants, AWD has an undisclosed number of lines to produce profile and sheet extrusions. AWD recently commissioned a Davis-Standard sheet line for its Monroe plant. It typically runs sheet inline with BMG (formerly Brown Machine Group) thermoformers. The company also utilizes a variety of proprietary offline processes to finalize the finished products.

In both its wick and sheet drain product lines, AWD has a half-dozen or so competitors. But it believes having multiple manufacturing processes and locations on both coasts give AWD a competitive advantage. Says Valdes, "We have more manufacturing flexibility because of the equipment that we have, some of which we buy, some of which we develop ourselves. Whereas most of our competitors, they have *a* manufacturing process, we have many." Adds Morris, "Of our competitors, we are the only ones with manufacturing capabilities on both sides of the country. And our business has expanded beyond the U.S. because of this level of flexibility. We have customers in Canada, Mexico, and have gone as far as India and Hong Kong."

Applications for AWD's drainage products include roadway edge drains as shown here.

On the sheet-drain side, products are driven by industrywide specifications. Valdes estimates there are roughly five core products, which as a result enables AWD to produce and inventory sheet in anticipation of demand.

And business has been robust at AWD, with Morris pointing to a 37% increase in revenue over the past few years. Morris attributes part of this increase to his state's appeal as a manufacturing and residential site.

FOCUS ON SUSTAINABILITY

AWD became focused on sustainability long before the term came into vogue. Fully 100% of the polymer it uses to make its products is postindustrial reclaim, PP- and HIPS-based. Valdes would divulge neither the source of his reclaim nor the quantity AWD buys. He notes: "But we have some partners that we had developed over the years. Getting the right suppliers is difficult. But every pound we receive is certified to our specifications. And we have worked with the recyclers to help them develop and refine their processes where the incoming material quality is consistent and steadily improving."

Strip drains are thermoformed extrusions wrapped in fabric and used as an alternative to corrugated pipe.

In its lab in North Carolina, AWD has a small extruder that runs samples for in-house testing. "If something is a little off, we know it can go back to our recycler and say, 'Hey, we might have an issue over here. Go back to the drawing board and check it out.'"

AWD is also constantly in search of more sustainable options among its fabrics, looking at cases where 100% virgin material might not be necessary. And Valdes points to an unspecified ongoing project that, when completed, will get AWD "very close to neutral carbon emissions."

Eric Horstman, AWD's director of sales, puts it this way: "We've innovated a lot since our first product in 1982, our prefabricated vertical drain (wick), which was a formed core and fabric. We've rounded out our product line with prefabricated strip drains that can replace pipe and stone, giving a building head-to-toe drainage in such applications as vertical backfilled walls and blindside walls, in addition to plaza decks, green roofs and under-slab applications.

"And we started to perforate the core for a double-side drainage in civil applications to allow water to flow from all directions. This innovation led to a green roof drainage and water reservoir to retain water for plant life and allow overflow to be taken away.

"But it does not end with a dimpled or wick air space. The shareholders continue to push the envelope of airspace with the development of the ability to create another airspace with an 'entangled mesh.' As a result, AWD can offer customers technical platforms with various products to meet the designer needs, and installers the ability to have the product of choice for a successful application." PT

AWD has developed a high-performance pattern for "entangled mesh" technology to meet the demands of the applications it serves.

INJECTION MOLDING

Servo-Hydraulic Injection Molding Machine With an Electric Injection Unit Premieres

In addition to all-electric machine models from the EcoPower and MicroPower series, Wittmann Battenfeld shows a servo-hydraulic SmartPower with an electric injection unit for the first time at Fakuma 2024. A company spokesperson told *Plastics Technology* that for a standard one-component servo-hydraulic SmartPower, the machine's clamp is servo hydraulic and the screw is electric. The company is now offering an electric injection unit as an option.

For the two-component (2K) machine at Fakuma 2024, the main injection unit is electric, while the auxiliary injection unit is servo hydraulic. The machine is molding a bottle opener at the show, with the larger electric injection unit shooting the PC substrate and the servo-hydraulic auxiliary unit overmolding TPE onto the PC part.

Wittmann says the optional electric injection unit enables the machine to combine the advantages of the servo-hydraulic SmartPower's larger mold space with the all-electric EcoPower's dynamic regulation and shot-to-shot consistency.

At Fakuma, a Combimold SmartPower B8X 120/350H/130S with an electric injection unit makes the aforementioned PC and TPE bottle opener on a tool from FKT Formenbau und Kunststofftechnik. The SmartPower features the Insider beside-the-press granulation and scrap reintroduction system, as well as a W918 robot and integrated conveyor. The robot inserts the metal parts fed from a magazine into the mold, where they are overmolded with polycarbonate. The PC and metal substrate is passed on to a second station by a rotary unit and overmolded with TPE.

