PLASTIC PIPES CONFERENCE ASSOCIATION

PPI Plastics Pipe Institute The Voice of an Industry.

teppfa

PE100+ ASSOCIATION

PLASTIC PIPES CONFERENCE & EXHIBITION

September 25 – 27, 2023
Walt Disney World Swan and Dolphin
Lake Buena Vista, Florida, USA

ABSTRACT BOOK

LAKE BUENA VISTA FL, USA
PLASTIC PIPES XXI

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WORD OF WELCOME

Dear Members of the Plastic Pipes Industry,

Welcome to the XXI Plastic Pipes Conference and Exhibition in Lake Buena Vista, Florida, USA. What a perfect location as Walt Disney World is home to imagination and creativity since 1971 and even earlier from Tomorrowland which seeded the concept for the "Experimental Prototype Community of Tomorrow" (EPCOT)." During this 3-day conference and exhibition, let us cultivate our inspired unbounded thoughts to continue attaining sustainable plastic pipe systems.

In reflection, how wonderful that our products, daily work and efforts improve the quality of life for many around the world. All should be proud knowing the factors critical to health and wellbeing, to include food security, clean water, energy and sanitation, are positively affected by the plastic pipes industry.

The PPCA Board of Directors, the PPXXI Organizing Committee and Evacon worked in earnest to present this forum of engagement. Please, participate and network; grow from this experience.

On behalf of "The Team", we look forward to engaging with you during PPXXI Lake Buena Vista.

Sincerely,

Sarah Patterson
PPXXI Organizing Committee Chair
PPI Hydrostatic Stress Board, Chair

THE PLASTIC PIPES CONFERENCE ASSOCIATION (PPCA)

E-mail: tonycalton@plasticpipesconference.com
Home Page: www.plasticpipesconference.com
Contact (primary): **David Fink,** PPCA Chairman
Contact (secondary): **Tony Calton**, Vice Chairman and Treasurer

The Plastic Pipes Conference Association (PPCA) was formed to organize and run the series of Plastic Pipes Conferences on behalf of the international plastics pipes industry. Member associations of the PPCA are the following:

- PE 100+ Association www.pe100plus.com
- Plastics Pipe Institute www.plasticpipe.org
- The European Plastic Pipe and Fittings Association www.teppfa.com

The organizations are represented by Robin Bresser (Secretary), David Fink (Chairman) and Tony Calton (Vice Chairman and Treasurer) respectively, all as voting board members. In addition, Sarah Patterson (PPXXI OC Chair) and Zoran Davidovski (PPXXI OC Co-Chair/ Technical Program Chair) serve on the board as non-voting members.

Each of the conferences are intended to be self-financing and profits from one event are re-invested in future conferences, educational tools or "spin-off" events. The mission statement emphasizes their focus in the industry:
"PPCA is a global association dedicated to the ongoing creation and distribution of technical and application information on plastic pipes systems in order to educate and expand their safe, cost effective and sustainable use."

The PPCA Board of Directors launched "Conference Partners"

The "Conference Partners" program was successfully initiated by the PPCA Board of Directors in 2020. This noteworthy endeavor stands as a testament to the esteemed contributions of plastic pipe trade associations that have been enthusiastically engaged in our conferences.
We take great pleasure in announcing and acknowledging the following entities for their invaluable role as advocates for PPCA conferences. Their dedicated support extends to fostering paper submissions, active involvement on organizing committees, and the hosting of spin-off conferences.

Conference Partners:

- China Plastics Piping Association (CPPA)
- European Council of Vinyl Manufacturers (ECVM)
- Australian Plastics Industry Pipe Association (PIPA)
- USA PVC Pipe Association (PVCPA)
- Southern African Plastic Pipe Manufacturers Association (SAPPMA)

PLASTICS PIPE INSTITUTE (PPI)

105 Decker Court, Suite 825, Irving, TX 75062 USA
Phone: +1-469-499-1044
E-mail: info@plasticpipe.org
Home Page: www.plasticpipe.org
Contact (primary): **David M. Fink**, President

With administrative offices located in Dallas, Texas, The Plastics Pipe Institute Inc. (PPI) is the major trade association representing all segments of the plastics piping industry. PPI members share a common interest in broadening awareness and creating opportunities that expand market share and extend the use of plastics pipe in all its many applications. As an association, PPI focuses collaborative efforts to accumulate data, concentrate facts and target resources toward advancements in applications and increases in widespread usage. PPI serves as a channel for information sharing, issues resolution, idea exploration and successful implementation guidance. The association is dedicated to advocacy and outreach efforts in support of these goals, and strives to expand the scope of overall education by broadcasting the many benefits and features of plastics pipe. The association is comprised of over 170 members and associates.

PPI promotes contemporary use of plastics piping for water and sewer, gas distribution, oil and gas production, industrial and mining uses, power and communications, telecommunications duct, hot & cold-water plumbing, hydronics, storm water and irrigation.

PPI vision and leadership resulted in the establishment of uniform testing and design criteria which became the foundation for all current applications of plastics piping. In addition, the methodology for the rating of long-term material strength and the adoption of standard preferred numbers to state specific properties were early PPI achievements. PPI also engineered the first code of acceptance for plumbing, industrial, commercial and gas distribution.

Values & Beliefs

PPI is a non-profit trade association dedicated to the advocacy and advancement of use of plastics in pipe infrastructure systems because they are smart, economical and sustainable solutions. The mission of The Plastics Pipe Institute is to advance the acceptance and use of plastic pipe systems through research, education, technical expertise and advocacy. This is accomplished through:

- Contributing to the development of standards
- Educating designers, installers, users and government officials
- Publishing up-to-date technical and general reports
- Collecting and publishing industry statistics
- Establishing forums for problem solving and new idea generation
- Maintaining liaisons with industry, educational and government group
- Providing a technical focus for the plastics piping industry
- Supplying associated web sites with up-to-date information

Diversity & Inclusion

Membership in PPI gives you and your company a voice in shaping the future of the plastics piping industry through education, research, advocacy, and networking. To be engaged, you must feel included and valued. PPI strives to build and nurture a culture reflective of the diversity of our association so that we may openly collaborate on initiatives for the advancement of our mission. We know through experience that different ideas, perspectives and backgrounds create a stronger and more creative work environment that delivers better results. We recognize that an inclusive and diverse work environment respects the unique characteristics, skills and experiences of all our members and employees.

Plastic Pipe Today

When it comes to selecting pipe materials for today's markets, what matters most? According to those who specify, install and pay for it, the answer is: security and reliability.
Today's different kinds of plastic pipe are cost-effective, durable, sustainable, and resilient choices.
Plastic pipes are in use now! And they are helping to replace crumbling infrastructure, conserving resources, eliminating loss and saving money. Plastics are the smart sustainable solution for now, and for generations to come.

LIST OF MEMBERS

Manufacturers

- Advanced Drainage Systems
- Agru America
- Ampacet Corporation
- APG Colors and Additives
- Aquatherm
- Armtec, Inc.
- Asahi-America
- Atkore-United Poly Systems (Atkore-HDPE)
- Auray Managing S.L.
- AVIENT CORPORATION
- BASF
- Battenfeld-cincinnati
- Bayport Polymers LLC
- Blue Diamond Industries
- Borealis
- Braskem Idesa
- Cabot Corporation
- Carriff Engineered Fabrics Corporation
- CB Supplies, LTD
- CDS (Custom Downstream Systems)
- Centennial Plastics
- Charlotte Pipe and Foundry Company
- Chevron Phillips Chemical
- Chroma Color Corporation
- Colloids Inc.
- Conventus Polymers, LLC
- Corma Inc.
- COSMOIND USA, Inc.
- Crumpler Plastic Pipe Inc.
- Davis Standard
- Dow Chemical
- Dura-Line LLC
- Endurance Poly Producers
- Evonik Corporation
- ExxonMobil Chemical Company
- Fast Fusion, LLC
- FB Balzanelli USA, Inc.
- FlexSteel Pipeline Technologies
- Flipping Iron Inc.
- Fluidos Industriales Mexicanos (FIMEX)
- Flying W Plastics
- Formosa Plastics Corporation
- Fratco, Inc.
- Georg Fischer Central Plastics LLC
- Golan Plastic Products LTD
- Hamilton Kent
- Harco Fittings
- Haviland Drainage Products
- Heatlink Group Inc
- Hubbell-Lyall

ORGANIZERS

- INEOS Olefins & Polymers USA
- Infra Pipe Solutions Ltd
- Ingenia Polymers Group
- INOEX
- Integrity Fusion Products, Inc.
- Interplast
- INVISTA
- IPEX USA LLC
- JM Eagle
- Kafrit NA Ltd
- Kerotest Manufacturing
- Krauss Maffei
- Lane Enterprises Holdings
- Les Plastiques DC Inc.
- Lubrizol
- LyondellBasell Industries
- Marco Polo
- McElroy Manufacturing, Inc.
- Milacron LLC
- Milford Companies
- Modern Dispersions, Inc.
- Modern Polymer Pipe and Extrusions
- Mr. PEX Systems
- Muehlstein
- NanoXplore
- Neat Companies Group
- NOV Fiber Glass Systems
- NOVA Chemicals
- NUPI Americas
- Orion Engineered Carbons
- OSI Plastics Division of Ohio Steel Industries
- Osterman & Company
- Pacific Corrugated Pipe – A Division of Lane Enterprises
- Performance Pipe
- Petroflex N.A., Ltd
- Pipeline Plastics, LLC
- Plasson USA
- Plastics Technology De Mexico
- Policonductos, S.A. DE C.V.
- Polyflow, LLC
- PolyPipe LLC
- Polytubes
- Prinsco Inc.
- QualPol LLC
- Quantum Polymers
- Rahn Plastics Inc.
- REHAU, Inc.
- Reliance Worldwide
- Rifeng Systems Co., LTD
- Ritmo America, LLC
- River Valley Pipe, LLC
- RTP Company
- SABIC
- Saco AEI Polymers, Inc
- SCITEQ A/S
- Shawcor Composite Production Systems
- Shell Polymers
- SICA America
- SIKORA International Corporation
- Smartpipe Technologies
- Soleno, Inc.
- Solvay
- Soucy Techno
- Southeast Culvert
- Southwire
- Sovereign Pipe Technologies, LLC
- Strongbridge-Tega
- TDR Pipe
- Teel Plastics
- Tex-Trude Pipe
- Timewell Drainage Products
- Titeflex Gastite Division
- Tododren
- Trademark Plastics Corporation
- Unicor North America
- Uponor, Inc.
- Valencia Pipe Company
- Valtic, S.A. DE C.V.
- Versaprofiles, Inc.
- Victaulic
- Viega LLC
- Watts Water Technologies
- Wavin (including Bow Plastics)
- Wegener Welding, LLC
- Widos Welding, LLC
- WL Plastics
- YogaPipe
- Zumbach Electronics Corporation
- Zurn PEX, Inc.

Distributors

- Core & Main
- Ferguson Industrial
- Gajeske, Inc.
- High Country Fusion Company, Inc.
- ICONIX Waterworks
- ISCO Industries, LLC
- PC Pipe LLC
- Sandale Utility Products, Inc.

Individual Consultants

- Harvey Svetlik Consulting
- Thompson McLean Associates

International Affiliates

- K-Flex
- Kan Therm USA
- MuoviTech AB

Professional Members

- Advanced Blending Technologies, LLC
- Advanced Pipe Services
- Alliance for PE Pipe
- American Society of Plumbing Engineers
- Bryan Hauger Consulting, Inc.
- Crossroads Engineering Services
- CSA Group
- Element Materials Technology
- Exponent Inc.
- Harvey Svetlik Consulting
- IAPMO
- ICC Evaluation Service
- IGSHPA
- JEE Consulting Services LLC
- Monolith Corporation
- NSF International
- PSILab, Inc.
- Simpson, Gumpertz & Heger
- SKZ Testing GmbH
- Thompson McLean Associates
- TRI Environmental
- UL Solutions

Honorary Lifetime Members

- Robert L. Ayres
- Michael Byrne
- Jim Craig
- Ivan DeBlieu
- Jim Goddard
- Gerry Groen
- Jim Inhofe
- Stan Mruk
- Gene Palermo
- Paul Petro
- Gary Runyan
- Harvey Svetlik
- George Zagorski
- Donna Stoughton

PE100+ ASSOCIATION

Phone: +49-1515-4398-858
E-mail: robin.bresser@borealisgroup.com
Home Page: www.pe100plus.com
Contact: **Robin Bresser,** President and Chairman

Founded in 1999, PE100+ Association is a global industry organization made of leading PE manufacturers (currently 14) whose objective is to promote consistent quality at the highest level in the production and the use of polyethylene for PE100 pipes.

Safety and quality control play critical roles in pressure pipe applications. PE100+ Association monitors and regularly tests the most critical properties of PE100 member materials against enhanced industry requirements. This way, PE 100+ Association is able to issue a "PE100+ Association Quality Materials List" on a regular basis.

PE100+ Association supports the plastic pipe industry by developing tools and sharing technical guidance for pipe design and installation, such as the PE Pipe Manual, PACE+ Design tool and No-Dig technical guide for trenchless installation. It also engages in CEN&ISO standardization and technical projects, such as Hydrogen permeation and a more sustainable detergent for accelerated testing.

PE100+ Association is a founding member since 2004 of the PPCA, which steers, further develops and organizes the Plastic Pipes Conference series.

PE100+ ASSOCIATION MEMBER COMPANIES

- Borealis
- Borouge
- Formosa Plastics Corporation
- Hanwha TotalEnergies
- INEOS O&P
- IRPC
- Korea Petrochemical IND. Co., LTD (KPIC)
- LyondellBasell
- PetroChina
- Prime Polymer
- SABIC
- SCG Chemicals
- Sinopec
- TASNEE

THE EUROPEAN PLASTIC PIPES AND FITTINGS ASSOCIATION (TEPPFA)

71. Avenue de Cortenbergh
Brussels, Belgium 1000
Phone: +32-273-963-78
E-mail: info@teppfa.eu
Home Page: www.teppfa.eu
Contact (primary): **Ludo Debever**
Contact (secondary): **Peter Sejersen**

TEPPFA – The European Plastic Pipes and Fittings Association – is the voice of the European plastic pipe and fittings manufacturers in Europe.

TEPPFA was founded in 1991 and is headquartered in the European Quarter of Brussels, close to the main European institutions. TEPPFA advocates the interests of 65 to 70% of the plastic pipe manufacturers designing and manufacturing sustainable plastic pipe system solutions for building and infrastructure on the European market.

TEPPFA's 14 multinational company members and 15 national associations across Europe represent 350 companies that manufacture plastic pipes and fittings. TEPPFA members' final products have an annual production volume of 3 million tons directly employing 40,000 people with €12 billion combined annual sales. TEPPFA members' final products are subdivided into two application groups: above ground systems for hot and cold water, surface heating and cooling, wastewater discharge and rainwater drainage, and below ground systems for sewers, stormwater, and drainage, drinking water and gas supply and, cable ducts.
During its more than 30 years history TEPPFA developed and updated > 200 product standards as part of CEN/TC 155 as well as >20 generic Environmental Product Declarations (EPDs)
Since 2021 TEPPFA has been implementing its new strategy, focusing on the sustainability credentials of plastic pipe systems in Europe.

Its new vision provides the focus:
"Plastic Pipe Systems are generally recognized as a durable, sustainable and high performant solution for critical infrastructure and essential services to society."

The new vision resulted in the definition of various sustainability projects with the aim to contribute to the achievement of its 3 must-win battles:
1. Plastic Pipe Systems contribute to the Circular Economy
2. Plastic Pipe Systems are sustainable as an end use solution and during manufacturing.
3. Plastic Pipe Systems are high quality and durable solutions
TEPPFA positions itself as polymer neutral.
For more information: www.teppfa.eu

TEPPFA COMPANY MEMBERS
(14) include world leading manufacturers of plastic pipes:

- Aliaxis
- Dyka
- Geberit
- Genuit Group
- Georg Fischer
- LK
- Molecor
- NUPI
- Pipelife
- Radius Systems
- Rehau
- TeraPlast
- Uponor
- Wavin

TEPPFA National Association members:

- Austria: FCIÖ
- Belgium: PolyConnect (Essenscia)
- Czech Republic: ADPP
- Denmark: Plastindustrien
- Finland: FIPIF
- France: UPB
- Germany: KRV
- Hungary: APPM
- Ireland: IPPMA
- Poland: PRiK
- Spain: AseTub
- Sweden: NPG
- Switzerland: VKR
- The Netherland: BureauLeiding
- United Kingdom: BPF Pipes Group

TEPPFA Associated Members:

Borealis, ECVM, LyondellBasell, Lubrizol

TEPPFA Supporting Members:

Rollepaal

Chair of the Organizing Committee

Sarah Patterson holds a Bachelor of Science degree in Chemical Engineering from Kansas State University. In 2000, she started her career with The Dow Chemical Company (Dow) as a run-plant engineer in production. In 2006, Sarah transitioned to the Polyethylene Pipe Technical Service and Development Group (TS&D). As a TS&D Research Scientist, her responsibilities included new business developments for various technologies using plastic materials to include non-pressure and pressure pipe applications.

In 2013, Sarah became the Technical Director of the Plastics Pipe Institute (PPI) and Chair of the PPI Hydrostatic Stress Board (PPI HSB). In 2019, she transitioned fully to the PPI HSB. Responsibilities include spearheading the technical board, which focuses on the long-term strength of thermoplastic pipe materials intended for pressure applications, and development of appropriate policies and procedures for the conduct of this activity; interfacing with >150+ manufacturers (domestic/ international). Over the years, industry participation includes PPI, ASTM (F17, D20, E07), ISO TC138 (SC2, SC4, SC5, SC8), ASME (BPV, NPPS), ASCE, CSA B137, PE100+ Association Advisory Council and the Plastics Pipe Conference Association (PPCA) BOD.

Co-Chair of the Organizing Committee / Technical Program Chair

Zoran Davidovski, the Head of R&D and Sustainability at Pipelife, brings over 25 years of experience in the plastic industry. With a master's degree in mechanical engineering from the University of Zagreb, Croatia, Zoran began his journey as the General Manager of Pipelife's Croatian factory in 1998. Upon becoming a part of the corporate headquarters in 2001, he has taken on diverse responsibilities in marketing and product management. Zoran is a key representative of Pipelife in TEPPFA (The European Plastic Pipes and Fittings Association), where he serves as chairman of WG EF, and a member of WG AG. Notably, he has chaired the Plastic Pipes conferences PPXIV, PPXVI, PPXVIII, and PPXX. Born in Croatia and now residing in Austria, Zoran's expertise and leadership contribute significantly to advancing sustainable practices and innovation in the industry.

Pipelife is a leading international manufacturer of sustainable piping solutions that connect people and communities with water, energy and data.

Co-Chair, Exhibition

Shane Schuessler holds Bachelor of Science degrees in Mechanical Engineering from the University of Illinois – Chicago, and Physics from Baker University. In 1997, he started his career with Phillips Driscopipe as a project engineer in their HDPE pipe-manufacturing group. In 2002, Shane joined ISCO Industries where he is currently the Vice President of Global EPC and International Sales.

Throughout his career, Shane has assisted numerous global industrial and power engineering firms in all aspects of HDPE design, installation and project execution. He has been an active member in the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code committees, assisting in developing rules for installing HDPE piping systems in ASME nuclear applications. Shane is currently the secretary of the ASME Section XI Working Group Non-Metallics Repair-Replacement. He is also a task group member on the Section IX HDPE Fusion and Section III HDPE Materials committees.

ORGANIZING COMMITTEE MEMBERS

- John Kurdziel – Advanced Drainage Systems
- Steve Sandstrum – Borealis Compounds Inc.
- Suleyman Deveci – Borouge Pte.
- Wang Zhanjie – China Plastics Piping Association (CPPA)
- Sayaka Yamada – Kobe Steel Ltd.
- Forest Hampton – Lubrizol Advanced Materials
- Douglas Keller – LyondellBasell
- Jim Johnston – McElroy
- Robin Bresser – PE100+ Association/ Borealis
- Randy Knapp – Plastics Pipe Institute (PPI)
- Lance MacNevin – Plastics Pipe Institute (PPI)
- Vincent Stone – PVC4 Pipes/ The European Council of Vinyl Manufacturers (ECVM)
- Christian Apel – Radius Group Procurement Company
- Dean Jenne – SACO AEI Polymers
- Carl Baker – Shell Polymers
- Jan Venter – Southern African Plastic Pipe Manufacturers Association (SAPPMA)
- Monica De La Cruz – Spanish Plastic Pipes and Fittings Manufacturers Group (AseTUB/ANAIP)
- Tony Calton – The European Plastic Pipe and Fittings Association (TEPPFA)
- Peter Sejersen – The European Plastic Pipe and Fittings Association (TEPPFA)
- Cindy Bray – The Plastics Industry Pipe Association of Australia (PIPA)
- Bruce Hollands – Uni-Bell PVC Pipe Association (PVCPA)
- André Nijland – Wavin Technology and Innovation B.V.

Event Organizer Company

evaCON CONFERENCE MANAGEMENT AND CONSULTING LTD.

KEY CONFERENCE ITEMS

Conference Venue: Walt Disney World Swan and Dolphin

1200 Epcot Resorts Blvd., Lake Buena Vista, FL 32830, USA
NOTE: PPXXI conference is hosted at The Swan: **https://swandolphin.com/**

A recipient of the prestigious Meetings & Conventions Hall of Fame Award, the Walt Disney World Swan and Dolphin is a nationally respected and recognized leader in the convention resort arena. In the heart of Walt Disney World® Resort, the award-winning Walt Disney World Swan and Dolphin is your gateway to Central Florida's greatest theme parks and attractions.

Ideally located in the heart of Walt Disney World. The resort offers unique Disney Differences with character appearances, theme park events, Disney Institute seminars, and much more.
Enjoy 22 world-class restaurants and lounges, including Mediterranean, steak, seafood, Italian, sushi, poolside dining and room service.

Paper Presentations

PPXXI conference and exhibition welcome and opening session begins Monday, September 25, 2023 at 9:00 am EDT. A 30-minute networking event immediately follows the opening session in the conference floor foyer. The first two concurrent technical sessions (A and B) are scheduled from 10:30 am – 11:30 am EDT. All technical sessions are scheduled to occur in the same two rooms.

The conference and exhibition are scheduled to close on Wednesday, September 27, 2023 by 3:40 pm EDT. During the closing ceremony, the dates and locations of PPXXII in 2025 and the 2024 Spin-Off conference will be announced.

Poster Gallery

The PPXXI posters highlight technical work in the industry. The posters are displayed in the conference foyer. These are viewable anytime during the conference. Each poster paper is included in the conference proceedings and details the author's name, company and their contact information.

Information Board, Messages

There will be a Message Board for official notes of the conference and program next to the Registration and information desk. Please, check the board daily and use it for important messages.

Exhibition

The PPXXI Exhibition Hall is scheduled to open Monday, September 25, 2023. The exhibition map appears in the mobile app, on the PPXXI web page and near the exhibition hall entry way.
All conference lunches and breaks will occur in the exhibition hall.

- Monday, September 25: 9:00 am–6:00 pm
- Tuesday, September 26: 9:00 am–5:00 pm
- Wednesday, September 27: 9:00 am–5:00 pm

REGISTRATION

All participants must check in at the PPXXI Registration desk to receive their badge and conference materials. Registration desks are in the foyer of the conference level in the Walt Disney World Swan. Hours of operation are shown below:

- Sunday, September 24th: 2:00 pm–8:00 pm
- Monday, September 25th: 8:00 am–5:00 pm
- Tuesday, September 26th: 8:00 am–6:00 pm
- Wednesday, September 27th: 8:00 am–6:00 pm

On-site registration and on-site payment (only cash is accepted) will be available on spot.

Badge

All registrants must wear their PPXXI badge when participating in the different events. This includes the Accompany Persons. The badge allows access to the technical program sessions, networking events to include the exhibition, Gala Dinner, Welcome Reception, lunches and breaks.

Accompanying persons

Registered Accompany Persons are invited to attend the Gala Dinner, Welcome Reception, lunches and breaks. All Accompany Persons must wear their PPXXI badge.

Internet access

The **Corporate Sponsor, Chevron Phillips Chemica**l, has provided internet access for all registered participants, free of charge. Connection details below

- **SSID:** PPXXI Conference
- **Password:** CPChemPPXXI

Online Proceedings

After registering on-site, Evacon will email the information to access the conference proceedings at https://ppca-onlineproceedings.com/. The login information is specific to the user holding the valid PPXXI registration.

The online conference proceedings contain the following information:

- All presentation and poster papers. These can be read online, downloaded or printed out.
- The technical program, which was included as a reference.
- Company profiles of the sponsors and exhibitors. These can be accessed without logging into the online conference proceedings.

CONFERENCE MOBILE APP

The PPXXI conference is supported by the Smart Abstract mobile app and **sponsored by McElroy**. For PPXXI registrants, use is free and the content is accessible. PPXXI participants are highly encouraged to use and to upload your photo, which helps others find you during the conference.

The PPXXI conference is supported by the Smart Abstract mobile app and sponsored by McElroy. For PPXXI registrants, use is free and the content is accessible. PPXXI participants are highly encouraged to use and to upload your photo, which helps others find you during the conference.

The mobile app provides access to all conference information to include bios for the authors and speakers; company profiles for the sponsors and exhibitors; the exhibition map and abstracts for the presentation and poster papers. Additional features include the following:

- in-app messaging for networking
- the ability to personalize an itinerary by selecting presentations of interest to you.
- pushed messages by the conference organizers
- Messages could include the following:
  - program changes
  - reminders of the networking events
  - confirmation of event locations
  - confirmation of event times

NOTE: Although messages will post next to the registration desks, the made communication method will be the mobile app.

If there are questions at any time, Evacon is ready to assist. Just stop by the conference registration desk to have your questions addressed.

To register in the PPXXI mobile app, follow the below instructions:

1. Scan the QR Code to use the mobile app.

NOTE: In case, the code is not working use the following direct link to reach the app:
app.ppxxi.smart-abstract.com

2. For installing the Conference App, please make the following steps:

- In Safari:
  - Click on the Share icon at the bottom of your view
  - Scroll down at select "Add to Home Screen"
  - Confirm that you want to add the app to your home screen
  - Open the app via the icon on the home screen
- In Chrome:
  - When you open the app, the installation note "Add this app to your home screen" opens automatically
  - Add the app to your home screen by confirming with "Install"
  - From now you can open the app directly via the app icon on your home screen.

3. Sign-in at the conference app into the personal agenda

- In order to create your personal agenda and able to see all the functions, please sign-in first:
  - Select „Sign-in "in the side menu
  - Enter your email (For authors/presenters, please use the same email address that you have made the abstract submission)
  - Insert name (display name on the app)
  - Choose password (upper- and lower-case letters, min. 8 characters)
  - Accept privacy policy and click "Continue"
  - You will receive an email to activate your access.

4. After activation, log in with your access data.

- Complete your user profile
- Open profile via your display name at the side menu
- Upload photo
- Check and complete your personal data

NETWORKING EVENTS

Welcome Reception Sponsored by iNOEX

The Welcome Reception is scheduled for Monday, September 25, 2023 in the Exhibition Hall. This event is open to all registered attendees and registered Accompany Persons. The suggested attire is business casual. Attendees are welcomed to gather in the foyer while waiting for the doors to open.

Time	*Event Description*
4:45 pm	• Guests to gather in the Exhibition Hall
5:15 pm	• Opening: PPXXI OC Chair • Sponsor Welcome: iNOEX
6:00 pm	• Closing

Gala Dinner sponsored by teppfa

The Gala Dinner celebration is scheduled for Tuesday, September 26, 2023 in The Swan Ballroom. This event is open to all registered attendees and registered Accompany Persons. The suggested attire is business / cocktail wear. Attendees are welcomed to gather in the foyer while waiting for the doors to open.
NOTE: Those attending the event are required to wear their badge to enter.

Time	*Event Description*
7:45 pm	• Guest to take their seats.
8:00 pm	• Opening, PPXXI OC Chair • Sponsor Welcome: TEPPFA
10:30 pm	• Closing

Lunches and Coffee Breaks

All lunches and coffee breaks will take place in the PPXXI Exhibition Hall.

Business Meeting Space

A meeting room, Parrot, is available by the Registration Desk. Availability is first-come-first-served.

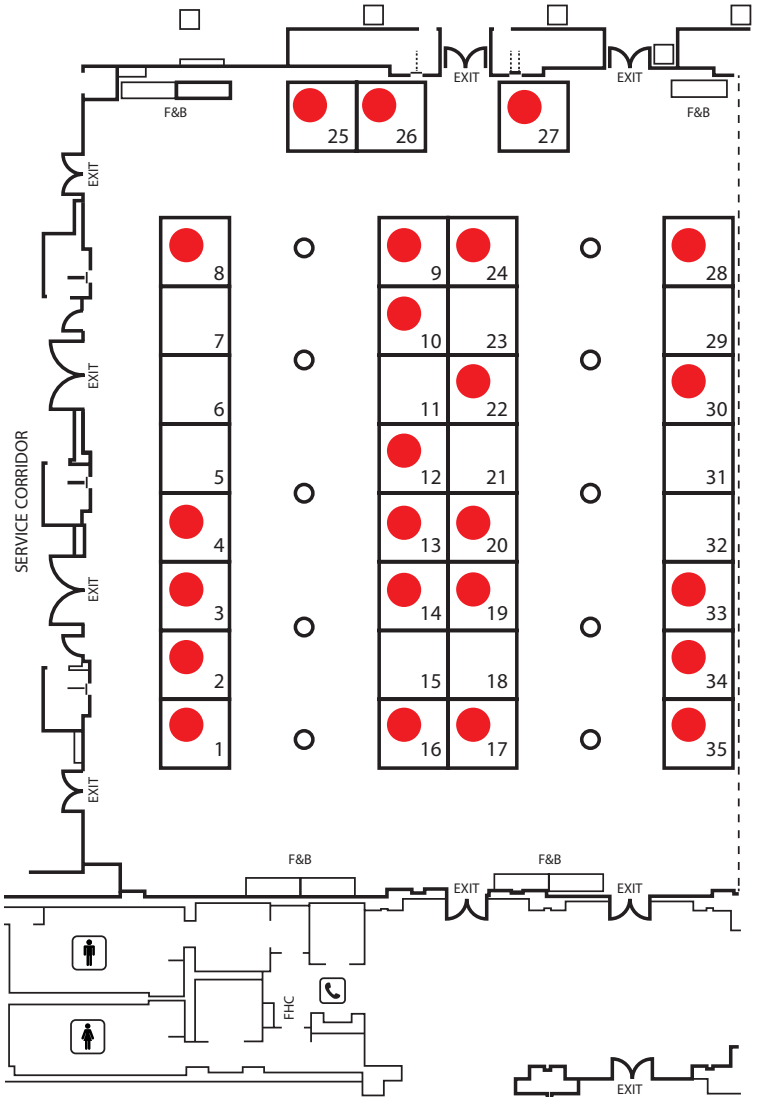
SPEAKER INFORMATION

Speakers

Each speaker, excluding those in the opening session, are assigned 20-minutes for presentation and questions. The session moderator will monitor the time and questions.

The speaker ready room is Macaw which is located by the Registration Desks.

MAP OF EXHIBITION



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*Subjects to updates.

CORPORATE SPONSOR

10001 Six Pines Drive
The Woodlands, Texas
77380, USA
Phone: +1-832-813-4100
Home Page: www.cpchem.com
Contact (primary): **Vivek Rohatgi**
Contact (secondary): **Jay Chaffin**

CPChem is one of the world's top producers of olefins and polyolefins and a leading supplier of aromatics, alpha olefins, styrenics, specialty chemicals, polymer resins and plastic piping.

Founded in 2000, through a joint venture between Chevron U.S.A. Inc. and Phillips 66 Company, Chevron Phillips Chemical global headquarters are based in The Woodlands, Texas USA, with sales and production facilities located throughout the world.

CPChem is committed to promoting excellence in research and development that fosters knowledge exchange to improve polymer materials, additives, processes, installation, and testing and characterization methods used in plastic pipes.

In January 2022, CPChem announced the first commercial sales of Marlex® Anew™ Circular Polyethylene, reaching a significant milestone in its efforts to help strengthen the circular economy for plastics. "Using advanced recycling technology, the company is now supplying this fully certified circular polyethylene product made from a feedstock processed from difficult-to-recycle plastic waste."
"These new certified products reflect our mission to manufacture chemicals and polymers the world needs, provide enriching careers, and create shareholder value because we care about each other, our customers, and our communities."

GOLD SPONSOR

battenfeld-cincinnati

823 South By-Pass
McPherson,
KS PO Box 832,
67460, USA
Phone: +1-620-241-6843
Fax: +1-620-241-0207
E-mail: usa@battenfeld-cincinnati.com
Home Page: www.battenfeld-cincinnati.com
Contact (primary): **Paul Godwin**
Contact (secondary): **Mark Malone**
Name of representative on the booth: **Paul Godwin, Mark Mulone, Andreas Türk**

battenfeld-cincinnati is a leading company that manufactures energy-efficient, high-performance extruders and complete extrusion lines providing complete solutions to customers' specifications. battenfeld-cincinnati offers sustainable solutions for a wide range of applications in all areas of pipe, profile, sheet, foam PVC sheet and pelletizing.

Sustainable Solutions is the promise to our customers. We ensure this by placing great value for efficient material processing and efficient energy consumption. Part of this sustainability is to deliver machine components that have long service lives and require minimal time for maintenance or cleaning. Sustainable Solutions include extrusion components that are well suited to new materials or recycled materials – helping the process of establishing closed-loop recycling.

Our global network, strong partnerships along the entire supply chain and cooperation with renowned institutions and associations, we are able to handle these challenges as a team and adapt to any situation for our customers.

We offer our customers Sustainable Solutions Worldwide with maximum performance and energy efficiency, together with our customers we will develop the product solutions for today and tomorrow.

battenfeld-cincinnati customers benefit from a comprehensive global sales and service network and production facilities in Germany, Austria, China and United States of America.

battenfeld-cincinnati's product portfolio includes:
- Single screw extruders
- Parallel and conical counter-rotating twin screw extruders
- Planetary roller extruders and pelletizing systems
- Monolayer and multilayer polyolefin and PVC pipe heads
- Co-extrusion feedblocks and roll stacks for sheet extrusion
- Downstream equipment for pipe and profile extrusion

GOLD SPONSOR

1221 McKinney Street
Houston, TX
77010, USA
Phone: +1-281-577-7568
E-mail: pilar.davis@lyondellbasell.com
Home Page: www.lyondellbasell.com
Contact (primary): **Pilar Davis**
Contact (secondary): **Doug Keller**
Name of representative on the booth: **Doug Keller**

About LyondellBasell
As a leader in the global chemical industry, LyondellBasell strives every day to be the safest, best operated and most valued company in our industry. The company's products, materials and technologies are advancing sustainable solutions for food safety, access to clean water, healthcare and fuel efficiency. LyondellBasell places high priority on diversity, equity and inclusion and is Advancing Good with an emphasis on our planet, the communities where we operate and our future workforce. LyondellBasell has stepped up its circularity and climate ambitions and actions to address the global challenges of plastic waste and decarbonization.

Our products are key to advancing a modern and more sustainable world and we are constantly innovating to develop better products to meet our customers' and society's needs. LyondellBasell believes that collaboration across the value chain is critical to address global challenges.

At the Plastic Pipes XXI conference, LyondellBasell will present innovative circular and traditional polymer solutions which address today's and tomorrow's market trends in the field of infrastructure.
For additional information, visit www.lyb.com or contact your LyondellBasell representative.

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Asj-vägen 7
582 54, Linköping
Sweden
Phone: +46-102-794-700
E-mail: info.emt.epp@element.com
Home Page: polymer.element.com
Contact (primary): **Shagan Dhillon**
Contact (secondary): **Mattias Svedberg**
Name of representative on the booth: **Shagan Dhillon**

ELEMENT, SILVER SPONSOR OF PPXXI and a global third-party independent testing provider for the plastic pipes and fittings industry. ISO 17025 accredited and ILAC recognized.

