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CURRENT LIST OF ACCEPTED ABSTRACTS

ABSTRACTS

FOR ORAL PRESENTATIONS

ID108

BENDING & DEFLECTION LIMITS OF PE PIPE – EXISTING & PROPOSED

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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.

ID112

RHEOLOGICAL CHARACTERIZATION AND FLOW MODELING OF SAG IN HDPE PRESSURE PIPE

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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).

ID113

ASTM F17 – FIFTY YEARS OF PLASTICS PIPING PROGRESS

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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).

ID116

POLYPROPYLENE (PP) – A CARBON FOOTPRINT ASSESSMENT

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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.

ID117

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

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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.

ID121

RE-ROUNDING OF DEFLECTED HIGH-DENSITY POLYETHYLENE PIPE

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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.

SAFEGUARDING OUR WATER: NSF/ANSI/CAN 61

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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.

ID123

3D PRINTING OF FLOW PROFILES FOR INSPECTION CHAMBERS AND MANHOLES

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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.

ID126

PUBLISHED HYDROGEN PERMEATION STUDY ON 4 DIFFERENT TYPES OF PE PIPES

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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.

ID129

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

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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.

ID132

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

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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 180ºC is enough to achieve a class MRS250 and a moderate increase (+5ºC or +10ºC) of the extrusion temperature leads to a smooth decrease in the slope of the regression curve at 20ºC and, therefore, to an increase of the predicted LPL100y values. Higher processing temperatures (≥195ºC) 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.

ID133

CRITICAL QUALITY CONTROL OF POST CONSUMER RECYCLED PVC

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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.

ID137

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

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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.

ID139

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

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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.

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

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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.

ID146

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

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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.

ID148

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

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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.

ID151

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

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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.

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

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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.

ID153

A HOLISTIC ENVIRONMENTAL FOOTPRINT ASSESSMENT OF THE EUROPEAN PLASTIC PIPE BUSINESS

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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.

"IF" (INTERFERENCE) – SCREW TECHNOLOGY

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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.

ID157

RECYCLED PE BLENDS FOR CORRUGATED PIPES: EFFECT OF PROCESSING PARAMETERS AND ADDITIVES ON THERMO-MECHANICAL PROPERTIES, DEGRADATION, AND CRACK PROPAGATION

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The consumption of polymers has risen all over the world, it will reach 417 million ton annually by the 2030 [1]. In Canada, it's growing at a rate of 8.4 % each year [2]. The total sales of plastics are estimated at CA$35 billion between plastic resins and product manufactured with plastic. The management of Plastic Solid Waste (PSW) is a global challenge, countries and industries must consider end of life of any product. To do so, a new economical model aimed at valorizing post-consumed plastic and consequently avoiding landfill disposal, promoting recycling, and favouring the transition toward a circular economy [3]. Mechanical recycling is the most known and easiest way to recover used plastics. It's suitable for contaminated plastic to be reused to manufacture new products. It includes several steps from sorting to pelletizing post-consumer plastic [4].

In pipe industry, recycled PE blends can be used to manufacture corrugated pipes provided that ultraviolet (UV) resistance is improved. Accordingly, additives such as carbon black (CB) are well known for that purpose [5].

This study emphasis on the effect of CB ratio and extrusion parameters (RPM and torque) on thermomechanical properties and CB dispersion in recycled PE matrix based on HDPE, HMW and LDPE. Tensile properties, Oxidative Induction Time (OIT), Notched Crack Ligament Stress (NCLS), Environmental stress Crack Resistance (ESCR) and Scanning Electronic Microscopy (SEM) of all blends are assessed and discussed.

MICROPLASTICS AND PLASTIC PIPES

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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.

ID159

SIMULATION DRIVEN OPTIMIZATION OF SPIGOT BEVELS

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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.

ID161

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

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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.

ID163

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

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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)[1]. 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" [2].

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[3], 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[4]. 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.

ID164

CLOSING THE LOOP FOR PE-X PIPE IN PRACTICE THROUGH ADVANCED RECYCLING

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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.

ID165

DESIGN METHODS AND ACTUAL PERFORMANCE OF LARGE DIAMETER STRUCTURED WALL PIPES

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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.

ID166

THE RECYCLING COMMITMENT OF THE EUROPEAN PLASTIC PIPE INDUSTRY

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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.

ID168

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

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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.

ID171

DESIGN OF HDPE WATER MAINS FOR THE LATERAL SPREAD SEISMIC HAZARD

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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.

ID175

LIFECYCLE COST BENEFITS OF PVC-U PIPES IN EUROPE

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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.

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

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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.