INJECTION MOLDING

All-Electric Injection Molding Machine Line Expands

Engel expands its range of fully electric injection molding machines with the Fakuma debut of the e-mac 500. Extending the compact e-mac series upward, the new e-mac has 562 tons of clamp force and features the "High" clamping drive and an encapsulated toggle lever mechanism.

Saying the new press is designed to bridge the gap between standard and high-performance applications, the e-mac features iQ motion control for automatically adjusting the acceleration of the moving platen according to the tool's weight. In addition to reducing cycle times, Engel says this feature can cut energy consumption by approximately 30% compared to comparable hybrid or hydraulic injection molding machines.

MATERIALS

ExxonMobil Launches New Materials Portfolio Brand

ExxonMobil's Signature Polymers portfolio offers a new approach to service and partnership with customers and the broader value chain. This new approach includes combining the polyolefin products under a single portfolio brand — Signature Polymers. New initiatives and programs include:

- Establish customer commitments to underpin the enhanced approach to serving customers and the broader value chain
- New "PolyView" events to facilitate industry dialogue through sharing market insights and bringing together the broader value chain
- Signature polymers product architecture standardization and naming simplified to improve portfolio navigation and product selection
- A new Signature Polymers Academy focused on delivering training and workshops for our customers in key markets.

To better equip team members to serve as partners, all Signature Polymers employees are enrolled in comprehensive training to recognize methods and opportunities to listen, learn and collaborate to ultimately meet customer needs and enhance customer experience. The Signature Polymers group is providing platforms to facilitate collaboration and exchanging ideas. New, exclusive PolyView industry events are designed to increase dialog between industry leaders and bring together experts from across the value chain to address the challenges and opportunities in the plastics industry.

ExxonMobil's polyolefins portfolio is now organized per industry feedback. "Our products are now positioned under a single brand, Signature Polymers. Over the next year, we will transition some of our brands and grade names to better reflect the attributes and benefits they provide. We'll have fewer, more significant brands," says Alechia Crown, global brand manager.

BLOW MOLDING

Lighter, Higher Performance Base Design for Premium rPET Bottles

Stretch-blow molding machinery and tooling supplier Sidel has a new addition to its StarLITE-R range of base designs for 100% rPET bottles. StarLITE-R Premium is described as a “sleek, high-performance bottle base” for premium PET bottles for liquid dairy products, flavored water, juices, nectars, soft drinks, isotonics and teas. It’s said to offer a “sophisticated, streamlined appearance,” along with superior performance in bottle stability and lower environmental impact than competing designs.

Premium PET bottles are typically heavier than standard designs to provide an enhanced consumer experience through greater bottle rigidity and preserved beverage quality. But thicker bottle bases are prone to deformation, especially if manufactured at high speeds, Sidel notes. However, StarLITE-R Premium is said to guarantee bottle stability with its wide-standing surface geometry. An enhanced cooling circuit in the mold base is especially efficient for molding rPET, which is typically processed at higher temperatures than virgin PET. Sidel says these technical features provide high performance at speeds up to 2,500 bottles per hour per mold.

The design uses a Sidel-patented vault technology to avoid any visible ribs on the bottle base, which has a tall central dome surrounded by lower radiating ridges with alternating widths and lengths. The bottle base is easy to blow and requires 25% lower blowing pressure than average premium bottles, which saves energy. Premium bottles typically require higher blowing pressure due to their greater thickness, which adds to their environmental footprint. Adaptation of the new base design to 100% rPET increases the sustainability advantages of StarLITE-R Premium.

The new base is compatible with a wide range of bottle designs — including round and square-round, opaque and transparent, and single and multiserve sizes from 0.25 L to 2 L. It can be produced on Sidel EvoBlow, Universal and Series 2 machines, and is suited to both regular and aseptic filling lines. It’s also said to be easy to retrofit into existing production lines.

AUTOMATION

Lower Compressed Air Consumption, Compact Servo-Driven Rotary Axes and Easier Camera Integration

Wittmann has focused on compressed air consumption because it’s often the most expensive form of energy in production plants. At Fakuma, the company shows how Eco-Vacuum provides a vacuum solution for linear robots, which — depending on the application — can enable the consumption of compressed air to be cut considerably. These reductions are achieved through the application of demand-based vacuum control. Following vacuum buildup, the Venturi nozzle will only come on again before the negative pressure becomes too low to hold the part safely in place, with the vacuum limit values able to be calculated individually for each specific part.