SILVER SPONSOR

1254 Enclave Parkway
Houston, TX
77077, USA
Phone: +1-800-258-2436
E-mail: jvaradi@dow.com
Home Page: www.dow.com
Contact (primary): **Jennifer Varadi**
Contact (secondary): **Todd Hogan**
Name of representative on the booth: **Todd Hogan, AC Banks**

DOW

With decades of industry-leading experience and collaboration throughout the value chain, Dow provides a rich portfolio of polyethylene (PE) resins that enable the development of durable pipe solutions, offering sustainable longevity with exceptional long-term performance, highly efficient processing and installation and reduced life cycle costs.

With a lineup that combines proven field performance with the latest breakthroughs, Dow offers technologically advanced materials for a tremendous range of applications, including:

- Municipal and industrial water pipe
- Natural gas distribution pipe
- Oil and gas gathering pipe
- Hot and cold-water pipe for plumbing
- Radiant floor heating systems
- Telecommunications and power conduit
- Corrugated pipe
- Microirrigation tubing and tape
- Geothermal

Dow's commitment goes far beyond the manufacturing and delivery of quality PE resins. Along with the company's global reach and continuous focus on R&D and innovation, Dow works closely with its customers and other members of the value chain to develop custom-tailored solutions that meet and exceed specifications.

With an innovation-first mindset and a push for collaborative efforts across the value chain, Dow is helping develop better, more sustainable pipe, irrigation and infrastructure throughout the world.

SILVER SPONSOR

Ctra M-206 Torrejón-Loeches Km 3.1
28890, Loeches, Madrid
Spain
Phone: +34-911-337-090
Fax: +34-916-682-884
E-mail: info@molecor.com
Home Page: www.molecor.com
Contact (primary): **Almudena Blazquez**
Contact (secondary): **Dolores Herran**
Name of representative on the booth: **Dolores Herran**

Molecor is a Spanish company specialized in infrastructure, sewage and edification solutions, whose pipes and fittings are marketed in more than 30 countries around the world. It was founded in 2006 with a focus on the development of Molecular Orientation technology applied to pressurized water pipes and since then its exponential growth and continuous improvement in the advancement of efficient and innovative solutions for the development of technology for the manufacture of Oriented PVC pipes, has made it the current world leader in the sector. In August 2020, the Spanish fund MCH Private Equity acquired a majority stake to provide Molecor with more strength to grow and develop its full potential, since in addition to the monetary contribution, MCH contributes with its industrial and financial expertise in both the organic and inorganic growth of the project. On September 30, 2021, Molecor completes the process of acquiring the production unit of Adequa (former Uralita Sistemas de Tuberías), adding to its portfolio of infrastructure solutions sanitation and edification to become one of the leading companies of pipes and fittings in Spain. In this way, it continues a great industrial project with a strong focus on technology, efficient water use and internationalization.

Our purpose: To improve the quality of life for people everywhere in the world, bringing affordable water within their reach through innovative, efficient and sustainable solutions.

Our values:

- **Nonconformism.** We seek to surpass previously achieved levels (quality, efficiency, innovation, safety, etc.) and we are not satisfied with what we have achieved.
- **Globality.** We are a global company, capable of offering our services and products anywhere in the world. To this end, we create an open, diverse and inclusive environment in which any talent can develop, regardless of nationality, location or origin.
- **Honesty.** We apply integrity at all levels in our relationships and decisions, within an environment of tolerance and respect. With transparency, but always respecting legality, regulatory limits and the principles of confidentiality and privacy.
- **Commitment.** We seek, value and are committed to the people around us, to the environment and to the communities in which we are present and in which we provide our services.
- **Attitude.** We like challenges and we are willing to face them actively, giving the best of ourselves, with maximum collaboration, flexibility, openness and sincerity.

The efficient transport and management of water is one of the fundamental bases for progress and therefore represents a great business potential. Molecor's objective is to be a world leader in the sector and a benchmark for quality, efficiency and sustainability. For this reason, it presents a complete portfolio of products for different applications:

- Edification solutions (EVAC+, AR®, floor evacuation, gutter system, siphons).
- Sanitation and drainage solutions (SANECOR® corrugated PVC sanitation, SANECOR® manholes, COMPACT SN4 smooth system, PVC drainage system).
- Supply and distribution solutions (TOM®, ecoFITTOM®, smooth PVC pressure, PE smooth pipe fittings)

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1913 Olde Homestead Lane Suite 101.
Lancaster, PA
17601, USA
Phone: +1-717-672-0870
Fax: +1-717-672-0872
E-mail: amgrier@inoex.com
Home Page: www.inoex.com
Contact (primary): **Adam Grier**
Contact (secondary): **Christine Fisher**
Name of representative on the booth: **Adam Grier**

iNOEX GmbH is the integrated solution provider for pioneering measurement and control technology for pipes, tubes, cables and profiles. iNOEX GmbH, founded in 1984, has it's headquarter in Melle, Germany, and is a subsidiary of CiTEX GmbH. It employs around 150 people worldwide.

Inspiration - Innovation - Integrity
Inspiration is the source of innovation. Innovation is at the heart of everything we do. Regardless of the industry solutions, software, processes or services, we have made it our mission to exceed industry standards so that manufacturers are guaranteed to offer high quality and reliable products. Our innovative strength is characterized by commitment, structure and investment in research and development.

We manufacture pioneering solutions that add value, increase efficiency and enable our customers to operate successfully in an increasingly competitive environment. Our fast response times, reliable and sustainable processing of customer requests as well as the dynamic development of our range of services are part of our quality management. These services distinguish iNOEX.

We are all united by success. Cooperation, collaboration and communication are another important pillar of our company. A committed team of employees is the most valuable thing for the company and carries the tasks with a sense of quality and responsibility. We act with respect, fairness and enthusiasm. The active participation of our employees in the development of the company always keeps the company's goals in mind. This is the only way to achieve the high quality of our products, services and processes.

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Avenue de Cortenbergh 71.
1000, Brussels
Belgium
Phone: +32-2-329-5103
E-mail: gaetane.bellefroid@plasticseurope.org
Home Page: www.pvc4pipes.com
Contact (primary): **Vincent Stone**
Contact (secondary): **Tobias Johnsen**
Name of representative on the booth: **Vincent Stone / Tobias Johnsen**

PVC4Pipes, a Value Chain Platform dedicated to PVC pipes

PVC4Pipes is a value chain platform created in 2003, with the clear vision to be a reference partner to promote the use of PVC in pipe systems through communication activities, technical projects and participation to standardisation work.

Our Partners come from all parts of the European PVC pipe industry's value chain. PVC4Pipes welcomes companies which produce raw materials – PVC resin and additives – and those which manufacture the wide array of PVC pipes and fittings available in today's market, as well as scientific and testing institutes and promotional associations.

The activities of PVC4Pipes are organized around 4 pillars. The first pillar on communication includes informing a wide audience on the benefits of PVC pipes on our website and social media accounts. With 3000+ followers, our LinkedIn account is the world's second most followed account dedicated to plastic pipes. Other activities under this pillar includes specific communication projects like the Training Package that has been developed for the sales representatives and the newcomer to PVC pipes. We also organize on a bi-annual basis, a Conference reaching out to the European PVC value chain. We further actively contribute to and financially support the organization of the Plastic Pipes conferences from the Plastic Pipe Conference Association, issue position papers alone or with other associations, as well as Newsletters.

The second pillar includes technical projects uncovering the technical and economic benefits of PVC pipes. Examples of projects include the competitiveness of PVC vs. non plastic pipes through Total Cost of Ownership and Cost Benefit Analyses (coll. Althesys), the optimization of extrusion conditions to meet a 100+ design lifetime (coll. CEIS), the development of models to predict the migration from PVC pipes (coll. FABES), or the running of permeation and leak tests proving the suitability of PVC pipes to transport hydrogen (coll. Kiwa).

PVC4Pipes actively participates in some selected working groups of CEN TC 155 and ISO TC 138, working on products and test methods requirements. PVC4Pipes also contributes to the work of other technical committees in a non-sector specific approach within CEN TC 249 (Plastics), in particular WG11 working on recycling.

Last but not least, the PVC4Pipes partners actively participate to the activities of TEPPFA.

For any info, please contact: info@pvc4pipes.com

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TECNOMATIC

Via Emilia 4 Azzano
San Paolo, 24052 (BG)
Italy
Phone: +39-0353-10375
Fax: +39-0353-11286
E-mail: info@tecnomaticsrl.net
Home Page: www.tecnomaticsrl.net
Contact (primary): **Alice Cantoni**
Contact (secondary): **Diego Lupi**
Name of representative on the booth: **Massimiliano Vailati**

TECNOMATIC, IN THE PIPE EXTRUSION SECTOR SINCE 1977

Located in the Industrial area of Bergamo, in the heartland of Lombardy region (Italy), it offers machineries and turnkey projects for the plastic pipes industry. The company has a worldwide presence and exports its production to over one hundred countries and to the major industrial groups in the sector. Technological innovation is one of the strong points of a company that grows in line with market changes, creating technological partnerships with pipe producers and with the major petrochemical companies, for the development of new types of products.

The production of the company includes a wide range of products, as:

- Single screw extruders and co-extruders available in 24, 30, 37, 40 L/D ratio, for outputs up to 1.800 kg/h (3.970 lbs)
- Extrusion die-heads for polyolefin pipes (mono and multilayers up to 3.000 mm) and PVC up to 1200 mm. Tecnomatic offers also custom-fit extrusion die-heads.
- Vacuum and cooling tanks, calibration sleeves for PE and PVC pipes with a range from 8 to 3.000 mm.
- Turn key projects for complete lines, feasibility studies for mono or multilayer plastic pipes and tailor-made solutions.

and it address to a large variety of applications for:

- Infrastructure and construction
- In house heating & plumbing
- Agriculture
- Irrigation with or without drippers.

Customer care from the design stage to after-sales is one of the company's objectives, combined with the passion, quality and preparation of the staff and its continuous training.

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3101 Browns Mills Rd.
Ste. 6, Box 302
Johnson City, TN
37604, USA
Phone: +1-423-268-2118
E-mail: info@fb-balzanelli.it
Home Page: www.fb-balzanelli.it
Contact (primary): **Neil Macdonald**
Contact (secondary): **Karen Perugini**
Name of representative on the booth: **Neil Macdonald**

As the leader in the production of automatic and semi-automatic coilers, FB Balzanelli manufactures coiling machines for large and small-diameter flexible pipes and creates packing and palletizing systems to optimize coiling and storing processes for different types of pipes.

In the 1980s, the founder, Vincenzo Balzanelli, was a leader in the production of electrical conduits. Dissatisfied with the lack of automatic coilers offered at that time, he felt the urge to design and build automatic coilers that were really fast, reliable, and guaranteed high-quality packing. Since then, a process of development and growth has been underway at the company's production facilities in north and south Italy. In all these years, FB Balzanelli has never lost sight of its mission: technology, innovation, quality, and customer care excellence. Avant-garde and technology constantly evolving for a better return on investment. Constant innovation to offer the perfect technical solution for every specific need in the fields of pipe coiling, packing, and palletizing; quality of all products, customized and guaranteed to the smallest detail. Customer care to ensure correct and reliable operation of the long-life systems.

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Via Stroppata, 28
48011, Alfonsine (RA)
Italy
Phone: +39-0544-88711
Fax: +39-0544-81340
E-mail: mpagani@sica-italy.it
Home Page: www.sica-italy.com
Contact (primary): **Marco Pagani**
Contact (secondary): **Martina Emaldi**
Name of representative on the booth: **Orlando Martinez, Marco Pagani**

Sica is a globally renowned Italian producer of downstream equipment for plastic pipes: haul-offs, saws, belling machines, packaging machines, automation and ancillary equipment. It promotes 200 different machine models, has 25 active patents, sells approximately 500 machines per year, exports 90% of its products all over the world and has a turnover of about 30 million euro. The company is fired by a strong drive to deliver value for customers, employees, shareholders, stakeholders and suppliers, while also pursuing honest business practice that is respectful of people and of the environment.

In 2016 SICA has opened its US division Sica America Corporation, based in Atlanta, Georgia. Sica America is nowadays an important reality on the North American market and can serve customers at best, through its Sales team and After Sales team, also enriched by the presence of 2 Service Engineers, visiting customers for installation, start-up and maintenance services.

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4111 East 37th Street North
Wichita, KS
67220, USA
Phone: +1-509-380-6361
E-mail: polymerforpipe@invista.com
Home Page: www.polymerforpipe.com
Contact (primary): **Peter Zut**
Contact (secondary): **Anne Burley**
Name of representative on the booth: **Peter Zut**

INVISTA is a global leader in the production of nylon intermediates and polymers. INVISTA has more than 45 years of experience creating nylon resins used in products spanning the automotive, oil and gas, and consumer electronic industries. From the tough, durable nylon piping used to transport hydrocarbons to the strong, flexible fibers found in everything from backpacks, commercial carpets, and air bags, INVISTA makes the core ingredients that make it all possible.

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1301 Solana Blvd, Suite 1440.
Westlake, TX
76262, USA
Phone: +1-817-693-4100
Fax: +1-817-693-4101
E-Mail: lchamblee@pipe.us
Home Page: www.pipe.us
Contact (primary): Mike Leathers
Contact (secondary): Stephen Boros
Name of representative on the booth: Mike Leathers

Pipeline Plastics is the Leading Manufacturer of High-Performance Polyethylene Pressure Pipe for drinking water, irrigation, mining, gas distribution, industrial, sewer, and oil and gas applications. With fusion joining our products are designed to last generations, leak-free, to help protect our environment and protect the quality of drinking water distributed to your home, business, or school.

Thanks to our great employees, Pipeline Plastics is known for the best service and quality in our market. Our products have always been produced to the highest standards and use only the best raw materials available. We manufacture our products in the newest, most advanced facilities in the world equipped with the latest in extrusion technology.

We are U.S. owned and operated and proudly manufacture our products in the USA. Contact us for your piping needs and we will direct you to one of our many distributor partners across the country as well as internationally.

Our Corporate Office is located in Westlake, Texas.
Plant locations: Decatur, Texas | Belle Fourche, South Dakota | Levelland, Texas | Fair Bluff, North Carolina.

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117 South Sunset St., Suite I.
Longmont, CO
80501, USA
Phone: +1-720-204-1529
E-mail: info@psilab.net
Home Page: www.psilab.net
Contact (primary): **Steve Ferry**

PSILab is a state-of-the-art ISO 17025 accredited testing laboratory that specializes in polymeric materials and piping products. We provide extensive physical, mechanical, and hydrostatic testing services that support additive and resin manufacturers, pipe and fitting manufacturers, as well as technical associations, engineers and system owners. PSILab also offers consulting services, failure analysis testing, as well as forensic investigation services.

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Shell Polymers

300 Frankfort RD
Monaca, PA
15061, USA
Phone: 1-844-776-5581
Home Page: https://www.shell.us/business-customers/shell-polymers.html
Contact (primary): **Carl Baker**
Contact (secondary): **Rob Donaldson**
Name of representative on the booth: **Carl Baker**

At Shell Polymers, we're committed to being a different kind of polyethylene supplier – the kind that always puts plastic converters' unique needs first – and we've conducted extensive industry research to understand just what those needs are. The result? An accessible Northeastern plant, diverse PE expertise, supply chain efficiencies, cutting-edge technology, and more to help you maintain a competitive edge in an ever-evolving industry. While we're proud of our innovative processes and ways of working, we're most excited to forge real connections with plastic converters like you. In the end, our greatest differentiator from the competition – and value to you – comes from (Real)ationships. It's a twist on today's traditional supplier relationship and a promise that we'll keep you at the forefront of all we do. This people-first mentality, combined with the deep experience and technological expertise of Shell Polymers, means we are uniquely suited to help move your business forward.

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P.O. Box 580550
Tulsa, Oklahoma
74158, USA
Phone: +1-918-836-8611
E-mail: jjohnston@mcelroy.com
Home Page: www.mcelroy.com
Contact (primary): **Jim Johnston**
Contact (secondary): **Dave Hughes**

McElroy is the leading manufacturer and innovator in the science of joining thermoplastic pipes. Founded in 1954 in Tulsa, Oklahoma, McElroy has successfully demonstrated a complete dedication to excellence that lies at the heart of the design, engineering, and manufacturing of its products. The company offers the industry's most complete line of butt, saddle, and socket fusion equipment for 1/2" CTS to 2000mm OD pipe, as well as quality assurance accessories that increase productivity and efficiency on the jobsite.

McElroy's fusion equipment spans a wide range of features, from the in-ground capabilities of the Pit Bull® line to the self-sufficient TracStar® iSeries line, with its ability to drive from one fusion joint to another. Machines are available in manual, hydraulic, and fully automatic models.

For polypropylene, which is growing in popularity in some of the world's most advanced HVAC, geothermal, and industrial applications, McElroy's fusion machines also lead the way in efficiency and reliability. That includes machines like the Polygon™, the premier, all-in-one solution for miter, butt, and socket fusion, and the Acrobat™, which tackles even the tightest of fusion locations – including in overhead and vertical configurations.

As worldwide infrastructure shifts toward a more sustainable and conservation-focused model, McElroy remains at the forefront of promoting plastic piping systems. Members of McElroy leadership are actively involved in numerous organizations and standards committees that pertain to plastic pipe systems, including the Plastic Pipes Institute, American Society for Testing and Materials, American Water Works Association, and International Ground Source Heat Pump Association.

In addition to providing the world's premier fusion equipment, McElroy prides itself on offering a suite of accountability tools that allow operators, contractors, and engineers to ensure each fusion joint is correctly performed. The DataLogger® 7 allows fusion technicians to log all parameters of each fusion, including GPS data and operator information. That data is then stored in the McElroy Vault™, a powerful cloud-based tool that allows for instant, credentialed access to the fusion information from anywhere in the world.

For additional information, please visit the McElroy website at McElroy.com.

EXHIBITOR

AENOR Global Certification

ceis Global Testing

C/ Génova, 6.
28004, Madrid
Spain
Phone: +34-619-110-254
E-mail: certificacionproducto@aenor.com
Home Page: www.aenor.com
Contact (primary): **Ricardo Pascual Galán**
Contact (secondary): **Federico Munoz Sánchez**
Name of representative on the booth: **Ricardo Pascual Galán**

AENOR works with companies and sectors to help overcome relevant competitiveness gaps at every economic moment. We provide confidence that the different actors have the knowledge and values important for their relationship with their key stakeholders; We provide competitiveness.

AENOR provides the added value of confidence through services that focus on conformity assessment, training, and information.

Certification of Management Systems.
Product Certification.
Inspection and Testing.
Certification of Persons.
Training in topics related to the fields of conformity assessment.
Distribution of standards, norms, publications and sectoral information.

Through its activities, AENOR is present in 90 countries. More than 3 million hours of audits are carried out annually, more than 100,000 certified products and more than 1.000 training courses in 20 countries have been attended by 15,000 trainees.

For this, it has a wide network of offices that in Spain is composed of 18 offices.

We also have a permanent presence in Mexico, Central America, Peru, Chile, Ecuador, Brazil, Italy, Portugal, Poland, the Dominican Republic and Morocco. The headquarters are located in the city of Madrid.

Regarding plastic piping systems certification, there are more than 60 different product families with updated Certification Rules for both civil works and building applications.

Using these certification rules, AENOR has issued more than 1.100 certificates in 34 countries, supported by more than 600 inspection visits per year, 4.500 samples selected, and more than 6.000 tests performed in CEIS, our partner accredited laboratory.

EXHIBITOR

500 Garrison Rd.
Georgetown, SC
29440, USA
Phone: +1-800-373-2478
Home Page: www.agruamerica.com
Contact (primary): **Richard Preedom**
Name of representative on the booth: **Natasha Arguijo**

AGRU
Since 1988, Georgetown, SC–based AGRU America, Inc. has built infrastructure for a sustainable future through innovative plastics solutions and strong relationships built upon the highest standards of quality, service, and dependability. AGRU America is a subsidiary of AGRU GmbH, an Austrian family-owned business since 1948 with production facilities in Austria, the United States, Germany, and China.

Products and Solutions
AGRU delivers award-winning precision-engineered geosynthetic solutions globally to support the design of environmental, industrial, and civil constructions. For over 70 years, AGRU has supported applications in closure, containment, mining, fluid transmission, and utilities. AGRU products and solutions help protect human health, conserve vital resources, and modernize infrastructure.

AGRULINE
Many issues surrounding water conservation and preservation—both key pillars for AGRU—stem from deficiencies in water and wastewater infrastructure. To help overcome these problems, AGRU has developed a line of products for impactful water and wastewater solutions.

AGRULINE pipe and fittings systems offer the best solution for many water and wastewater applications. These products are manufactured in AGRU's United States-based ISO 9001- and ISO 14001-compliant pipe and fittings production facilities and are emblematic of the company's ongoing commitment to quality and sustainability.

AGRULINE starts at an outer diameter of 2 ft and can reach up to 11.5 ft. These HDPE solid-walled pressure pipes are exceptionally durable, offer zero leakage rate at joints when properly installed, support horizontal directional drilling and other trenchless installation methods, and resist corrosion and seismic forces.

Beyond its products, AGRU prioritizes service and excellence. Everything starts with high-quality sourcing of raw resin, rigorous inspections and testing throughout the manufacturing process, and quality controls.

AGRU also manufactures lining systems, concrete protective liners, and semi-finished products. Overcome unique challenges and create infrastructure for a sustainable future with the Plastics Experts.

Learn more about AGRU America at https://agruamerica.com.

EXHIBITOR

Borealis AG, Trabrennstraße 6–8
1020, Vienna
Austria
Phone: +43-1-2240-0300
Fax: +43-1-2240-0333
E-mail: info@borealisgroup.com
Home Page: www.borealisgroup.com
Contact (primary): **Marlene Zimmermann** (Borealis)
Contact (secondary): **Norbert Jansen** (Borealis)
Name of representative on the booth: **Norbert Jansen** (Borealis)

About Borealis Infrastructure: Enabling life's essentials
As a trusted and experienced partner with more than 50 years of experience, Borealis offers market leading polyethylene and polypropylene materials for pipe systems in water and gas distribution, waste water and sewage disposal, plumbing, heating, and industrial, along with multi-layer steel pipe coating solutions for on-shore and offshore oil and gas pipelines. With the proprietary Borealis Borstar® technology as the main foundation, complimented by selected other processes, Borealis can offer a wide variety of tailored pipe solutions.

In addition, Borcycle™ M and the ISCC Plus certified Borcycle™ C compounds based on mechanically and chemically recycled feedstock as well as the ISCC Plus certified Bornewables™ compounds using renewable-based feedstock meet a growing demand for high-sustainability building and infrastructure pipe polymers. At the same time, they align with Borealis's EverMinds™ platform to promote and accelerate the transformation of the plastics industry towards circularity.

By offering more durable and reliable as well as circular pipe solutions, Borealis' step-change innovations continue to boost the sustainability of pipe networks by making them safer, leak free, longer lasting and more efficient with installation costs reduced by up to 60% compared to the traditional pipe material.
Based on Borealis' European assets, its Middle Eastern joint venture Borouge as well as the American joint venture Baystar®, Borealis confirms its position as a partner of choice for global pipe customers, helping to meet the growing needs and requirements of the building and infrastructure industry today and in the future.

EXHIBITOR

10 McCleary Court
Concord, Ontario
Canada
Phone: +1-905-669-9397
Fax: +1-905-738-4744
E-mail: info@corma.com
Home Page: www.corma.com
Contact (primary): **Stefan Lupke**
Contact (secondary): **Nick Lupke**
Name of representative on the booth: **Nick Lupke**

Corma Inc. is a world leader supplying equipment for the production of corrugated plastic pipe. Known for innovation, Corma has developed much of the technology and processes which are industry standards today; such as the doubled wall corrugated pipe system and several patented in-line coupling solutions.

Corma is a member of the PPI in the Drainage Division and proud to be celebrating its 50th Year Anniversary in 2023.

Corma has participated at several Plastic Pipe Conferences, both in Europe and North America, both as an exhibitor and presenter.

At this year's conference, Corma will be exhibiting our latest joint (coupling) system as part of a resilient piping system.

EXHIBITOR

Max Drossbach Str. 7.
86641, Rain
Germany
Phone: +49-909-070-20
Fax: +49-909-070-2199
E-mail: info@drossbach.de
Home Page: www.drossbach.de

Since 1919 Drossbach is premium manufacturer of corrugated pipe machinery which are used as sewer-, perforated drainage-, stormwater- or cable duct pipe.

Drossbach / HD-series briefly

- DROSSBACH machines and tools are suitable for the production of HDPE and PP without any change and extra equipment for the line
- Directly water-cooled mold block and integrated full vacuum system -> constant high quality -> lowest weight/ cost per meter
- Mold block inserts and tools are interchangeable between HD 1200 and HD 1800
- Mold block inserts with quick release hook for quick change
- Fully automatic, centralized lubrication system guarantees maintenance-free operation
- After having adjusted, the die head is fixed to the corrugator by means of the centering ring, no afterwards alignment necessary
- The machine can be electronically adjusted in vertical and horizontal direction
- HD 1800 has a diameter range from ID 500 mm (20") up to OD 1800 mm (70"), mechanical speed approx. 1,5 mtr. (5 feet) and output: 1535 kg (3377 lbs.) / h, weight: 43.000 kg (95.000 lbs.) without molds
- HD 1200 has a diameter range from ID 150 mm (6") up to OD 1200 mm (48"), mechanical speed approx. 4,0 mtr. (13 feet) and output: 1200 kg (2640 lbs.) / h, weight: 28.000 kg (61.600 lbs.) without molds
- HD 1200/1800 have Shuttle principle combined with parking station allows the production of different pipe lengths, also with integrated sockets
- DROSSBACH machine are equipped with a RCS (Remote Control System) to have access to the machine control systems. With this RCS we can support our customers online at any time and immediately
- The speed of DROSSBACH machines with inline socket is the same without inline socket (no speed reduction)
- Spiral mandrel die heads cares for a constant quality of the corrugated pipe with a consistent even wall distribution
- The complete electronic parts in the separate control cabinet are cooled by air conditioner
- DROSSBACH socket with reinforced glass-fiber tape SAFECONNEC is the most economical system (only 1 seal) and easy to install
- DROSSBACH SAFECONNEC ensures long-term stability of the socket connection
- DROSSBACH pipe and socket has the same stiffness, so the tightness is ensured at the system deformation
- Water cooling bath is mounted on rails and can be moved up direct to the corrugator (faster cooling, no pipe deformation)
- The saw is equipped with dimensionally accurate clamp halves (no pipe deformation or ovality and therefore ensures better quality of cut)
- Shuttle system have almost no wear
- Optimal design of the pipe profile -> less weight -> material consumption
- Latest models:
  – HD 700 from -> ID 100 mm (4") to OD 700 mm (28")
  – HD 65 -> high speed corrugator from ID 7 mm (3/8") to OD 65 mm (2 ½")

EXHIBITOR

HGI LAB
WWW.HGILAB.COM

154 East Brook Lane
Butler, PA
16002, USA
Phone: +1-724-283-1212
Fax: +1-724-283-5006
E-mail: hgi-lab@atspa.com
Home Page: www.hgilab.com
Contact (primary): **Scott Siddall**
Contact (secondary): **Rob Carroll**
Name of representative on the booth: **Mark Hensel**

HGI LAB is an American manufacturer of Hydrostatic Pressure Testing systems, that is located in Butler, Pennsylvania. With over fifty years of experience in engineering and designing customized hydrostatic testing equipment, HGI LAB has proved to be reliable and consistent. At HGI LAB, we back our quality products with our exceptional customer service and communication. To headline our products, we offer a Burst Test System line, as well as Static Test Systems. Our ability to manufacture custom products is what makes HGI LAB a dependable and reputable brand.

EXHIBITOR

Via dell'artigianato 13
48022, Lugo (Ravenna)
Italy
Phone: +39-342-830-6542
Fax: +39-054-530-911
E-mail: gianpaolo.contarini@ipm-italy.it
Home Page: www.ipm-italy.it
Contact (primary): **Gianpaolo Contarini**
Contact (secondary): **Gabriele Foschini**
Name of representative on the booth: **Gianpaolo Contarini, Gabriele Foschini, Alessandro Costa**

IPM is an Italian manufacturer of downstream equipment for PVC, PP and PE pipes and profiles extrusion lines, such as haul-offs, planetary saws, belling machines for smooth pipes and corrugated double wall pipes, bending machines, slotting machines, threading machines, packaging systems and special machines on request. Thanks, its 35-years-long experience in the field and to its remarkable projecting department, IPM is able to design customer-tailored machines on request. All the manufacturing process, from the design to the production of the machines, is done directly in the company, and this is a guarantee of the quality of the end product, as well as of its entirely MADE IN ITALY.

Particular attention is dedicated to research and development of products, which always fulfil the latest market requests – or even anticipate them. IPM analyses carefully the specific needs of each customer, creating customized machineries and services.

Commitment, passion and experience, thanks to which, since many years, we bring the "MADE IN IPM" into the world. Every day we cultivate our project of development, convinced, that you can grow through the comprehension of the culture of other Countries (today IPM export its products in more than 120 different countries). A vision, that brings us constantly to put us on the line, ready to welcome changes, news, and tips. "IF IT STILL DOES NOT EXIST, IT DOES NOT MEAN IT'S IMPOSSIBLE". Speaking all the main languages, the sales department is always at complete disposal to understand customer's requirements to advice the clients or to put its long-term experience at disposal of the customers.

IPM area managers are pleased to welcome the customers in the company or to visit them in their premises, as well as to meet them in the main international plastics exhibitions all over the world. A team of skilled technicians is always ready to travel to guarantee the commissioning and after-sale services at the customer's premises, wherever they are. The team consists in technicians speaking all the main languages.

IPM is also able to reduce the distances, and assist its customers in real time, thanks to the "Teleservice system" also made possible and facilitated by the advent of the broadband and by the increasing diffusion of corporate networks (wired or wireless). Through this service, IPM offers the possibility to connect, through and industrial router, the machines of its own production to the user's corporate network (that can be either by Ethernet or Wireless).

The company can delivery spare parts every day all over the world, and it guarantees supplies of spare parts for every machine model ever produced for at least 10 years. The production and sales of thousands of machines all over the world both in the markets of industrialized countries and developing countries, tangibly proves the seriousness and commitment as well as the machinery's quality and reliability.

EXHIBITOR

Wilmersdorf 50
7327 AC Apeldoorn
The Netherlands
Phone: +31-889-983-393
Fax: +31-889-984-420
E-mail: marco.mekes@kiwa.nl
Home Page: www.kiwa.com
Contact (primary): **Marco Mekes**
Contact (secondary): **Harald Ophoff**
Name of representative on the booth: **Marco Mekes**

Kiwa: expertise to improve quality
Kiwa is an independent highly qualified organization having testing and certification as its core activity. Kiwa wants to be a Partner for progress and create trust on the basis of its qualities as a recognized and renowned certification and testing company, relying on testing, inspection, training, technology and data services. The slogan 'Partner for progress' is our way of expressing our desire to develop long-term relationships based on equality and geared to helping you improve your organization, products, services, management systems and personnel. We have even made this motto a part of our corporate style, affirming that it is our objective to help companies and organizations move forward. You have the ambition; we have the expertise to be partners for progress. Kiwa is globally active in over forty countries with offices, our head office is located in the Netherlands. For plastics pipes, piping systems and materials the leading Kiwa location is in Apeldoorn, the Netherlands. Kiwa works for clients in the complete chain, from the raw material suppliers up to the pipe producer and installer.

Focus on polymer and elastomeric materials
Kiwa has the expertise and lab facilities to perform full testing works and life time prediction evaluations on both polymer pipe and fitting materials as elastomeric materials. We are able to perform for plastics and elastomeric materials all standardized testing works and further R&D testing works. Kiwa is actively involved in many standardization committees for plastics and elastomeric materials.

Focus on pipes and fittings
Kiwa has the expertise and lab facilities to perform full testing works for pipes and fittings whether intended for water, gas, sewerage, drainage or other applications. Whether the material is a PE, PVC(-O), GFR, PP, PE-X, PA or multilayer pipe, we are known to the products and materials.

Testing activities
Kiwa's testing activities are performed under ISO 17025 accreditation and the reports are recognized all over the world. Long term strength evaluations on materials and pipes can be monitored 24/7 via the Kiwa Online system.

Drinking water and the energy transition
Additional to all expertise and facilities on materials and testing Kiwa has its origin coming from the water and gas distribution. Kiwa nowadays still has the leading position in the world on materials and piping systems for drinking water, natural gas, hydrogen. This includes hygienic and drinking water aspects. Kiwa has knowledge and expertise on the energy transition to renewable gases like biogas and hydrogen including approvals and testing opportunities.
For more information on certification and testing of materials, pipes, fittings etc, please visit www.kiwa.com or visit our booth No. 19 at the Plastics Pipes Conference in Orlando.

EXHIBITOR

789 N. Dixboro Rd.
Ann Arbor, MI
48105, USA
Phone: +1-800-673-6275
E-mail: americas@nsf.org, europe@nsf.org, middleeast@nsf.org, asia@nsf.org
Home Page: www.nsf.org
Contact (primary): **Nasrin Kashefi**
Contact (secondary): **Laura Holguin**
Name of representative on the booth: **Nasrin Kashefi**

NSF provides risk assessment, testing, inspection, and certification services. NSF/ANSI 14 Plastics Piping System Components and Related Materials was developed over 50 years ago to ensure consistent performance, material properties, health effects, quality assurance and monitoring in the plastic piping industry. Today NSF/ANSI 14 is required by all US plumbing codes for all plastic piping system components.

NSF expertise in plastics piping systems is unmatched and capabilities include ASME, ASSE, ASTM, CSA, IAPMO, AWWA, ISO, DN, FM, NEMA, NSF and UL Standards. The NSF Mark is fully accepted in a variety of markets including chemical waste, drain, waste and vent, electrical conduit, fire safety, geothermal, natural gas, oil and gas gathering, potable water, radiant heating, reclaimed water, and sewage.

All drinking water products in the US are required to be certified to NSF/ANSI/CAN 61 Drinking Water System Components-Health Effects. NSF/ANSI/CAN 372 Drinking Water System Components-Lead Content demonstrates compliance with the US Safe Drinking Water Act requiring 0.25% or less lead content.

EXHIBITOR

SCITEQ

Gamma 3,
8382, Hinnerup
Denmark
Phone: +45-869-619-33
E-mail: sales@sciteq.com, ddh@sciteq.com
Home Page: www.sciteq.com
Contact (primary): **Linda Hedegaard**
Contact (secondary): **Dennis Damborg Hansen**
Name of representative on the booth: **Dennis Damborg Hansen**

SCITEQ Quality testing systems designed in Denmark since 1966 for the plastics industry and related industries.

With more than 50 years' experience, SCITEQ A/S is one of the world's leading specialists in process control and test equipment for the plastic pipe & fitting industry. We develop, produce and service quality control systems and laboratory test equipment of the highest standard. Our global customers and valued partners are leading manufacturers of pipes & fittings, raw material suppliers as well as national and privately held independent test institutes. SCITEQ is represented by sales agents globally in over 40 countries incl. North America.

We are offer test equipment and software complying with national as well as international test standards - for the complete laboratories as well as single stand-alone equipment. The SCITEQ range of quality test equipment consists of:

- Pipe & fitting testing i.e., pressure test, impact test, leak tightness test, rapid crack propagation test, compression test, tensile test, resistance to liquids and temperatures.
- Raw material testing i.e., melt flow test, density test, OIT, carbon black test.
- Preparation for test i.e., laboratory saw, copy miller, notch miller, conditioning chambers and ovens.
- Software: browser based and user-friendly software prepared for OPC UA, IoT and Industry 4.0. Offering recipe system, remote control of tests and easy configurable report output.

We help you perform even better through 100% accurate quality testing.
Our testing equipment and software is best in class developed and manufactured in Europe. When working with SCITEQ you gain full access to our extensive experience and competencies. We acknowledge the importance of moving forward and being innovative and we take pride in providing our customers with the most durable and future-proof solutions in the market.

Excellence in service
We believe service is the key to a fruitful and long-lasting cooperation. We are experts in testing, fully focused on helping our customers increase their performance. Our team of experienced project managers and engineers is dedicated to finding the best solution tailored to your plans and needs. The highly skilled SCITEQ service engineers perform global on-site service and training as well as online support 24/7, so you can rely on optimal performance.
Learn more here: http://www.sciteq.com

EXHIBITOR

SIKORA
Technology To Perfection

150 Huddleston Road, Suite 1300
Peachtree City, GA
30269, USA
Phone: +1-770-486-1233
E-mail: sales@sikora-usa.com
Home Page: www.sikora.net
Contact (primary): **Ashley Miner**
Contact (secondary): **John Dognazzi**
Name of representative on the booth: **Brandy Herrmann, Chris Johnston, Christian Schalich**

SIKORA is setting worldwide standards with exceptional measuring, control and testing devices for the hose and tube, pipe and sheet, wire and cable, and plastics industries. Certified according to ISO 9001:2015, SIKORA has been developing groundbreaking measuring technology and providing innovative product solutions and service since 1973.