ID179

BOOSTING THE FOOD SECURITY OF "THE FUTURE OF THE EGYPT" BY ENGINEERING ADVANTAGES OF LARGE DIAMETER PE100 PIPES

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The Egyptian government started to implement a megaproject to cultivate over 1 million acres, in a move aimed to boost food security in the Arab world's most populous country. These projects will need thousands of meters from 200 mm to 2700 mm to irrigate the newly developed lands.

Wastewater treatment facilities will be constructed to completement the current water resources, including the Nile River and ground water. The wastewater treatment facility will produce 6 million m3 water per day. The proposed water networks will utilize 2,700 mm and 2,500 mm with SDRs 26, 33 and 41 solid wall pipes. These pipes will be replacing the previously used open trench method of water transportation leading to significant water saving and supporting in addressing the following UN sustainability goals; 2 – Zero Hunger, 6 – Clean water and sanitation, 11 – sustainable cities and communities and 12 – responsible consumption and production.

The production of PE100 pressure pipes at this size and scale has never been attempted before in the African Continent. It is a testament to the success of PE100 pipes in key Egyptian projects that Contractors, Consultants and Project owners have taken on the deployment of large diameter PE100 pipes for such important projects.

The production of large diameter pipes is to achieve a pipe with uniform wall thickness distribution; the main challenge during production is sagging of the material that takes place around the circumference of the pipe, leading to pipes with dimensions outside the required standards.

There is also a challenge in handling, Installation and jointing of such large diameter pipe as the average weight of 12-meter pipe with OD 2500 mm and SDR 33 is around 7 Tons.

Alamal Alsharif, a leading pipe manufacturer in Egypt, has installed one of the world's largest solid wall pipe extrusion lines to produce the required pipes. Extrusion, sagging and butt fusion welding challenges of these large diameter thick wall pipes are addressed using Borouge's extra low sag BorSafe™ HE3490-ELS-H material.

This will be the first deployment of PE100 pipes above 1,600 mm in the African market and it will lead to further substitution of conventional pipe systems with PE100 pipes in projects to come in this ever grooving region. The success story of this prestigious project of large diameter PE100 pipeline will help consultants, contractors, and end users to shift from conventional materials to polyethylene solutions as a material of choice for the future mega and prestigious projects in North African and Arab countries.

ID180

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

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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

ID181

INNOVATIVE APPROACH TO MEASURE LAYER TRANSITIONS OF CORRUGATED PIPES

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Currently, there is no suitable equipment available to measure important parameters during corrugated pipe production. Manufacturers are limited in their ability to save scrap and increase quality. There are two crucial phases during the production of corrugated pipes. In the beginning of manufacturing, it must be ensured that the different layers of the pipes are concentric. This evaluation can take several minutes, even hours, where only scrap is produced. After the startup phase, the products must be evaluated in order to comply with predefined specifications at a certain line speed. In both cases, the measurement of corrugated pipes is an ambitious task, because of the outer pipe contour.

For corrugated pipe manufacturing, an innovative approach to quality control by using penetrative recording systems in order to measure the transitions of the individual layers of the pipe has been developed. Based on the detected layer transitions, radii, layer thicknesses and center positions of corrugated pipes can be determined. Therefore, this approach provides a desired solution for the plastics market to support pipe manufacturers to produce high-quality products with most efficiency.

In this paper, the innovative technological approach how to measure corrugated pipes by outlining the functional principle and giving real measuring examples is introduced.

ID186

UV STABILIZATION OF PP USED FOR COMPRESSION FITTINGS AND CLAMPING SADDLES

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Compression fittings and branching saddles manufactured from PP-B are one of the most used fittings in Irrigation projects and water transportation. PP is a thermoplastic material made from propylene monomer that is durable, rigid and semi crystalline. Because of the presence of tertiary carbon atom in the structure of PP it is less resistant to photo-oxidation and photo-degradation compared to PE[1]. Because of chain session originated form photo-oxidation the mechanical properties of PP materials would be suppressed in outdoor applications[2].

Unfortunately, there is no weathering test for the material in the international norms ISO 17885[3] and ISO 13460[4] used for compression fittings and branching saddles production. Since these fittings are mostly used in outdoor applications, the manufacturers normally use carbon black MB with or without UV MB having PP carrier in combination with PP-B natural grade to produce these types of fittings. The question is, if this would be enough to protect the PP-B material from photo-degradation or it need more advance stabilization.

In this paper different scenarios of production and mixing of CB MB and UV MB were tried. In each case the 1500 hours UV weathering test applied and tensile properties in 0, 600 and 1500 hours inspected and reported. Further, the FTIR test was utilized to identify the carbonyl group, while the crystalline structure of the samples was evaluated using the DSC test. Finally, in the last part of the project a solution was offered and communicated with upper value chain and successfully developed a new material grade for this application.