The largest energy-saving potential is possible when handling inserts or molded parts with a smooth surface. For structured surfaces, however, the vacuum must be readjusted more often. During Fakuma, a Primus 128 linear robot demonstrates how EcoVacuum, which is available for the entire range of Wittmann robots, works in practice.

Wittmann says new servo-driven rotary axes can boost performance and efficiency, with even more compact and lighter combined rotation sequences now possible. The company says these weight savings enable higher load capacities for grippers and parts so that in many applications smaller robot models can be used than were previously enlisted. Various combinations of axes are shown at the fair, including A-, B- and C-servo-axes combinations.

At Fakuma 2024, Wittmann also introduces a new interface it developed in-house, enabling cameras from select manufacturers to be able to communicate with the robot. During the five days of the fair, a W918 robot demonstrates live how effectively this works in practice, with the operating screen of the camera software displayed by the Wittmann R9 robot Teachbox.

INJECTION MOLDING

Electric Injection Molding Machine Line Expands

German injection molding machine maker Dr. Boy GmbH & Co. KG presents three new models of its Electric series at Fakuma. The Boy 35 Electric, Boy 50 Electric and Boy 80 Electric machines feature clamping forces from 35 to 80 tons. Promising precision and efficiency typically associated with all-electric machines, the Electric series' drives for injection and dosing, as well as the ejector, are electromechanically designed.

Boy applied for a patent for the machine's use of dynamic pressure measurement on the injection mechanism via a strain sensor. Boy says the electromechanical drive enables precise positioning, dynamic motion and shorter cycles because of the parallel clamping force structure for injection. The two-platen clamp, which is servo-hydraulically powered, is combined with an electromechanical ejector for a oil- and lubricant-free mold installation space.

The new ejector provides more dynamic, precise travel, as well as parallel movements without a double pump, which can shorten cycle times and protect molded parts, the tool and robotics. The compact low-maintenance Output Signal Switching Device (OSSD) maximizes safety.

FEEDING

Feeders Now Furnished With Portable Touch-screen Controller

A new Portable Touchscreen Controller (PTC) is now available across all gravimetric and optometric feeders from Movacolor. (Optometric dosing involves a dosing disk and an optical sensor to count plastic pellets individually.) Designed with flexibility and efficiency in mind, the PTC reportedly reshapes the way production processes are managed. It is said to maintain the functionalities of the previous controller while introducing significant enhancements to meet the demands of modern production management.

These include:

- Ergonomic 8" full-color touchscreen for easy navigation and control, providing an intuitive, user-friendly interface
- Single CAN-bus cable offering up to 15 meters of portability, enabling convenient placement and increased flexibility during maintenance and production tasks.
- Storage capacity for up to 1,000 recipes with Basic Recipe Mode (BRM) for faster setup times and more efficient operations
- Manage up to 15 gravimetric solutions from one control screen, enhancing production flexibility and simplifying workflow management
- Multiple mounting options, including screws, ties, CMB, VESA and magnetic mounts for easy installation in any environment
- Continuous data logging and process monitoring, ensuring efficient and flexible production management

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1. Paid/Requested Outside-County Mail Subscriptions	18,934	20,898
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I certify that all information furnished on this form is true and complete.

Richard G. Kline, Jr., President

MATERIALS

Braskem Introduces Bio-Circular Polypropylene

Braskem announced the launch of its bio-circular polypropylene (PP), which will sell under the Wenew brand. Derived from used cooking oil, the PP is ISCC Plus certified bio-circular by mass balance. "Bio-circular" refers to "waste and residues of biological origin, as well as the biodegradable fraction of industrial and municipal waste," according to ISCC.

According to Braskem, the bio-circular PP is identical to traditional PP in properties and performance.

Bill Diebold, V.P. at Braskem America Polyolefins, says, "Our bio-circular PP is currently being supplied to various converters which support the quick service restaurant industry (QSR). Ideal users include QSR chains, retail food suppliers, traditional restaurants and snack food companies, especially those seeking to enhance circularity from their cooking oil usage. This versatile material is suitable for a wide range of applications, including food packaging, flexible packaging (such as films) and consumer goods."

Used cooking oil is collected and repurposed upstream to produce certified bio-circular ISCC Plus propylene. Braskem has partnered with several suppliers in the value chain who, through their production facilities, convert bio-circular feedstock into PP. As a mass-balanced product, Braskem's bio-circular PP retains the same properties and performance as traditional PP, enabling continuous integration into existing downstream converter production and end-of-life recycling.