SIKORA has many years of experience in manufacturing measuring devices for quality control during pipe production. Developing technology that reduces unnecessary plastic consumption and ensures the production of safe, sustainable hoses, tubes and pipes is a passion as much as it is a priority. SIKORA looks forward to connecting with customers and colleagues at the Plastic Pipes Conference, and they will present on a new application of their pipe measuring technology.

EXHIBITOR

Colinas 11850; Parque Industrial El Florido, 1 Seccion
Tijuana
22237, Mexico
Phone: +52-477-330-0817, +1-800-626-2180
Home Page: www.trelleborg.com/en/seals-and-profiles
Contact (primary): **Stephen Abelson, Donna Gunter**
Contact (secondary): **Bernal Lopez-Chaves**
Name of representative on the booth: **Stephen Abelson**

INTRODUCING TRELLEBORG

Trelleborg is a world leader in engineered polymer solutions that seal, damp and protect critical applications in demanding environments. Its innovative solutions accelerate performance for customers in a sustainable way. The Trelleborg Group has annual sales of about SEK 30 billion (EUR 2.83 billion, USD 2.97 billion) in about 40 countries. The Group comprises two business areas: Trelleborg Industrial Solutions and Trelleborg Sealing Solutions. The Trelleborg share has been listed on the Stock Exchange since 1964 and is listed on Nasdaq Stockholm, Large Cap. www.trelleborg.com

Being part of the Trelleborg Group, Trelleborg Seals & Profiles benefit from over 100 years of experience in engineered polymer solutions. Our portfolio includes solutions for sealing and repairing water and wastewater pipes. Our applications expertise and polymer knowhow enable best-in-class solutions found all over the world. Meeting the exacting needs of our customers, time after time.

We accelerate performance for our customers by,
- Better Function: Our solutions boosting the performance of our customer's applications and systems.
- Better Business: When everything works without fail, our customer's businesses are enhanced significantly.
- Better Sustainability: Sustainability is an added value that comes with many of our solutions.

With our global reach, we deliver continuous innovation, logistics and a sales network spanning over 50 countries in Europe, the Middle East, Africa, North and South America, and Asia Pacific. We will see you through from the beginning of your project right to the very end with the most advanced polymer technology and engineering expertise.

The high-performance level of our seals ensures fulfilment of the highest possible reliability standards. Whether you need an entirely new system or improvements to your existing one, you can choose from a range of market-leading seals and rehab solutions that we offer.

Find out more about how we can be of help to your business by visiting our website www.trelleborg.com/en/pipe-seals

EXHIBITOR

Bamberger Strasse 20
96317, Kronach
Germany
Phone: +49-9261-4090
Fax: +49-9261-409-199
E-mail: info@hansweber.de
Home Page: www.hansweber.de
Contact (primary): **Christian Stützinger**
Contact (secondary): **Rainer Viessmann**
Name of representative on the booth: **Rainer Viessmann**

Hans Weber Maschinenfabrik GmbH combines expert knowledge with innovative technologies, a legacy we have upheld for over 100 years. With a workforce of over 500 employees, our company excels in engineering plastics extrusion and granulation, as well as patented wood sanding and metal grinding machine processes, additive manufacturing, and vision-controlled industrial robotics and automation. For over 60 years, we, the Hans Weber Machine Factory, have been developing and manufacturing extruders, extrusion systems, and extruder screws.

Our machines find applications in various industries such as pipe extrusion, extrusion of technical plastics, window profile extrusion, and granulation. In addition to our focus on development and production, we place great emphasis on the connectivity of our machines. We offer a combined solution of a production control system and a manufacturing execution system with our MES solution, NEXXT365.

Just like with our larger extruder sizes, customers benefit from the extensive expertise that Hans Weber Maschinenfabrik has acquired over several decades. The WEBER brand represents process engineering expertise, durability, reliability, and quality "Made in Germany".

By leveraging the synergies of our other business divisions, namely additive manufacturing, automation, and grinding, we can provide complete production processes from a single source."

WEBER distributes its products in over 60 countries worldwide. As a family-owned and owner-operated company, our headquarters are based in Kronach, Germany. The Managing Directors are Dr.-Ing. Markus Weber and Ludwig Weber M.Sc.

EXHIBITOR

85 Swanson Rd., Ste 170. Boxborough, MA
01719, USA
Phone: +1-978-406-7056
E-mail: welsetamericas@welsetamericas.com
Home Page: www.welset.com
Contact (primary): **Venkat Appaji**
Contact (secondary): **Irina Aibamouni**
Name of representative on the booth: **Venkat Appaji**

Welset originated as manufacturer from India way back in late sixties as a manufacturer of PVC Compounds, Masterbatches

We are a global manufacturer of Colorants and Additives for PVC Pipe and PE pipes.

A complete portfolio of masterbatches to support a variety of piping applications.
- HDPE Conduit
- HDPE Corrugated Pipes
- PPR PIPES
- PVC Pipes
- Impact Modifier for PVC Pipes

Markets served.
- Building and Construction
- Power and Communications
- Drainage
- Sewer
- Water transport
- Energy Piping Systems
- Municipal and Industrial

Welset discloses information for various industry approval like:
- NSF International

Welset is the leading company in the business of coloring and compounding solutions for plastics industry

EXHIBITOR

ZhongyunTech®

No.777, Dongfang Road, New & Hi-tech Industrial Development Zone
Weifang, Shandong Province
China
Phone: +86-536-222-5511
Fax: +86-536-222-5565
E-mail: mkt@zhongyuntech.com
Home Page: www.zhongyuntech.com
Contact (primary): **Zhao Gang**
Contact (secondary): **Man Jianliang**
Name of representative on the booth: **Man Jianliang, Bi Zhenlei**

As a leading manufacturer of corrugated pipe machinery in China, ZhongyunTech has been focusing on the R&D and manufacturing of corrugated pipe machinery for more than 22 years.

With great innovation vitality, ZhongyunTech has always been committed to help customers continuously reduce pipe production costs and improve their competitive edge, and has won trusts of professional customers in more than 40 countries around the world.

With the vision of becoming a world-class pipe corrugator manufacturer, ZhongyunTech, adheres to the operating philosophy of "continuous innovation, advanced manufacturing and full life services", has been leading the development of pipe corrugator in China. The company has 4 production bases and 1 R&D center, with a total area of 440,000 square meters and more than 300 employees.

By virtue of the world-class management software from SAP Germany, advanced, efficient and standardized management provides a solid backing for ZhongyunTech to manufacture high-precision and high-stability corrugated pipe machines. The company has always attached great importance to manufacturing and quality control; equipped with more than 100 sets of high-precision processing equipment, such as CNC Machines from TOSHIBA, DMG MORI, MIKRON, PAMA; and adopts the world top apparatus to strictly control the dimensional accuracy and position accuracy of each part, such as Swedish Hexagon 3D coordinate measuring instrument and Leica laser tracker. Manufacture durable and stable corrugated pipe machines with a craftsmanship spirit.

Day	Start	End	Duration	A-sessions	B-Sessions
SEPTEMBER 25TH: CONFERENCE OPENING AND TECHNICAL SESSIONS					
Monday	9:00 am	10:00 am	1:00	**OPENING SESSION**	
	9:00 am	9:10 am	0:10	PPXXI WELCOME – **Sarah Patterson – U.S.A.** (Plastics Pipe Institute (PPI))	
	9:10 am	9:35 am	0:25	• **ID264** – DEVELOPING CIRCULAR SOLUTIONS IN THE PETROCHEMICALS INDUSTRY – **Jay Chaffin – U.S.A.** (Chevron Phillips Chemical)	
	9:35 am	10:00 am	0:25	• **ID168** – SUSTAINABILITY AT THE CORE OF STRATEGIES TO ACCELERATE THE JOURNEY TOWARDS CARBON NEUTRALITY – **Zoran Davidovski – Austria** (Pipelife), **Robin Bresser – Germany** (Borealis)	
	10:00 am	10:30 am	0:30	**COFFEE BREAK SPONSORED BY** INVISTA™	
	10:30 am	11:30 am	1:00	**1A – WATER SECURITY** **Chair: Zoran Davidovski – AUSTRIA** (Pipelife)	**1B – QUALITY INFRASTRUCTURES** **Chair: Tony Calton - UNITED KINGDOM** (The European Plastic Pipe and Fittings Association – TEPPFA)
	10:30 am	10:50 am	0:20	• **ID158** – MICROPLASTICS AND PLASTIC PIPES – **Peter Sejersen – BELGIUM** (TEPPFA)	• **ID113** – ASTM F17 – FIFTY YEARS OF PLASTICS PIPING PROGRESS – **Steve Sandstrum – U.S.A.** (Borealis Compounds Inc.)
	10:50 am	11:10 pm	0:20	• **ID122** – SAFEGUARDING OUR WATER: NSF/ANSI/CAN 61 – **Kathryn Foster – U.S.A.** (NSF)	• **ID152** – HOW TO STRENGTHEN THE DEVELOPMENT OF CHINA'S PLASTIC PIPE INDUSTRY IN THE NEW MARKET ENVIRONMENT – **Wang Zhanije – CHINA** (China Plastics Piping Association – CPPA)
	11:10 pm	11:30 pm	0:20	• **ID240** – THE FUTURE HARMONIZED CERTIFICATION SCHEME FOR PRODUCTS IN CONTACT WITH DRINKING WATER – **Peter Sejersen – BELGIUM** (TEPPFA)	• **ID205** – COMMITMENT TO SUSTAINABILITY IN STRUCTURED-WALL PVC-U PIPES FOR SEWERAGE. "CIRCULAR CERTIFICATION" FOR "CIRCULAR PRODUCTS" – **Ricardo Pascual – SPAIN** (AENOR)
Monday	11:30 am	12:30 pm	1:00	**LUNCH SPONSORED BY** TECNOMATIC	
	12:30 pm	2:10 pm	1:40	**2A – STRUCTURED DESIGN** **Chair: John Kurdziel – U.S.A.** (Advanced Drainage Systems)	**2B – WHOLISTIC APPROACH** **Chair: Vincent Stone – BELGIUM** (PVC4 Pipes/ The European Council of Vinyl Manufacturers – ECVM)
	12:30 pm	12:50 pm	0:20	• **ID165** – DESIGN METHODS AND ACTUAL PERFORMANCE OF LARGE DIAMETER STRUCTURED WALL PIPES – **Anders Andtbacka – FINLAND** (Uponor)	• **ID117** – FISHER-TROPSCH HYDROCARBONS AS PROCESSING AIDS IN INJECTION MOLDING & EXTRUSION – **Steve Torchia – U.S.A.** (Sasol Chemicals LLC)
	12:50 pm	1:10 pm	0:20	• **ID236** – A NEW CONCEPT FOR TESTING OF NEW GENERATION OF THERMOPLASTIC STORM-WATER RETENTION TANKS – **Shad Sargand – U.S.A.** (Ohio University)	• **ID187** – FRACTURE MECHANICS AS A TOOL FOR THE ASSESSMENT OF THE DEGREE OF GELATION OF U-PVC PIPES – **Antonio Rodolfo Jr. – BRAZIL** (Braskem S/A)
	1:10 pm	1:30 pm	0:20	• **ID262** – SANDBOX TESTING FOR STRUCTURAL ASSESSMENT OF PLASTIC MANHOLES – **Ricky Selle – GERMANY** (Selle Consult)	• **ID119** – NEW CYCLIC METHOD FOR PVC FORCE MAINS – **Jay Parvez – U.S.A.** (Uni-Bell PVC Pipe Association)
	1:30 pm	1:50 pm	0:20	• **ID227** – THE CARBON COST OF OUR BURIED INFRASTRUCTURE – IS IT OUT OF SITE AND OUT OF MIND? – **PAUL O'REGAN – UNITED KINGDOM** (AquaSpira Limited)	• **ID258** – PROJECT AND EXECUTION OF WORKS FOR THE EXPANSION AND IMPROVEMENT OF THE POTABLE WATER SUPPLY CAPACITY TO THE METROPOLITAN AREA OF MONTEVIDEO – **Ignacio Muñoz – SPAIN** (Molecor Tecnologia)
	1:50 pm	2:10 pm	0:20	• **ID123** – 3D PRINTING OF FLOW PROFILES FOR INSPECTION CHAMBERS AND MANHOLES – **Ton Schoenmaker – THE NETHERLANDS** (Pipelife)	• **ID199** – THERMOFORMING PROCESS FOR SOCKETS INTEGRATED WITH RIEBER SYSTEM IN MOLECULARY ORIENTED POLYVINYL CHLORIDE (PVCO) PIPES FOR PRESSURIZED WATER DISTRIBUTION – **Orlando Martinez, Marco Pagani – ITALY** (SICA S.p.A.)

PROGRAM – DAY1, MONDAY 25TH

Day	Start	End	Duration	A-sessions	B-Sessions
Monday	2:10 pm	2:40 pm	0:30	**COFFEE BREAK SPONSORED BY** PIPELINE PLASTICS	
	2:40 pm	4:20 pm	1:40	**3A – APPLICATION OF RECYCLATES** **Chair: Douglas Keller – U.S.A.** (LyondellBasell)	**3B – SAVVY TOOLS** **Chair: Jim Johnston – U.S.A.** (McElroy)
	2:40 pm	3:00 pm	0:20	• **ID133** – CRITICAL QUALITY CONTROL OF POST CONSUMER RECYCLED PVC **– Shane Harton – U.S.A.** (C.W. Brabender)	• **ID245** – LEVERAGING DATA INSIGHTS TO IMPROVE SAFETY, QUALITY AND ROI **– Nayib Joussef – CHILE** (McElroy Manufacturing Inc)
	3:00 pm	3:20 pm	0:20	• **ID241** – THE BRAZILIAN PVC PIPE ASSOCIATION QUALITY ASSURANCE PROGRAM: 30+ YEARS OF SUCCESS **– Antonio Rodolfo Jr. – BRAZIL** (Braskem S/A)	• **ID225** – ACCELERATING SUSTAINABILITY WITH DIGITAL SOLUTIONS **– Joseph Venegas – THE NETHERLANDS** (Rollepaal)
	3:20 pm	3:40 pm	0:20	• **ID120** – EXAMINING SGF ORIENTATION IN POLYETHYLENE REINFORCED WITH SHORT GLASS FIBERS PIPE **– Mitsuaki Tokiyoshi – JAPAN** (C. I. TAKIRONCIVIL Corporation)	• **ID142** – USING A MULTI FREQUENCY MICROWAVE INSPECTION APPROACH TO ACCURATELY INSPECT AND CATEGORIZE HDPE BUTT FUSIONS **– Robert Stakenborghs – U.S.A.** (Advanced Microwave Imaging)
	3:40 pm	4:00 pm	0:20	• **ID263** – PERFORMANCE EVALUATION OF SUSTAINABLE POLYPROPYLENE BLENDS FOR CORRUGATED DRAINAGE PIPE APPLICATIONS **– Michael Pluimer – U.S.A.** (University of Minnesota)	• **ID260** – APPLICATION FOR GEOLOCATING WATER NETWORKS **– Dolores Herran – SPAIN** (Molecor)
	4:00 pm	4:20 pm	0:20	• **ID194** – ESTABLISHING REQUIREMENTS FOR RECYCLED HDPE IN HDPE CONDUIT **– Michael Pluimer – U.S.A.** (University of Minnesota)	• **ID151** – PROGRESS IN INLINE PLASTIC PIPE MEASUREMENT – NEW APPLICATION FIELDS DUE TO ADVANCED RADAR TECHNOLOGY **– Jan Hendrik Beckmann – GERMANY** (iNOEX GmbH)
	4:45 pm	6:00 pm	1:15	**WELCOME RECEPTION SPONSORED BY** iNOEX INSPIRE BEYOND MEASUREMENT	

Day	Start	End	Duration	A-sessions	B-Sessions
SEPTEMBER 26TH: TECHNICAL SESSIONS					
Tuesday	9:00 am	10:40 am	1:40	**4A – FOOD SECURITY** **Chair: Robin Bresser – Germany** (Borealis)	**4B – ENERGY** **Chair: Randy Knapp – U.S.A.** (Plastics Pipe Institute – PPI)
	9:00 am	9:20 am	0:20	• **ID213** – INNOVATING FOR SUSTAINABILITY ENHANCEMENTS IN POLYETHYLENE BASED MICROIRRIGATION PRODUCTS **– Rachel Anderson – U.S.A.** (DOW Inc.)	• **ID126** – PUBLISHED HYDROGEN PERMEATION STUDY ON 4 DIFFERENT TYPES OF PE PIPES **– Norbert Jansen – GERMANY** (Borealis Polymere GmbH)
	9:20 am	9:40 am	0:20	• **ID244** – FIELD AND FEM PERFORMANCE OF AGRICULTURAL MAINS **– Kevin White – U.S.A.** (E. L. Robinson Engineering of Ohio)	• **ID145** – DESIGN OF UNPLASTICIZED POLYAMIDE 12 OILFIELD LINE PIPE BASED ON PUBLISHED REGRESSION CURVES AND ASTM F3524 **– James F. Mason – U.S.A.** (Mason Materials Development LLC)
	9:40 am	10:00 am	0:20	• **ID200** – UNDERSTANDING THE SCIENCE IN ESTABLISHING EQUIVALENCY OF VARIOUS CARBON BLACK MASTERBATCHES IN QUALIFICATION APPROVALS **– Bill Gauthier – U.S.A.** (Baystar)	• **ID223** – LEAK TIGHTNESS OF PVC FITTINGS WITH HYDROGEN **– Roland Valk – THE NETHERLANDS** (Kiwa Technology)
	10:00 am	10:20 am	0:20	• **ID252** – HOW PVC PIPES CAN CONTRIBUTE TO FOOD SAFETY IN THE WORLD'S MEGA-CITIES **– Tobias Johnsen, Ole Grøndahl Hansen – DENMARK** (PVC Information Council Denmark)	• **ID257** – FUSION TEST PROGRAM ON POLYAMIDE PIPING SYSTEMS FOR DISTRIBUTION NETWORKS UP TO 16 BAR **– Carine Lacroix – FRANCE** (GRTgaz RICE)
	10:20 am	10:40 am	0:20	• **ID139** – RESULTS OF A 2022 COMPREHENSIVE STUDY OF WATER MAIN PERFORMANCE IN THE USA AND CANADA **– Steven L. Barfuss – U.S.A.** (Utah State University)	• **ID259** – SOLUTIONS FOR REINFORCED THERMOPLASTIC PIPES (RTPS) **– Ali M. Alghamdi – SAUDI ARABIA** (SABIC)
Tuesday	10:40 am	11:10 am	0:30	**COFFEE BREAK SPONSORED BY** PSILab	
	11:10 am	12:50 pm	1:40	**5A – INSTALLATION DESIGN** **Chair: André Nijland – THE NETHERLANDS** (Wavin Technology and Innovation B.V.)	**5B – JOINING TECHNOLOGY** **Chair: Forest Hampton – U.S.A.** (Lubrizol Advanced Materials)
	11:10 am	11:30 am	0:20	• **ID108** – BENDING & DEFLECTION LIMITS OF PE PIPE – EXISTING & PROPOSED **– Chris Ampfer – U.S.A.** (WL Plastics)	• **ID132** – PVC-U PIPES: OPTIMAL EXTRUSION CONDITIONS FOR A 100+ YEAR DESIGN LIFETIME **– Joaquin Lahoz – SPAIN** (Centro de Ensayos, Innovación y Servicios – CEIS)
	11:30 am	11:50 am	0:20	• **ID229** – CUT-AND-COVER PIPELINES WITH POOR TRENCH WALLS **– Amster Howard – U.S.A.** (Civil Engineering Consultant)	• **ID243** – SELECTION AND EVALUATION OF ORGANOTIN STABILIZER CHEMISTRIES FOR PVC AND CPVC PIPE AND FITTING SYSTEMS **– Robert Smith – U.S.A.** (PMC Organometallix)
	11:50 am	12:10 pm	0:20	• **ID228** – MYRIAD OF CHOICES FOR BURIED PIPE INSTALLATION **– Amster Howard – U.S.A.** (Civil Engineering Consultant)	• **ID146** – SUSTAINABLE RESTRAINT JOINT FOR PE PIPES AS AN ALTERNATIVE TECHNOLOGY FOR SUEZ **– Jennifer Ravereau, Catherine Giorni – FRANCE** (SUEZ – CIRSEE)
	12:10 pm	12:30 pm	0:20	• **ID242** – NEW APPROACH TO HDPE PIPE FUSION PROVIDES THE ABILITY TO "MEET THE PIPE WHERE IT LAYS" **– Chris Greggs – U.S.A.** (McElroy Manufacturing)	• **ID251** – SUSTAINABILITY & THE RETURN OF THE PRR GASKET **– Guido Quesada – COSTA RICA** (Simulation Driven Engineering)
	12:30 pm	12:50 pm	0:20	• **ID211** – AN INVESTIGATION OF THE EFFECT OF BACKFILL TYPE ON THE PERFORMANCE OF LARGE DIAMETER POLYOLEFIN PIPE UNDER HIGHWAY LOADINGS AT MINIMUM COVER **– Joseph Babcanec – U.S.A.** (Advanced Drainage Systems)	• **ID217** – STRUCTURAL HEALTH MONITORING OF PLASTIC PIPELINES BY SHORT CARBON FIBER REINFORCED ELECTROFUSION JOINT **– Riwu Yao – CHINA** (Zhejiang University)

PROGRAM – DAY2, TUESDAY 26TH

Day	Start	End	Duration	A-sessions	B-Sessions
Tuesday	12:50 pm	1:50 pm	1:00	**LUNCH SPONSORED BY** FB Balzanelli	
	1:50 pm	3:10 pm	1:20	**6A – MANUFACTURING TECHNOLOGY** **Chair: Christian Apel – GERMANY** (Radius Group Procurement Company)	**6B – NEW LEARNINGS** **Chair: Carl Baker – U.S.A** (Shell Polymers)
	1:50 pm	2:10 pm	0:20	• **ID249** – 2.7 METERS AND GROWING **– Henning Stieglitz – GERMANY** (BC Extrusion Holding GmbH)	• **ID207** – LONG-TERM PERFORMANCE IN PE100 AND PE100RC RESINS: DOES THE COMONOMER LENGTH MATTER? **– Carlos Domínguez – SPAIN** (LATEP – Rey Juan Carlos University)
	2:10 pm	2:30 pm	0:20	• **ID156** – "IF" (INTERFERENCE) – SCREW TECHNOLOGY **– Rainer Viessmann – GERMANY** (Hans Weber Maschinenfabrik)	• **ID215** – DEVELOPMENT OF A NEW QUALITY CONTROL TEST METHOD TO ASSESS THE STRESS CRACK RESISTANCE OF HDPE WITH RECYCLED CONTENT **– Michael Pluimer, Sara Stone – U.S.A.** (University of Minnesota)
	2:30 pm	2:50 pm	0:20	• **ID112** – RHEOLOGICAL CHARACTERIZATION AND FLOW MODELING OF SAG IN HDPE PRESSURE PIPE **– Harry Mavridis – U.S.A.** (LyondellBasell)	• **ID214** – A NEW GENERATION OF HIGH PERFORMANCE BIAXIALLY ORIENTED POLYETHYLENE AND POLYPROPYLENE PRESSURE PIPES – AN UPDATE **– Ajay Taraiya – THE NETHERLANDS** (SABIC)
	2:50 pm	3:10 pm	0:20	• **ID265** – RE-DISTRIBUTION OF RESIDUAL STRESS IN PLASTIC PIPES AND ITS EFFECTS ON HYDROSTATIC PRESSURE TEST RESULTS **– Suleyman Deveci – U.A.E.** (Borouge PTE Limited)	• **ID148** – A NEW HIGH PERFORMANCE BIMODAL POLYETHYLENE RESIN FOR POWER AND TELECOMMUNICATION APPLICATIONS **– Olivera Bilic – U.S.A.** (Chevron Phillips Chemical Company)
	3:10 pm	3:40 pm	0:30	**COFFEE BREAK SPONSORED BY** Shell Polymers	
Tuesday	3:40 pm	5:00 pm	1:20	**7A – RESILIENCE AND SUSTAINABILITY** **Chair: Dean Jenne – U.S.A** (SACO AEI Polymers)	**7B – RECYCLING LONG-TERM** **Chair: Monica De La Cruz – SPAIN** (Spanish Plastic Pipes and Fittings Manufacturers Group – AseTUB/ANAIP)
	3:40 pm	4:00 pm	0:20	• **ID237** – INNOVATIVE ADDITIVE TECHNOLOGY FOR IMPROVING THE CHLORINE RESISTANCE OF POTABLE HDPE PIPES WITH LOW NIAS (NON-INTENTIONALLY ADDED SUBSTANCES) **– Gregor Huber – SWITZERLAND,** **Tobias Eltze – USA** (BASF)	• **ID166** – RECYCLING COMMITMENT OF THE EUROPEAN PLASTIC PIPE INDUSTRY **– Ludo Debever – BELGIUM** (TEPPFA aisbl)
	4:00 pm	4:20 pm	0:20	• **ID233** – DIFFERENT THERMO-OXYDATIVE TESTS IN COMPARISON FOR ONE INDUSTRIAL PE PIPE COMPOUND **- Norbert Jansen – GERMANY** (Borealis Polymere)	• **ID220** – FROM FISHING NETS TO PLASTIC PIPES: NEW CHALLENGES FOR RECYCLED POLYETHYLENE FLOWS IN A CIRCULAR ECONOMY **– Rafael A. García-Muñoz – SPAIN** (King Juan Carlos University)
	4:20 pm	4:40 pm	0:20	• **ID164** – CLOSING THE LOOP FOR PEX PIPE IN PRACTICE THROUGH ADVANCED RECYCLING **– Robin Bresser – GERMANY** (Borealis)	• **ID221** – EFFECT OF POLYPROPYLENE (PP) POST-CONSUMER RECYCLATE ON THE SLOW CRACK GROWTH RESISTANCE OF A VIRGIN PP PIPE MATERIAL **– Jessica Hinczica – AUSTRIA** (Polymer Competence Center Leoben GmbH)
	4:40 pm	5:00 pm	0:20	• **ID234** – DRIVING TOWARDS A CIRCULAR ECONOMY-EVALUATION OF PEX RECYCLING **– Jacob John – U.S.A.** (Uponor Inc)	• **ID196** – WHAT NEEDS TO BE UNDERSTOOD TO USE RECYCLATES IN PLASTIC PIPES: THE INFLUENCE OF IMPURITIES ON LONG-TERM PROPERTIES **– Mario Messiha – AUSTRIA** (Polymer Competence Center Leoben GmbH)
	7:45 pm	11:00 pm	3:15	**GALA DINNER SPONSORED BY** teppfa	

Day	Start	End	Duration	A-sessions	B-Sessions
27TH SEPTEMBER: TECHNICAL SESSIONS AND CLOSING					
Wednesday	9:00 am	10:40 am	1:40	**8A – TEST METHODS** **Chair: Peter Sejersen – BELGIUM** (The European Plastic Pipe and Fittings Association – TEPPFA)	**8B – RESOURCING SUSTAINABILITY** **Chair: Steve Sandstrum – U.S.A.** (Borealis Compounds Inc.)
	9:00 am	9:20 am	0:20	• **ID141** – INFLUENCING FACTORS OF CRACKED ROUND BAR TEST **– Yanlei Hu – CHINA** (National Test Center of Polymer and Building Materials (NTC), SINOPEC (Beijing) Research Institute of Chemical Industry Co., Ltd.)	• **ID153** – A HOLISTIC ENVIRONMENTAL FOOTPRINT ASSESSMENT OF THE EUROPEAN PLASTIC PIPE BUSINESS **– Ludo Debever – BELGIUM** (TEPPFA aisbl)
	9:20 am	9:40 am	0:20	• **ID161** – THE EFFECT OF THE NOTCH RADIUS ON THE NOTCHED PIPE TEST RESULTS **– Suleyman Deveci – U.A.E.** (Borouge Pte.)	• **ID253** – IMPROVING MECHANICAL SORTING OF POST-CONSUMER PLASTIC WASTE TO ACHIEVE CIRCULAR USE OF PLASTIC PIPES **– Márton Bredács – AUSTRIA** (Polymer Competence Center Leoben GmbH)
	9:40 am	10:00 am	0:20	• **ID163** – FATIGUE CRACK GROWTH RESISTANCE OF POLYPROPYLENE PIPE COMPOUNDS CONTAINING POST-CONSUMER PACKAGING RECYCLATES **– Paul J. Freudenthaler – AUSTRIA** (Johannes Kepler University Linz)	• **ID201** – ONE SMALL STEP FOR EDUCATION – ONE GIANT LEAP FOR THE SUSTAINABLE FUTURE OF OUR INDUSTRY'S WORKFORCE **– White G. Jee – U.S.A.** (JEE Consulting Services LLC)
	10:00 am	10:20 am	0:20	• **ID193** – ALTERNATIVE SLOW CRACK GROWTH TEST FOR THE HDPE CONDUIT INDUSTRY: CORRELATION BETWEEN ESCR AND NCLS **– Patrick Vibien – U.S.A.** (Plastics Pipe Institute)	• **ID182** – THE ALLIANCE FOR PE PIPE LAUNCHES INAUGURAL YEAR OF CERTIFIED PROFESSIONALS PROGRAM **– Edward Alan Ambler – U.S.A.** (Alliance for PE Pipe)
	10:20 am	10:40 am	0:20	• **ID261** – HOW TO CONTROL CRACKS IN PIPES TO GUARANTEE A SAFE OPERATION **– Gerald Pinter – AUSTRIA** (Montanuniversitaet Leoben)	• **ID129** – HOW AN INDUSTRY LEAD PVC PLASTIC PIPES RECYCLING SCHEME CAN CHANGE PERCEPTIONS, EDUCATE, AND PROVIDE VALUABLE INSIGHTS FOR A MORE SUSTAINABLE SOLUTION **– Cindy Bray – AUSTRALIA** (Plastics Industry Pipe Association of Australia)
Wednesday	10:40 am	11:10 am	0:30	**COFFEE BREAK**	
	11:10 am	12:30 pm	1:20	**9A – CASE STUDIES** **Chair: Lance MacNevin – U.S.A.** (Plastics Pipe Institute – PPI)	**9B – NEW TEST METHODS** **Chair: Suleyman Deveci – U.A.E.** (Borouge Pte.)
	11:10 am	11:30 am	0:20	• **ID180** – PE100 MATERIAL SUPPORTS WORLD'S LARGEST WASTEWATER TREATMENT PLANT – BAHR EL BAQAR, EGYPT **– Sultan Alkendi – U.A.E.** (Borouge)	• **ID209** – DEVELOPMENT OF HYDRO-AXIAL TENSION METHOD FOR WHOLE PIPE TENSILE TEST **– Robert Stakenborghs – U.S.A.** (Advanced Microwave Imaging)
	11:30 am	11:50 am	0:20	• **ID138** – THE USE OF PE100+ MATERIALS IN TRENCHLESS TECHNOLOGY APPLICATIONS **– Robin Bresser – THE NETHERLANDS** (PE100+ Association)	• **ID137** – A SUCCESS STORY: NEW TESTING ALTERNATIVES FOR SPANISH AND LATAM PE100RC PIPE MANUFACTURERS **– Federico Muñoz – SPAIN** (Centro de Ensayos, Innovación y Servicios – CEIS)
	11:50 am	12:10 pm	0:20	• **ID232** – HIGH DENSITY POLYETHYLENE (HDPE) PIPE BRINGS SAFE SHORES AND RELIABLE ELECTRICITY TO RWANDA **– Richard Coombs – U.S.A.** (ISCO Industries)	• **ID222** – THE QUALITY OF OLD AND NEW PE PIPES USING THE PENT AND CPENT TEST **– Roland Valk – THE NETHERLANDS** (Kiwa Technology)
	12:10 pm	12:30 pm	0:20	• **ID204** – ADVANTAGES OF PE-RT II PIPES IN DISTRICT HEATING APPLICATION SYSTEM **– Abdullah Saber – U.A.E.** (Borouge)	• **ID219** – MAKING THE ACCELERATED NOTCH PIPE TEST (ANPT) FUTURE-PROOF **– Ernst van der Stok – THE NETHERLANDS** (Kiwa Technology)

PROGRAM – DAY3, WEDNESDAY 27TH

Day	Start	End	Duration	A-sessions	B-Sessions
Wednesday	12:30 pm	1:30 pm	1:00	**LUNCH SPONSORED BY** Sica America Corp.	
	1:30 pm	3:10 pm	1:40	**10A – DESIGN CONSIDERATIONS** **Chair: Bruce Hollands – U.S.A.** (Uni-Bell PVC Pipe Association – PVCPA)	**10B – ENVIRONMENTAL CONSIDERATIONS** **Chair: Cindy Bray – Australia** (Plastics Industry Pipe Association of Australia – PIPA)
	1:30 pm	1:50 pm	0:20	• **ID159** – SIMULATION DRIVEN OPTIMIZATION OF SPIGOT BEVELS **– Guido Quesada – COSTA RICA** (Simulation Driven Engineering)	• **ID175** – LIFECYCLE COST BENEFITS OF PVC-U PIPES IN EUROPE **– Vincent Stone – BELGIUM** (Europe Council of Vinyl Manufacturers)
	1:50 pm	2:10 pm	0:20	• **ID121** – RE-ROUNDING OF DEFLECTED HIGH-DENSITY POLYETHYLENE PIPE **– Kevin White – U.S.A.** (E. L. Robinson Engineering of Ohio)	• **ID118** – UPDATED ENVIRONMENTAL PRODUCT DECLARATION FOR PVC AND PVCO PRESSURE PIPE AND PVC NONPRESSURE PIPE **– Richard Nichols – U.S.A.** (Uni-Bell PVC Pipe Association)
	2:10 pm	2:30 pm	0:20	• **ID216** – MICROWAVE INSPECTION DEVELOPMENT AND EVALUATION FOR SPOOLABLE REINFORCED THERMOPLASTIC PIPE **– Chantz Denowh – U.S.A.** (ADV Integrity Inc)	• **ID256** – INSIGHTS GAINED IN DEVELOPING ENVIRONMENTAL PRODUCT DECLARATIONS FOR PLASTIC PIPES IN AUSTRALIA **– Matthew Hynes, Lucy Croker – AUSTRALIA** (Iplex Pty Limited, Vinidex Pty Limited)
	2:30 pm	2:50 pm	0:20	• **ID171** – DESIGN OF HDPE WATER MAINS FOR THE LATERAL SPREAD SEISMIC HAZARD **– Michael O'Rourke – U.S.A.** (Rensselaer Polytechnic Institute)	• **ID116** – POLYPROPYLENE (PP) – A CARBON FOOTPRINT ASSESSMENT **– Steve Sandstrum – U.S.A.** (Borealis Compounds)
	2:50 pm	3:10 pm	0:20	• **ID246** – BUILDING PIPELINES THROUGH EMBANKMENTS TO LAST **– Shawn R. Coombs – U.S.A.** (Advanced Drainage Systems)	• **ID177** – NEW CRADLE-TO-GATE DATA FOR THE PRODUCTION OF FOSSIL PVC IN EUROPE **– Vincent Stone – BELGIUM** (Europe Council of Vinyl Manufacturers)
	3:10 pm	3:40 pm	0:30	**CLOSING** **– Sarah Patterson – U.S.A.** (Plastics Pipe Institute – PPI)	

ABSTRACTS
PRESENTATION PAPERS

DEVELOPING CIRCULAR SOLUTIONS IN THE PETROCHEMICALS INDUSTRY

Jay Chaffin – Chevron Phillips Chemical Company, Bartlesville, United States of America
E-mail: chaffjm@cpchem.com
Shima Holder – Uponor, Virsbo, Sweden
Tijana Duric – Neste, Geneva, Switzerland
Kaisa Suvilampi – Wastewise Group, Nokia, Finland

Since the development of the polymers industry, plastics have become a widely accepted packaging option worldwide for good reason - these materials are known their high strength, light weight, extraordinary flexibility, low energy usage and low toxicity. But these same materials that offer so many societal advantages are also under increasing environmental scrutiny due largely to gaps in the infrastructure required to handle post use materials.