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

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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.

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

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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) [1]. 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 [2]:

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) [3]. 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.

ID199

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

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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.

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

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"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."

ID207

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

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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 bimodal 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.

ID212

FOLLOWING SLOW CRACK GROWTH IN POLYETHYLENE PIPES USING PAUT

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For polyethylene pipes, slow crack growth is considered to be a major failure mechanism for the technical lifetime. In 2016, at the Plastic Pipes conference in Berlin, the possibility of detecting slow crack growth non-destructively using Phased Array Ultrasonic Testing (PAUT) was presented by Gueugnaut et al.[1] Based on this, Kiwa Technology is testing the possibility of following the development of a crack within a pipe when performing tests that accelerate slow crack growth. The objective is to both get better insight in the process of slow crack growth initiation and development over time, and the possibility of following this process using PAUT. Furthermore, these tests should help to improve the ability to measure cracks in existing polyethylene pipes.

Purpose of this project is to advance towards non-destructive quality monitoring and assessment of PE piping systems. Current practice for assessing the remaining quality of polyethylene pipes that are in use is limited to taking out samples and perform destructive tests measuring the resistance to slow crack growth, e.g. using hydrostatic pressure tests. A major problem with destructive testing is to remove enough samples to get representative results. Therefore, a non-destructive system that is able to detect starting cracks is preferable. It is possible to detect cracks using PAUT, however, detection and proper sizing is dependent on sizes and orientations of the crack surfaces. In order to interpret results properly, better knowledge about the crack growth pattern is needed. Also, development and better understanding of the possibilities and limitations of the PAUT technique with respect to crack detection is valuable.

In this research accelerated slow crack growth pipe tests like the Point Load Test (PLT) and the Accelerated Notch Pipe Test (ANPT) are used to follow crack initiation and growth using PAUT. These tests have the advantage that cracks are similar to real life cracks and the approximate location where they will initiate is known. First tests have been performed using the point load test on used first generation HDPE 50 pipes, because of their known susceptibility to SCG and hence short failure times in accelerated tests. By performing these tests, the PAUT measurement itself is developed as well, showing the possibilities and limitations of detecting and accurately measuring the crack size. A next step is to perform measurements with other types of PE and other types of accelerated tests like the ANPT or plane hydrostatic pressure testing.

ID213

INNOVATING FOR SUSTAINABILITY ENHANCEMENTS IN POLYETHYLENE BASED MICROIRRIGATION PRODUCTS

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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.

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

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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.

ID216

MICROWAVE INSPECTION DEVELOPMENT AND EVALUATION FOR SPOOLABLE REINFORCED THERMOPLASTIC PIPE

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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.

ID217

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

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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.

ID219

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

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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 [1]. 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 [2], because it is very toxic to aquatic life with long lasting effects and endocrine disrupting [3]. 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.

PLASTIC PIPES XXI

LAKE BUENA VISTA FL. USA

ID220

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

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Plastics are one of the most demanded materials by industries around the world, resulting in the production of large volumes of plastic waste[1]. 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[2]. 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[3]. 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[4]. 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[5]. 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.

ID221

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

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In Europe, only 1.8 million tons of recycled material is processed in new products within the building and construction sector[1]. 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[2]. 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[3]. 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[4]. 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.

DETERMINING THE QUALITY OF OLD AND NEW PE PIPES USING THE CPENT

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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[1]. 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[2]. 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[3, 4].

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[5].

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

ID227

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

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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.

ID228

MYRIAD OF CHOICES FOR BURIED PIPE INSTALLATION

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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.

ID232

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

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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.

ID233

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

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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.[1]
- 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[2]

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

ID237

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

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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.

ID240

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

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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.

ID241

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

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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.

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

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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.

ID243

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

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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.

ID244

FIELD AND FEM PERFORMANCE OF AGRICULTURAL MAINS

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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.

ID245

LEVERAGING DATA INSIGHTS TO IMPROVE SAFETY, QUALITY AND ROI

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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.

ID246

BUILDING PIPELINES THROUGH EMBANKMENTS TO LAST

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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.

ID249

2.7 METERS AND GROWING

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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.

ID251

SUSTAINABILITY & THE RETURN OF THE PRR GASKET

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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.

ID252

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

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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.

ID253

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

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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 [1]. 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 [2, 3], 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 [3]. 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 [4] 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.