TOOLING

Servo-Electric Core-Pulling Units

Servomold, a supplier of injection mold tooling automation, is presenting a new generation of SLY-type, servo-electric, core-pulling units, positioning them as a compact, powerful and clean alternative to hydraulic and pneumatic cylinders. Equipped with ball screw drives, the core-pull units can achieve positioning of slides, cores and plate movements in tools to the micron.

To ensure such accuracy, the unit's carriage contains precision bores with special, fine-centering elements for the assembly of universal slides. In addition, linear guides are integrated into the units versus slide guides inside the mold frame. Servomold says placing these outside the mold frame enables more compact tools and reduces maintenance costs.

Typical applications for the cleanroom-compatible linear motion systems are sleeve-shaped parts, including medical housings and cartridge holders for applications like auto-injectors. All versions are suitable for mounting on both new and existing molds as a retrofit.

The SLY-S-150 core pull has a 150-mm stroke, with a 100-mm stroke for the SLY-S-100 and 75-mm for the SLY-S-075. Thrust of 6 kN is standard, and a retrofittable planetary gearbox can double that value to 12 kN. Servomold says different slider bodies can be mounted on the carriage, enabling application-specific systems, while multistage movements can be tailored to a specific demolding process. Optional motor brakes securely hold the system in position in the event of a power failure.

Prices of PP, PET Drop; PE, PS and PVC to Follow

Going into fourth quarter, prices of the five commodity resins were heading downward, barring supply interruptions.

By Lilli Manolis Sherman
Contributing Editor

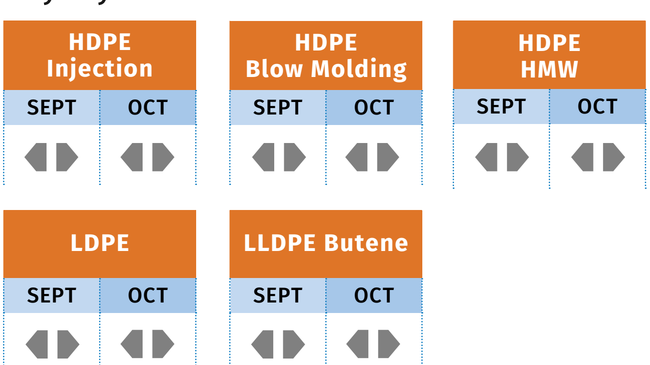
Prices of the five commodity resins appeared to be heading downward by the start of fourth quarter. PP and PET prices dropped in September, while PE, PS and PVC prices rolled over, despite supplier price hike attempts. Moreover, a buyer's market had emerged, due to across-the-board lower feedstock costs, rising resin inventories, slowed domestic and exports demand, as well as the impact of new capacity in the case of PE and PVC. Lower prices by year's end were forecast for all.

However, this trajectory could be reversed barring any supply interruptions due to weather-related or other production issues. Also, it was "touch-and-go" when the International Longshoreman's Association (ILA) began a massive strike on October 1 against the nation's East and Gulf Coast ports. However, the strike came to an end on October 3, when the ILA and the U.S. Maritime Alliance (USMX) came to a tentative agreement effective through Jan. 15, 2025. Estimations of such an event are that it could have resulted in more than $100 million a day of both imports and exports being jeopardized. In the plastics resins arena, it would particularly affect PE — over 40% of which is exported, and PVC, of which 30-35% is exported. Imports of PET would also be impacted. One industry source noted that each day of closing would translate to six days of resin supply.

Market Prices Effective Mid-October 2024

Resin Grade	¢/lb
POLYETHYLENE (railcar)	
LDPE, LINER	68-70
LLDPE BUTENE, FILM	65-67
HDPE, G-P INJECTION	65-67
HDPE, BLOW MOLDING	63-65
HDPE, HMW FILM	68-70
POLYPROPYLENE (railcar)	
G-P HOMOPOLYMER, INJECTION	66-68
IMPACT COPOLYMER	69-71
POLYSTYRENE (railcar)	
G-P CRYSTAL	97-99
HIPS	102-104
PVC RESIN (railcar)	
G-P HOMOPOLYMER	57-59
PIPE GRADE	55-57
PET (truckload)	
U.S. BOTTLE GRADE	63-65

Polyethylene Price Trends



PE PRICES FLAT, THEN DOWN

PE prices in September rolled over, though suppliers were out with a 5¢/lb increase being pushed up to October. ExxonMobil adjusted its increase to 3¢/lb, which was likely to be supported by others, though it was unlikely that any increase would be implemented. This outlook is according to PCW's Associate Director for PE, PP and PS David Barry; CEO Michael Greenberg of The Plastics Exchange (TPE); Mike Burns of Plastic Resin Market Advisors; and Kevin Mekaru, RTi's senior business leader commodity plastics.