Industry is engaged in an unprecedented effort to create and deploy sustainable circular approaches that address end of life innovations designed to reclaim valuable hydrocarbon resources and return them to commerce – that is, developing a circular economy.

In this seminar, we will explore the innovations that have made synthetic polymers the material of choice for so many applications, the drivers behind the growth of this industry, the challenges we face, solutions under development and the collaborative efforts needed to responsibly repurpose post use plastics to circular solutions that meet societal needs.

ID264

SUSTAINABILITY AT THE CORE OF STRATEGIES TO ACCELERATE THE JOURNEY TOWARDS CARBON NEUTRALITY

Zoran Davidovski – Pipelife, Vienna, Austria
E-mail: zoran.davidovski@ wienerberger.com
Robin Bresser – Borealis, Burghausen, Germany

Sustainability and slowing down global warming is clearly one for the top priorities for the planet and also for our plastic pipe industry. In recent years the pace of real action and ambitious company and government commitments has been accelerating due to increased awareness, tightening of legislation and poor image of plastics due to shortcomings in waste management.

It's a journey, everyone is learning, and we don't have all the answers as an industry with a high degree of uncertainty & implementation complexity as well as regional deviations around the globe. In Europe we have a 2050 vision with the Green Deal: carbon neutral by 2050; Fit for 55: EU climate law cementing 55% CO_2 reduction by 2030 and what starts to be a more defined roadmap with initiatives as Taxonomy and the Renovation Wave.

In this paper the authors will share sustainability strategies and learnings of two large companies in different parts of the value chain – virgin and recycled polymer production and pipe system production. The main focus is on closing the loop quickly with circular solutions and achieving CO_2 footprint reduction in the construction as well as the use phase while already considering end of life in construction and eventually demolition.

This is clearly a collaboration challenge for the entire plastic pipe and even the construction industry. The authors will bring in their experience from different Associations such as TEPPFA and PE100+ as well as many discussion Fora on the exciting subject of sustainability.

ID168

MICROPLASTICS AND PLASTIC PIPES

Peter Sejersen – TEPPFA aisbl, Brussels, Belgium
E-mail: peter.sejersen@teppfa.eu
Ludo Debever – TEPPFA aisbl, Brussels, Belgium

Microplastics in drinking water and in food in general has been a topic with ever increasing interest since a publication of a study in the British newspaper The Guardian. The microplastics topic has also high focus on governmental level, e.g. in Germany where a report of Fraunhofer Umsicht estimates the amount of microplastics coming from plastic pipe systems to be 12 grams per year per capita. Since then, we have seen several attacks from producers of piping systems made of traditional materials: Copper, concrete and ductile iron.

Measuring microplastics is considered as being difficult. Although it is challeging, it is important for the plastic pipe industry to understand and follow the development of technologies. TEPPFA has therefor initiated several studies to investigate if plastic pipes are a source for microplastics and to quantify if possible. Two studies have been performed on pipes for drinking water and one study for storm water pipes.

In the first drinking water study the Raman method was used and in the second the particles were analysed using laser direct infrared imaging with a particle identification by help of a software.

The studies on drinking water pipes have been done in a test rig where a normal pattern for drinking water supply in buildings are simulated: A pressure of 4 bars, a water flow of 1,2m/s and a start/stop schedule.

In the first study PE80, PE100, PErt and PVC-U were investigated. In the second study more polymers were added and also PB, PVC-C, PP-rct and PPr were tested. Furthermore, the second study also included test at 60 degree Celsius.

Results of the studies were very encouraging although it also was evident how complicated it is to measure microplastics in an environment where you constantly have fibres and particles in the air in the laboratories.

The third study was concentrating on storm water gravity pipes. When comparing to sewer pipes, it must be expected that abrasion and wear inside the pipes are more likely to happen in pipes transporting surface water. A PVC and a PP storm water pipe, that has been in use in around 30 years in Denmark were dug up and inspected by an accredited institute. After inspection it could be concluded that no wear was found, and therefore storm water pipes cannot be a significant source of microplastics in the aquatic environment.

The paper will explain the test-set-up, the methods used and the results of both the study on drinking water and the study on storm water pipes.

ID158

ASTM F17 – FIFTY YEARS OF PLASTICS PIPING PROGRESS

Steve Sandstrum – Borealis Compounds, Port Murray, United States of America
E-mail: steven.sandstrum@borealisgroup.com
Kevin Shanahan – ASTM International, West Conshocken, United States of America
Sarah Patterson – Plastics Pipe Institute, Irving, United States of America

2023 marks the 50 year anniversary of the ASTM International's (ASTM) F17 Committee on Plastics Piping Systems. Since its inception in 1973, ASTM F17 has played a pivotal role in the sustained growth and expansion in the use of plastics piping systems in North America and around the globe.

Standardization has been instrumental in the development, design, installation and operation of plastics piping systems. In this discussion, the origin and evolution of ASTM F17; its numerous initiatives and milestone; and its overall structure and relevance within the North American and international plastic pipe industry are examined and presented.

The discussion concludes with a perspective regarding the role of ASTM F17 in the ongoing responsible use of plastic piping systems as a sustainable choice for critical quality of life applications to include the collaboration and coordination with other ASTM committees such as D20 (plastics) and E60 (sustainability).

ID113

SAFEGUARDING OUR WATER: NSF/ANSI/CAN 61

Kathryn Foster – NSF International, Ann Arbor, United States of America
E-mail: kfoster@nsf.org

NSF/ANSI/CAN 61: Drinking Water System Components: Health Effects1 (NSF 61) is North America's flagship standard for drinking water system components. This standard establishes health-based criteria to address the potential contaminants and impurities that are directly imparted to drinking water from the wetted surfaces of the products, components, and materials that make up drinking water systems. The standard covers water contact products used across the entire water distribution system, from source to tap. 49 U.S. states and the majority of Canadian provinces/territories have requirements that water system components comply with NSF 612. Since NSF 61 was first published in 1988, plastic pipe and fittings have been evaluated against the rigorous requirements of that standard, demonstrating their suitability for use with potable water.

NSF 61 is a dynamic standard maintained by a consensus body that continually works to improve and update the standard in response to updates in technologies available on the market, updates in regulations, and the current state of toxicological science. This continual revision cycle allows the standard to maintain and increase its rigor and ensure public health and safety even as new public health concerns arise. This continuous improvement in the standard is exemplified by the in increasingly stringent requirements for lead leaching from drinking water system components over the years, with allowable lead limits decreasing to only fractions of the levels that were allowed when the standard was first published. Today, the joint committee that oversees the standard is working on initiatives that address some of the most pressing concerns in the water industry today, including nanotechnology, PFAS compounds, and microplastics.

This talk will provide a high-level refresher on the requirements of NSF 61 and illustrate how NSF 61 and the closely related lead content verification standard, NSF/ANSI 372 provide assurance that plastic piping products tested and certified under the standards will not have a negative impact on public health. It will also review the manner in which testing to the standards is mandated via national and international regulations. Finally, the talk will address the ways in which the standards are constantly being revised in order to address future needs and concerns of both the plastics pipe industry and the regulators, public health officials and members of the public who together seek to ensure and maintain the quality of the water we all drink.

ID122

HOW TO STRENGTHEN THE DEVELOPMENT OF CHINA'S PLASTIC PIPE INDUSTRY IN THE NEW MARKET ENVIRONMENT

Wang Zhanije – China Plastics Piping Association (CPPA), Beijing, China
Guo Jing – China Plastics Piping Association (CPPA), Beijing, China
Wang Lin – China Plastics Piping Association (CPPA), Beijing, China

In the past two years, China's plastic pipe industry has faced a complex and changeable development situation. The domestic economy is facing the pressure of shrinking demand, supply shocks and expected weakening, and the market has changed greatly. Superimposed by the epidemic situation and many adverse factors, the downward pressure increases. In the new market environment, the development of China's plastic pipe industry presents new characteristics. Although the annual output growth is not large, the volume is still considerable; Industry concentration has been strengthened and industrial structure has been continuously upgraded; The level of intelligence has been improved, and the innovation drive has reached a higher level; The quality level has been improved, the green development has become increasingly obvious, and the industry as a whole has maintained a steady development trend.

In 2021, China's plastic pipe industry overcame various difficulties and made constant efforts in the economic downturn environment. The annual total output reached 16.6 million tons, an increase of about 1.5% year on year, and made some progress in industrial scientific and technological progress, market expansion, quality development and other aspects.

In the future, China's plastic pipe industry will still have development toughness and potential while facing new situations, new challenges and new opportunities. New urbanization, rural modernization and the "China Built" will bring new opportunities for the development of the industry.

This article will describe the development status of China's plastic pipe industry in the past two years, as well as the difficulties and challenges, and will discuss how China's plastic pipe industry should cope with the new market situation, how to achieve innovation, how to achieve environmental protection and sustainable development, how to improve its service level and promote the development of the industrial chain in the future.

ID152

THE FUTURE HARMONIZED CERTIFICATION SCHEME FOR PRODUCTS IN CONTACT WITH DRINKING WATER

Peter Sejersen – TEPPFA aisbl, Brussels, Belgium
E-mail: peter.sejersen@teppfa.eu
Ilari Aho – Uponor OY, Helsinki, Finland

European standardization of plastic pipe systems has been on the agenda since the eighties and almost all applications are now described in common European standards. An important expectance however is the hygienic requirements of pipes for drinking water: Most of the EU Member States currently do not coordinate their implementation efforts. The result is a multitude of different national requirements for the marketing of materials and articles incontact with drinking water. As of today, more than 15 different certification and test organisations within the European Union regulate the products and materials suitable for use with drinking water. The industry is therefore challenged by lack of coordination which makes trade across boarders difficult and expensive.

To support a future European harmonization an alliance of European associations representing the industries which manufacture and supply products that are used in drinking water applications was establish. The members of the initiative called „European Drinking Water ", include representatives from the pipe-, pump-, valve-, tap-, fitting-, seal-, meter-, water heater and water treatment equipment-industry, i.e. the entire industry supply chain ranging from the raw materials suppliers to water distribution. It is a high priority area for the manufacturer of plastic pipes and TEPPFA and its members are therefore deeply involved in the project.

The EDW has since 2015 advocated for establishing a European harmonization in connection to the revision of the Drinking Water Directive. The effort was successful and in January 2021 the new EU Drinking Water Directive came into force with a decision to set-up uniform requirements for materials in contact with drinking water. The regulation is described in see Article 11 "Minimum hygiene requirements for materials that come into contact with water intended for human consumption".

The regulation is right now being rolled out, and the 4MSI system, based on the principles of positive lists will be the foundation for common European certification scheme.

The paper will describe the process, the principles in the 4MSI system, the expected timeline as well as the position that EDW and the plastic pipe industry have.

ID240

COMMITMENT TO SUSTAINABILITY IN STRUCTURED-WALL PVC-U PIPES FOR SEWERAGE. "CIRCULAR CERTIFICATION" FOR "CIRCULAR PRODUCTS"

Ricardo Pascual Galan – AENOR, Madrid, Spain
E-mail: rpascual@aenor.com

Social awareness with aspects related to the conservation of the environment and sustainability, the acceptance by citizens of the need to reduce consumption, reuse products, repair as far as possible and, fundamentally, the action of recycling at the end of its life, facilitates the availability of recycled plastics on the market for which suitable applications must be sought.

Nowadays, the CEN Standardization Committees related to plastic products are dealing with the percentages of recycled plastics that some standardized products will have to contain in the future, and consequently, in a later stage, this characteristic will have to be also evaluated for those products that wish to hold a voluntary quality mark.

In this frame, AENOR, in line with other actions in the field of circular economy of plastics, defines a certification scheme based on the EN 15343 for the content of recycled material in PVC-U wall structured pipes for non-pressure underground drainage and sewerage.

Considering the lack of availability of a reliable technology for an analytical determination through testing of the content of recycled material in a product, the certification system is based on an audit for the complete production process, including the following stages:

- Analysis of the theoretical design calculations for each diameter and series of defined nominal stiffness.
- Origin, adequacy, traceability and characterization of the recycled material to be used, with clear reference to its pre-consumer or post-consumer origin. These recycled materials must meet the requirements established in the standard for the characterization of recycled PVC, EN 15346, and must arrive at the converter facilities with a CoA defining density, ash content, colour, impurities and particle size.
- Production process, extrusion equipment, feed equipment and coextrusion systems for the manufacture of the pipes. The extrusion equipment must allow at all times to check on the control screens that monitor the dosage the discharges of material from the different feeders, as well as ensure a final record of the discharges during the production of a batch.
- Verification of the use and calibration of dosing equipment of the extrusion lines
- Final verification through mass balance with a real production during the audit of the recycled content used

All these evidences have to be complemented with the confirmation of the compliance of pipes with recycled content with all the physical, mechanical and performance requirements established in the applicable standard for that product, in this case EN 13476.

The paper will put attention in the mentioned points with the support and explanation of real cases.

ID205

DESIGN METHODS AND ACTUAL PERFORMANCE OF LARGE DIAMETER STRUCTURED WALL PIPES

Anders Andtbacka – Uponor, Vantaa, Finland
E-mail: anders.andtbacka@uponor.com
Peter Sejersen – TEPPFA aisbl, Brussels, Belgium

In the late nineties TEPPFA carried out a study of the behavior of buried thermoplastics pipes. The project had input and participants from both the Plastic Pipe industry as well as from external organizations. Six external leading experts in the field of pipeline design, not necessarily plastics pipes design, have been involved as consultants in the project. The experimental work included a number of less ideal installation circumstances, in order to fully understand the where the border line of safe installations is. Pipe material were at that time mainly PVC-U. The results have been used in standardization work, e.g., in developing CEN TS 15223, "Validated design parameters of buried thermoplastics piping systems".

Although the physical rules stay the same the world has changed. The need for watertight solutions in large diameter sewer pipes has given plastic pipe solutions a significant increase in market share in Europe, very well supported by the introduction of the EN 13476 standard which describes a number of different ways to design and produce a structures wall pipe. Therefore, we extend the Buried Pipe Study by introducing an online tool for calculating the design of large diameter structured wall pipes of PE and PP in the diameter range Ø1000 to 3000mm.

As a follow-up on the project, we have made a comparison of the results of our design tool with other commonly used European tools, such as ATV-127 and BS 9295. Furthermore, we have compared the results of the calculation methods with actual measurements of real-life installations in Sweden, Finland and Denmark.

The paper will elaborate on the principles behind our company calculation method and also shows the variation between different calculation methods, where it is evident that most calculations methods are conservative compared with real-life experience.

The initiative of making a transparent and easy-to-use method available to the marked will contribute to give plastic pipes their rightful share of the market for large diameter pipes.

ID165

FISCHER-TROPSCH HYDROCARBONS AS PROCESSING AIDS IN INJECTION MOLDING & EXTRUSION

Steve Torchia – Sasol Chemicals LLC., Houston, United States of America
E-mail: steve.torchia@us.sasol.com
Justyn Miller – Sasol Chemicals LLC., Houston, United States of America
Gavin Guo – Sasol Chemicals LLC., Houston, United States of America

In the polymer world, the balance between processability and finished product property is always a hot theme. Converters are continuously evaluating the potential options to reduce total costs by increasing line speed, reducing energy consumption to obtain improved product property with lower scrap rate. Among them, the processing aids are acting the key role to achieve the optimized results.

To improve the processability of polyolefins during extrusion and injection molding, Sasol developed a highly crystalline Fischer-Tropsch hard wax branded EnHance. It is highly compatible with polyolefins and, when used at the recommended loadings, are dissolved in the polymer matrix.

The Fischer-Tropsch (FT) wax acts as a viscosity modifier during the processing of polyolefins, allowing faster plasticization. The addition of FT wax allows for the use of lower temperature profiles and hence reduces cooling times. These factors ultimately result in faster line speed or faster cycle times. With the assistance of FT wax, the lower melt index resins which have better mechanical properties can be processed. Moreover, the easier flowability of FT wax added resins can further reduce the melt pressure, which translates to power saving. Fischer-Tropsch wax can also be used to aid the dispersion of inorganic fillers and pigments in polyolefins during compounding prior to extrusion or injection molding. Ultimately, FT wax as the polyolefin processing aid is an effective additive for converters to reduce costs and improve product quality.

ID117

A NEW CONCEPT FOR TESTING OF NEW GENERATION OF THERMOPLASTIC STORMWATER RETENTION TANKS

Shad Sargand – Ohio University, Athens, United States of America
E-mail: sargand@ohio.edu
John Kurdziel – Advanced Drainage Systems (ADS), Hilliard, United States of America
Issam Khoury – Ohio University, Athens, United States of America

Water management has become a major challenge with climate change disrupting typical weather patterns, leading to shortages via drought and drop in water table. It has become imperative to manage stormwater runoff in particular. One solution in development is the buried stormwater drainage retention crate. The crate is typically a rectangular box structure made of thermoplastic components (flat panels and columns) assembled in a modular form. The function of the top panel is to transfer the load to the columns. This load can be due to live and dead load, backfill, etc.

The structural performance of the crate has generally been limited to laboratory experiments consisting of placing a concrete block on top of a panel placed on columns. In the field, the panel will potentially experience local buckling or excessive tension. When employing this type of laboratory testing procedure, the panel will not be subjected to these failure modes.

A unique apparatus was constructed to test a crate system module with a load that includes a layer of granular material between the module and the concrete weight. This experimental setup more realistically replicates actual field conditions than those currently under consideration for international specifications [ISO, 2023].

ID236

FRACTURE MECHANICS AS A TOOL FOR THE ASSESSMENT OF THE DEGREE OF GELATION OF U-PVC PIPES

Antonio Rodolfo Jr. – Braskem S/A, Sáo Paulo, Brazil
E-mail: antonio.rodolfo@braskem.com
Vanderley John – State Univerity of São Paulo, Brazil

Unplasticized (U-PVC) ABNT NBR 5647-2 regular industrial pipe samples, with nominal diameter DN 100, outside diameter 110 mm, nominal wall thickness 7.8 mm, Ca/Zn stabilized were studied using essential work of fracture (EWF) approach. These pipe samples were also tested for the degree of gelation via differential scanning calorimetry (DSC) and tensile strength. By applying a methodology previously developed [1-4], using curved three-point bending (CTPB) specimens, it was possible to confirm previous findings that this specimen configurations is very suitable for EWF testing of pipe samples. When comparing results from this study with previous publications from the authors, it is shown that EWF seems to be an interesting alternative approach for gelation assessment, since it is evident from these results that there is some high degree of correlation between one of the EWF parameters and the DSC degree of gelation.

ID187

SANDBOX TESTING FOR STRUCTURAL ASSESSMENT OF PLASTIC MANHOLES

Ricky Selle – Selle Consult, Leipzig, Germany
E-mail: info@selle-consult.de

Since about 50 years, circular plastic manholes gain constantly market shares in drainage and sewerage networks in competition with traditional concrete products. Manufacturers of plastic manholes point to advantages as a higher media resistance and thus a longer technical service life and installations with less effort due to the significantly lower weight.

Structural behavior of flexible plastic manholes is very different from rigid concrete manholes. That is why, only unrealistic small windows of application are determined in structural assessment, if traditional soil models and soil coefficients are applied. These models are based on rigid wall structures and do not account for the flexibility and soil interaction of the manholes. Since plastic manholes are flexible, horizontal soil pressure on the elements is significantly lower than on rigid concrete rings. This is comparable with pipes, where flexible materials allow for much lighter and leaner structures.

In the last decades, tremendous practical experience was gained on structural behaviour of plastic manholes. International product standards as EN 13598 define mechanical requirements to assure safe installations. However, no international standard exists on design of these products. Therefore, an extensive in-situ testing of a state-of-the-art manhole in a sand-box was conducted in a German test house. Deflections were measured of the manhole from different loads with varying durations. Since concerns of design engineers are mostly about the resistance against traffic loads, i.e., horizontal soil pressure from wheels sitting close to the manhole, the focus of testing was on this kind of loading.

The presentation will introduce the most relevant results for structural assessment. It will be explained how vertical soil pressure is distributed in the subsurface 3D space and why most part of the vertical loads is not acting on the flexible manhole. Based on these findings, key approaches for realistic soil coefficients are presented to prove the structural adequacy of plastic manholes for realistic windows of application.

ID262

NEW CYCLIC METHOD FOR PVC FORCE MAINS

Jay Parvez – Uni-Bell PVC Pipe Association, Irving, United States of America
E-mail: jparvez@uni-bell.org
Richard Nichols – Uni-Bell PVC Pipe Association, Irving, United States of America

All thermoplastic and thermoset pipes must consider the impacts of cyclic loading on overall performance. Since its first use, PVC pipe has been tested for its resilience to such loading. As testing evolved over time, the method to determine cyclic capacity for gasketed PVC pipe has improved. Previously, the cyclic equation was quite complex, requiring an iterative process or use of a 3-axis graph, and was accurate within a certain range of stress amplitude. Recently, the PVC pipe industry worked with Utah State University to develop a new equation to calculate cyclic life for gasketed PVC pipe, which is simple to use and accurate for any stress amplitude. This new method has been recently incorporated into the new AWWA C900-22 standard. This presentation will review the history of cyclic design for PVC pipe and present the new, simplified method, known as the Folkman method.

ID119

THE CARBON COST OF OUR BURIED INFRASTRUCTURE – IS IT OUT OF SITE AND OUT OF MIND?

Paul O'Regan – AquaSpira Limited, Nelson, United Kingdom
E-mail: po@aquaspira.com
Nigel Cassidy – Univeristy of Birmingham, Birmingham, United Kingdom

A 2020 report by the UN Environment Programme (UNEP) estimated that the building sector accounts for a staggering 38% of world-wide energy-related CO_2 emissions and that the construction industry is responsible for nearly 30% of this figure. Modern-day pipes, sewers and water drainage systems are predominantly made of plastic, usually high-density polyethylene (HDPE) or polyvinylchloride (PVC), ceramic or cast and/or reinforced concrete. These materials have a high embedded carbon cost, but considerable effort is being made by manufacturers to reduce the carbon cost of their products.

Under current pipeline installation standards, fresh aggregate materials (usually sand and/or gravel) are required for the fill materials around the pipe to guarantee installation integrity and quality – it is a pipe-soil system that is being provided. As such, there is a significant added carbon cost in the excavation and off-site removal of the original soils and the import of fresh aggregates to backfill the pipe trench and reinstate the surface. To reach the goal of net zero by 2050 this installation requirement needs to be challenged and maybe changed.

In a current InnovateUK funded research programme, A Steel Reenforced High Density Polyethylene (SRHDPE) pipe manufacturer has collaborated with the University of Birmingham to develop almost 100% recycled SRHDPE "SmartSense" pipes that can be installed with recycled or as-dug embedment materials using embedded sensing to autonomously monitor ground conditions. Key to this research is developing a better understanding of the detailed physical and geotechnical properties of the embedment material and how the whole pipeline installation performs when ground loading conditions change around the pipe. We present the latest experimental findings from the research programme highlighting the sensing capabilities of the SRHDPE system under 'real-world' loads and installation conditions.

ID227

PROJECT AND EXECUTION OF WORKS FOR THE EXPANSION AND IMPROVEMENT OF THE POTABLE WATER SUPPLY CAPACITY TO THE METROPOLITAN AREA OF MONTEVIDEO

Ignacio Muñoz – Molecor Tecnologia, Loeches, Spain
E-mail: ignacio.munoz@molecor.com

Society has recently lived few strange and peculiar years, to say the least. COVID impacted personal lives, businesses, industries. And it is undeniable, the big elephant in the room arrived years before COVID and will remain much more: CLIMATE CHANGE. And as broad as this topic is, this paper would like to focus on the impact that it has on pipe industry from the point of view of sustainability.

We believe that R&D in industries drives the change into society, and that reflects into its purpose: "To improve the quality of life for people everywhere in the world, bringing affordable water within their reach through innovative, efficient and sustainable solutions". Thanks to the technology developed by our company, a unique, air based, automatic and very stable system, it has been possible to enlarge the range from DN400 mm (16") in year 2006 (year of establishment of our company), to DN1200 mm (48") nowadays (ISO 16422:2014). This technology opens up plastic pipes possibilities to large diameters and high pressures (25 bar or 305 psi depending on the geography considered).

Large PVC-O pipes are today a reality and can very well bring added value to water networks under pressure where only steel or ductile iron pipes were considered before because of size and high-pressure requirements. If there were to be corrosive soils, water table, welded unions, cathodic protection, etc. the alternative of having a plastic pipe with a push in joint 100% watertight, it is something to have into consideration. That is just from the point of view of the installer but, looking into the energy requirements to pump that water, having higher speed less head loss means less energy consumption. In certain markets the energy savings along the projected live of the project are more than the project itself.

PVC-O pipes are the most sustainable solution for water transportation under pressure and this paper covers a case study in detail to support this statement.

ID258

3D PRINTING OF FLOW PROFILES FOR INSPECTION CHAMBERS AND MANHOLES

Ton Schoenmaker – Pipelife, Enkhuizen, The Netherlands
E-mail: ton.schoenmaker@pipelife.com

For years the way of producing a flow profile for Inspection Chambers and Manholes could be divided into 3 methods:

- Injection moulding
- Roto moulding
- Hand Assembling

For the standard orientations, for example straight through and cross, the IM profile integrated with a base is by far the best option.

But for nonstandard configurations; different orientations, inlet heights and inlet sizes, the only option is to hand weld them together from injection moulded parts, pipes and plates.

This is a time-consuming way of producing with high production cost and often aesthetic-wise of a challenging level. This is not necessary anymore after the introduction of 3D printing as a new production method for flow profiles in chambers and manholes.

3D printing is in many industries an accepted production method which can produce parts of high quality and high accuracy. The systems to print have faced a huge development in the last 10 years and prints are often close to perfection. The only disadvantage of these printing systems is the maximum size of the print. But since the introduction of 3D robot printing, products with a diameter of 1 meter can be printed without any problem.

3D robot printers were up to recently, used for prototypes, one-off products and art objects. Now a production area is created on which multiple products can be produced in a row without human interference.

The most common materials used for 3D printing are ABS and PLA. These materials have good adhesion, almost no shrinkage and a good appearance. Unfortunately, these materials are not common in our industry. We need PP, PE or PVC. While our manholes and inspection chambers are from PP we also need PP flow profiles. The advantage of using a 3D robot printer is that it uses granulates instead of filaments or special powder. This makes the material cost part almost equal to injection moulding.

Another advantage is also that recycled material can be used. Own scrap can be used but also waste from other markets.

The main reason that flow profiles are ideal for 3D printing is that nonstandard flow profiles are very labor-intensive. So 3D printing really helps out here. Besides that, there is a lot of freedom in design. This helps to design in such a way, that the final profile is hydraulically optimal.

This prevents the overflowing of manholes during heavy rain showers. Of course, these products should fulfill all requirements of the EN13598-2.

Even though major development steps are made in 3D printing during the last 5 years, 3D robot printing is still in the exploring phase and we find many hurdles on our way. This presentation will show how our industry can use 3D printing and what are the pros and cons.

ID123

THERMOFORMING PROCESS FOR SOCKETS INTEGRATED WITH RIEBER SYSTEM IN MOLECULARY ORIENTED POLYVINYL CHLORIDE (PVCO) PIPES FOR PRESSURIZED WATER DISTRIBUTION

Orlando Martinez – SICA S.p.A., Cotignola, Italy
E-mail: omartinez@sica-america.com
Giorgio Tabanelli – SICA S.p.A., Cotignola, Italy

In plastic pipes for distribution of pressurized water, the socket jointing technique made with the Rieber system is mainly used in PVC-U pipes. In a pipe socket made with the Rieber system, the gasket is integral with the socket wall, and it is no longer removable or even replaceable. On the other hand, in Molecularly Oriented Polyvinyl Chloride (PVCO) pipes, it is customary for a removable and replaceable gasket to be added to the socket joint after the socket is formed. The Rieber socket shape, despite its known operational advantages, is not used in PVCO pipes and the motivation is essentially due to the difficulty of implementing a heated Rieber socket forming process in industrial socketing machines for PVCO pipe. The Rieber socketing or belling process for PVCO pipes is conditioned by compliance with fundamental requirements such as: adhesion of the gasket to the socket wall; preservation of the structural integrity of the gasket during the belling process; repeatability of the belling process; increase in the orientation factor of the PVCO material in the socket wall; and guaranteeing the shape and dimensions of the socket suitable for the functionality of the joint. Recently, a new thermoforming process has been developed that allows the Rieber system socketing of PVCO pipes for the distribution of pressurized water, which guarantees all the requirements described. The procedure is then applicable to all PVCO pipes of different operating pressure classes and to all PVCO pipes of different orientation level of the material. Specifically, it is applicable to ISO 16422 systems for pipes with nominal diameters from DN/OD 63 mm (2.48") up to DN/OD 630 mm (20.80") and to ANSI/AWWA C909 systems for pipes with nominal diameters from DN/OD 4" up to DN/ OD 24".

The procedure can be applied both to PVCO pipes with orientation obtained by inflation in a tank and to PVCO pipes made and oriented directly in the extrusion line. Special characteristics of the heated Rieber socket forming process are the physical phenomena of PVCO pipe and of the sealing gasket, which are considerably different from those that result in PVC-U pipe. Controlling these phenomena required the development of unconventional but absolutely effective technological solutions.

The article contains the description of the Rieber belling technology for PVCO pipes with peculiar reference to the new technical process solutions that have made it possible to control the thermo-mechanical phenomena specific for the hot forming of the Rieber socket in the PVC-O pipe, as well as the analysis of the results of the experimental validation tests of this technology.

ID199

CRITICAL QUALITY CONTROL OF POST CONSUMER RECYCLED PVC

Shane Harton – C.W. Brabender Instruments, South Hackensack, United States of America
E-mail: shane.harton@cwbrabender.com

Recycling and re-using commodity polymer-based products is an attractive way to reduce overall waste and move the extruded and molded plastics industries toward global sustainability. Post-consumer recycled (PCR) poly(vinyl chloride) (PVC) blends can be produced from articles such as discarded vinyl window profiles, credit cards, and vinyl siding. However, lot-to-lot variability and diminished processability due to lowered degradation thresholds relative to virgin PVC can make the use of such compounds less attractive and more costly. With implementation of robust analysis and quality control (QC) methods, low-cost production of extruded products from PCR PVC blends can be achieved while providing customer and shareholder value as well as achieving environmental sustainability goals.

Torque rheometry has been the standard instrument used in PVC QC testing for decades, making it an obvious candidate for QC testing of PCR PVC blends. Torque rheometry has been used to determine the fusion/gelation behavior as well as the thermal stability times of 6 PCR PVC blends composed of 100% recycled PVC according to ASTM D2538. Because PCR PVC compounds have already been melt processed, the standard fusion/gelation times are not relevant. However, by confirming the underlying thermal behavior using modulated differential scanning calorimetry, it has been shown that multi-phases/gels are present in some of the recycled feedstocks, but not others, making torque rheometry an essential differentiator for incoming QC of recycled PVC. The measured thermal stability times were used to establish process windows for counter-rotating conical twin screw extrusion, with melt viscosities measured with a low-shear rheometric die at 190ºC resin stock temperature. Results show similar melt flow profiles as a function of shear rate for all 6 PCR PVC blends, with no obvious differences between the blends with and without multi-phases/gels present. These findings are highly relevant for incorporating recycled PVC into plastic pipe formulations. Torque rheometry is sensitive to multi-phases/gels, which can be detrimental to performance of the final product, even if these multi-phases/gels do not significantly impact the processability of the resin feedstock. Furthermore, thermal stability times can be used to guide stabilizer addition to recycled PVC feedstocks, and the final formulation can be tested using both torque rheometry and extrusion viscometry.

ID133

LEVERAGING DATA INSIGHTS TO IMPROVE SAFETY, QUALITY AND ROI

Nayib Joussef – McElroy Manufacturing Inc, Santiago, Chile
E-mail: njoussef@mcelroy.com
Sergio Vaccaro – EMIN Ingeniería y Construcción S.A., Santiago, Chile
Chris Zenthoefer – McElroy Manufacturing Inc, Tulsa, United States of America
Hermann van Laak – Evonik Resource Efficiency GmbH, Marl, Germany
Tobias Bauer – SKZ – Das Kunststoff-Zentrum, Würzburg, Germany

Butt fusion of HDPE pipe has long been shown to be an extremely beneficial process in producing leak-free, monolithic piping systems. Continued growth of the Chilean mining sector has necessitated a substantial increase in polyethylene pipe sizes and wall thicknesses, with diameters well beyond 630 mm up to 2m diameter pipe. The methods to effectively and efficiently move, manipulate and fuse large diameter pipes following rigorous safety standards has further complicated the job site. This case study will show how a Chilean company has implemented new equipment and technologies to plan, construct and monitor their tailing and leachate pipelines construction processes. Taking tracking and traceability further, this company has been leveraging real time data analytics to continuously measure their key performance indicators of productivity, quality, and safety, allowing them to take immediate actions to prevent undesirable events while increasing productivity in a safe and sustainable way. These efforts have also allowed them to reduce their total support equipment and staff on the job site, helping them reach environmental sustainability goals while further improving safety. Through the combination of new equipment and actionable data, this company has demonstrated they can simultaneously increase their pipe diameters, improve all key performance metrics, reduce their environmental footprint, and improve their return on capital investment.

ID245

THE BRAZILIAN PVC PIPE ASSOCIATION QUALITY ASSURANCE PROGRAM: 30+ YEARS OF SUCCESS

Antonio Rodolfo Jr. – Braskem S/A, Sáo Paulo, Brazil
E-mail: antonio.rodolfo@braskem.com
Luciana Oriqui – Associação Brasileira dos Fabricantes de Materiais para Saneamento, Sáo Paulo, Brazil
Mauro Adamo Seabra – Associação Brasileira dos Fabricantes de Materiais para Saneamento – ASFAMAS-PVC, São Paulo, Brazil

In this manuscript it is presented how the Brazilian PVC pipe industry has successfully implemented and maintained since 1988 programs of quality assurance related to the PVC solutions used in Brazil. These programs cover infrastructure, including water distribution networks (in nominal diameter ranges varying from DN50 up to DN 600) and sewage collection (in nominal diameter ranges varying from DN100 up to DN 1000), as well as solutions for this material used in building hydraulic installations, including PVC pipes and fittings for water, sewage, and building drainage.

The Brazilian PVC pipe industry maintains the elaboration of specific mechanisms of intense and continuous evaluation of the products regularly offered to the market. It is carried out by an independent third-party technical entity, within known public rules and based on the best practices of conformity assessment.

The objective is to ensure that the PVC pipes made available to sanitation companies, builders, and users in general have satisfactory performance and conform to the requirements established by the Brazilian technical standardization required for each application. It aims to promote full compliance with the needs of consumers and users, in an environment of isonomic and healthy technical competitiveness among manufacturers.

The results achieved in more than 30 years of activity are quite expressive in their respective segments. Among the Brazilian companies operating in the PVC market, each program counts on the adhesion and voluntary participation of more than 90% of market players, whether large, medium or small. Sectoral indicators of compliance with normative requirements reach close to 100%. It is also important to mention that the Brazilian PVC pipe industry has been intensively active in the evolution of the Brazilian standards, acting as the leader of the respective committees.

ID241

ACCELERATING SUSTAINABILITY WITH DIGITAL SOLUTIONS

Joseph Venegas – Rollepaal Pipe Extrusion Technology, The Netherlands
E-mail: j.venegas@rollepaal.com

Digital tools can be a catalyst to accelerate the change we need to meet the goals of the Paris Climate Agreement ("The Paris Agreement"). Across all industries and all walks of life we need to speed up the pace of sustainable innovation. Fortunately, within the plastic pipe industry we have several forms of structured wall pipes as well as PVC-O which offer significant material savings and an enormous reduction in the environmental impact of our products. The issue is now, is that we must move more quickly than ever before to implement these new technologies.

Digital tools offer three main benefits which can accelerate the adoption of new technologies. First, they can turn data from a new process into the information needed to optimize that process. This can come in the form of cloud data systems or AI analysis tools. Second, digital tools can offer the user of new technology access to support on demand, when it's needed. This speeds up adoption by reducing delays. Finally, digital tools can help companies replicate previous successes across new investments.