ID255

ACCEPTANCE CRITERIA FOR DEFECTS IN WELDED ASSEMBLIES, COUPLING PHASED ARRAY ULTRASONIC TESTING AND DESTRUCTIVE TESTS

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As a promising reference technique for non-destructive evaluation of both electrowelded and butt-fused assemblies, Phased Array Ultrasonic Testing (PAUT) is still studied extensively in several laboratories worldwide and is supported by the draft standard ISO DTR 16943 (Wermelinger et al. in Plastic Pipes Conference PPXX). During the last ten years, several joint projects have been completed aiming at evaluating the acuity of PAUT applied to both pipes and electrofused assemblies either exhumed from the field or prepared in laboratory (Seonghee et al. in Plastic Pipes Conference XVII; Hagglund et al. in 11th European Conference in Non-Destructive Testing; Gueugnaut et al. in Plastic Pipes conferences XVI/XVII/XVIII/XIX). More recently, a focus has been made on fixing some acceptance criteria combining PAUT data and long term resistance of the laboratory joints (Troughton et al. in Plastic Pipes XVIII; Postma et al. in Plastic Pipes XVIII). This paper presents the updated data obtained on electrofused assemblies – 63 mm saddles and 110 mm sockets – containing different types of defects such as: insufficient heating time, pipe under-penetration in the socket, excessive loaclized scraping, pollutants and calibrated thin strips, in both mass and cross configuration, put at the interface pipe-saddle. PAUT scanning on the different specimens, both during the welding phase and after cooling, confirms the capability of the technique to visualize and size the Heat Affected Zone (HAZ), which can be revealed and compared afterwards on sample sections. Moreover, most of the defects are detected and sized, confirming the fairly good Probability of Detection (POD) of PAUT, except for the smallest strips which are located in non accessible zones, due to the particular design of the saddle. Long term resistance of the welds is then evaluated by Hydrostatic Pressure Tests (HPT) followed by a decohesion test after rupture, according to the requirements of both the ISO 13956 and NF EN 1555 standards. Under such test conditions, every joints comply with the requirements of the standards (rupture time greater than 1,000 hours at 80 °C and 5 MPa), even those violating the critical proportions of non-welded zones.

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

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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.

ID258

PVC-O DN1200 (48”): THE MOST SUSTAINABLE SOLUTION FOR TRANSPORTING WATER UNDER PRESSURE UP TO 25 BAR (305 PSI) OF PRESSURE

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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.

APPLICATION FOR GEOLOCATING WATER NETWORKS

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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.

ID261

HOW TO CONTROL CRACKS IN PIPES TO GUARANTEE A SAFE OPERATION

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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 [1]. Additionally, a much-neglected topic is residual stress in the pipe as well [2]. 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 [3].

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

ID262

SAND-BOX TESTING FOR STRUCTURAL ASSESSMENT OF PLASTIC MANHOLES

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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.

ID263

PERFORMANCE EVALUATION OF SUSTAINABLE POLYPROPYLENE BLENDS FOR CORRUGATED DRAINAGE PIPE APPLICATIONS

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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.

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

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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.

ABSTRACTS
FOR POSTER PRESENTATIONS

ID134

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

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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.

ID136

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

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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.

ID170

ENHANCING RECYCLED MATERIALS THROUGH COMPATIBILIZATION TECHNOLOGIES TO ENABLE HIGH PERFORMANCE

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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.[1, 2, 3]

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.

ID178

VINYLPLUS 2030 COMMITMENTS FOR PVC PIPES

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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.

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

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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 CO_2 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.

ID195

PLASTIC PIPES FOR SAFE AND RELIABLE TRANSPORTATION OF CHEMICALS

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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.

ID198

HYDRAULIC ROUGHNESS COEFFICIENT TESTING OF PVC PIPE

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When designing pressure or gravity pipelines, knowing the actual hydraulic friction factor of the pipe is essential to the calculation and determination of pipe size, flow velocity, system pressure losses, pump sizing and more. It is commonly understood that PVC pipe has a smooth interior wall which allows it to have excellent hydraulic characteristics. Laboratory friction factor tests on PVC pipe have provided validity to that fact.

Utah State University was commissioned to perform hydraulic testing on PVC pipe to determine the Hazen-Williams C, Manning's n, and Darcy friction factor of 6-inch and 12-inch PVC pipe. This paper describes the tests that were performed along with the results, how the roughness coefficient of the pipe changes with Reynold's number and how the data should be used in practice. It is anticipated that utilities and consulting engineers will want to use this data for PVC pipe design and specifications.

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

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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.

ID203

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

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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.

ID204

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

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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 [1].

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.

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

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Up to now it was not possible to derive an accelerated procedure for the point load test (PLT) as a pipe test [1, 2]. 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.