As for the October-November time frame, sources indicated that the prevailing industry sentiment was downward, with some consultants projecting a 5¢/lb decrease, according to PCW's Barry. Based on the decline of PE spot prices, he ventured that a total drop of 5¢ to 7¢/lb was possible. He noted this is a very competitive marketplace with new supply making an impact and that reduced price negotiations were already taking place "behind the scenes." Barry also said suppliers were entertaining lowering export prices as export activity had been lackluster. Concurring, RTI's Mekaru noted that demand had softened while supplier inventories were very high.

Reporting for TPE on September's end, Greenberg said prices of all spot PE commodity grades were flat. "This is bucking producers' intent to implement a nickel price increase for September contracts," Greenberg said. "To the contrary, challenging export conditions have led to bulging upstream resin stocks and backups at packaging warehouses, which has shifted the implementation of the current domestic nickel nomination from still possible to unlikely."

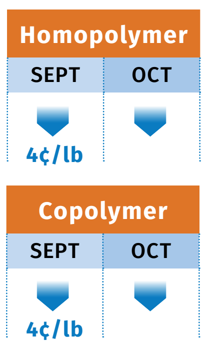
Plastic Resin Market Advisors' Burns noted that reduced prices and improved resin availability in the secondary market are leading indicators heading into the last quarter of the year. "Processors should expect favorable pricing and additional opportunities to improve prices," Burns said.

PP PRICES DROP

PP prices in September dropped by 4¢/lb in step with propylene monomer, according to PCW's Barry; Spartan Polymers' Newell; TPE's Greenberg; and Paul Pavlov, RTi's vice president of PP and PVC. Moreover, further decline within the October-November time frame was very possible. Both Barry and Newell saw potential of at least another 5¢/lb decrease, particularly if propylene monomer assets continued to run well.

Barry noted that PP suppliers were losing market share due to higher prices and were running at high operating rates, while spot prices were dropping. Asian PP resin and finished goods continued to add to an already competitive market. Newell noted that for six straight months this year, PP demand was 'impressive,' citing an increase in domestic sales of 5.95% through August, compared to year-to-date with 2023's average. Barry added, however, that 2023 was not a good year for PP overall.

Polypropylene Price Trends



RTi's Pavlov ventured that PP prices had potential to drop a total of 10¢ to 12¢/lb by year's end. These sources agree that industry sentiment does not reflect these gains, with processors being very cautious as to how things progress into 2025. While propylene availability was good in the fourth quarter, these sources cautioned that this could change fast in the first quarter of 2025 due to unscheduled shutdowns. "Monomer has had a real history of going up in price within first quarter over the last few years," Barry said.

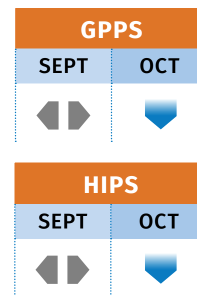
At September's end, TPE's Greenberg saw a more active spot PP market as sellers sensed a downward shift and lowered prices to keep material moving. "While plenty of processors are well stocked with resin, having beefed up supplies during the hurricane season, others welcomed the softer prices and picked away with purchase orders," Greenberg said. He noted that PP contract prices were cost-pushed 9¢/lb between June and August, but due to the monomer's price trajectory reversal, PP contract prices followed suit in September, with further decline in October possible.

PS PRICES TO FLATTEN THEN DROP

September PS prices rolled over for the sixth straight month, despite lower feedstock costs, including benzene and ethylene. A downward trajectory was likely through fourth quarter, according to PCW's Barry and RTi's Mekaru. Barry said September's implied styrene price — based on a 30% ethylene/70% benzene spot formula — was down more than 3¢/lb over four weeks.

September benzene contracts settled down to $3.61/gal from August's $3.80. Spot benzene prices of $3.18/gal going into October were expected to translate to an equal drop in October contract prices — about a 40¢/gal decline. As such, Barry and Mekaru anticipated a 4-to-5¢/lb downward movement for PS before the end of fourth quarter. Barry did note that benzene prices during first quarter historically rise due to scheduled and unscheduled shutdowns.

Polystyrene Price Trends

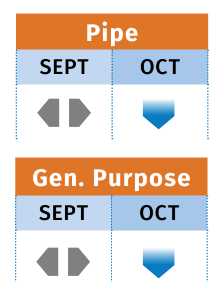


Meanwhile, PS supply remained adequate despite the outages at Chicago area plants operated by Americas Styrenics and Ineos Styrolution, though restart was expected for a general-purpose PS line at Ineos Styrolution's Channahon, Illinois, plant by early October.