All three of these avenues use digital tools to turn data into information. Information that allows people and organizations to be agile and responsive, which is exactly what is needed to meet the goals set forth in the Paris Climate Agreement.

ID225

EXAMINING SGF ORIENTATION IN POLYETHYLENE REINFORCED WITH SHORT GLASS FIBERS PIPE

Mitsuaki Tokiyoshi – C. I. TAKIRONCIVIL Corporation, Kasumigaura, Japan
E-mail: mitsuaki_tokiyoshi@live.com
Yutaka Sawada – Kobe University, Kobe, Japan
Yasuhiko Otsuki – Prime Polymer, Ichihara, Japan
Kensei Inoue – Prime Polymer, Ichihara, Japan
Takashi Kuriyama – Yamagata University, Yonezawa, Japan
Toshinori Kawabata – Kobe University, Kobe, Japan

Polyethylene reinforced with short glass fibres (PE-sGF) pipe, manufactured by combining short fiber glass (sGF) with PE100 as a reinforcing material, has a higher pipe rigidity in the pipe circumferential direction than that of PE100 because of the reinforcing effect of the reinforcing material and a performance similar to PE100 in terms of flexibility in the pipe axial direction. This performance is clarified by the numerical value of the tensile yield stress or tensile modulus of elasticity, which can be obtained by tensile tests that use specimens extracted from the PE-sGF pipe in the circumferential or axial direction.

However, the factors behind the mechanical behavior remain unclear. Therefore, the orientation of the sGF was confirmed using X-ray CT analysis. The results show that the striped pattern orientation angle mapping results were obtained in the extrusion direction and thickness directions. This striped pattern indicates that the orientation of the sGF is cross-oriented with a slight inclination to the extrusion direction; the orientations switch at an interval of constant thickness. These thicknesses are equivalent to the thickness of each layer of the PE-sGF pipe, similar to the cross-winding molding method. Therefore, the sGF were proven to be oriented according to the extruded manufacturing angle, while the pipe was mostly reinforced in the circumferential direction. Thus, while physical properties and orientation analysis are being clarified, in this study, I focused on the glass fibers flow during extrusion molding and performed a flow analysis to see how the sGF orientation was formed in the die.

ID120

USING A MULTI FREQUENCY MICROWAVE INSPECTION APPROACH TO ACCURATELY INSPECT AND CATEGORIZE HDPE BUTT FUSIONS

Robert Stakenborghs – Advanced Microwave Imaging, Baton Rouge, United States of America
E-mail: rjstak@advancedmwimaging.com

The use of microwave inspection techniques on many composite materials has been available for some time. This method has been used since 2004 for inspecting hDPE butt and Electrofusions and has been shown to be successful in assessing the quality of HDPE butt fusions in field inspections, including sizes from 6" t0 55" and wall thicknesses up to 2.67" (24" DR9). Microwave inspection of HDPE butt fusions is included in bothe ASME Section III, Appendix XXVI and ASTM E3101, with training and certification requirements described in ASNT SNT-TC-1A. The use of a multi-frequency interrogating approach has recently been introduced to the industry and has proven to be more accurate in detecting various flaws in HDPE butt fusions. The innovative technique allows for isolating the reflected signal at various depths within the fusion, thus improving the overall ability to inspect and assess the quality of a butt fused joint. The paper will demonstrate the technique and provide examples of determining an effective accept/reject criterion for a set of HDPE butt fused joints.

ID142

PERFORMANCE EVALUATION OF SUSTAINABLE POLYPROPYLENE BLENDS FOR CORRUGATED DRAINAGE PIPE APPLICATIONS

Michael Pluimer – University of Minnesota – Duluth, Emily, United States of America
E-mail: mpluimer@d.umn.edu
Joe Babcanec – Advanced Drainage Systems, Hilliard, United States of America

While corrugated HDPE pipes are still the dominant plastic pipe product in the United States for culvert and storm sewer applications. Corrugated polypropylene pipes have continued to gain market share over the past decade. There are currently several different ASTM and AASHTO standards for these products, including ASTM F2764 *(Standard Specification for 6 to 60 in. [150 to 1500 mm] Polypropylene [PP] Corrugated Double and Triple Wall Pipe and Fittings for Non-Pressure Sanitary Sewer Applications), ASTM F2881 (Standard Specification for 12 to 60 in. [300 to 1500 mm] Polypropylene [PP] Dual Wall Pipe and Fittings for Non-Pressure Storm Sewer Applications), and AASHTO M 330 (Standard Specification for Polypropylene Pipe, 300- to 1500-mm [12- to 60-in.] Diameter).*

The growth of polypropylene pipes in the United States has prompted research into various mineral additives to enhance the performance and the sustainability of the products. There are several different types and grades of mineral additives that have been traditionally used in polypropylene, including calcium carbonate, talc, and glass fibers. The behavior of these additives in polypropylene can vary, depending on the size and grade of material, as well as the presence of interfacial modifiers and other treatments to the mineral additives and base resin.

In this research project, seven different pipes ranging in diameter from 300 mm to 1500 mm were manufactured with various blends of polypropylene and calcium carbonate masterbatches to see how their finished product properties were affected and to determine their compliance with the respective ASTM and AASHTO product standards. Material tests included melt index, density, Izod impact, tensile and flexural properties, and stress crack resistance testing via NCLS and UCLS. Finished product tests included cold temperature and room temperature impact testing, pipe stiffness, and flattening tests. All tests were conducted in accordance with the AASTHO and ASTM standards. Long-term testing was conducted to evaluate compliance with the Florida DOT protocol for 100-year service life. Several different material formulations were also evaluated, and the life cycle impacts of the additives were assessed.

The results of the research project concluded that corrugated PP pipes can be manufactured with various types of mineral additives to meet or exceed the finished product requirements in the current ASTM and AASHTO standards for corrugated PP pipes. This significant finding will allow pipe manufacturers to incorporate more sustainable materials into their product formulations, improving performance, cost, and sustainability.

ID263

APPLICATION FOR GEOLOCATING WATER NETWORKS

Dolores Herran – Molecor, Loeches, Spain
E-mail: dolores.herran@molecor.com

Our company, continuing with its line of leading water infrastructure sector with its technological products, has recently developed an application with which users can geolocate the different pieces that form a water network.

This is a new tool that allows to geolocate, of course our PVC-O pipes and fittings, but also other elements within the water network, in order to obtain a complete traceability. For our pipes and fittings the information would be complete, from the creation of the product to its installation. In this way, all the parties involved in a certain project can have complete and real-time technical information about all the products that form the network.

After being registered in the application, users will be able to add more people involved in the project who, in turn, will be able to add the different pieces to the network until they get the complete layout of it, include images of the products, send comments, request technical support or report incidents, among many other possibilities.

This paper covers the development process of the App, from finding the need to the final product and also, real cases of water networks as well as the advantages and added value that the users found with the use of this new solution.

ID260

ESTABLISHING REQUIREMENTS FOR RECYCLED HDPE IN HDPE CONDUIT

Michael Pluimer – University of Minnesota – Duluth, United States of America
E-mail: mpluimer@d.umn.edu
Christian Herrild – Teel Plastics, Baraboo, United States of America
Patrick Vibien – Plastics Pipe Institute, Irving, United States of America

With enhanced interest in a circular economy and the potential use of recycled HDPE within HDPE conduit, a research project was undertaken to investigate the necessary technical requirements when using recycled HDPE.

High Density Polyethylene (HDPE) conduit is a durable product designed to protect cables buried underground or encased in concrete. Although not subject to long term internal pressure as is seen in water and gas piping, HDPE conduit is subject to coiling and installation stresses and in-service stresses generated from installed curvature, soil loading, rock impingement, etc. These stresses typically do not generate ductile failure; however, they can produce brittle failures if the HDPE material is not sufficiently resistant to this failure mode. The North American conduit industry has long standing material requirements, including a requirement for Environmental Stress Crack Resistance (ESCR) that has served the industry well and has resulted in few, if any, brittle failures in service.

Using recycled material (post-consumer, post-industrial, post-commercial) introduces the possibility of incompatible contamination that could initiate cracking within the wall. The North American HDPE corrugated pipe industry has already proven the concept and implemented the use of recycled materials. This was done through extensive research and establishing new requirements, based on the ASTM F3181 *Standard Test Method for The Un-notched, Constant Ligament Stress Crack Test* (UCLS) for HDPE Materials Containing Post-Consumer Recycled HDPE (UCLS) test, that assess the final compound's resistance to brittle cracking.

As the physical form, installation methods, and in-service requirements for conduit and corrugated drainage pipe differ significantly, a technical assessment of the requirements for HDPE conduit was undertaken. The assessment includes product packaging, storage, installation, and in-service application needs. In particular, the assessment focused on coiling, in-service temperature, and soil loading effects.

This paper provides the results of the technical assessment. Potential requirements in consideration of the applications are discussed and the results of initial testing of blends containing recycle are presented. The recycled blends included both reprocessed pelletized Post-Industrial Recycled (PIR) materials as well as reprocessed pelletized Post-Consumer Recycled (PCR) materials, and they were formulated to meet the baseline requirements and cell classification of the current conduit standards in North America. Recycled content of the finished blends ranged from 30%- 70%. The recycled materials were supplied by various commercial suppliers in North America, and the minimum ASTM D3350 cell classification of the recycled material was 324220B.

ID194

PROGRESS IN INLINE PLASTIC PIPE MEASUREMENT – NEW APPLICATION FIELDS DUE TO ADVANCED RADAR TECHNOLOGY

Jan Hendrik Beckmann – iNOEX GmbH, Melle, Germany
E-Mail: jan.beckmann@inoex.de

For several decades now plastic pipes have been measured in-line [1]. However, currently used technologies also challenge the user in many ways, either by elaborate conversion work on the system for dimensional changes or by frequent calibration procedures [2] or in some cases the use of water as coupling medium [3]. For corrugated pipes no in-line measurement system was available at all and pipes are still measured destructively. The contactless radar technology overcomes all these points and gives a high additional value to the user [4].

This work will demonstrate an advanced radar sensor technology which is able to resolve 2mm (0.078in) thin-walled plastic pipes and measure pipes in-line with an accuracy of ±0.03mm (±0.0012in). The sensor technology itself and the wide range of use cases will be demonstrated. As a highlight the first inline measurement system in the market for corrugated pipes, used for sewage and rainwater applications, will be presented.

As a focus this work will demonstrate the principal of the corrugated pipe measurement for pipe sizes between 12in inner diameter and 72in outer diameter and the corresponding benefits for the operator to optimize the corrugation process to produce a cost-efficient pipe. Different structures of the pipe such as crest, liner, valley, bell or spigot can be measured and handled separately.

ID151

INNOVATING FOR SUSTAINABILITY ENHANCEMENTS IN POLYETHYLENE BASED MICROIRRIGATION PRODUCTS

Rachel Anderson – DOW Inc., Midland, United States of America
E-mail: andersonrc@dow.com
Stephanie Whited – DOW Inc., Midland, United States of America
Todd Hogan – DOW Inc., Midland, United States of America
Joel Wieliczko – DOW Inc., Midland, United States of America
Rujul Mehta – Univation, Freeport, United States of America
Alex Stolarz – DOW Inc., Horgen, Switzerland

Growing worldwide demand for sustainably-made irrigation systems has driven the creation of new resins for longer-lasting, more durable, recycle friendly, and cost-effective pipe that can better tolerate extreme conditions year after year. Microirrigation systems deliver vital water and nutrients where they're needed most – plant root systems. When compared to conventional flood and sprinkler systems, microirrigation allows up to 50% reduction in water usage and increased crop yields. Polyethylene microirrigation piping systems are typically divided into two categories: thin wall tapes (4-25 mil) and thick wall tubing (>25 mil). Thin wall tapes typically see application in shorter life cycle, high value crops such as berries, while thick wall tubing is used in more permanent installations such as orchards and vineyards. Innovative new resin designs have been developed for both of these piping systems.

For thin wall tapes, a new bimodal medium density polyethylene (MDPE) resin has been developed that allows for downgauging by several mils, 10% higher production rates and incorporation of post consumer and post industrial (PCR and PIR) materials. The bimodal design results in irrigation tapes with high environmental stress crack and burst resistance.

For thicker wall tubing products, a new one-pellet PCR rich linear low density polyethylene (LLDPE) compound was developed that can be used directly to make microirrigation tubing with 65% recycled content. Compared to standard PCR available in the market place, this fully formulated offering offers highly consistent composition, processability and end use properties in tubing. This compound can also be used in combination with materials recovered after end of life of existing microirrigation installations to further boost the recycled content.

As manufacturers look to close the loop in microirrigation, these products offer enabling technology through resin design.

ID213

PUBLISHED HYDROGEN PERMEATION STUDY ON 4 DIFFERENT TYPES OF PE PIPES

Norbert Jansen – Borealis Polymere GmbH, Burghausen, Germany
E-mail: norbert.jansen@borealisgroup.com
Andrew Wedgner – PE 100+ Association, Sittard, The Netherlands
Rainer Kloth – PE 100+ Association, Sittard, The Netherlands

Hydrogen is going to be an important energy source for the future. Existing gas networks and new gas networks need to be compatible to hydrogen and mixes of hydrogen and/or natural gas or biogas.

The physical performance and chemical resistance to hydrogen at the common distribution network pressures have been tested for different PE pipes in laboratory and field tests. Several papers at recent Plastic Pipes Conferences[1][3] have confirmed that the systems made of classified PE80, PE100 and PE100-RC are resistant to hydrogen and there is no physical or chemical degration observed nor expected. As the hydrogen is a smaller molecule, a higher permeation through different materials is expected compared to natural gas. However a quantification, helpful for example for the risk assessment of a gas network owner, was partly missing.

Therefore, the PE100+ Association has sponsored a technical investigation[2] to define the permeation rate of hydrogen through polyethylene pipes at an external expert laboratory in Germany. 4 different types of PE pipe materials according to EN1555-1 in the same pipe size OD 110mm SDR17 have been evaluated at the 3 different target temperatures 8°C, 14°C and 20°C and at one target pressure level of 6,3 barg and exposed to 100% hydrogen. The presentation will show the individual test results.

ID126

FIELD AND FEM PERFORMANCE OF AGRICULTURAL MAINS

Kevin White – E. L. Robinson Engineering of Ohio, Ohio, United States of America
E-mail: kwhite@elrobinson.com
Shad Sargand – Ohio University, Athens, United States of America

The current standard of practice for the installation of agricultural mains is in accordance with ASTM F449, Standard Practice for Subsurface Installation of Corrugated Polyethylene Pipe for Agricultural Drainage or Water Table Control. ASTM F449 has several limitations. Currently, the allowable maximum height of fill is limited unless an engineering design is performed. In addition, the material requirements of F449 limits agricultural mains to corrugated high density polyethylene (HDPE) pipe meeting the requirements of ASTM F667 or F2648. The original overall objective of the research project is to perform an engineering analysis, including field verification, with supporting documentation to evaluate corrugated HDPE pipe of 12 to 60 in diameter in agricultural main installations using various shaped trench bottoms. This research will serve as a basis for engineering designs that can be referenced by manufacturers, specifiers, and owners. The project encompasses four phases including a literature review, finite element analysis of 30" and 48" pipe, and monitoring of an instrumented 36" field installation.

ID244

DESIGN OF UNPLASTICIZED POLYAMIDE 12 OILFIELD LINE PIPE BASED ON PUBLISHED REGRESSION CURVES AND ASTM F3524

James F. Mason – Mason Materials Development LLC, Wyomissing, United States of America
E-mail: jim.mason@mmd-llc.com
Akshay Ponda – Evonik Operations Smart Materials, Allentown, United States of America
Hermann van Laak – Evonik Resource Efficiency GmbH, Marl, Germany
Tobias Bauer – SKZ – Das Kunststoff-Zentrum, Würzburg, Germany

The long-term strength of polyamide 12 (PA-U12 180) has been characterized using standard methods for plastic pressure pipe during the qualification process for use in buried piping systems for natural gas delivery operating at low ambient temperatures, usually less than 20 to 30°C at pressures previously served only by steel pipe.

The high strength characteristics of the material also made it interesting as a steel substitute for aboveground and buried industrial applications in diameters up to 12 inch (324 mm) with wall thicknesses up to DR7. Assuming a design factor of 0.5 applied to the PPI TR-4 listed HDB, DR7 PA12 pipes have a maximum pressure at 23°C of 525 psig (3.6 MPa), although design pressures will typically be lower. These industrial systems can operate at much higher temperatures, often above 50°C. Design engineers need the temperature dependent strength curves to properly design a thermoplastic pressure piping system. Therefore, the regression curves have been extended by LTHS tests up to 120°C. Corresponding test durations enabled to define the location of knees with determination of second branches. These branches are caused by hydrolytic degradation of the polymer resulting in brittleness of the polyamide after long times at elevated temperature in sufficiently wet environments or services. The first appearance of a knee is at 70° C and approximately 50 years.

This paper describes various standards to which PA-U line pipe and materials must conform, and the development of standardized, temperature dependent, long-term strength reference curves for PA-U12 pressure pipe, including the transition from ductile to brittle behavior at long times and high temperatures. These standardized curves apply to both PA-U12 and PA-U11. An example of a typical pipe design is presented, applying chemical resistance derating factors for oil and gas applications in the design process.

ID145

UNDERSTANDING THE SCIENCE IN ESTABLISHING EQUIVALENCY OF VARIOUS CARBON BLACK MASTERBATCHES IN QUALIFICATION APPROVALS

Bill Gauthier – Baystar, Pasadena, United States of America
E-mail: bill.gauthier@baystar.com
White G. Jee – JEE Consulting Services LLC., United States of America
Leonardo Cortes – Baystar, Pasadena, United States of America

In the production of quality HDPE pressure piping system components (pipe and fittings), the manufacturer(s) may have the option to utilize a PE4710 or PE100 black compound or the use of in-line compounding (aka, "salt and pepper" blending). From a technical and commercial perspective, there are advantages in utilizing either option. This poster presentation focuses on the carbon black science in the selection of the carbon black types that are utilized for pressure pipe applications. Additionally, the testing results conducted to establish equivalency among the various black masterbatches to assure that the carbon black incorporation into black pressure piping system components meet or exceed the requirements of the applicable standard on which the piping system component is manufactured to are displayed.

ID200

LEAK TIGHTNESS OF PVC FITTINGS WITH HYDROGEN

Roland Valk – Kiwa Technology, Apeldoorn, The Netherlands
E-mail: roland.valk@kiwa.com
René Hermkens – Kiwa Technology, Apeldoorn, The Netherlands
Sjoerd Jansma – Kiwa Technology, Apeldoorn, The Netherlands
Stefan Pouw – Kiwa Technology, Apeldoorn, The Netherlands

The use of hydrogen gas as an energy carrier is considered a key component in the energy transition. This results in new challenges among which the transport and distribution of this gas. The current low pressure (natural) gas distribution grid in the Netherlands consist mostly of PVC and is presumed to be suitable to transport hydrogen in the (near) future[1]. To further support this concept, both the maximum angle of deflection before leakage for PVC joints and the permeation for both PVC pipes and PVC joints have been determined using hydrogen gas. The loss of hydrogen due to leakage and permeation are important from a safety aspect due to the possibility for hydrogen to accumulate in a closed room. From an environmental point of view, as hydrogen is an indirect greenhouse gas, and it also gives insight in the economic losses.

In this project joints of unplasticized PVC (PVC-U) and impact-resistant PVC (PVC-Hi) have been tested on their mechanical behaviour by deriving the maximum angle of deflection before leakage. This is done on old joints excavated from the natural gas distribution grid. The joints have been tested either without additional ageing or with ageing. The ageing consisted of 1000 hours at 60°C in an environment of hydrogen (inside the pipes)[2]. Both tests show that the maximum angle of deflection, even after ageing, fulfils the requirements of the appropriate standard EN-ISO 13844[3] and NEN 7231[4] (both cover only PVC-Hi).

Also the permeation rate for three PVC-U pipes and three PVC-Hi pipes has been determined[5] [6]. After correction for the pipe dimensions and applied hydrogen pressure, the permeation coefficient is calculated. The permeation coefficient is used to determine the permeation rate for different scenario's. For instance, a PVC-U pipe Dn250, SDR 41, 12 meters in length and with a hydrogen pressure of 100 mbar will result in a hydrogen permeation rate of less than 200 ml/day. The permeation rate of four PVC joints (2x PVC-U and 2x PVC-Hi) including a pipe length of approximately 0.6 m has been determined at 200 mbar hydrogen. The permeation rate ranges from 6.5 ml/day to 7.5ml/day.
As a reference; For natural gas distribution, leaks above 5 l/h are not allowed[7]. The reported permeation rates are far below the 5 l/h and therefore no safety problems due to hydrogen permeation are expected.

ID223

HOW PVC PIPES CAN CONTRIBUTE TO FOOD SAFETY IN THE WORLD'S MEGA-CITIES

Tobias Johnsen – PVC Information Council Denmark, Kobenhavn, Denmark
E-mail: tj@pvc.dk
Ole Grøndahl Hansen – PVC Information Council Denmark, Kobenhavn, Denmark
E-mail: ogh@pvc.dk
Marianne Mikkelsen – PVC Information Council Denmark, Kobenhavn, Denmark

Urbanisation is set to continue at a rapid pace in the coming decades. Already today, 55% of the world's population – which is expected to reach 9 billion in 2050 – live in urban areas, and up to 80% of all food produced globally is consumed in cities. With a growing global population that will primarily settle in urban areas, more and more agricultural land will be converted into dwellings, roads etc. As the demand for food in 2050 will be 60% greater than today, a conflict between Sustainable Development Goals 2 (Zero Hunger) and 11 (Sustainable Cities and Communities) is imminent.

According to the Food and Agriculture Organization of the United Nations, urban farming can make cities' food supply more resilient and thus contribute to a better trade-off between the two SDGs. 800 million people worldwide are involved in urban farming, ranging from traditional farm methods to hydroponics, aeroponics, aquaponics, vertical farming and other high-tech systems. Farming is done in reused pipes in Kigali, Rwanda, on abandoned land in Detroit, in large-scale indoor LED lit facilities in Singapore and on huge rooftops in Paris.

The potential is great: when designed properly, a vertical farm offer 40 times the yield of a traditional outdoor farm. With less transport from farm to fork, CO_2 emissions are reduced. Urban farms can also contribute to community building, increased biodiversity, and better access to nutritious foods.

For years professional farmers and do-it-yourself growers have looked to PVC plastic in the form of pipes and profiles when they design their growing systems. PVC is highly durable, weather-resistant and very stable when it comes to chemical and mechanical properties. PVC can be made highly UV-resistant to maintain whiteness for decades, which is important for optimum growing conditions. PVC can also withstand being in contact with plants, nutrients, water, and fish excrements for many years without corroding or leaching any unwanted substances to the growth medium, plants, or fish.

Pipe sizes vary between farm types. An example is a hydroponic system that uses OD 110 mm pipes for transport of water and OD 75 mm pipes for the plants. Operating conditions also vary. Ideal growing temperature for indoor plants is between 21 to 27 degrees Celcius during the day and 18 to 21 degrees Celcius during the night. This is achieved by using LED lights. In hydroponic and aquaponic farms the pipes are also in constant contact with water. In outdoor farms, temperatures and humidity vary between location.

Reused PVC pipes provide inclusive and sustainable plant containers for community kitchen gardens. An example is the VinylPlus-supported Garden to Connect project in Rwanda and more than 10 locations around Aarhus, Denmark. The pipes are sourced free of charge at local construction and demolition sites and recycling centers. Sizes depend on what is available, ranging from OD 110 mm to 600 mm. The suitability of PVC-U pipes for the hot and humid climate found in Rwanda has been already demonstrated for decades. Studies show that reusing PVC instead of using virgin PVC can reduce the GHG emissions of hydroponic structures of about 85%. PVC pipes and profiles for urban farms are also advantageous when it comes to end-of-life. Studies document that PVC can be recycled 8 to 10 times without losing functional properties.

ID252

FUSION TEST PROGRAM ON POLYAMIDE PIPING SYSTEMS FOR DISTRIBUTION NETWORKS UP TO 16 BAR

Carine Lacroix – GRTgaz RICE, Villeneuve La Garenne, France
E-mail: carine.lacroix@grtgaz.com
Danielle Mark – PG&E, Palo Alto, United States of America
Philippe Louvel – GRDF, Paris, France

To allow a broader and safer use of Polyamide (abbreviated PA) pipeline systems for gas network, an extensive trial plan aiming at evaluating Polyamide fusibility in adverse conditions, and with different methods for both electrofusion and butt fusion, was conducted. Polyamide samples were saturated with humidity then fused, and peeling tests and failure surface identification demonstrated the strong influence of humidity condition of pipes and fittings for Polyamide fusibility. These results show that special care need to be taken care when operating on Polyamide networks that may have been subjected to wet conditions and emphasize the need to master these conditions to broaden polyamide use for natural gases, but also for new gases such as biomethane and hydrogen.

The use of Polyamide pipelines for natural gas transportation for pressures up to 16 bar has several advantages compared to steel, especially easy and fast installation and cheaper maintenance. Another notable advantage of Polyamide is its compatibility to new gases, with a lower permeability to hydrogen, and an inert behavior toward biogases.

In order to evaluate the robustness of Polyamide network installation, an extensive trial plan was conducted, with a focus on installation and fusibility in harsh conditions. Polyamide 11 and 12 were tested for both Electrofusion with couplers and tapping tees, and Butt Fusion with several conditions. With pipelines or fittings fused "as received" or voluntarily aged or saturated with water, quality of PA fusion was evaluated. Cross-fusion of PA11 and PA12 was also evaluated.

Results showed that there is definitely an influence of water saturation of the pipeline on the quality of the fusion and that a combination of tests were needed to correctly evaluate the fusion quality. Peeling tests procedures usually performed on Polyethylene needed to be adapted to Polyamide in order to be used effectively. Polyamide 11 and 12 showed some notable differences in behavior, both for water saturation and fusion capability. These results will be presented during the conference and recommendation regarding the fusion of PA materials will be made.

ID257

RESULTS OF A 2022 COMPREHENSIVE STUDY OF WATER MAIN PERFORMANCE IN THE USA AND CANADA

Steven L. Barfuss – Utah State University, Logan, United States of America
E-mail: steve.barfuss@usu.edu

In 2022, USU completed the most comprehensive water main break survey ever undertaken in North America to determine the performance of different pipe materials. More than 800 utilities responded to the survey. The survey respondents from this study represent 370,000 or 15.5% out of an estimated 2.45 million miles of pipe that is installed in the United States and Canada, making this the largest survey of its kind. A full report of these most recent survey results will be published in 2023. Similar surveys were undertaken by USU in 2011 and 2017, with reports published in 2012 and 2018. This presentation discusses the current study results and compares these results with previous reports to aid in understanding North American trends in water main breaks. Survey results continue to show that PVC water pipe has the lowest failure rate compared to traditional materials commonly used in water systems like asbestos cement, cast iron, ductile iron and steel. Survey results will be presented in terms of pipe diameter (from 3 to 48-inch nominal), pipe material, pipe age, soil corrosivity and geographical region.

ID139

SOLUTIONS FOR REINFORCED THERMOPLASTIC PIPES (RTPS)

Ali M. Alghamdi – SABIC, Riyadh, Saudi Arabia
E-mail: ghamdiams@sabic.com
Recep Yaldiz – SABIC, Geleen, The Netherlands
Yousof Ghazzawi – SABIC, Riyadh, Saudi Arabia
Faisal Almana – SABIC, Riyadh, Saudi Arabia
Abdul Rahim Arafath – SABIC, Riyadh, Saudi Arabia
Ratnesh Khandelwal – SABIC, Bengaluru, India
Azzedine Kioul – SABIC, Teesside, United Kingdom
Abdullah Alahaideb – SABIC, Riyadh, Saudi Arabia
Turki Al-Shahrani – SABIC, Riyadh, Saudi Arabia
Salem Al-Anazi – SABIC, Riyadh, Saudi Arabia
Sarfraz Abbasi – SABIC, Riyadh, Saudi Arabia
Mohammed Aljasser – SABIC, Riyadh, Saudi Arabia
B. Parthipan – SABIC, Bengaluru, India
A. Kavya – SABIC, Bengaluru, India
H. Caelers – SABIC, Geleen, The Netherlands

Reinforced thermoplastic pipes (RTPs) are multilayer structured pipes reinforced with high-strength materials such as fibers (glass, aramid, or carbon fibers). RTPs are used to transport highly corrosive mediums at elevated pressures and temperatures. An example of that is the use of RTP in the Oil & Gas industry to transport oil containing aliphatic and aromatic hydrocarbons, water, hydrogen sulfide and carbon dioxide at temperatures exceeding 82 °C and pressures exceeding 100 bar. Those pipes gained popularity as a replacement for the incumbent steel pipes with great success. This stems from their exceptional strength-to-weight ratio, chemical resistance, spoolability, and long-term reliability.

In this work, high-density polyethylene (HDPE) resins classified as PE4710, PE100, and PE-RT II have successfully been qualified and validated for RTP liners and jackets. Unidirectional glass fibers reinforced high-density polyethylene (GPE) tapes have also been qualified for RTP reinforcement layer. The qualification is based on industry standards such as API 15S.

This paper demonstrates the validity of predicting an RTP performance with finite element analysis. Conventional shell elements were used to model the RTP, while appropriate boundary conditions were selected to represent the end-fittings used for testing. The burst pressure of an RTP can be predicted by selecting an appropriate failure criterion for the composite laminate. In order to validate our FEA models, RTPs with an outer diameters (4 – 5") were evaluated as representative case studies.

The suitability of HDPE resins for the application was assessed by generating data on tensile creep at room and elevated temperatures according to ASTM D2990, compression creep at 85°C and stress-relaxation. Furthermore, the effect of swelling by a mixture of aromatic and aliphatic hydrocarbon on polyethylene's mechanical performance was examined by exposing coupons of the material to those fluids at the operating temperatures of the pipes, followed by tensile and flexural tests.

Similarly, the suitability of the GPE tape for the application was assessed. The tapes' tensile creep and cyclic fatigue were tested. Thermomechanical aging experiments in an acidic environment were performed.

ID259

BENDING & DEFLECTION LIMITS OF PE PIPE – EXISTING & PROPOSED

Chris Ampfer – WL Plastics, Fort Worth, United States of America
E-mail: cris.ampfer@wlplastics.com
Harvey Svetlik – Harvey Svetlik Consulting, Pipe Creek, United States of America

The current polyethylene (PE) pipe bending limits (longitudinal and circumferential deflection) are based on a circumferential (tangential) strain tolerance limit of approximately 1%. Research in the late 1970's using constant tensile strain focused on what strain can be imposed on HDPE by bending and not have it progress into SCG. After some rational consideration of the allowable stress intensity on PE materials of the 1980's when 192-hours of ESCR (Environmental Stress Crack Resistance, ASTM D1693) was the standard, industry leaders (Frank Rice, Amos Shriver, and others) picked 1% as the circumferential strain limit. Today, with slow crack growth resistance > 2000 hours (PENT, ASTM F1473), the circumferential strain limit of PE4710 is much higher than 1%. With viscoelastic strain relaxation, PE4710 sheds about 60% of the related stress over time keeping the slow-crack growth stress-intensity well below the crack initiation threshold.

The existing circumferential (ring) deflection limits for buried pressurized PE pipe are lower than the deflection limits for buried non-pressurized pipe. Combined loading from internal pressure and external soil load does not shorten the life of PE pipe but can increase its life. The ring deflection limits should be the same for both pressurized and non-pressurized pipe. The ring deflection limit can be based on limiting strain or based on limiting flow reduction in the pipe. If limiting flow reduction to less than 1% is a concern, a ring deflection limit of 8% should be used for all PE4710 pipe regardless of DR. The PE pipe ring deflection limits in ASTM F714, ASTM F1962, and the PPI Handbook of PE Pipe (Chapters 6 and 12) should be updated to the proposed value of 8% (see Table 12) without differentiation between pressurized and non-pressurized.

The existing long-term longitudinal bending coefficients used to determine minimum bending radii for PE pipe are 3 to 7 times greater than the calculated critical bending coefficients and have longitudinal strains of 2.5% or less and circumferential strains of 1.125% or less. Revised minimum bending coefficients have been proposed that are 2 times greater than the critical bending coefficients and have circumferential strain of less than 4%. These proposed minimum bending coefficients are similar to published short-term bending coefficients. The PPI Handbook of PE Pipe (Chapters 7 and 10) should be updated to have a single minimum bending coefficient for each DR based on those proposed. The terms short-term and long-term in reference to bending coefficients should be removed.

ID108

PVC-U PIPES: OPTIMAL EXTRUSION CONDITIONS FOR A 100+ YEAR DESIGN LIFETIME

Joaquin Lahoz – Centro de Ensayos, Innovación y Servicios (CEIS), Móstoles, Spain
E-mail: jlahoz@ceis.es

It is well known that the extrusion conditions decisively affect the degree of gelation of PVC-U and through it, the physical characteristics and properties of PVC-U pipes for the transport of pressurized water. The design lifetime of PVC-U pipe will, as a consequence, also be impacted. The selection of optimal extrusion conditions can lead to an extension of the design lifetime up to 100+ years keeping the initial design stress values and design coefficients unchanged.

An investigation project was launched in 2020 to clarify the relationships between the processing conditions and the design lifetime of PVC-U 250 pipes. Ca/Zn stabilised pressure pipes were extruded with different processing temperatures and characterised by their DSC 'onset' temperature and degree of gelation. Their long-term hydrostatic strength was predicted using the methods described in ISO 9080. The desired outcome of this project was to set up a correlation between the extrusion temperature and the 97.5% Lower Prediction Level of the stress that a PVC-U pipe can withstand after 100 years (LPL100y).

The result of this study shows that an extrusion temperature of 180°C is enough to achieve a class MRS250 and a moderate increase (+5°C or +10°C) of the extrusion temperature leads to a smooth decrease in the slope of the regression curve at 20°C and, therefore, to an increase of the predicted LPL100y values. Higher processing temperatures (≥195°C) result in only marginal increases in the Lower Prediction Levels, with evident risk of material degradation during processing.

The increase of LPL_{100y} allows the initial MRS250 classification to be extended up to 100+ years. The resulting advantage for the prescriptors and designers of pressurized water supply networks is to make possible the use of design stress and design coefficient values typically used for a design lifetime of 50 years.

ID132

CUT-AND-COVER PIPELINES WITH POOR TRENCH WALLS

Amster Howard – Civil Engineering Consultant, Lakewood, United States of America
E-mail: amsterk@comcast.net

This paper explores the use of a composite soil stiffness as a valuable design tool to consider when a pipeline traverses through poor soil conditions. Thermoplastic pipe are flexible pipe and require good soil support at the sides of the pipe to minimize deflection. However, sometimes the trench walls are weak soils and decrease the effectiveness of the compacted embedment beside the pipe. Some of the options are to encase the pipe, widen the compacted embedment to support the pipe, or to (preferred) to use the concept of composite E prime.

Based on the work of Leonhardt and incorporated into the European ATV method, the current procedure in the United States is to use tables of values and determine the type of soil and percent compaction for the embedment material. This procedure has now been adopted in several AWWA and ASTM standards and manuals. Several consulting firms use it routinely.

The stiffness of the trench wall soil and the stiffness of the embedment soil are combined into a composite value that can be used in various equations to estimate what the deflection may be. In addition to stiffness, the width of the trench at springline (horizontal diameter of pipe) also affects the composite value.

When pressurized, the pipe will tend to re-round but sometimes the pipe may sit for months, or even years, before it goes into operation. The pipe may be continually deflecting during that time. The more the pipe deflects, the harder it might be re-round the pipe. Over deflection may threaten the integrity of the pipe. While not a common problem, the pipe behavior during sitting empty for some time should be checked.

ID229

SELECTION AND EVALUATION OF ORGANOTIN STABILIZER CHEMISTRIES FOR PVC AND CPVC PIPE AND FITTING SYSTEMS.

Robert Smith – PMC Organometallix, Lansdale, United States of America
E-mail: robert.smith@pmc-group.com

Today's PVC and CPVC pipe and fitting applications require balanced levels of fusion promotion, rheological control, shear stability, and static stability. Tin mercaptide stabilizers have been the dominant rigid PVC stabilizing system in the US for the last 50 years. Since their introduction, tin stabilizers have evolved from carboxylates to high efficiency tin mercaptides.

This presentation will review the evolution in stabilizer chemistry and the methods of shear and static stability evaluation with examples of stabilizer performance from each of the three primary tin stabilizer systems (2-EHMA, reverse-ester, and mixed mercaptan). This review will include torque rheometer-based fusion (ASTM D-2538) and dynamic shear stability testing, 2-roll mill dynamic stability testing, static oven testing, and dehydrochlorination testing. The discussion will include the effect of tin level on performance properties and establish a set of selection criteria based on performance attributes. We will then evaluate case studies in PVC water pipe, PVC fittings, and CPVC pipe using the established criteria.

ID243

MYRIAD OF CHOICES FOR BURIED PIPE INSTALLATION

Amster Howard – Civil Engineering Consultant, Lakewood, United States of America
E-mail: amsterk@comcast.net

This paper focuses on the confusing plethora of choices that a design engineer in the United States faces when selecting installation instructions for pressure thermoplastic pipelines. For polyethylene pipe, the decision is between AWWA Manual M55, ASTM D2774, ASTM F1668, the PPI Handbook, MAB-3, manufacturer instructions, or their historical organizational specifications. Information on use of uncompacted bedding, an uncompacted padding over the pipe, use of composite stiffness, maximum particle size in embedment and backfill soil, terminology, soil classification, trench width, flowable fill, and use of a basic installation varies. Their historical organizational specifications are often out of date and need to reflect updated advancements. Use of ASTM standards that have been out of date for over 20 years sometimes appear in specifications.

A move to unify the standards and manuals started with adopting the Uniform Soil Classes. Previously, pea gravel had 13 different names in the various documents. Now, many of the manuals and standards use a single description of Class II for pea gravel based on the Uniform Soil Classes.

Changes are currently being considered for many of the installation documents. However, revisions taking years to adopt, changes not being coordinated, and reluctance to revisions create a problem. Confusion can lead to poor installation practices. We need to help the design engineers, not put barriers in their way.

ID228

SUSTAINABLE RESTRAINT JOINT FOR PE PIPES AS AN ALTERNATIVE TECHNOLOGY FOR SUEZ

Jennifer Ravereau – SUEZ – CIRSEE, Croissy sur Seine, France
E-mail : jennifer.ravereau@suez.com
Catherine Giorni – SUEZ – CIRSEE, Croissy sur Seine, France
Frederic Mohier – SUEZ Eau France, La Défense, France
Mehdi Ahmadi – SUEZ Eau France, La Défense, France
Benjamin Rabaud – SUEZ – CIRSEE, Croissy sur Seine, France

Pipe installation and renewal are critical for network management and extension both in terms of cost and of logistics for installation. Plastic materials, as polyethylene, are constantly evolving to offer additional benefits (chemical resistance improvement, mechanical resistance, innovative functionalities). However, they may bring about drawbacks for operators related to installation requirements such as the use of welding techniques.

Our work aims to evaluate new solutions for improving productivity and safety of operators during work on water distribution network by proposing innovative plastic pipes with restraint joint. Thus, it aims to assess different pipe solutions considering following criteria: durability, safety, ease, and cost of installation.

Two locked technologies were tested through two main steps: a field test in France and accelerated ageing tests on a pilot. On the field, the restraint technologies were compared to two traditional technologies (ductile iron and electro-welded polyethylene pipes). Through a daily evaluation, objective criteria (laying rate, required equipment, safety), subjective criteria (operators feeling, ease of manutention) and overall criteria (cost, environmental impact) were assessed. On the pilot, accelerated ageing tests of polyethylene jointing methods (welded, electro-welded, and restraint joints for PE pipes) were carried out during 18 months under different conditions: oxidative solutions (ClO_2, HOCl and reference H_2O), pressure (6 bar), and temperature (40°C) [1, 2]. During the ageing tests, the performance of each technology was assessed based on i) hydraulic pressure tests (watertightness, water hammers, and excess burst pressure); and ii) chemical structure of the fittings and the corresponding joints.

The field test validated the benefits of locked joint technologies in terms of laying rate, cost, safer working conditions, and environmental impacts compared to traditional materials and techniques. The long-term performance assessed through the accelerated ageing tests allowed to select the most reliable restraint joint technology and discard the less efficient.

This work was carried out thanks to the active participation of the experts of the research center, and the close collaboration between the purchasing and the technical divisions.

ID146

NEW APPROACH TO HDPE PIPE FUSION PROVIDES THE ABILITY TO "MEET THE PIPE WHERE IT LAYS"

Chris Greggs – McElroy Manufacturing Inc., Tulsa, United States of America
E-mail: cgreggs@mcelroy.com

Much has been done to improve the quality and efficiency of HDPE pipe installations over the years. Now, a totally new concept for meeting the pipe where it lays to improve worksite safety, boost jobsite efficiency, and minimize the amount of time spent between fusions has been developed. This case study shows how PSAH Pty Ltd (Australia) has used this new approach to streamline their field operations.

Traditional fusion practices involve positioning the fusion machine at the joining location, loading pipe into the machine, fusing the pipe ends, then lifting the pipe up and out of the machine so either the pipe or machine can be repositioned for the next weld. This has been done due to the inherent design of legacy fusion machines which allowed pipe to be loaded into the machine from above.

This new approach allows the pipe to be positioned for fusion without the machine or operator in place, improving safety and minimizing the potential for damage to the machine during the loading process. The operator can then drive into position for welding and lower the carriage onto the pipe from above. Once the weld is complete, the operator simply raises the carriage up to clear the pipe, so either the machine or the pipe can be safely and efficiently repositioned for the next weld.

This case study introduces this new approach and discusses the inherent advantages in a wide variety of field applications such as pipelining, fuse & pull, fabrication, in-ditch and confined space.

ID242

SUSTAINABILITY & THE RETURN OF THE PRR GASKET

Guido Quesada – Simulation Driven Engineering, San José, Costa Rica
E-mail: gquesada@side-cr.com
Mark Weih – HULTEC/Terramix, S.A., San José, Costa Rica

The gasket approach known as Plastic Retainer Ring (PRR) is an old friend of pipe joints and it is still used among other sealing solutions developed more recently. Although it is difficult at this point to trace its origins, it is recognized among the first solutions that were developed for gasketed pipe joints in both pressure and non-pressure applications. It is very likely to have influenced the shape of raceways. Since it requires some extra room for the plastic retainers, the raceways in several types of joints whether rectangular (mostly for non-pressure pipe) or triangular (such as the Anger B style for pressure pipe), are relatively wide, even if they no longer use a PRR.

Their most distinctive advantage is the ability to hold relatively soft and flexible rubber parts in place inside a raceway in the socket before joint assembly. The PRR also provides stability during spigot insertion and blocks the way to seal blow-out under pressure.

Given the early success of PRR, the technology available for their initial analysis and development, such as the nonlinear Finite Element Method (which was developed around 1970 and not extensively used for pipe joint design before 1990) was very limited. As a result, with few modern exceptions, their prevailing designs remain relatively primitive and not very efficient in terms of assembly force, material volume and sealing performance. This has given the advantage to other seal design approaches with bonded, embedded, or interlocked metal or plastic inserts, which offer the same advantages as PRR with manufacturing methods regarded as more efficient.

However, the need for sustainability actions such as recycling materials used in the piping industry, has given the old PRR a range of opportunities to come back with new designs and advantages that were previously overlooked. One of these are the ease to separate components made of different materials and avoiding damage that could be produced by accidentally leaving the seals in plastic pipes that are recycled.

This paper reviews old and new PRR designs analyzed and developed by the authors, as well as opportunities that are opening for new designs, which may expand the range of applicability to joint systems in which it has not been used before.

ID251

AN INVESTIGATION OF THE EFFECT OF BACKFILL TYPE ON THE PERFORMANCE OF LARGE DIAMETER POLYOLEFIN PIPE UNDER HIGHWAY LOADINGS AT MINIMUM COVER

Joseph Babcanec – Advanced Drainage Systems, Powell, United States of America
E-mail: joe.babcanec@ads-pipe.com
Issam Khoury – Ohio University, Athens, United States of America
Shad Sargand – Ohio University, Athens, United States of America

The use of corrugated HDPE and PP pipe for gravity flow storm sewers is a growing trend throughout the United States. Many of these drainage pipes are buried in shallow cover conditions (~1') under roads with heavy traffic. It is well established that thermoplastic pipe installations under shallow cover respond differently to loads than those under deep cover. In shallow cover conditions the pipe experiences greater stresses, due to more load. The selection of backfill material and level of compaction have a greater impact on the performance of pipes under shallow cover. A comprehensive study is being initiated at the Accelerated Pavement Load Facility at Ohio University. This study is an investigation of the response of the pipe systems under shallow cover under highway live loading. Factors being examined for influence on pipe response and performance include backfill type, level of compaction, pipe material, pipe diameter, cyclic loading, and temperature. Instrumentation used includes strain gauges on pipe and pavement, soil pressure cells, string potentiometers, and thermocouples.

ID211

STRUCTURAL HEALTH MONITORING OF PLASTIC PIPELINES BY SHORT CARBON FIBER REINFORCED ELECTROFUSION JOINT

Riwu Yao – Zhejiang University, Hangzhou, China
Email: yaoriwu@zju.edu.cn
Jianfeng Shi – Zhejiang University, Hangzhou, China
Jinyang Zheng – Zhejiang University, Hangzhou, China

Plastic pipelines have been widely applied in various industries, such as gas and oil transportation and nuclear power plants. The safe operation of pipelines is a critical concern[1], and structural health monitoring methods of plastic pipelines are attracting broad interest in both industry and academia[2]. In this work, electrofusion joints were manufactured using short carbon fiber reinforced conductive composites (SCFRCCs), which can be made from recycled carbon fibers. The SCFRCCs joints were used for connecting steel wire wrapped HDPE pipes, and the pipes in this study are 110 mm in diameter and have a wall thickness of 12 mm. A piezoresistive behavior-based structural health monitoring method for plastic pipelines was developed[3]. By measuring the resistance of the SCFRCCs joints under internal pressure, it was found the monitoring resistance followed closely the internal pressure change of the pipeline, and the monitoring results were quite stable after multiple cycles. The monitoring method was validated against the monitoring results of strain gauge. The results showed that the monitoring method could timely respond to the internal pressure changes of the pipeline, and showed a sensitivity as high as 90 times that of strain gauge. Owing to the improved electrical conductivity of the SCFRCCs joints materials, the monitoring method exhibited an ability to capture the damage initiation and propagation inside the joints. A significant increase in monitoring resistance was observed before the joint failure due to damage initiation and propagation inside the joint. By quantitatively characterizing the damage degree of the SCFRCCs joint, a good correlation was established between the change in monitoring resistance and the damage degree of the SCFRCCs joint. The results indicate the proposed SCFRCCs joints and the structural health monitoring method are promising in improving the safety and reliability of plastic pipelines.

ID217

2.7 METERS AND GROWING

Henning Stieglitz – BC Extrusion Holding GmbH, Bad Oeynhausen, Germany
E-mail: stieglitz.h@battenfeld-cincinnati.com

Urbanization and the increasing effects of climate change have meant the supply of fresh water and the disposal of wastewater, have become increasingly important in recent years. It is foreseeable that this demand will continue and intensify. In this context, plastic pipe plays a major role due to its unique properties. The performance of the plastic pipe in water management has increased over the years through optimized materials, improved machine technology and manufacturing methods.

Due to the vast volume of water that must be transported, the demands on the diameter of the pipes are constantly increasing. One of the latest technical and commercial developments in this field is HDPE (PE100) pipe with a diameter of 2.7m.

The production challenges of such large dimensions will be presented. In this context, both processing aspects, such as measures to reduce the sagging effect, and mechanical engineering design issues such as the structure of the components are examined so that they can also be transported. Additionally, the start-up procedure will be presented to understand how it possible to start such a big diameter pipe and produce the first meters.

The audience is given a comprehensive insight into the machine technology and the process flow during the production of large diameter pipes and a glimpse of the future design discussions and challenges for larger diameters.

ID249

LONG-TERM PERFORMANCE IN PE100 AND PE100RC RESINS: DOES THE COMONOMER LENGTH MATTER?

Carlos Domínguez – LATEP – Rey Juan Carlos University, Mostoles, Spain
E-mail: carlos.dominguez@urjc.es
Predrag Micic – QENOS Pty Ltd., Melbourne, Australia
Rafael Juan – Rey Juan Carlos University, Madrid, Spain
Nuria Robledo – Rey Juan Carlos University, Madrid, Spain
Rafael A. García- Munoz – Rey Juan Carlos University, Madrid, Spain

Slow Crack Growth (SCG) resistance is the most critical mechanical property that must be controlled and evaluated for determining the long-term performance of polyethylene (PE) pipes. Last generation of bi-modal and multimodal ethylene-α-olefin copolymers with exceptional balance of mechanical properties and processability have been developed in the last years. The inclusion of branched chains, preferentially in the high molecular weight region, has been crucial to favor the entanglements and tie molecules formation [1], which are the responsible for inhibiting the crazing phenomena that precedes the crack formation and subsequent SCG process [2,3]

The outstanding SCG resistance of the last generation PE100RC resins has led to the development of new and faster testing methodologies capable of assessing the pipe long-term performance. Accordingly, the latest revision of the standard EN1555 for pipes of gaseous fuels already includes these tests: Strain Hardening (SH) test, Crack Round Bar (CRB) test, Accelerated Full Notch Creep Test (AFNCT) and Accelerated Notch Pipe Test (ANPT). α-olefin comonomers like C4 (1-butene), C5 (1-pentene) and C6 (1-hexene) are some of the most used in the plastic pipes industry. Although the influence of the size of the side chain on properties as SH has been pointed out by some authors [4,5] it is difficult to separate this influence from others as relevant as the length of the main chain and the molecular weight distribution.

In the present work, different PE100 and PE100RC resins have been evaluated following the different standards for measuring the SCG performance. All pipe grades investigated in this work have been commercial products with long history of use in pipes for pressure applications. Interestingly, the resins have almost the same average molecular weight and molecular weight distribution, but different comonomer type: C4, C5 and C6, which permitted the evaluation of the influence of the short chain branching length on SCG phenomena.

ID207

"IF" (INTERFERENCE) – SCREW TECHNOLOGY

Rainer Viessmann – Hans Weber Maschinenfabrik, Kronach Germany
E-mail: rainer.viessmann@hansweber.de

This presentation introduces a new screw geometry for counter rotating twin screw extruders. This new design offers a different processing technique to the conventional screw design. It describes the rheological and technical consequences in processing thermoplastic materials.

1. Functional principle of conventional counter-rotating twin-screw extruders for PVC processing:
In counter-rotating, intermeshing twin-screw extruders, the material is plasticized mainly by introducing mechanical energy into the preheating zone and the compression zone. A large part of the energy is produced by the calendar effect between the two screws and the compression of the plastic between the feed and compression zones. Only a small part of the energy supplied comes from the heat supply to the cylinder from the outside. To date, this basic principle has applied to all conventional counter-rotating twin screws in use.

The mixing effect with counter-rotating twin-screw extruders is only moderate due to the process and is significantly worse than with compounders. The chamber volume filled with material remains almost unmixed in the C-chamber from intake to the metering zone.

The mixing effect of a conventional screw can only be improved by additional mixing tips in the metering zone and grooves in the compression area. Without mixing elements, streaks or defects on the extrudate are often the result.

The task of every extruder is to achieve a melt that is as homogeneous as possible over the outlet cross section. This is a prerequisite for the design of the tools and for an optically good product.
To improve these three tasks, plasticizing, homogenizing and dispersing, we have developed a new, patented screw geometry.

2. How does the IF- screw differ from the conventional screw design?
In contrast to the conventional screw, the screw threads of the wave screw (IF screw) are wave-shaped in the circumferential direction.

The shape of the flanks is selected in such a way that, despite the fact that both screws roll off one another, the flank clearance is as narrow as possible without touching one another.

3. Process-related effects of the screw geometry:
Due to the relative movement between the screw and the chamber volume filled with PVC, snake-like movements occur. This creates an additional internal friction effect between the PVC particles. This causes a significantly higher and faster introduction of mechanical energy into the plastic. This makes the screw system more effective. In addition, the C-shaped screw chamber volume is plasticized more evenly over the entire cross section.

The homogeneity of the melt is improved and the so-called 'banana peel' effect is minimized. In addition, the chamber volume filled with PVC is conveyed more frequently through the roller gap due to the greater forced conveyance in the circumferential direction and additionally accelerates the plastification. Due to the wave geometry, different backlashes occur in the gusset area. This has an additional positive effect on the homogenization.

ID156

DEVELOPMENT OF A NEW QUALITY CONTROL TEST METHOD TO ASSESS THE STRESS CRACK RESISTANCE OF HDPE WITH RECYCLED CONTENT

Michael Pluimer – University of Minnesota Duluth, United States of America
E-mail: mpluimer@d.umn.edu
Sara Stone – University of Minnesota Duluth, United States of America

Currently, the majority of test methods for determining the stress crack resistance (SCR) in recycled polyethylene (PE) blends ignore crucial information regarding the stress cracking mechanism for these materials. Specifically, most test methods for assessing the SCR of PE materials involve notching the specimens and therefore only address crack propagation, ignoring the initiation of the cracks. Because the prevalence of contaminants and impurities is more likely in recycled materials than for virgin materials, it is especially important to assess crack initiation as well as propagation. The UCLS test (ASTM F3181) is currently the only ASTM-standardized test method for assessing the SCR of recycled PE blends that does not involve notching the test specimens, therefore giving an accurate depiction of both crack initiation and crack propagation in the polymer. The UCLS test is conducted on un-notched specimens in water at elevated temperatures and can be used to predict the service life of pipes manufactured with recycled materials when conducted in accordance with AASHTO R 93, Standard Practice for Service Life Determination of Corrugated HDPE Pipes Manufactured with Recycled Content.

While the UCLS test is an excellent predictor of the service life of HDPE materials containing recycled content, one of its drawbacks is that the failure times can be quite long, making it more useful for a quality assurance test than a quality control test. As such, there is a need for a test method that can more quickly assess the SCR of recycled material blends so that pipe manufacturers can more efficiently develop and qualify various materials. This research will develop a new accelerated test method for assessing the SCR of recycled PE blends correlating with the UCLS test but have considerably shorter failure times, making it more useful for a quality control test.

The research investigates the strain hardening test (at both room and elevated temperatures) as well as a new dynamic accelerated fracture test, with both tests being conducted on un-notched specimens similar to those used in the UCLS test. The research will also include an assessment of the variability of material performance within a given lot. The research is currently underway and will establish a correlation between the dynamic accelerated fracture test, the strain hardening tests, and the UCLS test to affirm the validity of these new tests for these applications and to provide additional quality control testing methods to allow pipe manufacturers to more efficiently develop and qualify blends of recycled materials.

ID215

RHEOLOGICAL CHARACTERIZATION AND FLOW MODELING OF SAG IN HDPE PRESSURE PIPE

Harry Mavridis – LyondellBasell, Cincinnati, United States of America
E-mail: harry.mavdiris@lyb.com

Demand for thick-wall (i.e., greater than about 2"-3" in thickness [1]) HDPE pressure pipe is increasing worldwide for water, mining and oil & gas gathering applications. Resin producers have been developing HDPE resins that combine performance requirements (PE4710 or PE100) with processability attributes needed for thick-wall pipe, while pipe extruder manufacturers and converters have made advances in equipment and methods to optimize the process for maximum pipe wall thickness and thickness uniformity from a given resin. The present paper is concerned with a first-principles analysis of the pipe extrusion sag effect and the development of a rheological test for the purpose of characterizing the sag resistance of a particular HDPE resin or composition. A single metric is extracted from the rheological test so that multiple HDPE candidate materials can be compared. The test can fundamentally account for melt temperature and molecular weight effects and can be useful for HDPE pipe quality control and characterization purposes. A mathematical model is also presented to predict the pipe thickness variation for a given HDPE resin and pipe extrusion setup, based on polymer rheology and pipe processing conditions. The model can predict effects of resin rheology, melt temperature, pipe dimensions and processing conditions (e.g., effect of die offset or internal pipe cooling).

ID112

A NEW GENERATION OF HIGH PERFORMANCE BIAXIALLY ORIENTED POLYETHYLENE AND POLYPROPYLENE PRESSURE PIPES – AN UPDATE

Ajay Taraiya – SABIC, Geleen, The Netherlands
E-mail: ajay.taraiya@sabic.com
Peter Degenhart – SABIC, Geleen, The Netherlands
Mark Boerakker – SABIC, Geleen, The Netherlands

In PPXX, a technology was presented for the first time that could bi-axially orient polyolefin pipes. With this technology, it is possible to prepare pipes that have a performance far beyond the standard ones. One approach to achieving this performance is via a continuous in-line process. To optimize the in-line technology and bring it to the market, a commercial scale pilot line was built. The pilot line made it possible to investigate the influence of process parameters, post processing conditions, and resin design on the performance envelope of these types of pipes. A detailed study of the orientation of 32- and 63-mm outer diameter pipes with the former having a wall thickness between 1.9 to 3 mm and the latter having a wall thickness between 3.7 to 5.7 mm will be presented in this paper. Additionally, pressure test results for pipes produced under these process conditions will be reported. To investigate the performance of these pipes as part of a network, pipes were joined using different fittings to form a closed loop and submitted to cyclic thermal testing according to the EN12293:1999 norm. The resistance of joints to bi-axially oriented pipes, was evaluated by a pressure cycling (water hammer) test according to the EN12295:1999 norm. The result of these tests will be presented in this paper.

ID214

RE-DISTRIBUTION OF RESIDUAL STRESS IN PLASTIC PIPES AND ITS EFFECTS ON HYDROSTATIC PRESSURE TEST RESULTS

Suleyman Deveci – Borouge PTE Limited, Abu Dhabi, United Arab Emirates
E-mail: suleyman.deveci@borouge.com
Birkan Eryigit – Borouge PTE Limited, Abu Dhabi, United Arab Emirates
Bhagabata Das – Borouge PTE Limited, Abu Dhabi, United Arab Emirates
Aisha Khaleel – Borouge PTE Limited, Abu Dhabi, United Arab Emirates

Short and long term hydrostatic pressure resistance of plastic pipes are measured according to ISO 1167 [1], by applying an internal pressure that is calculated for the target hoop stress considering outer diameter and wall thickness of the pipe samples. Due to the nature of the extrusion process, wall thickness distribution of a pipe around the circumference is not homogenous, therefore it is always the minimum measured wall thickness that is considered for hoop stress calculations.

In a previous work [2], we have explained the significance of the wall thickness distribution on the hydrostatic pressure test results. It was shown that there is a linear relationship between the eccentricity of the pipe and the failure hours at hydrostatic pressure tests. As a continuation of the previous work, the current study explores the thermo-physical reasons behind this observation.

The work explains how the residual stress and its distribution around the circumference are changing as a function of the pipe eccentricity. Furthermore, how the circumferential orientation of molecular chains forming at the pipe wall as a result of "eccentricity driven re-distribution of residual stresses" is also discussed. Finally, we propose a revision for the hydrostatic pressure test method (ISO 1167) to include a maximum relative eccentricity value for the pipes being tested in order to ensure a proper evaluation of different materials and pipes using this test method.

ID265

A NEW HIGH PERFORMANCE BIMODAL POLYETHYLENE RESIN FOR POWER AND TELECOMMUNICATION APPLICATIONS

Olivera Bilic – Chevron Phillips Chemical Company, Bartlesville, United States of America
E-mail: bilico@cpchem.com
David Hukill – Chevron Phillips Chemical Company, Bartlesville, United States of America
Brody Peterson – Chevron Phillips Chemical Company, Bartlesville, United States of America
Vivek Rohatgi – Chevron Phillips Chemical Company, Bartlesville, United States of America

Demand for conduit pipe is expected to surge globally due to rapid industrialization and urbanization in residential and commercial sectors. Just in the U.S., according to Market Research analysis, expected growth of the plastic conduit pipe market is at a CAGR of more than 5% over the next ten years. Due to this growth, a new high performance bimodal HDPE resin is developed. The presentation will cover the improved resin properties such as tensile strength, flexural modulus and ESCR that meet or exceed the requirements of the ASTM conduit standards such as F2160, D3485 and UL 651A. Several production runs have been conducted with this new resin at standard industry operating conditions for extruder and die temperature profile for sizes ranging from 1.25-inch IPS Schedule 40 to 6.0-inch IPS SDR 13.5. These trials have shown excellent processability (lb./hr and feet/min.) needed to maximize conduit production rates with or without the incorporation of post-industrial recycle content.

ID148

INNOVATIVE ADDITIVE TECHNOLOGY FOR IMPROVING THE CHLORINE RESISTANCE OF POTABLE HDPE PIPES WITH LOW NIAS (NON-INTENTIONALLY ADDED SUBSTANCES)

Gregor Huber – BASF Corporation, Florham Park, United States of America
E-mail: gregor.huber@basf.com
Tobias Eltze – BASF Corporation, Florham Park, United States of America
Tania Weyland – BASF Schweiz, Kaisten, Switzerland

A significant amount of water is lost while in transit from the water treatment plant to the consumer. The root cause of water leakage can be multiple: old assets, bad installation, lack of maintenance and the use of disinfectants. The use of chlorine-based disinfectants is known to be extremely effective in eliminating waterborne pathogens, but they also weaken the additive stabilization system used to prevent the polymer from premature degradation. Operators report that a pipe maintenance is estimated to be 1000 times more expensive than the cost of the pipe. The problem is global but predominant in the warm regions of the world (Australia, South Europe, ME, Americas) since the use of higher amount of chlorine disinfectant associated with hotter temperature of the ground accelerate the kinetics of the polymer degradation.

Furthermore, the migration of NIAS in potable water is a recurring topic for the distribution of cold and warm drinking water and related materials industry. There are chemical compounds that are present in drinking water contact materials but have not been added during the production process. Erik Arvin from the Technical University of Denmark identified a series of organic migrating substances which were degradation products of the essential additives included in the polymer. The identity of these migrating compounds was published in 2000 and are known since then as Arvin substances #1 to #10.

In this paper, BASF presents the performance of an innovative additive solution that is expected to provide a 50 years' service life of the HDPE pipe in contact with chlorinated water. The new solution is in compliance with drinking water regulations and features a very positive contribution to the reduction of the NIAS. BASF performed migration experiment of the new technology in chlorinated water in accordance with the European Standard EN 12873 to measure the amount of degradation substances in drinking water migrating out of pipes in hot water, the harsher test condition, followed by a sound evaluation of the toxicological properties of the substances identified.

ID237

RECYCLING COMMITMENT OF THE EUROPEAN PLASTIC PIPE INDUSTRY

Ludo Debever – TEPPFA aisbl, Brussels, Belgium
E-mail: ludo.debever@teppfa.eu
Peter Sejersen – TEPPFA aisbl, Brussels, Belgium

The European Plastics Strategy is a top-priority for the European Union. Uptake of more recycled content in new plastic products is paramount to save resources and to reduce the global warming potential. That's why the Circular Plastics Alliance has been established. The alliance is gathering public and private stakeholders in the plastics value chains to promote voluntary actions and commitments for more recycled plastics and ensure that 10 million tons of recycled plastics are used in new products in in Europe in 2025.

The European plastic pipes and fittings industry has through TEPPFA signed the Circular Plastics Alliance declaration and is now initiating and implementing activities to deliver according to the commitment.

In 2021 TEPPFA adapted its strategy to meet changing sustainability requirements and societal expectations. It set itself the ambition to pave the way to increase use of recycled content in plastic pipe systems in Europe whilst maintaining the performance of its systems.

This paper provides background to support growth in the use of recycled material for pipe applications and outlines some of the achievements to date and the challenges which lie ahead to meet the target. The challenge will be to utilize recycled material from many different waste streams whilst maintaining product performance and durability. The industry considers it to be essential that the desire to recycle should not be at the cost of compromising on the fitness for purpose or lifetime expectancy of products.

Most current European Product Standards restrict the use of recycled material and thus modifications to these are required and in parallel need to be developed to demonstrate durability. The change of the material clauses in non-pressure standards are therefore one of TEPPFA main priorities. Other important activities are the development of new and faster test methods, eco-design of products, innovation and product development.

The paper will next to standards also explain the European plastic pipe industry activities in response to the standardization request for standards for design for recycling and on our efforts to opening-up of some country specific product regulations that are restrictive in allowing the use of recycled material.

ID166

DIFFERENT THERMO-OXYDATIVE TESTS IN COMPARISON FOR ONE INDUSTRIAL PE PIPE COMPOUND

Norbert Jansen – Borealis Polymere GmbH, Burghausen Germany
E-mail: norbert.jansen@borealisgroup.com

Modern Polyolefin pipe materials are designed for best fit to the intended application and to fulfil the set of tests, which should secure and predict the lifetime of the pipe at different temperatures in real life and in parallel to pass the stringent set of different mechanical properties of standards.

A practical requirement of temperature resistance of min. 50 years at 70°C was raised for the Extra High Voltage (EHV) corridor projects in Germany and experts were discussing what are the best suited tests to proof the suitability of a resin for the cable protection pipes installed with speed and maybe in harsh conditions (without sand bedding) and with new installation methods in the field. The PE100-RC pipe will be pressure less during the application, but not stress less and has to remain in shape to allow the cable pull-in also for a second time after about 50 years. We looked at those different test methods where a thermal ageing is applied to samples for a time and measured the properties of one natural PE100-RC pipe grade to compare those methods with each other:

- ISO 9080 hot water pressure test including 95° and 110°C, Arrhenius
- OIT (Oxygen Induction Time) is often falsely considered to be used to judge materials when talking about quality and an expected lifetime prediction. This is simply wrong, OIT does not predict any lifetime as many times published.
- The classical oven-ageing test might need to run at too high temperatures for an extrapolation to long times so that the additivation reacts in a strange way with the oxygen. At lower temperature the testing times can go into several years and might not be practical.
- The High-Pressure Autoclave Test (HPAT) was introduced at the last Plastic Pipe in Amsterdam by Zanzinger. Here a number of test points and conditions have to be tested to be able to give a min. lifetime estimate at 70°C

The paper gives a test program overview, both for thermal ageing as well as from PE100-RC documentation perspective.

ID233

FROM FISHING NETS TO PLASTIC PIPES: NEW CHALLENGES FOR RECYCLED POLYETHYLENE FLOWS IN A CIRCULAR ECONOMY

Rafael A. García-Muñoz – King Juan Carlos University, Mostoles, Spain
E-mail: rafael.garcia@urjc.es
Rafael Juan – King Juan Carlos University, Mostoles, Spain
Mónica de la Cruz – AseTUB – Spanish Plastic Pipes and Fittings Sector Group, Madrid, Spain
Beatriz Perdes – King Juan Carlos University, Mostoles, Spain
Carlos Dominguez – King Juan Carlos University, Mostoles, Spain

Plastics are one of the most demanded materials by industries around the world, resulting in the production of large volumes of plastic waste. These residues are a significant source of environmental pollution, both on the land and ocean, with associated important economic and health impacts. For this reason, various organizations and industries have promoted a series of actions and guidelines aimed at reducing the production of plastic waste and improving their recycling. All these measures try to encourage the transition from a linear to a sustainable and Circular economy in the plastic sector.

In this context, mechanical and chemical recycling of plastic waste have made significant progress in recent years. However, the high energy costs of the latter makes that mechanical recycling is still a much more widespread option. It is thus easier to obtain recycled resins from post-consumer plastic waste, but often with worse properties than raw because of material degradation and contamination with other plastic and impurities. Therefore, in certain high-requirement applications, the use of recycled plastics is challenging, mainly in the plastic pressure pipe industry. Nowadays, recycled high density polyethylene (HDPE) is only used in non-pressure pipes, mainly because of the high structural and loading requirements that must be accomplished. However, considering new legislations and revisions of current European Standards that promote the incorporation of recycled plastics in new products, it is necessary to evaluate the capacity to incorporate recycled materials into pipes, not only in non-pressure pipes but also in pressurized systems.

Therefore, the present study evaluated the feasibility of incorporating recycled materials in the manufacture of polyethylene pipe grades. Different recycled HDPE streams were analyzed, from commercially available recyclates to plastic pipes, as well as other innovative rHDPE from IBC containers, fuel tanks or even fishing nets. All recycled resins have been blended with raw HDPE resins (PE100 pipe grade) at different ratios to enhance their final properties. Polyethylene pressure pipes must fulfill high specifications, where two critical properties stand out among the rest: the Slow Crack Growth (SCG) and Rapid Crack Propagation (RCP) resistances. Both properties and the influence on them of incorporating HDPE recyclates were deeply analyzed and discussed in this work.

ID220

CLOSING THE LOOP FOR PEX PIPE IN PRACTICE THROUGH ADVANCED RECYCLING

Robin Bresser – Borealis, Burghausen, Germany
E-mail: robin.bresser@borealisgroup.com
Ilari Aho – Uponor Corporation, Vantaa, Finland

Through innovation and experience, PE-X pipe solutions have been enabling comfortable heating and safe plumbing with a successful 50 year track record. They are an important facilitator of the green energy transition and the ambitious climate targets of, for example, the EU Green Deal by enabling energy efficient plumbing and heating solutions. Furthermore, the crosslinking increases temperature resistance, mechanical robustness and resilience to environmental influences and thereby ensures a long and trouble- free life span. To enable true circularity, however, the closing the loop with production/construction site waste as well as in future end of life demolition waste needs to be addressed.

Sustainability principles for circularity are based on the waste hierarchy of firstly reduction & reuse, secondly mechanical recycling and thirdly advanced (chemical) recycling. The reduction and reuse for PE-X has been maximised through the crosslinking of the pipes which optimizes wall thickness (reduce) as well as lifetime (reuse). Mechanical recycling is the first recycling option but is limited to certain down-cycled applications whaile advanced Chemical recycling could close the loop with non mechanically recycled PE-X waste to produce a high quality, drinking water safe PE-X pipe system with the same quality as virgin.

In practice, this third option of advanced chemical recycling requires close co-operation and co-ordination along the whole value chain. This paper will show how four experienced companies have worked together to successfully recycle PE-X waste pipes back into high quality PE-X pipe systems. The learnings of this circularity project will be presented and we hope will stimulate transparency and constructive discussion on the environmental benefits of closing the loop for PE-X pipes. While the initial pilot project used small diameter (17 x 2.0 mm) production scrap, broadening the pool to job-site waste, and finally including pipes at their end of their life will continue to be an exciting subject where value chain cooperation is essential and strong complementary synergies for the green transition of the construction sector can be achieved.

ID164

EFFECT OF POLYPROPYLENE (PP) POST-CONSUMER RECYCLATE ON THE SLOW CRACK GROWTH RESISTANCE OF A VIRGIN PP PIPE MATERIAL

Jessica Hinczica – Polymer Competence Center Leoben GmbH, Leoben, Austria
E-mail: jessica.hinczica@pccl.at
Mario Messiha – Polymer Competence Center Leoben GmbH, Leoben, Austria
Florian Arbeiter – Montanuniversitaet Leoben, Leoben, Austria
Gerald Pinter – Montanuniversitaet Leoben, Leoben, Austria

In Europe, only 1.8 million tons of recycled material is processed in new products within the building and construction sector. Recyclates and blends of recyclates with virgin materials are already used for different products in the plastic pipe industry, such as cable trays, or storm water management and drainage systems as well as sewage pipes. Currently available recycled polypropylene (PP) fractions do not fulfill the requirement of long service life due to their low and highly inconsistent quality. However, adding only a small fraction of recycled material to virgin PP grades may lead only to a slight decay of long-term properties of pipe products. The cyclic cracked round bar (CRB) test is an excellent method to study the slow crack growth (SCG) resistance, which is a key factor regarding pipe performance. Therefore, this study focuses on CRB tests, according ISO 18489, of PP recyclates as well as PP impact copolymer (PP-ICP) virgin grades and their blends with recyclates. For this purpose, blends with a recyclate content up to 50 % were produced. Pure recyclates depicted low SCG resistances compared to conventional virgin extrusion grades. In fact, high fluctuation in SCG resistance of PP recyclates were found. The CRB tests of the blends showed that with 25 % recyclate content the SCG resistance started to decrease leading to a drastic drop at 50 %. In conclusion, the CRB test was found to be a suitable method to rank recycled materials with regard to lifetime relevant properties. The purity of the recyclate is of high interest: the better it is, the higher the applicable content at similar SCG resistance.