PVC PRICES TO ROLLOVER THEN DROP

PVC prices in September rolled over after August's 2¢/lb drop, despite the 3¢/lb increase sought by all four domestic suppliers, according to RTi's Pavlov. Moreover, he ventured that another 1¢ to 3¢/lb was likely to come off by year's end. He cited slowed domestic and export demand and high supplier inventories, along with new capacity from Formosa by year's end. While domestic suppliers saw an 11% increase in demand for the first half of the year — which included an export advantage as global PVC prices were much higher — the trajectory of the latter had reversed to much lower.

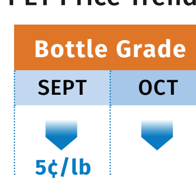
PVC Price Trends



PET PRICES DOWN

PET prices were dropping by 5¢/lb in the September-October time frame, based on lower raw material formulation costs, according to RTi's Mekaru. He saw potential for further downward movement by year's end, barring unscheduled shutdowns and the outcome of the port strike. He noted that the latter would affect the significant volume of PET imports, tightening supply and stopping any price relief.

PET Price Trends



Plastics Processing Contraction Slows Slightly

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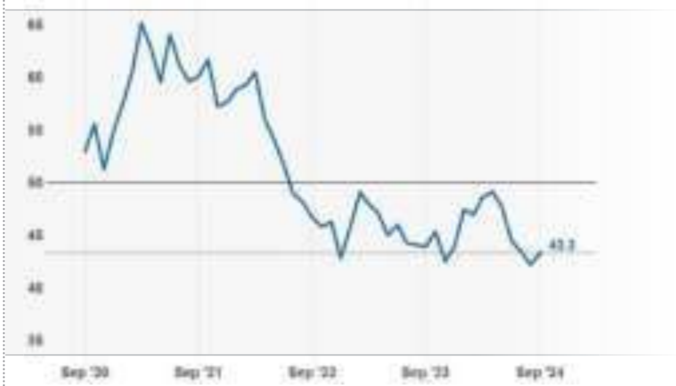
While the market is still sluggish, future business outlook rose significantly.

FIG 1 Gardner Business Index (GBI): Processing



The GBI is an indicator of the current state of plastics processing. Over 50 is expansion. Under 50 is contraction.

FIG 2 GBI Components Scorecard: Plastics

Shade = distance from 50 (darker shades are farther from 50)
Direction = change (pointing up is better)

FIG 3 Future Business Index: Plastics Processing

Numbers in Perspective

The GBI Plastics Processing Index continued to decline in September, reaching 43.3, which is 6.7 points below the growth threshold of 50. Although there was a slight improvement from 42.2 in August, the three-month moving average at 43.0 indicates continued sluggishness in plastics processing. On a brighter note, the future business outlook component remained steady, with a three-month moving average of 55.3 in September.

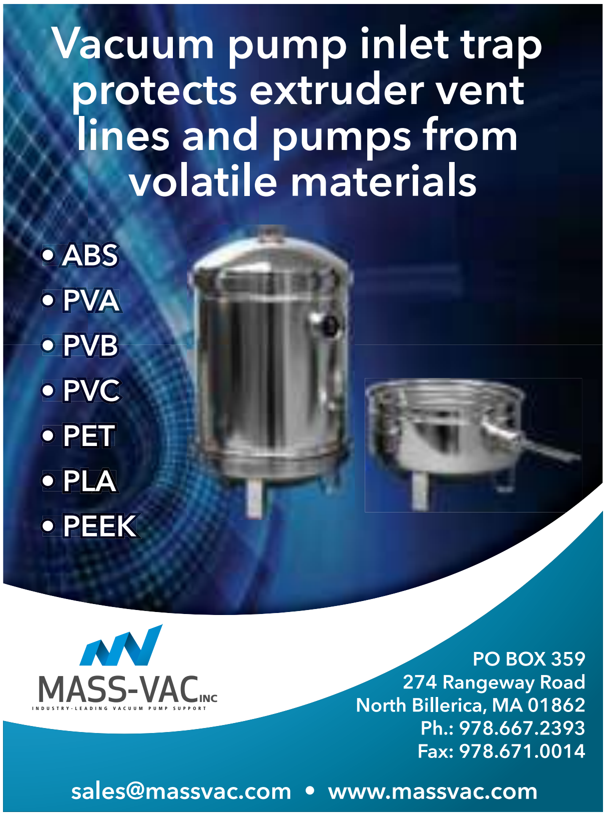
By Perc Pineda

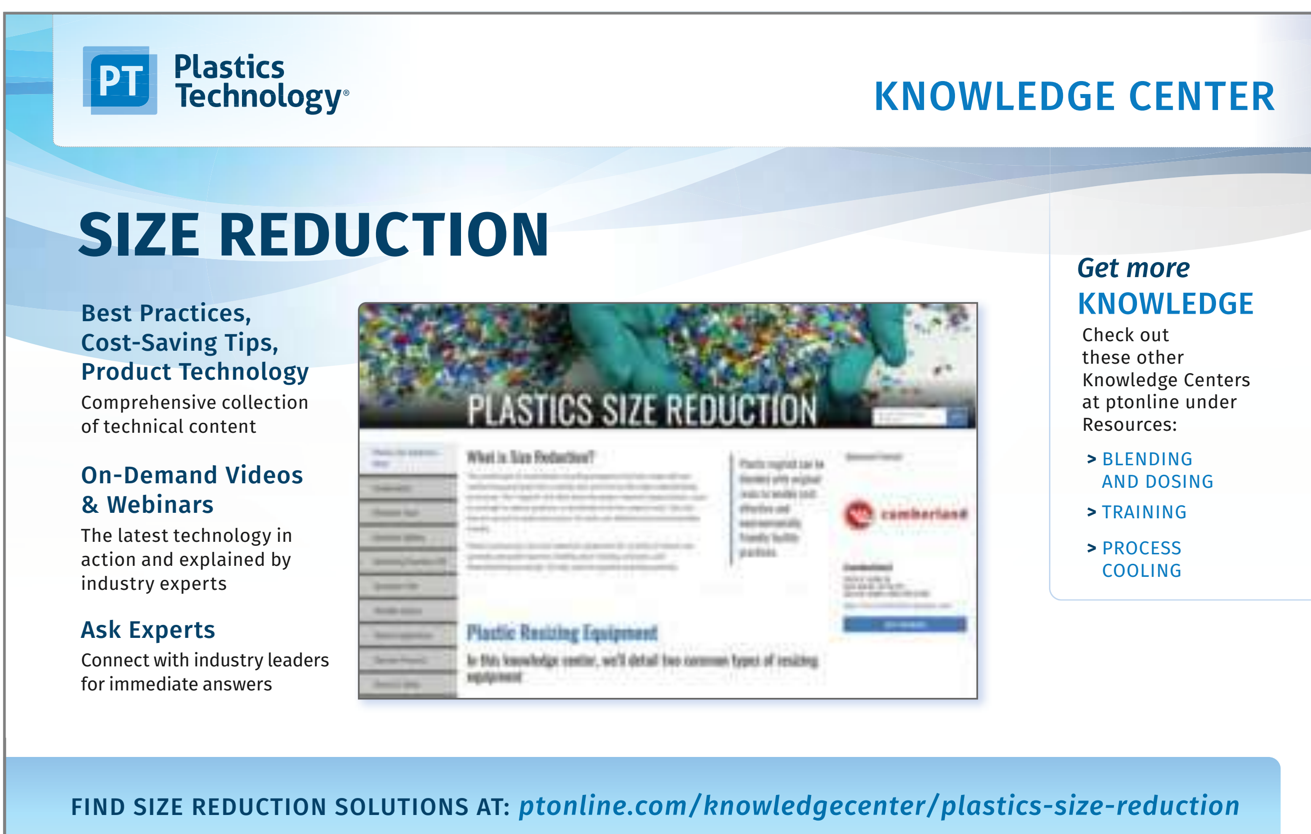
Three factors are noteworthy when analyzing the September GBI: Plastics Processing:

- **Seasonal Slowdown:** Summer typically represents a weaker period for manufacturing and international trade. Export and import activities usually drop during these months.
- **Economic Conditions:** While data for the third quarter is still incomplete, early indicators suggest manufacturing is stable but lacks significant growth drivers. Because manufacturing is a key market for plastics, the sector's interest-rate-driven slowdown has constrained plastics processing growth. Even with the Federal Reserve's 50 basis-point rate cut in September, immediate gains in manufacturing are unlikely due to the lag effects in monetary policy.
- **Labor Market Trends:** September's job report showed 254,000 nonfarm payroll employees were added, but 79.5% of them were in the services sector, with only 8.3% in the goods producing sector. Manufacturing lost 7,000 jobs, including 4,000 in motor vehicles and parts, which negatively affected plastics processing, while food manufacturing added 2,400 jobs. Plastics and rubber products manufacturing lost 1,700 jobs, with the unemployment rate increasing to 5.9% from 4.2% in August. PT

ABOUT THE AUTHOR: Perc Pineda, Ph.D., chief economist of the Plastics Industry Association (PLASTICS), is an industry thought leader and PLASTICS' primary expert and spokesperson on the U.S. and global economy, industry research, statistics, trends and forecasts. He produces PLASTICS' two annual flagship publications — *Size & Impact* and *Global Trends* — and trademarked the Global Plastics Ranking. Read his views and insights on the economy and the plastics industry at *plasticsindustry.org*.