ID221

DRIVING TOWARDS A CIRCULAR ECONOMY-EVALUATION OF PEX RECYCLING

Jacob John – Uponor Inc, Apple Valley, United States of America
E-mail: jacob.john@uponor.com
Suresh Shenoy – Uponor Inc, Apple Valley, United States of America
Patrik Roseen – Uponor, Virsbo, Sweden

Crosslinked polyethylene (PEX) tubing continues to gain popularity in plumbing and indoor climate applications around the globe due to its ease of installation and versatility. Circular economy and net-zero environments are key initiatives in plastic industry today. This paper will discuss the potential pathways to applying these initiatives to PEX.

The paper will focus on 3 such pathways; decrosslinking, recycling and chemical recycling. Some of the initial results will be shared. The new PEX pipes containing recycled material evaluated using the PEX production standards. Results of the study will include the pipe performance requirements set by the vigorous industrial standards described in ASTM and ISO standards. Excessive hot/cold pressure requirements, and environmental stress crack growth resistance (ESCR) tests will be a focus for this evaluation. Pipe dimensions of OD/Wall (~16mm/2mm) will be discussed in this evaluation
Based on the results, the hurdles to achieve net zero/circular economy will be discussed including some recommendations.

ID234

WHAT NEEDS TO BE UNDERSTOOD TO USE RECYCLATES IN PLASTIC PIPES: THE INFLUENCE OF IMPURITIES ON LONG-TERM PROPERTIES

Mario Messiha – Polymer Competence Center Leoben GmbH, Leoben, Austria
E-mail: mario.messiha@pccl.at
Jessica Hinczica – Polymer Competence Center Leoben GmbH, Leoben, Austria
Márton Bredács – Polymer Competence Center Leoben GmbH, Leoben, Austria
Florian Arbeiter – Montanuniversitaet Leoben, Leoben, Austria
Gerald Pinter – Montanuniversitaet Leoben, Leoben, Austria

Engineering structures, such as operating plastic pipes, are often submitted to unexpected influences that may shorten their lifetime. An increasing understanding about the processes that govern these sudden failures has been attained in the last decades. This has led to a remarkable improvement of pipe performances by enhancing the material's slow crack growth (SCG) resistance (e.g. from PE63 to PE100RC). Still a great deal of uncertainty is associated with the use of non-virgin grades. This is mainly, because of the unknown effects of impurities that are found in recycled materials. The effects on lifetime relevant properties with regard to contaminants can be divided into three categories:

I. polymeric contaminants of a different kind (e.g. PE in PP, etc.)

II. polymeric contaminants of the same kind (e.g. PE-LD in PE-HD, etc.)

III. non-polymeric contaminants (e.g. inorganic particles, etc)

In that context, effects of impurities were studied in this work by mixing virgin polypropylene (v-PP) grades with actual polypropylene recyclates (r-PP) into different compositions (v-PP/r-PP in %: 100/0, 90/10, 75/25, 50/50 and 0/100). Subsequently, these materials were tested via hydrostatic pressure tests on pipes. A profound dependency of contamination content on final failure time (tf) could be demonstrated. Additionally, a deeper analysis of fractured pipe samples revealed a clear correlation between the maximum size of incorporated inorganic impurities and tf. This indicates, that two seemingly identical pipe samples, with regard to content of recycled material, can still have vastly different resulting failure times, based on the size of the introduced critical contaminant (amax). Results show, that it is not only necessary to understand the influence of the content and distribution of recyclates on the resulting lifetime of pipes, but more importantly the maximum introduced defect size as well. Consequentially, pipe manufacturers should choose recycled grades carefully, and only after knowing about the feedstock itself, treatment- and mechanical sorting history.

ID196

INFLUENCING FACTORS OF CRACKED ROUND BAR TEST

Yanlei Hu – National Test Center of Polymer and Building Materials (NTC), SINOPEC (Beijing) Research Institute of Chemical Industry Co., Ltd., Beijing, China
E-mail: huyl.bjhy@sinopec.com
Jin Sun – National Test Center of Polymer and Building Materials (NTC), SINOPEC (Beijing) Research Institute of Chemical Industry Co., Ltd., Beijing, China

Traditional slow crack growth tests have several limitations. For example, they require too much time, use chemical reagents, and have poor reproducibility. As a result, accurately evaluating the slow crack growth resistance of polyethylene pipe special materials and developing new materials is often slow. Given recent rapid advancements in pipe special materials, there is a growing need for alternative evaluation methods that are fast, environmentally friendly, and reliable. The Cracked Round Bar (CRB) test is one such method that meets these requirements. Notably, the CRB test can be carried out at room temperature without surfactants and has several advantages such as reducing test time and cost while offering good repeatability and high reliability of test results.

Previous research on the CRB test has mainly focused on changing different samples, with little attention given to how the sample preparation method, sample size, and test parameters may influence the test results. This paper aims to address these gaps by exploring the impact of various sample preparation methods (compression molding, injection molding, and machining from pipe samples), sample sizes (sample diameter and notch depth), and test conditions (temperature, load ratio, and frequency). Our goal is to identify the optimal test conditions for achieving the most accurate results.

ID141

A HOLISTIC ENVIRONMENTAL FOOTPRINT ASSESSMENT OF THE EUROPEAN PLASTIC PIPE BUSINESS

Ludo Debever – TEPPFA aisbl, Brussels, Belgium
E-mail: ludo.debever@teppfa.eu
Peter Sejersen – TEPPFA aisbl, Brussels, Belgium

The Circular Plastics Alliance is an initiative under the European Strategy for Plastics. TEPPFA is one of more than 300 signatures for the Alliance. We thereby committed to a significant contribution to boosting the EU market for recycled plastics to 10 million tonnes by 2025. Moreover, one of the must win battles of the new industry strategy is to contribute to the circular economy by paving the way to increase the use of recycled content whilst maintaining the performance of the systems.

The use of recycled materials in new products is scientifically recognized as one of the major tools to reduce the carbon footprint and to transition from a linear to a circular economy. The European plastic pipe industry is already now using more than 400.000 tons recycled materials per year in new products, which represents an average content of 10% in the products. The recycled materials are almost solely used in non-pressure products.

Although the industry is working for an increased uptake of recycled materials, we wanted a holistic view of our options to mitigate the climate change. We have therefore commissioned a study to elaborate and quantify our options.

To conduct the study a third-party company was chosen. The company is a global sustainability consultancy company that can combine broad and deep sustainability expertise with robust commercial and operational capabilities. Anthesis was supported by World Wildlife Fund in Switzerland who acted as a "critical friend and sparing partner" to us and secured us the correct focus throughout the project.

The study had three main components: A membership survey, a sectorial footprint study and a mitigation scenario study based on a hotspot analysis. We explored a set of potential 'mitigation scenarios', which could reduce the impact of the sector:
– Introduce recycled material
– Introduce biobased material
– Reduce metal parts in fittings and ancillary components
– Greener energy schemes for virgin material providers
– Recovery of pipes for further recycling

When all scenarios are applied together, the potential reduction could be 3-3.5 Mt CO2eq: 25-30% of current carbon emissions.

The paper will explain our findings in detail and also show the likely implementation costs, compared with the global abatement cost benchmarks from the International Energy Agency.

ID153

THE EFFECT OF THE NOTCH RADIUS ON THE NOTCHED PIPE TEST RESULTS

Suleyman Deveci – Borouge Pte, Abu Dhabi, United Arab Emirates
E-mail: suleyman.deveci@borouge.com
Aisha AlHashmi – Borouge Pte, Abu Dhabi, United Arab Emirates
Sulistiyanto Nugroho – Borouge Pte, Abu Dhabi, United Arab Emirates
Fatima AlHameli – Borouge Pte, Abu Dhabi, United Arab Emirates

High density polyethylene materials, with high-molecular-weight and bi-modal structure, with 1-butene or 1-hexene comonomer incorporation, known as PE80, PE100 and PE100RC, have successfully served-pressurised water and gas network for many years in standard applications. Their performance requirements with regards to hydrostatic pressure and slow crack growth (SCG) resistance have been defined in application-related product specifications. Notched Pipe Test (NPT) according to ISO 13479, originally developed by Allwood and Beach, is one of the most common and industry accepted SCG test methods. In this test, a plastic pipe with four axial predefined notches at the outer surface around its circumference is subjected to hydrostatic pressure in a water bath at 80 °C. Following a recent international round robin study, it was proposed to have control on notch radius by setting a maximum limit to improve reproducibility of the NPT method. In this study we present a method to measure and quantify the notch radius, which is used to investigate the effect of notch radius on the failure time of NPT. Identical pipes were notched with five different notch radiuses and tested until failure to develop a correlation between notch radius and failure hours. Brittle fracture depth of each notch is measured together with microscopic analyses of fracture surfaces. The outcome of this work is expected to help the revision of ISO 13479 and improve the reproducibility of the test method.

ID161

IMPROVING MECHANICAL SORTING OF POST-CONSUMER PLASTIC WASTE TO ACHIEVE CIRCULAR USE OF PLASTIC PIPES

Márton Bredács – Polymer Competence Center Leoben GmbH, Leoben, Austria
E-Mail: marton.bredacs@pccl.at
Jutta Geier – Polymer Competence Center Leoben GmbH, Leoben, Austria
Mario Messiha – Polymer Competence Center Leoben GmbH, Leoben, Austria
Gernot Oreski – Polymer Competence Center Leoben GmbH, Leoben, Austria
Raphael Horvath – IRsweep AG, Staefa, Switzerland
Szilveszter Gergely – University of Technology and Economics Budapest, Hungary
Gerald Koinig – University of Leoben, Leoben, Austria
Gerald Pinter – University of Leoben, Leoben, Austria

In 2020, 367 million tons of plastics were produced globally, whereof in Europe 20 % was used in the building & construction sector to manufacture in significant proportion polyethylene (PE) and polypropylene (PP) pipes. To increase the current 30 % of recycling rate improving the quality of recyclates and consequently facilitate the production of recycled high-value products such as pipes is essential. Previous studies, showed that improved mechanical sorting of post-consumed plastics would improve the quality of recyclates and pipes containing recycled PO grades.

State of the art near infrared (NIR) sensors of mechanical sorting lines limit the sorting degree due to the characteristics of the recorded overtone vibrations. Thus, the objectives of this work are to improve the current NIR sorting technology applying multivariate data analysis and to investigate the applicability of dual comb spectroscopy in the mid-IR spectral range as a new sensor technology in mechanical recycling. Applying principal component analysis (PCA) separation of virgin high-density PE and PP grades were found to be possible, hence higher degree of sorting could be achieved for post-consumed PO products with NIR sensors. In fact, PCA of post-consumed PO indicate that processing method (e.g.: extrusion, injection molding) based separation is possible. Moreover, PE density can be predicted accurately with partial least square regression relying on Raman and FTIR spectroscopy. Although the current NIR spectra are not suitable for MFR and density prediction during the sorting process, an emerging new method applying dual comb spectroscopy provides high spectral resolution and allows the accurate prediction of MFR and density of PE. An in-line, mid-IR spectroscopy based MFR and density prediction could lead to pure recycled fractions containing only PE pipe grades. Such enhancement would be a significant step towards increased plastic recycling and towards circular plastic pipe products.

ID253

FATIGUE CRACK GROWTH RESISTANCE OF POLYPROPYLENE PIPE COMPOUNDS CONTAINING POST-CONSUMER PACKAGING RECYCLATES

Paul J. Freudenthaler – Johannes Kepler University Linz, Linz, Austria
E-mail: paul.freudenthaler@jku.at
Joerg Fischer – Johannes Kepler University Linz, Linz, Austria

The European Commission set high recycling targets for plastic packaging waste, which will lead to an increased availability of polypropylene (PP) post-consumer recyclates (PCRs). Application of these recyclates for new packaging products is obvious, but food safety is yet not achieved for PP PCRs with a feedstock from communal collecting sources, hence limit their applicability to non-food applications. Therefore, the European Commission also suggested other applications for PCRs as for instance pipes as they show "good potential for uptake of recycled content".

Pipe products set high demands on the long-term mechanical performance of the used materials, which cannot be achieved by packaging grades or PCRs comprised of them. One solution could be the compounding of virgin high-performance pipe grades with recyclates to achieve sufficient long-term performance, at least for the use in less demanding applications such as drainage pipes and/or fittings. Preceding research was done on polyethylene based compounds, but no preceding publication was found for polypropylene compounds.

Within this presented research, compounds containing two virgin high-performance PP-B pipe grades, which were compounded with two different PP PCRs originating from packaging waste streams at recyclate contents from 10 m% to 30 m%. The resulting compounds were characterized in terms of basic parameters (melt mass-flow rate (MFR), density, melting peaks, oxidation behavior, and tensile properties) and one of the most lifetime determining factors found in pipe materials, their fatigue crack growth (FCG) resistance measured with cracked round bar experiments. As the recyclates originate from packaging materials and hence were used for thermoforming and/or injection molding processes, their MFR was much higher than usually found in pipe grade materials. The compounds show MFRs in between the blending partners, rising with the recyclate content. Furthermore, the FCG resistance decreased with rising recyclate content. Recyclate compounds which used the first, higher performing virgin pipe grade showed higher FCG resistances than the second, lower performing virgin pipe grade. All the compounds showed a higher FCG resistance than a third virgin pipe grade used for injection molding of fittings, even at comparable MFRs.

ID163

ONE SMALL STEP FOR EDUCATION – ONE GIANT LEAP FOR THE SUSTAINABLE FUTURE OF OUR INDUSTRY'S WORKFORCE

White G. Jee – JEE Consulting Services LLC, Sugar Land, United States of America
E-mail: wgjee@jeeconsulting.net

"Education is the most powerful weapon you can use to change the world." "Education is our passport to the future, for tomorrow belongs to the people who prepare for it today." "Education is not the learning of facts, but the training of the mind to think." "Live as if you were to die tomorrow. Learn as if you were to live forever." These quotes about education from people of various interests (government leaders, activists, scholars, etc.) emphasizes the importance of assuring the next workforce generation (Millennials, Gen-X, Gen-Y, Gen-Z) are prepared to assure the continuous growth and improvement of our plastic piping industry. As one of the many Baby Boomers that is approaching retirement in this industry, it is of utmost importance that we communicate our experiences and mentor the next workforce generation to continue the vibrant growth of our industry that has blessed all of us in our careers and livelihood.

Demographic studies relative to a trained sustainable workforce have indicated an urgent need to assure the knowledge and skills of our industry are growing by an increased emphasis in training and education of relevant topics to the next generation of available workers. As engineering, polymer chemistry and material science courses are developed and taught by university professors, do you know if the topic of plastics piping systems is being covered as an introduction to the students? This paper/presentation highlights the efforts that have been taken to develop such an introduction at a university highly recognized for its engineering and science curriculum and the resources that are available through industry associations that can be supplied and donated to support the initiative. This paper/presentation will also cover some of the topics available in these various resources that can be supplied to universities as well as the on-going journey experiences in being an invited special alumni guest speaker in 2022 and subsequent invitation to be a guest speaker on plastic piping systems as a lecture to the students in 2023. "Education is only a ladder to gather fruit from the tree of knowledge, not the fruit itself." "Example isn't another way to teach, it is the only way to teach."

ID201

ALTERNATIVE SLOW CRACK GROWTH TEST FOR THE HDPE CONDUIT INDUSTRY: CORRELATION BETWEEN ESCR AND NCLS

Patrick Vibien – Plastics Pipe Institute, Irving, United States of America
E-mail: pvibien@plasticpipe.org
Kevin Copher – Blue Diamond Industries, Lexington, United States of America

High Density Polyethylene (HDPE) conduit is a durable product designed to protect cables for multiple generations buried underground or encased in conduit. Conduit is subject to coiling stresses, installation stresses and in-service stresses, such as those generated from installed curvature, soil loading, rock impingement. These stresses are typically low enough that they do not generate ductile failure; however, these stresses can produce brittle failures if the material is not sufficiently resistant to this failure mode. The North American HDPE conduit industry has adopted a material performance requirement based on the ASTM D1693 *Standard Test Method for Environmental Stress-Cracking of Ethylene Plastics Environmental Stress Crack Resistance* (ESCR). This requirement has served the industry well with few, if any, brittle failures in service.

The stipulated requirement is a failure time (F_{10}) greater than 96h. The ESCR test has been anecdotally reported to have significant inter- and intra-laboratory variation. This variability is supported by the ASTM D1693 test method stated precision and bias. As this test is frequently used as a QC test for outgoing and incoming materials, the minimum test time of 3.5 days can result in significant delays in material shipping by the HDPE material producer or in accepting and transferring materials into inventory for the conduit manufacturer.

The ASTM F2136 *Standard Test Method for Notched, Constant Ligament-Stress (NCLS) Test to Determine Slow-Crack-Growth Resistance of HDPE Resins or HDPE Corrugated Pipe* has been adopted with success by the North American HDPE corrugated pipe industry as a replacement for the ESCR test. The NCLS test is reported to provide improved reproducibility and acceleration over the ESCR test, both desirable properties for the HDPE conduit industry.

A round-robin test program was conducted based on 10 materials with a range of known ESCR performances. Multiple labs conducting both the ESCR and NCLS tests on samples generated from these materials. This paper provides the analysis and results of the correlation study between both methods. Significant variability within the ESCR test results was confirmed. Based on the correlation, the HDPE conduit industry may adopt an NCLS based requirement shown to be equivalent to the existing ESCR requirement. Additionally, the finding may be used to support the introduction of recycled HDPE in conduit applications.

ID193

THE ALLIANCE FOR PE PIPE LAUNCHES INAUGURAL YEAR OF CERTIFIED PROFESSIONALS PROGRAM

Edward Alan Ambler – Alliance for PE Pipe, Tulsa, United States of America
E-mail: aambler@pepipe.org
Dustin Langston – WL Plastics, Fort Worth, United States of America

The Alliance for PE Pipe (PEA) kicked off its Certified Professionals Program in 2022 with ten individuals in the inaugural year of the program. The Certified Professionals Program has been developed in order to enhance knowledge of HDPE within the municipal water and wastewater markets and develop the Professionals ability to clearly communicate this expertise with others. This hybrid in-person online program included detailed in-person presentations, an in-person retreat mid-year, monthly zoom meetings, participation in PEA webinars and roadshows, and individual and group homework and project assignments. The syllabus for the program covers broad and in-depth topics including HDPE general knowledge, installation methods, organizations, markets, fusion qualifications and inspections, technical notes, standards and testing. The program includes assignments for individuals from both the technical and non-technical sides of the industry with detailed information that is expected to advance knowledge of highly seasoned veterans and novices to the industry alike.

The group benefited from sharing personal experiences within the HDPE industry as well as lots of lessons learned from successful and failed construction projects. Expert instructors, such as Jim Williams, PE, Richard Kolasa, Vik Rhotagi and Doug Keller, contributed to the monthly zoom meetings and webinars for a comprehensive look at all things HDPE. Several Master's students will graduate from the program this December and the current Qualified Professionals will become Master's students for their final year of the program. All homework and project assignments were designed to challenge and expand knowledge in various aspects of the syllabus.

ID182

HOW TO CONTROL CRACKS IN PIPES TO GUARANTEE A SAFE OPERATION

Gerald Pinter – Montanuniversitaet Leoben, Leoben, Austria
E-mail: gerald.pinter@unileoben.ac.at
Florian Arbeiter – Montanuniversitaet Leoben, Leoben, Austria
Johannes Wiener – Montanuniversitaet Leoben, Leoben, Austria
Otmar Kolednik – Austrian Academy of Science, Erich Schmid Institute of Materials Science, Leoben, Austria
Jan Poduska – Czech Academy of Sciences, Institute of Physics of Materials, Brno, Czech Republic
Pavel Hutar – Czech Academy of Sciences, Institute of Physics of Materials, Brno, Czech Republic

Crack initiation and subsequent crack growth are known to be the key factors which determine the final lifetime of a polymeric pipe. Subsequently, exact knowledge regarding the crack growth behavior is a key issue to guarantee safe operation. Furthermore, ever increasing demands concerning the performance of plastic pipe materials, be it with regard to the total lifetime, the utilization of recycled materials, trenchless burying techniques, etc. require new ideas to make ends meet. The current work shows a summary of the main findings of the scientific work of the last ten years on several approaches to control cracks in both pressurized- and non-pressurized pipes.

With regard to pressurized pipes, research has shown that it is possible to use a combination of materials with different elastic properties, as well as resistance against slow crack growth to be able to use recycled material safely in polyethylene pipes. By applying a layer of high performing PE100-RC on the surface of a recycled material, it is possible to shield the weakened material if the elastic properties are chosen correctly. Additionally, a much-neglected topic is residual stress in the pipe as well. By introducing compressive residual stresses, opening cracks can also be unloaded – effectively increasing the lifetime of a pipe as well. This can be extremely helpful, if a crack is expected on the outside of a pipe, as it might happen during the application of burst-lining or similar techniques.

Another possibility to govern the crack growth is the use of vastly different material properties within one pipe. By using a much softer material in between individual layers, it is possible to stop a crack completely from growing – factually forcing it to re-initiate once again. Furthermore, due to the crack-shielding effect of the surrounding stiffer layers, the local crack driving force is also drastically decreased, ultimately leading to an increased crack resistance of the structure via extrinsic toughening.

Combining some, or even all of the approaches shown in this work, will pave the way towards future pipe structure designs.

ID261

HOW AN INDUSTRY LEAD PVC PLASTIC PIPES RECYCLING SCHEME CAN CHANGE PERCEPTIONS, EDUCATE, AND PROVIDE VALUABLE INSIGHTS FOR A MORE SUSTAINABLE SOLUTION

Cindy Bray – Plastics Industry Pipe Association of Australia, North Lakes, Australia
E-mail: cindy.bray@pipa.com.au

For over two decades, the plastics pipe industry in Australia has aimed to recycle the maximum amount of usable plastic pipe and other suitable materials into new plastic pipes through programs such as take-back schemes and providing collection facilities on manufacturing sites. In Australia long-term sustainability is strongly driven by the Australian National Waste Policy and Action Plan Targets. These targets include the ban of exporting waste plastic, paper, glass and tyres by 2022, significantly increasing the use of recycled content by governments and industry, 80% average recovery rate from all waste streams by 2030 and make comprehensive, economy-wide, timely data publicly available to support better consumer, investment and policy decisions.

These targets initiated an opportunity for the plumbing industry to work collaboratively with industry associations, PVC pipe manufactures, PVC pipe distributors and end users to play a role in diverting off-cuts of plastic pipes from landfill and recycling them into new PVC pipes.

The Construction Plastics Recycling scheme was launched in November 2021 with the support of the Queensland Government with the aim to educate and change the perception of PVC plastic pipes, change end user behaviours, capture valuable and reliable data on waste generated during construction, with the goal of using the insights from the scheme to implement long-term sustainable solutions for the collection of PVC pipe and fitting off-cuts.

The presentation takes you on the journey the partners have taken from developing the scheme, launching, the insights and learnings, along with the challenges, the key areas for success and the importance of education. The scheme highlights the environmental commitments of not only the partners involved in the scheme but the industry as a whole and the momentum being gained for further opportunities to implement similar schemes more broadly across Australia.

ID129

PE100 MATERIAL SUPPORTS WORLD'S LARGEST WASTEWATER TREATMENT PLANT – BAHR EL BAQAR, EGYPT

Sultan Alkendi – Borouge Pte. Ltd., Abu Dhabi, United Arab Emirates
E-mail: sultan.alkendi@borouge.com
Peter Youssef – New Mena Plast – Krah Misr, Obour City, Egypt
Hussein Basha – Borouge Pte. Ltd., Abu Dhabi, United Arab Emirates

Bahr El-Baqar Water Treatment Plant, which produces 2 billion m^3 per year, introduces a sustainable solution for environmental pollution recovery and irrigation water source (via recycling the water of Bahr El-Baqar drain); whereas it protects the environment and generates water to support the cultivation of 4000 km^2 in Sinai. Bahr El-Baqar treatment plant has a total footprint of 650,000 m^2.

The geographic location of this massive project proved to be one of the biggest technical challenges to overcome. Near the banks of the Suez Canal the soil conditions where not ideal for such an ambitions project. With the high-water table and loose soil conditions excluding most types of conventional piping materials due to the expected ground movement and aggressive nature of the surrounding environment. The solution was the use of pipes made of HDPE, as both solid and structured walled HDPE pipes have been used in key Egyptian projects with great success.

Given the large diameter requirements of this project and the tight delivery schedule the use of structured wall pipes became the piping solution of choice for all project pipe requirements from intake to outfall. Krah Misr was selected to supply the spiral wound HDPE pipes for the project. The company is the local licensee of a German machine manufacturer with over 35 years of experience in the design, development, and construction of production plants for large diameter pipes and fittings. They manufactured and supplied 2.7 km of 1600 mm and 2500 mm diameter spirally wound PE pipes for low-pressure application (2.2 bar) for the wastewater treatment plant. Given that the project required pipes with different stiffnesses and pressure ratings; the pipe manufacturer decided on using a PE100 material to allow for effective modeling and designing of the pipeline network. Borouge BorSafe™ HE3490-LS is a bimodal PE100 material that combines processability and mechanical properties. Lending itself well to be used in the production of spiral wound pipes with stringent design and project requirements.

The benefits of HDPE Spiral wound pipes:

- Low installation cost – HDPE is flexible and lighter compared to conventional piping systems
- Low maintenance cost – Corrosion resistance during the operational life of the pipeline
- Low operational cost – Pipes made from HDPE have smooth internal bores that facilitate superior flow
- Weldability – Because of its weldability, PE joints have low leakage rates leading to superior performance throughout its full life cycle

ID180

DEVELOPMENT OF HYDRO-AXIAL TENSION METHOD FOR WHOLE PIPE TENSILE TEST

Robert Stakenborghs – Advanced Microwave Imaging, Baton Rouge, United States of America
E-mail: rjstak@advancedmwimaging.com
Sunwoong Choi – Hannam University, Daejeon, South Korea

Tensile testing whole pipe or pipe/joint assembly is limited by the large capacity tensile equipment requirement for delivering high loads as pipe dimensions increase. Therefore, the hydro-axial tension (HAT) method was developed to alleviate the problems associated with such a high load in performing the axial tensile test on the whole pipe or whole pipe/joint assemblies. The HAT method employs a way to eliminate or minimize the tensile hoop stress developed in the pipe when internally pressurized. Hence, the axial stress becomes the maximum principle stress, which drives the axial tensile failure of the whole pipe or the pipe/joint assembly. The development of the HAT test is described and applied to assess the structural integrity of polyethylene pipes, their butt fusion, and electrofusion joints. The performance of HAT in whole pipe tensile test and its ability to depict unflawed/flawed PE4710 (PE100) pipes and fusion joints are demonstrated. The current HAT apparatus is made to test up to 355 mm/SDR 9 pipes and joints. Larger pipe sizes can be tensile tested to failure using less than 100 bar pressure with larger HAT apparatus.

ID209

THE USE OF PE100+ MATERIALS IN TRENCHLESS TECHNOLOGY APPLICATIONS

Robin Bresser – PE100+ Association, Apeldoorn, The Netherlands
E-mail: robin.bresser@borealisgroup.com
Andrew Wedgner – PE100+ Association, Apeldoorn, The Netherlands

PE100 pipes are the most widely used material for the installation, rehabilitation and replacement of pressure pipes for water and gas supply and for pressure sewers. Such pipes can be installed using a broad range of trenchless technologies and hence the selection of the most appropriate method and identification of the correct standards can be a challenge for end user organisations.

The PE100+ Association, working with trenchless industry experts developed an online guide to educate end users about the different technologies. The guide also aids users in selecting appropriate trenchless methods for the use of PE100 pipes in both new installation and rehabilitation works.

The paper and presentation will provide an overview of the trenchless methods that can be used to install PE100 pipes, together with a summary of the EN ISO 11295 family of standards that cover these trenchless methods and an introduction to the online guide.

ID138

A SUCCESS STORY: NEW TESTING ALTERNATIVES FOR SPANISH AND LATAM PE100RC PIPE MANUFACTURERS

Federico Muñoz Sanchez – Centro de Ensayos, Innovación y Servicios (CEIS), Móstoles, Spain
E-mail: fmunoz@ceis.es

Following the recent approval of European Standards series EN 1555 for Polyethylene piping systems for the supply of gaseous fuels which introduces the PE100RC, a new material with enhanced resistance to Slow Crack Growth (SCG) and anticipating the imminent revision of European Standard series EN 12201 for Polyethylene piping systems for water supply which also introduces the same PE grade, we noticed the need to introduce in Spain/LATAM the new tests required to evaluate such materials from granulate, pipe or fitting.

Considering the big influence of the European Standardisation is having in LATAM region and taking into account that the EN1555 is commonly consider by gas companies in LATAM during the design and construction of gas distribution network, the complete package of accelerated tests required to check the resistance to Slow Crack Growth of both PE100RC grades and the pipes/fittings manufactured with them in a single testing hub with clear benefits for the market, which could take advantage of using new PE100RC materials previously evaluated by independent and reliable testing labs.

The paper describes, first, the current situation of the standards and will also put attention to the points of the mentioned standards which should be a challenge for the effective implementation of the new evaluation methods. The challenges would include both, the need of approval of the standards, so the expected timing for the effective implementation will be analysed, but also some technical issues related to the tests themselves which must be taken into consideration for the success of the evaluation scheme.

The new tests introduced in the mentioned standards are Accelerated Full Notch Creep Test, Strain Hardening Test, Crack Round Bar Test and Accelerated Notched Pipe Test. The paper will also include a brief description of the mentioned methods.

ID137

HIGH DENSITY POLYETHYLENE (HDPE) PIPE BRINGS SAFE SHORES AND RELIABLE ELECTRICITY TO RWANDA

Richard Coombs – ISCO Industries, Woodlands, United States of America
Email: richard.coombs@isco-pipe.com
Shane Schuessler – ISCO Industries, Louisville, United States of America
Mohamed Hageb – Union Pipes Industry LLC, Abu Dhabi, United Arab Emirates
Gregorios Vigellis – Union Pipes Industry LLC, Abu Dhabi, United Arab Emirates
Abdullah Saber – Borouge Pte., Abu Dhabi, United Arab Emirates
Chandra Basavaraju – Borouge Pte., Abu Dhabi, United Arab Emirates

Buried HDPE piping systems have been installed in power generation facilities for decades in numerous applications such as cooling water, firewater and wastewater. This paper will present the use of HDPE piping materials for an innovative power generation project in Central Africa. The discussion will include how this versatile material allowed for unique design and fabrication options to extract and transport methane gas from one of the world's deepest freshwater lakes to be used as fuel for a new power generation plant.

Bordered by Rwanda and the Democratic Republic of Congo sits Lake Kivu, an African Great Lake formed along the East African Rift. Lake Kivu is one of the world's deepest freshwater lakes and contains enormous quantities of dissolved carbon dioxide gas held at depths greater than 1100 feet (350 meters) due to a suspended mineral barrier and forced down by water pressure above. The carbon dioxide is trapped with methane, both products of decomposing biological matter and volcanic activity. The vast amounts of carbon dioxide and methane contained in Lake Kivu present a potentially grave risk for the local shoreline communities. A lake in Cameroon with similar carbon dioxide levels realized an event known as "lake turnover" in 1986. A carbon dioxide cloud was release into the atmosphere effecting local shoreline villages resulting in numerous human and livestock fatalities.

An innovative power company recognized that there could be a way to minimize the potential for a lakeside disaster at Lake Kivu, while also harnessing the lake's suspended methane for power. The idea was to pull methane-rich water from the depths of the lake, utilize a gas-water separator to extract the methane, then transport the methane to fuel a new onshore power generation facility.

The final design includes an offshore facility of four barges to house the gas processing equipment. The barges also support eight submerged water – gas separators as well as large diameter HDPE pipe risers that operate as a natural siphon to deliver the gas to the separators and discharge the degassed water. The collected methane gas is then transferred in a submerged HDPE pipeline approximately eight miles (twelve kilometers) to the power generation facility.

ID232

THE QUALITY OF OLD AND NEW PE PIPES USING THE PENT AND CPENT TEST

Roland Valk – Kiwa Technology Apeldoorn, The Netherlands
E-mail: roland.valk@kiwa.com
Stefan Pouw – Kiwa Technology Apeldoorn, The Netherlands

To gain insight in the residual quality of first-generation polyethylene (PE) pipes used in the Dutch gas distribution grid, pipe segments from all over the Netherlands are excavated by the Dutch Distribution System Operators (DSOs) and tested by Kiwa Technology. The remaining quality is determined by performing the Pennsylvania Edge Notch Tensile (PENT) test in accordance with ASTM F1473 / ISO 16241. The test specimens are directly taken from the pipe segments. However, this test is not practical for the latest generation of polyethylene grades (for example PE 100-RC and PE 4710 PLUS) as the testing time ends up being impractically long. The Cyclic Round Bar (CRB) test method in accordance with ISO 18489 can solve this problem and an correlation with the PENT has been shown. In many pipes, however, the wall thickness is too thin to produce suitable test specimens from the pipe. A practical alternative is the Cyclic PENT (CPENT). This is a test method that combines the PENT specimen shape with the cyclic loading as in CRB. This method was introduced in 2018 by the Deakin University in Australia.

This study compares the PENT to the CPENT. Multiple (old) pipes are tested using the PENT as well as the CPENT test. The failure time for the PENT is compared to the cycles to failure for the CPENT. Additionally, pipe material is artificially aged using hydrostatic pressure at elevated temperature and afterwards tested using PENT and CPENT. The failure time and cycles to failure decrease as a results of artificial aging (hydrostatic pressure at 3 MPa and 80°C for 500 hours or up to failure of the pipe). This indicates that both tests are able to assess the reduction in residual quality.

To evaluate the results in further depth, microscopic images are taken from the fracture surfaces. Via optical microscopy, different zones were distinguished such as a knife blade surface which is the initial crack from the notching, a smooth region which represents the slow crack growth (SCG) during the test, and a rough zone where the final (rapid) fracture occurred. As the surface area decreases during the test, the stress rises resulting in a ductile fracture. The different zones can be found for the specimens from both PENT and CPENT.

Additionally, the elongation of the test specimens during both the PENT and CPENT was studied. These results are evaluated further using elongation data in which the different zones can be distinguished by the slope.

This paper gives insight into expanding the applicability of the well-known PENT to the newest and best pipe materials using the CPENT.

ID222

ADVANTAGES OF PE-RT II PIPES IN DISTRICT HEATING APPLICATION SYSTEM

Abdullah Saber – Borouge, Abu Dhabi, United Arab Emirates
E-mail: a.saber@borouge.com
Xin Zhou – Borouge, Shanghai, China
Shuqiang Wang – Zibo Jielin Plastic Pipe Co., Ltd, Zibo, China

PE-RT II (PE100 classification) is designed >50 years lifespan at elevated temperature which aims to the growing demands on the applications of hot water and other industrial applications.

District heating is a growing market in Greater China. However, the conventional pipes have serious corrosion issue in this application.

In this paper, an old steel pipeline has leakage issue after few years operation due to corrosion with district heating system, then a PE-RT II pipeline system with dn63~dn315mm, S5 was introduced to replace the corroded steel pipeline. The max. working pressure is 0.5MPa and water temperature is set at 50°C.

Plenty benefits of PE-RT II were found in the replacement inclusive easy to transport and installation, better heat insulation performance and no leakage issue. Meanwhile, around 20% ~ 30% investment saving with pipe diameter dn63mm ~ dn160mm, S5 was calculated by PE-RT II pipeline. And 5% operation cost was saved inclusive water saving and electrical power saving with each heating cycle, Furthermore, 70% saving was calculated through the whole life cost calculation model compared to conventional steel pipe.

ID204

MAKING THE ACCELERATED NOTCH PIPE TEST (ANPT) FUTURE-PROOF

Ernst van der Stok – Kiwa Technology Apeldoorn, The Netherlands
E-mail: ernst.van.der.stok@kiwa.com
Nadia Luijsterburg-Vleugels – Kiwa Technology Apeldoorn, The Netherlands

The latest generation of polyethylene grades (PE 100-RC and PE 4710 PLUS) have a raised resistance to slow crack growth, that can be initiated by either a scratch during installation or a rock indentation during use. To evaluate the long-term behavior of the pipes in a fast and reliable way the accelerated notch pipe test (aNPT) is standardized in 2022 in the ISO 13479. This test method is used in the standard for PE piping systems for the supply of gaseous fuels in Europe (EN 1555) and it is proposed in the international version ISO 4437.