EXTRUSION AUXILIARY EQUIPMENT





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JAPAN
Jeff Sloan, Publisher
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MALPACK — AJAX, ONTARIO

Leading Cast Film Processor Adding Blown Film Capacity

Malpack adds two multilayer blown film lines for agricultural, stretch hood and shrink films.

By Jim Callari
Editorial Director

Known primarily for its cast-film technology for producing nanolayer stretch film, Malpack is now venturing into blown film for the first time. In the months ahead, the Ajax, Ontario-based supplier of flexible packaging, which is part of the Trioworld Group, will install and commission two multilayer blown film lines furnished by Windmoeller & Hoelscher (W&H).

The first will be a five-layer Optimex II line for stretch hood and shrink film. The second will be a seven-layer Varex II line mainly for agricultural film. Malpack has been providing agricultural film from a sister plant in Europe, notes Lynne Elliott, the company's director of marketing and sustainability.

Malpack will be soon be adding its first two lines for blown film, including this Varex II 7-layer line for producing agricultural films. Source: W&H

The seven-layer line will enable Malpack to produce high-performance agricultural and stretch hood films with enhanced strength, durability and precision, which is essential for optimal film performance. Among other things, it features a system for injecting polyisobutylene into the melt stream, and a winder with advanced automated roll loading and off-loading capabilities, keeping manual intervention to a minimum.

'MEANINGFUL LEVELS OF PCR'

The line will produce structures primarily consisting of PE and ultimately what Malpack calls "meaningful levels of PCR." Malpack officials add that the seven-layer technology will enable it to reduce film thickness up to 15% compared to 3- or- 5-layer films without compromising mechanical strength and durability.

Malpack says it is committed to using PCR in its film products through its Loop product lines, which contain at least 30% PCR. "As we unveil this new production line and advance our Loop initiative, we are not only enhancing our technological capabilities but also reinforcing our commitment to sustainability," says Ricardo Cardoso, CEO of Malpack and president of Trioworld North America. "We are dedicated to creating a closed-loop system that minimizes waste and extends the life cycle of the materials that are used in our products, contributing to a more sustainable future for the industry.

"We are excited to collaborate with W&H and introduce this state-of-the-art production line," he adds. "This expansion not only enhances our manufacturing capabilities but also reinforces our commitment to delivering industry-leading products.

A number of Malpack's cast-film lines are also supplied by W&H. Notes Andrew Wheeler, president of W&H in North America: "W&H and Malpack have enjoyed a long-standing partnership and we're excited to support their next phase of product development in North America. Our seven-layer technology is designed to achieve the highest standards of performance, and we are proud to see it applied by Malpack."

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			1 - 23 doz. pr.	24+ doz. pr.	1 CASE	2+ CASES	
LIGHT WEIGHT COTTON	LADIES	312-L	$3.01	$2.85	$2.69	$2.57	100 doz. pr.
	MENS	312-X	$3.33	$3.15	$2.97	$2.84	100 doz. pr.
	MENS JUMBO	312-XJ	$3.57	$3.38	$3.19	$3.05	100 doz. pr.
MEDIUM WEIGHT COTTON	LADIES	315-L	$3.83	$3.62	$3.41	$3.25	100 doz. pr.
	MENS	315-X	$4.27	$4.04	$3.82	$3.64	80 doz. pr.
	MENS JUMBO	315-XJ	$4.48	$4.24	$3.99	$3.80	80 doz. pr.
HEAVY WEIGHT COTTON	LADIES	317-L	$4.70	$4.45	$4.20	$4.01	80 doz. pr.
	MENS	317-X	$5.46	$5.17	$4.88	$4.66	80 doz. pr.
	MENS JUMBO	317-XJ	$6.07	$5.75	$5.43	$5.18	80 doz. pr.
HEMMED LINT FREE NYLON ***BEST QUALITY!***	LADIES SMALL	550-SH	$9.30	$9.00	$8.75	$8.55	100 doz. pr.
	LADIES	550-LH	$9.50	$9.20	$8.95	$8.75	100 doz. pr.
	MENS	550-XH	$9.75	$9.45	$9.20	$9.00	100 doz. pr.
	MENS JUMBO	550-JH	$9.95	$9.65	$9.40	$9.20	100 doz. pr.

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