In the aNPT method, four longitudinal notches are machined in the outer surface, evenly distributed over the circumference of the pipe. The pipe is pressurized hydrostatically and, to accelerated failure, the pipe is submerged in a detergent solution at 80°C.

To optimize the test efficiency a previous study has shown that the amount of detergent can be minimized by creating small containers for each individual pipe. To further improve the test efficiency the pipes are placed vertical instead of horizontal. The orientation of the pipes are not standardized in ISO 13479. In this study the differences between these two orientations are investigated, which can be used for future improvements of the standard.

Additionally, this study explores the use of a new detergent. ISO 13479 currently prescribes Arkopal N100 as detergent to be used. However, this is a nonylphenol ethoxylate that is currently restricted under REACH Regulation as prepared by the European Chemical Agency, because it is very toxic to aquatic life with long lasting effects and endocrine disrupting. This means that the detergent cannot be imported, distributed and sold within Europe. There is an exception for laboratory use, but up to now, no importer has been found by any of the European test labs. To be able to determine if the PE 100-RC pipes indeed meet the minimum requirements as given in EN 1555, a new detergent for the aNPT has to be found fast. In this study a comparison is given between the failure times of pipes that were tested in Arkopal N100 and in a new detergent; Dehyton. The aggressivity and ageing effects of the detergent are continuously monitored with pH sensors and will be presented as well.

ID219

SIMULATION DRIVEN OPTIMIZATION OF SPIGOT BEVELS

Guido Quesada – Simulation Driven Engineering, San José, Costa Rica
E-mail: gquesada@side-cr.com

Spigot bevels (also referred to as chamfers) for plastic pipe joints using elastomeric seals are well-known and often prescribed in standards such as ISO 1452 for PVC-U and 16422 for PVC-O. The most common type of bevel is a simple straight cut at a 15° angle with respect to the pipe axis, leaving approximately 50% of the pipe thickness at the tip of the spigot. While this is a very popular and even standardized bevel, it has been found to be significantly less than optimal and even potentially problematic if it adheres strictly to the sketches or guidelines commonly found in technical plastic pipe literature.

A poorly designed or executed bevel can sink its edge on the surface of the seal, thereby wiping off the lubricant and increasing the axial force at a critical stage of the assembly in which the seal could be dislodged from its adequate position as installed in the raceway. Furthermore, even if this initial risk is avoided, a sharp edge at the OD side of the chamfer has been found to increase assembly force. This is in contrast with the general objective of pipe makers to achieve joints that are easy to assemble with relatively low force.

The purpose of this paper is to explore design possibilities and propose what may be regarded as an optimal bevel design, in terms of minimizing the risk of dislodging the seal, minimizing assembly force, and minimizing the volume of material removed, while remaining as compliant as possible with existing standards.

Alternatives to the simple bevel described above already exist. They are documented mostly by ductile iron pipe manufacturers, although there are also practical examples from plastic pipe manufacturers. One simple approach is to specify rounds to break the edges of the bevel. Another approach is to shape the bevel as a quarter of an ellipse. These alternatives and their dimensional parameters are evaluated.

To avoid making unfair comparisons or referring to actual products, the bevel design exploration is performed on relevant standardized pipe thicknesses using generic socket and seal designs. However, for the purpose of validating the findings from Finite Element Method (FEM) simulations with results from physical testing, specific practical examples are shown (subject to authorization by the owners of this information), which the author has studied over the course of his career as a pipe joint design engineer.

Additional analysis and remarks address practical issues, such as cuts made in the field with power or hand tools and achieving a smooth profile with typical tooling already available at the manufacturing plants. This may encourage further discussion with participants at the presentation of the paper.

ID159

LIFECYCLE COST BENEFITS OF PVC-U PIPES IN EUROPE

Vincent Stone – Europe Council of Vinyl Manufacturers, Brussels, Belgium
Email: vincent.stone@plasticseurope.org
Alessandro Marangoni – Althesys Srl, Milano, Italy

Up to date lifecycle cost calculations across the whole lifecycle of the water and sewer pipe networks are critical to help the owners to make informed selection decisions on the pipe material. In order to help the European pipe network owners in such selection, lifecycle cost data comparing plastic vs. non plastic pipe materials have been regularly generated and updated since the late 2000's. These data have been generated using the Total Cost of Ownership (TCO) tool, an analysis meant to uncover all the lifetime costs that follow from owning certain kinds of assets.

In the first part of the presentation, the results of up-to-date TCO analyses comparing PVC to non-plastic pipe materials in Germany and Italy will be presented. These analyses consider the costs to purchase pipes, install, operate, maintain and dismantle the pipeline. Significant benefits have been evidenced for PVC in both the water and the sewer lines.

The TCO analyses have demonstrated that the recycling of plastic pipes after dismantling can be a significant lever to reduce the lifecycle costs. In the second part of the presentation, the cost benefits of PVC pipe recycling vs. other end of life scenarios (landfilling, incineration) have been estimated in monetary terms, using the Cost Benefit Analysis (CBA) methodology defined by the OECD, and applied on PVC pipes used in water and sewer networks in Germany and Italy. On one hand, the CBA considers the costs of recovering, separating and treating PVC pipes at their end of life. On the other hand, the study accounts for the pipe waste disposal savings, the value of the recovered pipe material, the carbon emission savings, the positive economic and employment fall-outs from the recycling business.

In line with the PPCA Comparison Principles, cost benefits will be highlighted only through comparisons between PVC-U and non-plastic pipes.

ID175

RE-ROUNDING OF DEFLECTED HIGH-DENSITY POLYETHYLENE PIPE

Kevin White – E. L. Robinson Engineering of Ohio, Grandview Heights, United States of America
E-mail: kwhite@elrobinson.com
Shad Sargand – Ohio University, Athens, United States of America

Re-rounding is a technique for remediating excess deflection in corrugated high-density polyethylene (HDPE) pipe meeting AASHTO M-294 with diameters between 12" and 60" using a pneumatic device vibrating from within the pipe and pushing against the inside crown and invert to redistribute the surrounding backfill and restore the original pipe shape. The process has not been evaluated on corrugated HDPE pipe outside of a few reports, and the method is routinely used by contractors to remediate deflected corrugated HDPE pipes. The researchers were contracted by Ohio Department of Transportation to evaluate the technology as a low cost, less disruptive alternative to removal and reinstallation of deflected pipes. Three 36 in corrugated HDPE pipes were installed in a well-graded crushed stone aggregate, sand, or AASHTO #57 open-graded aggregate (ODOT Structural Backfill, Type 1, 2, and 3, respectively), and two 18 in pipes were installed in Type 2 and 3 Structural Backfill. Pipes were intentionally installed using substandard installation techniques to ellicit substantial deflection (10% or more) and then re-rounded. The pipe conditions before and after re-rounding were measured and monitored by collecting profiles, measuring vertical deflections, monitoring soil pressures and soil accelerations, backfill characteristics, and depth of pipe corrugations.

ID121

UPDATED ENVIRONMENTAL PRODUCT DECLARATION FOR PVC AND PVCO PRESSURE PIPE AND PVC NONPRESSURE PIPE

Richard Nichols – Uni-Bell PVC Pipe Association, Irving, United States of America
E-mail: rnichols@uni-bell.org
Jay Parvez – Uni-Bell PVC Pipe Association, Irving, United States of America

This paper aims to inform users about the improved environmental impacts of PVC pipe reported in the new 2023 Environmental Product Declaration (EPD). The PVC pipe industry published a life cycle assessment (LCA) and environmental performance review of underground piping in North America conducted according to ISO 14040 series standards, which included the subsequent publication in 2015 of a PVC pipe EPD. The purpose of the LCA and EPD is to provide transparent information regarding the environmental impacts of products and allow end users to make informed decisions regarding what building materials they use. The EPD complied with ISO 14025 standards and was independently certified by the global health organization NSF International. The ISO methodology and requirements for LCA's are the most rigorous and transparent in the world. The EPD was updated in 2021-22 and shows an overall reduction of embodied energy and most other environmental impacts for PVC water and sewer pipe compared to the 2015 study, owing to improvements in PVC pipe manufacturing and upstream production of PVC resin. Also, the environmental impacts of gasketed PVCO pipe has been evaluated for the first time.

ID118

MICROWAVE INSPECTION DEVELOPMENT AND EVALUATION FOR SPOOLABLE REINFORCED THERMOPLASTIC PIPE

Chantz Denowh – ADV Integrity Inc., Magnolia, United States of America
E-mail: chantz.denowh@advintegrity.com
Bob Stakenborghs – Advanced Microwave Imaging, Baton Rouge, United States of America
Liang Yu – Baker Hughes Flexible Pipe Systems, Houston, United States of America

The use of spoolable reinforced thermoplastic pipe (RTP) technologies in the onshore oil and gas industry has expanded significantly over the past decade. It is anticipated that interest will only continue to grow as oil and gas operators transition to transporting alternative fuels such as hydrogen and carbon dioxide. Currently, these technologies have been limited to non-regulated lines such as gathering lines or produced water transport, but the need is growing to expand into the high-pressure transmission pipelines. These lines will typically be in the 4-inch to 8-inch size range and rated up to 3,000 psig. There are several gaps in knowledge to address though before making this step. One gap is the need for viable inspection technologies that pipeline operators can for long-term integrity management.

This study works to address this gap by progressing the multifrequency microwave technology and evaluating its accuracy against simulated defects that commonly occur to spoolable RTPs in the field. The phases of the study described in this paper include an initial calibration of the microwave technology to the pipe design, material types, and layer depths. Following calibration, an open inspection was completed on pipes with known defect location, size, and depth. This information was shared with the microwave vendor to improve sizing and location accuracy of equipment and software. Additional pipes with similar defects were then used for a closed inspection to evaluate the technology's ability to accurately locate and size unknown defects. The pipe used in this study was nominal 4-inch with a nominal pressure rating of 1,500 psig.

The last phase of the study included inspection of pipe samples with simulated damage that commonly occurs in the field. Examples of recreated damage include pipe ovalization, overbending (kinking), and over-tensioning. This damage was recreated in a laboratory setting. The damaged pipes were subjected to destructive testing following the inspection (test results not included in this paper). Results and findings from each of the above phases are described in this paper including an evaluation of the location and sizing accuracy. Inspection of the simulated damage is discussed and compared to results of the destructive testing where damage indicated the presence of damage in the pipe reinforcement.

ID216

INSIGHTS GAINED IN DEVELOPING ENVIRONMENTAL PRODUCT DECLARATIONS FOR PLASTIC PIPES IN AUSTRALIA

Matthew Hynes – Iplex Pty Limited, Sydney, Australia
Lucy Croker – Vinidex Pty Limited, Sydney, Australia
E-mail: matthew.hynes@iplexpipelines.com.au, lcroker@vinidex.com.au
Cindy Bray – Plastics Industry Pipe Association of Australia Limited, North Lakes, Australia

In Australia, the first Environmental Product Declaration (EPDs) covering plastic pipes were published circa 2015 /16 by two local manufacturers, supported by the peak industry association. Although this was a milestone event at the time, the reality was that the broader industry did not understand the information given in these EPDs including how to use or interpret them, resulting in their limited use.

There is now an increased focus on environmental impacts in the built environment. However, to maximise the benefits of EPDs users still require a more detailed understanding in order to interpret them correctly.

To assist in educating the broader industry, a project to develop credible educational material on how to correctly interpret EPDs for plastic pipes and other pipe materials was initiated. This included providing clearer context to the results of the EPDs to allow fair and transparent comparisons. The ReCiPe2016 life cycle impact assessment was also explored as a means to communicate a more holistic approach to identifying hotspots and trade-offs. Through the duration of the project, the two local manufacturers were also updating their EPDs.

Working simultaneously on these projects, led to several key learnings being identified. The work highlighted the critical importance of ensuring appropriate selection of datasets from the respective Life Cycle Assessment (LCA) databases. It also became apparent that there were differences between LCA databases which could potentially be misleading for product comparisons. As EPDs become more widespread, it would be desirable for pipe resin manufacturers product specific EPDs to replace the existing generic material data sets. Similarly, the future development of pipe specific Product Category Rules (PCR) will enable more representative comparisons. These refinements would provide significant benefits to the pipe industry and pipe users.

The installation module, A5, is an important part of pipe life cycle assessment. However, due to the number of variables, it is very difficult to define a 'typical' installation scenario that can be scaled across a product group. The influence of these variables is explored.

In Australia the need for manufacturer specific product EPDs is seen as one of the first steps on the journey toward 'Net Zero'. To date this has been mainly driven through ratings schemes from various sustainability infrastructure and built environment organisations and other stakeholders including large tier one construction companies. However, it is expected that the demand for rigorous scientific and transparent communication to support decision making about construction products will only increase as we move towards our goals. Collaboration between industry and other stakeholders is critical to ensuring EPDs support sustainable construction.

ID256

DESIGN OF HDPE WATER MAINS FOR THE LATERAL SPREAD SEISMIC HAZARD

Michael O'Rourke – Rensselaer Polytechnic Institute, Clifton Park United States of America
E-mail: orourm@rpi.edu

The required wall thickness for a fully fused HDPE water main subject to an earthquake induced lateral spread is addressed in this paper. The water main is assumed to be buried via cut and cover (i.e., open cut with typical burial depths in the 2 to 15 feet range) procedures and any laterals have small diameters and do not affect the overall seismic of the main. For the lateral spread hazard, the required wall thickness is a function of site information (burial depth and unit weight of the backfill soil), the acceptable pipe axial strain, and geometric characteristics of the hazard specifically the amount of ground movement δ and length of the lateral spread zone L.

Included in the paper are the relationships for calculation of the required pipe wall thickness as well as a flow chart for ease of use. The presentation will include an example of the application of the design tables as a case study. Recommendation for acceptable levels of pipe axial strain for this seismic hazard are provided along with procedures from others for estimation of both geometric parameters δ and L. Finally, the paper includes tables for the required wall thickness for common values of the governing variables. The tables show that even for large amounts of ground movement and poor burial conditions (heavy backfill and deep burial depth), the required wall thickness is met by currently available HDPE pipe diameter ratios. This is consistent with the excellent seismic performance of HDPE pipe in past earthquakes.

ID171

POLYPROPYLENE (PP) – A CARBON FOOTPRINT ASSESSMENT

Steve Sandstrum – Borealis Compounds, Port Murray, United States of America
E-mail: steven.sandstrum@borealisgroup.com
Chris Ziu – Nupi Americas, Inc., St Augustine, United States of America

Plastic pipe is an environmentally responsible choice for a broad array of piping applications. The exceptional chemical/corrosion resistance, superior joining techniques and overall durability of these piping products have resulted in industry-leading life-cycle analyses (LCA's) in the applications for which they are intended. In this paper we investigate one specific environmental aspect of plastic pipe, specifically the estimated comparative carbon footprint for polypropylene (PP) pipe.

A case study involving the installation of dual-wall, pre-insulated PP pipe at the University of Illinois in the Unites States was presented by the authors at Plastic Pipes XX in Amsterdam in 2021. The case study provided insights into a number of innovations that were associated with the University of Illinois hydronic heatng project. Included within these innovations were: a) dual-wall, pre-insulated PP pipe (250 mm DR 17 outer pipe/160 mm DR7.3 inner pipe), b) simultaneous dual-wall heat fusion of the PP pipe, and c) both direct burial and horizontally directionally drilled (HDD) installation techniques.

In this paper, the authors re-visit the same project from a different perspective, specifically from the viewpoint of the carbon footprint associated with this unique installation. As indicated in the original paper, the hydronic heating project at the University of Illinois was initially specified for steel pipe. This provides an opportunity to make a comparative carbon footrprint assessment for this project on the basis of the PP pipe that was installed versus the carbon steel pipe that was originally specified. While a detailed carbon footprint analysis of this project is beyond the scope of this writing, the authors will utilize industry accepted criteria and resources in constructing a reasonable comparative carbon footprint assessment. From an assessment such as this, the reader will gather an understanding of the intrinsic benefits of plastic pipe, specifically PP pipe, as a responsible approach from an engineering, environmental and social perspective based on a comparison to a more traditional piping material such as steel.

ID116

BUILDING PIPELINES THROUGH EMBANKMENTS TO LAST

Shawn R. Coombs – Advanced Drainage Systems Inc., York, United States of America
E-mail: shawn.coombs@adspipe.com

Pipelines through embankments should be designed to withstand everyday stressors and extreme weather-related events. As climate changes and extreme weather-related events are on the apparent rise, it is important to ensure proper design, construction, and inspection practices are understood and executed. This paper discusses the common stressors that act on pipelines through embankments such as internal and external hydrostatic pressure, seepage, scour, Ph, and backfill; and provides suggested design, construction, and inspection practices, that limits impacts of extreme events and everyday stressors on pipelines. A few of the suggested practices discuss are identifying hydrostatic forces, backfill selection and placement, proper pipe and joint selection, inspection practices during and after installation, and use of geotextiles.

The goal of this paper is to aid designers, contractors, and inspectors to understand common stressors, and strategies to improve the durability of pipelines as they are constructed through embankments.

ID246

NEW CRADLE-TO-GATE DATA FOR THE PRODUCTION OF FOSSIL PVC IN EUROPE

Vincent Stone – Europe Council of Vinyl Manufacturers, Brussels, Belgium
Email: vincent.stone@plasticseurope.org

Plastic pipes can be responsible for many environmental impacts at different stages in the pipe life cycle (product stage, construction stage, use stage, end of use stage). Comparison of the environmental impacts derived from ISO 1404X-compliant lifecycle analyses and summarised in environmental product declarations, increasingly becomes a key selection criterion for the pipe material by the network owners.

The production of the plastic resin is one of the principal contributors to the lifecycle environmental impacts of a plastic pipe. For the climate impact, up to two-third of the carbon footprint of a plastic pipe can be accounted to the plastic resin. Accurate cradle-to-grave lifecycle analyses for plastic pipes heavily relies on accurate cradle-to-gate data for the production of the plastic resin used. Cradle-to-gate is a partial product life cycle assessment from resource extraction (cradle) to the gate factory of the resin manufacturer, i.e., before the resin is transported to the compounder or the pipe manufacturer. Industry averaged cradle-to-gate assessments of the major plastic resins manufactured in Europe are regularly updated for PlasticsEurope by third party consultants. The results of these analyses are summarized in publicly available eco- profiles.

This presentation will review the main results of the updated eco-profile for the manufacture of suspension PVC (sPVC) and its monomer VCM in Europe, using new cradle-to-gate data available for chlorine and ethylene and new data from the VCM and sPVC plants of the members of the European Council of Vinyl Manufacturers (85% of the PVC production in Europe).

Thanks to new energy mixes developed in many European countries and a complete switch to the membrane electrolysis process, the environmental impacts of the production of chlorine could dramatically be reduced in Europe during the last decade. The climate impact in 2020 could be reduced by 22.3 % vs. the previous data available (2011). Thanks to the high chlorine content in PVC (57%), these improvements automatically reduce the environmental impacts for PVC.

ID177

ABSTRACTS
POSTER PAPERS

SUN LIGHT AND HEATING AGING OF PE-XA PIPES AND PROTECTION

Yunyan Li – Hongyue Plastic Group Co., Qinhuangdao, China
E-mail: tianjin02@163.com
Qianshi Ma – Hongyue Plastic Group Co., Qinhuangdao, China
Haihua Yu – Hongyue Plastic Group Co., Qinhuangdao, China

Effect of sunlight and high temperature on PE-Xa pipe's performance was investigated in this work. Pipes with different formulations, including formulations without and only with antioxidant, and formulation with both antioxidant and light stabilizer were employed to study the relationship of cross-linking density, tensile strength, hydrostatic strength with exposure time.

The results showed that the cross-linking density for all formulations decreased with exposure time and especially, the most severely for pipes without antioxidants or light stabilizer. The cross-linking density of pipe without and with only antioxidant is much lower than 70% after exposure for 90 days and 140 days respectively. However, for pipes with both antioxidant and light stabilizer, the cross-linking density is still higher than 70%, even after being exposed for 500 days. Further, for pipes without and with only antioxidant, the tensile strength increases at the initial stage and decreases later. Specifically, for pipe without antioxidant, the tensile strength approach to a maximum of 23.2 MPa after being exposed for 98 days and decreased to nearly 0 MPa after 370 days. For pipe with only antioxidant, the tensile strength increases to 23.5 MPa after being exposed for 140 days and decreased to 0 MPa after 427 days. However, for pipes with both antioxidant and light stabilizer, the tensile strength is just fluctuating within a small range and keeps to be 18.2 MPa after 500 days. And also, the results showed, exposure may lead to a poor tough and hydrostatic strength, that is, pipe without and with only antioxidants and pipe with both antioxidant and light stabilizer, all failed when taking the 95°C/22hours hydrostatic sustained pressure testing, after being exposed for 35,112 and 370 days respectively.

Performance of pipes with antioxidant and pipe with both antioxidant and light stabilizer that have been properly stored for 500 days is not much different with that before the experiment. Proper protection can ensure the performance and service life of pipes with reasonable and high-quality formulations. However, the performance of pipes without antioxidants is still slightly degraded after 500 days of storage, indicating that the poor or unqualified formulations can not stand the test of time even if they are properly stored.

ID134

POSTER PAPER

APPLICATION OF PE-RT II PREFABRICATED INSULATION PLASTIC PIPE IN HEATING ENGINEERING

Haihua Yu – Hongyue Plastic Group Co., Qinhuangdao, China
E-mail: yuhaihnao0703@163.com
Qianshi Ma – Hongyue Plastic Group Co., Qinhuangdao, China
Zhong Yi – Hongyue Plastic Group Co., Qinhuangdao, China

The residential district adopts central heating for low temperature radiators system. Due to the disrepair of the secondary heating pipe network that pipe from heat exchange station to user entrance, the running, leaking, dripping and leakage are serious, and the accidents occur frequently. The heat transmission efficiency is low and the energy consumption is large. From the beginning of heating water injection, the maximum daily maintenance increases up to 28 times, the water loss of pipe network increases up to 17T/h, the maintenance cost approaches to 45,000 CNY/year while the water loss cost is 135,000 CNY/year. To ensure normal heating for residents, the heat company raised the mixed water temperature of the heat exchange station by 5℃, but the indoor heating temperature of residents could only be kept at 15℃.

Compared with steel pipe, pre-insulated plastic pipe with PE-RT type II pipes has the characteristics of long service life (≥50 years), lower weight, better thermal insulation performance, small hydraulic loss, simple laying and easy bending. A typical case is just as the thermal company. By comparing various pipes, they finally choice of SDR11 PE-RT type II plastic pipes as the secondary heating pipe network of the residential district for centralized transformation. After renovation, the operating temperature is 60℃ and 40℃, PD 6 bar. The average indoor heating temperature of residents was 20℃~24℃. Up to now, after a five-heating period operation monitoring.

No complains occurs for the heating system network which has good operation effects. According to the operation data of the residential district in past five years, the total cost of water and labor is saved at least 850,000 CNY, including 340,000 tons of water saving and over 200,000 CNY of maintenance cost saving.

ID136

ENHANCING RECYCLED MATERIALS THROUGH COMPATIBILIZATION TECHNOLOGIES TO ENABLE HIGH PERFORMANCE

Jie Wu – DOW, Lake Jackson, United States of America
E-mail: jwu19@dow.com
Yushan Hu – DOW, Lake Jackson, United States of America
Todd Hogan – DOW, Lake Jackson, United States of America

Recycling of plastic materials is key to demonstrating that these high value materials are much more than a waste stream and a key component of a sustainable future. The plastic pipe market effectively utilizes in-plant recycle systems where standards and codes allow to recapture the value of these high-performance plastics. Market segments such as corrugated pipe have extended the use of recycle to include post-consumer recycled (PCR) materials generated from collecting and reclaiming single use packaging.

One limitation of the use of PCR in high performance applications such as plastic pipe is that the materials collected are mixtures of incompatible polymer materials. Two common PCR streams include polyethylene (PE) mixed with polypropylene (PP) or ethylene vinyl alcohol (EVOH). These polymers are immiscible and incompatible so that their blends typically exhibit poor properties. In this work, various non-reactive ethylene-based and propylene-based polyolefin elastomers were evaluated to compatibilize PE/PP blends. The effect of compatibilizer type and loading level on the mechanical properties of polymer blends, such as impact strength, tensile, and flexural modulus were examined. Blend morphology was also analyzed with atomic force microscopy to establish structure and property relationships. The results showed that ethylene-based elastomers were more effective compatibilizers than propylene-based elastomers in improving stiffness and toughness balance of PE rich mixtures with PP. For the compatibilization of PE/EVOH mixture, the reactive maleic anhydride (MAH)-functionalized polyolefin resins were used. It was found that the mechanical properties of PE/EVOH blends, such as impact strength were significantly increased with the incorporation of MAH functionalized resins as a result of compatibilization. These studies suggest that the use of compatibilizers could transform mixed PCR into more valuable materials suitable for the appropriate plastic pipe applications.

ID170

POSTER PAPER

USING SYNTHETIC APERTURE FOCUSED MICROWAVE NDT DATA TO CREATE A 3D RENDERED IMAGE OF AN HDPE ELECTRO FUSION JOINT TO SIMPLIFY ACCEPT/REJECT CRITERIA

Robert Stakenborghs – Advanced Microwave Imaging, Baton Rouge, United States
E-mail: rjstak@advancedmwimaging.com

The use of microwave inspection techniques on many composite materials has been available for some time. This method has been shown to be successful in assessing the quality of HDPE electro-fusions (from 4" to 24" have been field inspected) and because of its capability to assess the entire joint above and below the fusion wire plane, it is considerably simpler and easier to use than other methods including ultrasound techniques. Recently, the use of a multi-frequency interrogating approach has been introduced to the industry and its use has been shown to further simplify the inspection technique and allow for greater accuracy in detecting the most common errors in the HDPE electro-fused joints. This innovative technique is further enhanced by using a Synthetic Aperture radar focusing technique coupled with a 3D render og the entire joint. This approach is used in this paper and allows for rapid assessment of joint quality by showing areas of poor fusion in the two fusion zones as well as the pipe gap distance in one 3D image. The paper will demonstrate the technique on several 4" samples and provide examples of determining an effective accept/reject criterion for a set of HDPE electro-fused joints.

ID172

VINYLPLUS 2030 COMMITMENTS FOR PVC PIPES

Vincent Stone – VinylPlus aisbl, Belgium, Brussels
E-mail: vincent.stone@vinylplus.eu

VinylPlus 2030 is the 10-year voluntary Commitment of the European PVC industry to Sustainable Development launched in June 2021. With its renewed Commitment, VinylPlus aims to contribute proactively to addressing the global sustainability challenges and priorities. Building upon a track record of 20+ years of progress and achievements, the European PVC value chain has set a series of new commitments developed through open dialogue with stakeholders, identifying key challenges for PVC on the basis of The Natural Step System Conditions for a Sustainable Society.

VinylPlus 2030 aims to contribute to the United Nations 2030 Agenda for Sustainable Development, with a particular focus on sustainable consumption and production, climate change and partnerships. It also seeks to align with the set of EU policies of the EU Green Deal which aims to set the EU on the path to a green transition, with the ultimate goal of reaching climate neutrality by 2050. A main building block of the EU Green Deal is the Circular Economy Action Plan (CEAP), a set of initiatives to promote circular economy processes across the entire life cycle of products. The CEAP targets how products are designed, encourages sustainable consumption, and aims to ensure that waste is prevented and the resources used are kept in the EU economy for as long as possible. In line with the CEAP, the European plastic industry has launched with the support of the EU Commission, the Circular Plastics Alliance (CPA) to boost the EU market for recycled plastics to 10 million tonnes by 2025.

VinylPlus 2030 identifies three sustainability pathways: scaling up the circularity of the PVC value chain to contribute to the commitments of the CPA; advancing towards carbon neutrality and minimizing our environmental footprint; and building global coalitions and partnering for the SDGs. The three pathways are further broken down into twelve action areas and 39 timed and measurable targets and that outline concrete steps to be taken by the European PVC industry for the sustainable development of PVC. This poster will review the targets and current achievements directly related to PVC pipes.

ID178

POSTER PAPER

MEETING THE EUROPEAN NORDIC QUALITY REQUIREMENTS FOR PVC PIPES WITH RECYCLED MATERIAL

Tobias Johnsen – PVC Information Council, Silkeborg, Denmark
E-mail: info@wuppi.dk

The European Nordic region has very high quality requirements for plastic piping systems. Sweden, Norway, Denmark and Finland introduced the voluntary Nordic Poly Mark in 2005. To obtain the mark, pipe producers must meet the requirements of the Specific Rules for Certification (SBC) for each product. The SBC is set by INSTA-CERT, a Nordic group of certification bodies. The SBC specifies requirements for products and inspections. While they are based on existing European product standards or specifications, they are in many cases stricter than the original product standard or specifications. To ensure the highest possible quality, INSTA-CERT SBCs only allow virgin material or own reprocessed material. A major deviation from the European standards is testing of impact resistance at -10 °C instead to mimic the often cold weather that the pipes must be able to withstand when installed.

In order to accelerate the circular plastic pipe economy in the Nordics, a partnership between a PVC collection system, a PVC pipe producer and a utility company was established in Denmark. The aim was to test whether a PVC-U sewer pipe with recycled content could meet the strict quality requirements of INSTA-CERT, thus paving the way for introducing recycled PVC in pipes for the Nordic market.

First, PVC pipe waste was collected among local sewage installation companies. After collection the waste was reprocessed by the pipe producer, which already today reprocesses and uses its own scrap. A sample was sent to the Danish Technological Institute for testing of lead. No lead was detected, which was crucial, as lead-stabilised PVC products cannot be certified by the INSTA-CERT system and the Danish Statutory Order on Lead since 2002 prohibits products with a lead-content above 0.01%.

The reprocessed PVC was then co-extruded with virgin PVC to create a batch of OD 200 mm sewer pipes with three solid layers. The core layer was made from recycled PVC, covered by virgin PVC on the inside and outside. To make clear that the pipes contain recycled PVC, the pipes were marked rPVC and the inner core coloured black.

The pipes were tested according to INSTA-CERT SBC EN 13476, which builds on the European standard EN 13476. For pipes with OD between 200.0 and 200.5 mm, the SBC prescribes minimum 1.0 mm wall thickness for the inner layer, minimum 0.6 mm for the outer layer and minimum 5.9 mm in total. Tests confirmed that the rPVC pipes perform as well as pipes made from 100% virgin PVC. EPD calculations show a 50% reduction in CO2 emissions compared to pipes made from virgin PVC.

The pipes are now ready for installation, and will be put in the ground at a new development in Lemvig, Denmark in 2023 and connected to the sewer system. Monitoring will be set in place to test the pipes' actual performance.

As the first of its kind in the Nordics, the project demonstrates it is possible to meet the region's very high quality requirements for plastic piping systems with recycled PVC. Potentially, the use of recycled PVC in new pipes can lead to reduced carbon emissions and demand for virgin material, as well as enabling the Nordic plastic pipe industry to contribute to EU's recycling targets.

ID192

PLASTIC PIPES FOR SAFE AND RELIABLE TRANSPORTATION OF CHEMICALS

Karin Jacobson – PDS Consulting AB, Nacka, Sweden
E-mail: karin.jacobson@pdsc.se
Daniel Ejdeholm – GPA Flowsystem AB, Stockholm, Sweden

Plastic pipes often have much better corrosion resistance than metallic pipes and have, in addition, the benefits of low weight and flexibility. Thanks to this, they are often used to convey chemicals. There is, however, still a large potential for a much more extensive use of plastic pipes for this application. The lack of data and long-term effects of chemicals on plastic pipes are often missing and some is out-dated. Many installations are thus full-scale experiments. The fact that many of these installations are very successful should be used to make new installations more fact-based. Analysing the pipes after successful long-term use of chemical transportation to draw conclusions about their behaviour could be done much more often than what is found today. These results could then, when applicable, be used to up-date safety factors and recommendations. It is also important that, in case of failures, these are investigated to determine if they are due to a limitation based on intrinsic properties of the material, or due to other factors such as welding or poor installation

The most commonly used plastic pipe material for conveying chemicals are PVC-U, PVC-C, Polyethylene, Polypropylene, Fluoroplastic and Fibre Reinforced Vinyl Esters (GRP). Even if these materials often show very good chemical resistance and often complement each other in suitability in different types of media, a negative impact on the service life might occur. It important to understand what the underlying mechanism to this loss is due to. In chemical resistance tables it is most often only given a very general description if the material is compatible or not with the media. It might be that even a material very good chemical resistance could be unsuitable in an application if diffusion through it can cause problems. And, on the other hand, a media – polymer combination that is listed as unsuitable, might be the best cost-performance option in some cases, as long as the limitations are known and controlled.

The aim of this paper is to describe and discuss the considerations that must be made when using plastic pipes for conveying chemicals. In addition, the knowledge gaps to fill for taking advantage of the large potential for a much more extensive use of plastic pipes for safe and reliable transportation of chemicals are pointed out.

ID195

POSTER PAPER

EFFECTS OF POLYMER DESIGN PARAMETERS ON THE SLOW CRACK GROWTH RESISTANCE BASED ON CRACKED ROUND BAR TEST

Eunjin Park – Hanwha Total Energies Petrochemical, Seosan-Si, Republic of Korea
E-mail: ej.park@htpchem.com
JaeHyuck Han – Hanwha Total Energies Petrochemical, Seosan-Si, Republic of Korea

This study investigates the influence of various parameters on polymer design to determine the slow crack growth. HDPE (High Density Polyethylene) materials with different molecular weight distribution and different comonomer types, comonomer content and comonomer distribution for PE100-RC pipe were investigated with cracked round bar test. The cracked round bar test provides accelerated slow crack growth of HDPE materials for pipe within less than a week at 23°C, thus predicting long-term slow crack growth behavior of PE100-RC pipes. To evaluate the correlation between polymer design and slow crack growth, conditions of polymer design parameters were controlled. And, the suitability of the cracked round bar test was evaluated through comparison with the results of other slow crack growth test methods, Full Notch Creep Test(FNCT) and Strain Hardening Test(SHT). In addition, among the various polymer design parameters that affect the slow crack growth test results, the factors that affect the cracked round bar test results more sensitively were identified. Results show that the certain correlation between the polymer design parameters and slow crack growth property by cracked round bar test.

ID203

POSTER PAPER

DEVELOPMENT OF AN ACCELERATED POINT LOAD TEST FOR THE EVALUATION OF PIPES MADE OF PE 100-RC

Ernst van der Stok – Kiwa Technology, Apeldoorn, The Netherlands
E-mail: ernst.van.der.stok@kiwa.com
Mirko Wenzel – SKZ – KFE, Würzburg, Germany
Thomas Kratochvilla– TGM Kunststofftechnik, Vienna, Austria
Kurt Engelsing– SKZ – KFE, Würzburg, Germany
Werner Weßing– Office for Green Gas, Krefeld, Germany
Britta Gerets – SKZ – KFE, Würzburg, Germany

Up to now it was not possible to derive an accelerated procedure for the point load test (PLT) as a pipe test. Further research and testing were therefore necessary to establish appropriate requirements for EN 1555-1:2021, among others. This is necessary in order to rule out uncertainty in the market. The PLT is a central product test for the user. The damage mechanism occurring in this test is close to real damage patterns from practice. Therefore, there is a need for a reproducible and accelerated PLT as an application-related component test for the qualification of pipes made of PE 100-RC.

This paper describes the work of three research laboratories to develop such an accelerated point load test. It will explain that the results of the conventional, non-accelerating point load test with Arkopal® N100 at 80 °C and 4 MPa show small scatter within each laboratory. Proposals to minimize the scatter have been drafted and incorporated in the latest version of the ISO test standard (ISO/CD 22102:2020).

Tests carried out with alternative detergents at 90 °C and 4 MPa on two PE 100 grades showed either a failure outside the point load range or no acceleration compared to Arkopal® N100. The point load test is intended to simulate a rock pressing into a pipe. Failure at the point load is therefore required, to ensure that the correct failure mechanism was investigated. Therefore, additional tests were carried out at 80 °C and 4 MPa, which led to failure in the point load range for at least one chosen detergent (Disponil® LDBS 25).

Despite the work of the three research laboratories, the failure behavior in the point load test proves to be very complex. Further research activities could address the choice of detergent, especially in the context of availability problem concerning Arkopal® N100, and/or how to force the failure to appear in the point load range.

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